DEVELOPMENT OF SEEDLING UPROOTING UNIT FOR SYSTEM OF RICE INTENSIFICATION

By

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DECLARATION

I hereby declare that this thesis entitled **"Development of seedling uprooting unit for system of rice intensification"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me for any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS AND ABBREVATIONS

%	Percentage
°	Degree
cm	Centimeter (s)
et. al	And others
Fig.	Figure
g	Gram (s)
g cm^{-1}	Gram per centimeter
g cm^{-3}	Gram per cubic centimeter
ha	Hectare
ha h^{-1}	Hectare per hour
hp	Horse power
i. e.	Tat is
IS	Indian standard
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
kg h^{-1}	Kilogram per hour
kg cm^{-2}	Kilogram per centimeter square
kg ha^{-1}	Kilogram per hectare
kgf	Kilogram force
km h^{-1}	Kilometer per hour
KW	Kilo Watt
l h^{-1}	Litre per hour
MPa	Mega Pascal
mm	Milli meters
ms^{-1}	meter per second
MS	Mild steel
Nos.	Numbers
PoP	Package of Practice
rpm	Rotations per minutes

RARS	Regional Agricultural Research Station
Rs.	Rupees
s	second
SRI	System of Rice Intensification
TNAU	Tamil Nadu Agricultural University
viz.	Versus
w.r.t.	with respect to

INTRODUCTION

CHAPTER 1

INTRODUCTION

Rice (*Oryzasativa* L.) is one of the most important staple foods, feeding more than half of the world's population. India occupies the second position in total rice grain production, next to China. It is one of the oldest food crops, domesticated over 4000 years ago. It is a nutritious cereal crop, provides 20 % of calories and 15 % of protein consumed by world's population. The global production of rice has been estimated to 650 million tonnes and the area under rice cultivation is estimated at 156 million hectares (FAOSTAT, 2008). Asia is the leader in rice production, accounting for about 90% of the world's production. Over 75% of the world supply is consumed by people in Asian countries and thus, rice is of immense importance to food security of Asia. The demand for rice is expected to increase further in view of expected increase in population. Besides being the chief source of carbohydrate and protein, it also provides minerals and fibre. Rice straw and bran are important animal feed in many countries.

India is the largest rice growing country accounting for about one-third of the world acreage under the crop. It is grown in almost all the states of India, covering more than 30 per cent of the total cultivated area. Its cultivation is mostly concentrated in the river valleys, deltas and low lying coastal areas of north-eastern and southern India, especially in the states of Andhra Pradesh, Assam, Bihar, Chhattisgarh, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal, which together contribute about 97 % of the country's rice production, contributing about 42 % to country's food grain production. Rice not only forms the mainstay of diet for majority of its people (>55 %), but also is the livelihood for over 70 % of the population in the traditional rice growing region.

In India, rice is cultivated by following two methods, namely direct seeding and transplanting. Direct seeding method is one of the traditional methods of rice cultivation. In this method, rice seeds are directly sown in the puddled field by broadcasting. Either dry seeds or pre-germinated seeds are sown in the field by a labour that carries the seeds in a small basket and scatters them uniformly on the field. The uniformity of seed distribution depends solely on the experience of the labour performing the task. The present trend is to use direct paddy seeders for sowing pre-germinated seeds, in direct paddy seeders, the seeds are filled in the perforated drums of the seeder and sown by pulling the drum seeder in the levelled field by a labour. The direct seeding of dry seeds manually or with a seed drill, broadcasting or line sowing of dry seed in the puddled fields are the prevailing practices. In India, manual transplanting of 3-4 weeks old nursery seedlings after puddling is the most commonly used conventional practice of rice cultivation. Manual transplanting is pre-dominant practice in almost all the rice growing areas but scarcity of labour, high cost of transplanting and less plant population are associated with this practice. (Anonymous, 1971).

In transplanting method, the seedlings raised in the nursery are uprooted 15 to 30 days after sowing and transplanted in the main field. Transplanting is carried out either manually or mechanically. Transplanting of rice gives a more uniform crop stand, with higher yield, than direct seeding (swain *et al.*, 1991).

Rice is largely grown by transplanting the seedling in puddled field conditions. The usual practice in most countries is to pull the seedlings and tie them into bundles of convenient size for handling. The roots are rinsed in water to remove soil and tips of the leaves are cut off, to reduce evaporation and give rigidity to the plants when transplanted. Manual transplanting is a tedious work, involving human drudgery and stress, in poor weather conditions. The work needs about 250 to 300 man-hours per ha, which is roughly 25 % of the total requirement of man hour for the crop (Singh *et al.*, 1983).

Rice transplanting has emerged as a major problem in the rice growing region of India due to the acute shortage of labour. Optimum plant density and timeliness in operation has been considered important for optimizing rice yield. Transplanting operation demands a high degree of control and precision, hence it is considered to be one of the most difficult operations to mechanize in developing countries (Khan and Sharigi, 1990).

In the traditional rice growing areas, which is considered to be surplus in labour, 33 % crop is late transplanted; even if the field operations are not delayed. Timeliness in transplanting operations are considered to be essential for optimizing the yield and this can be achieved if dependence on labour can eliminated or minimized. Hence, mechanical transplanting has been observed to be the most promising option as it saves labour, minimizes stress and drudgery, ensures timely transplanting, and optimum plant density, contributing to higher productivity. There is a steady reduction in the area of cultivation and yield of paddy in Kerala. Rice is cultivated mainly in fragmented fields of varying sizes, both in irrigated and rainfed conditions, under different agro climatic conditions. Labour shortage has been a major problem in Kerala for farm mechanization and is felt during paddy transplanting, harvesting and threshing periods. Transplanting was found to be the most tedious operation for the farm labourers.

Paddy transplanters are classified as soil bearing (mat) type and root washed seedling type, depending on the type of seedlings used. Mat type transplanters from China are getting popular in India. Mat type seedlings require great precision of field levelling, good water management practices and high technical skills.

System of Rice Intensification (SRI) is a method developed in Madagascar in the early 1980's, where, it has been shown that yields can be enhanced by suitably modifying certain management practices such as controlled supply of water, planting of younger seedlings and providing wider spacing. This methodology provided momentum for the increase in rice production in the country. In this method, 15 days old seedlings are transplanted on well puddled fields. Only one seedling is transplanted per hill, with row to row and hill to hill spacing of 25 cm. Early transplanting of rice seedlings assures in obtaining higher yields in SRI cultivation. Rice seedlings lose much of their growth potential if they are transplanted later than 15 days after emergence in nursery (Rajendran *et al.*, 2014). Hence, it is essential to transplant the seedling at right time in a checkrow planting of 25×25 cm with single seedling per hill.

Missing hills is one of the problems arising while using the transplanters. The missing hills observed in self propelled riding type transplanters were 0 to 14.1 % (Chaudhary and Varshney, 2003). The number of missing hills was primarily due to non uniformity of seedling distribution in the mat. The non uniformity of seedlings was greater at lower density, leading to greater number of missing hills. It was observed that the transplanting fingers cut an area of mat during operation of the machine irrespective of absence of seedlings in the mat. The mechanical transplanter showed a relative variation in the number of seedlings per hill due to the entanglements of roots and failure of paul and ratchet mechanism. In India, rice is transplanted traditionally by root washed seedlings. The farmers in the region are unwilling to change their traditional system of transplanting. The preparation of mat type soil bearing seedlings is difficult, since it requires a lot of skill. For this reason, the adoption of the soil bearing seedling transplanter has not been very successful. In root washed seedling type transplanter, rice seedlings with 3 to 5 leaves and height of 10 to 15 cm are uprooted before transplanting and thoroughly washed with water. The performance of the machine depends on trimming of their leaves and roots to 20 cm and 2 cm respectively. These seedlings are then neatly arranged on the seedling platform or boxes in the machine for transplanting. Thus more labour is required for the preparation and transplanting the seedlings (Swain and Maity, 1981).

The existing practice of the preparation of seedlings is not suitable for root washed transplanters. In this circumstance, there is a need for mechanization in uprooting, washing and feeding the seedling to root washed transplanter. This mechanism will act as an interface between soil bearing and root washed transplanters, since it can increase the efficiency and ease of operation of root washed seedling transplanters. This study is an effort to develop a seedling uprooting unit for a root washed transplanter with the following objectives;

i. To develop seedling uprooting unit for System of Rice Intensification.
ii. Optimization of machine parameters for seedling uprooting machine.
iii. Performance evaluation of seedling uprooting unit.

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

The study is aimed in the development of a new mechanism for the collection of paddy seedlings from nursery for using it as root washed seedling. The chapter contains earlier research works on different transplanting methods and properties of transplanting seedlings, details of cutting blades, SRI method in rice cultivation and different uprooting mechanisms.

2.1 Transplanting methods

2.1.1 Manual rice transplanting

In India manual transplanting of 3-4 weeks old nursery seedlings in puddled fields is the most commonly used conventional practice of rice cultivation. Though, this is the most predominant practice in almost all the rice growing areas but this has a very high labor demands.

Anonymous (1975) reported the manpower requirements for various farm operations of paddy cultivations. The data revealed that transplanting along with nursery raising accounted for about 45-65 per cent of total manpower required on bullock and tractor operated farms. The time required for different farm operations were evaluated and found that the manual transplanting required maximum labour and power as compared to any other methods.

Srivastava et al. (1986) and Shanmugam et al. (1995) compared the methods of manual transplanting and direct seeding and found that labour requirement was 280 man-hrs/ha in transplanted rice as compared to direct seeding which required only 14.5 man-hrs/ha. The labour requirement for manual transplanting was 360 man-hrs/ha while that of direct seeding 29 man-hrs/ha. ..

Sahoo et al. (1994) also found the manual transplanting of rice as a labour consuming methods and required about 25 per cent of total labour requirements of crop.

Sangeetha and Basker (2015) conducted a study on rice productivity with the influence of different crop establishment methods. They did manual transplanting with the requirement about 306 man-h ha^{-1}, which is almost 42 % of the total labour required for rice production. The transplanting of rice seedlings in the traditional way is a laborious, time consuming process and causes drudgery. During transplanting, acute labour shortage results in increased labour wages and delay in the transplanting operation. Manual transplanting also results in non-uniform and inadequate seedling populations. These problems necessitated the introduction of mechanized rice transplanting to achieve timely planting and better crop stands.

2.2 Mechanical rice transplanting

Singh *et al.*, (1981) noticed that the field capacity of a locally manufactured 12 row comb type root washed seedling Chinese transplanter was 0.07 ha h^{-1} and field efficiency was 20 %. The labour requirement was 42 man-ha h^{-1} compared to 157 man- ha h^{-1} for manual transplanting .

Swain and Maity (1981) conducted field evaluation of Annapurna transplanter and found that the man-hour requirement per ha in machine transplanting is much less in comparison to that of hand transplanting, the man-h requirement for filling up the seedling tray reduces the advantage of transplanters to a larger extent. The maximum variation in net power requirement for cutting the seedling mats. Mat area requirement and plants per hill were 0.008 to 0.109 HP, 275 to 450 cm^2/100 strokes and 5.6 to 9.1 respectively (Garg *et al.*, 1982)

Sing and Hussain (1983) noticed that the effective field capacity of the modified IRR1 transplanter was 0.014 ha h^{-1}. The labour requirement for transplanting one hectare was about 55 % of that of hand transplanting method. The average pull required by the machine in a levelled field with 5 to 7 cm water depth was 8 kg.

According to Khan and Sharigi, (1990) Rice transplanting has emerged as a major problem in the whole rice growing region of India due to acute shortage of labour. Transplanting operation needs a high degree of control and precision and is considered to be one of the most difficult operations to mechanize in developing countries.

Swain and Maity (1991) reported that the rice transplanters are classified as soil bearing seedling (mat) type transplanters and root washed seedling type transplanters. In root washed transplanter, rice seedlings with 4-6 leaves and height of 18-35 cm are uprooted to be transplanting and thoroughly washed with water. The performance of the machine depends on the trimming of their leaves and roots to 30 cm and 2 cm respectively. These seedlings are then neatly arranged on the seedling platform or boxes of the machine for transplanting. Thus more labour is required for the preparation and planting the seedlings.

Garg *et al.*, (1997) noticed the field capacity of a manually operated 6 row transplanter as 0.4 ha per day including uprooting and transplanting of the nursery.

Yibin and Yun (1997) pointed out the dynamic simulation of separation and planting mechanism of rice transplanter. They used mass centre path and applied force methods for traditional simulation. The mass centre method applied use of graphic and analytic method to observe the mass centre position of mechanism in an action cycle. The action stability and vibration property of mechanism are evaluated with the ring size in the closed curve ring of mass centre path, whereas, applied force method uses graphical method for the measurement of applied force on every hinge and chain when the crank is at different positions in an action cycle. The dynamic simulation methods were done through computers which has certain advantages over traditional method of simulation. The driving forces are easily monitored using dynamic method. Moreover, it is a less time consuming and an accurate method when compared with the traditional methods.

Chaudhary and Varshney (2000) observed mechanical transplanting as the most promising option as it saves labour minimum stress and drudgery, it ensures timely transplanting and attains optimum plant density contributing higher productivity.

Behra and Varshney (2003) investigated a self propelled rice transplanter. The number of hills transplanted by the machine varied from 25.2 to 28.8 per sq. m. The average hill mortality after 15 days of transplanting was about 250 kg ha^{-1} higher than the manually transplanted fields. Transplanting by this machine saved

45 % cost and 60 % labour as compared to manual transplanting. Field capacity of a self propelled rice transplanter was 0.149 ha h^{-1} and field efficiency was 58.32 %.

2.2 Age of seedlings for transplanting

Swain and Maity (1981) used 12 to 15 cm high and 4 to 5 leaf stage seedlings for better performance in Annapurna Transplanter. Seedling height of 25 cm, which would be attained in 20 to 30 days, was found to be the most suitable for transplanting. The seedlings below 20 days were not fully developed while seedling above 40 days wrapped around the planting arms.

According to Gosh (1982) the grain yield was found to be decrease with the increase in seedling age. Crop raised from younger seedlings produced higher number of tillers and panicles per unit area, more grains panicle, greater percentage of filled grains and higher grain weight than those raised from older seedlings. Singh (1983) reported that in normal wet method, seedlings will get ready for transplanting within 20-25 days and for dapog method it is 11-14 days.

Jgingh (1983) observed that under ill drained conditions, the long duration varieties like Pankaj, Jagannath and IR5 may be planted 30 days after sowing. The seedlings become ready for transplanting in kharif season within 20 to 25 days where as in rabi season it may take 30 to 40 days. The seedlings should not be allowed to grow beyond this period. Delayed transplanting leads to early flowering of the main shoots and consequently reduce the yield.

Hari *et al.*, (1989) noticed significant reduction in productive tillers per m with increase in seedling age. Sixty days old seedlings gave lower yield than 30 and 45 days of old seedlings for the variety HKR120.

Reddy and Reddy (1990) noticed that the crop planted with 30 days old seedlings gave higher grain yield compared to 40 and 60 days old seedlings for the variety Surekha. Number of tillers per hill was found maximum for 30 days old seedlings.

Joseph (1991) conducted a study on the influence of age of seedling and delayed transplanting on performance of rice varieties. The study carried out in Regional Agricultural Research Station, Pattambi. The experiment was conducted in a split-plot design with 5 main plot and 5 sub-main plot treatment on sandy clay loam of lateritic origin having high available N and medium available P and K. By the observation it was noticed that no significant variation in the grain yield of rice when transplanting 33 to 47 days old seedling during kharif season. Rice varieties CNM 539 and IET 9757 were found promising under the arrival of monsoon and delayed transplanting.

Kurmi *et al.*, (1993) reported that grain yield of rice was directly related to the duration of variety and was found to decrease with increase in seedling age at the time of transplanting. The decrease in yield due to transplanting of aged seedling was less in late maturing variety than early maturing variety.

Muhammad *et al.*, (1999) noticed that seedlings are ready to be pulled out when they attain the stage of 4-5 leaves, about 18 days after sowing in the case of short duration varieties and 20-25 days after sowing in the case of medium duration varieties.

Alum *et al.* (2002) reported that age of seedling significantly influenced plant height, number of total tillers, number of effective tillers, panicle length, number of total spikelets per panicle, number of filled grain per panicle, number of sterile spikelets per panicle and grain yield. Thirty five days old seedlings produced highest number of total tillers per hill (8.8), panicle length (25.77 cm), number of total spikelets per panicle (120.23) and number of filled grain per panicle (104.89) compared to 21 and 28 day old seedlings of Aman rice. Plant height (129.10 cm) and grain yield (4.26 t ha^{-1}) was highest for 35 days old seedlings which was statistically on par with 28 days-old seedling.

The rooting establishment of transplanted rice seedlings, including nursery seedling depends on growth of new roots. In a nursery seedling even when all roots were cut at 1.5 cm from the base of the root, growth of the seedling was same as that of seedling without treatment (Ryouji, 2004).

Khahwani *et al.* (2005) found that younger seedlings gained more plant length than older ones and this is due to less root damage during uprooting, as their root length was shorter than that of older ones. This resulted in soil utilization of the root structure in absorption of nutrients and their upward flow in young seedlings produce vigorous plants at later growth stages.

The age of transplanting has effect on different growth factors and yield of crop. Seedlings planted earlier than the optimum period has belated rooting establishment, resulted in low plant height, less number of panicles per unit area, less grain yield and low grain weight. On the other hand, late transplanting contributes more damage to the roots and the seedling loses vigour and finally results in early flowering of the main shoots and reduction in yield. Mat type seedlings are transplanted at younger age than root washed seedlings. Different investigators suggested different age of seedlings. Variation may be due to difference in duration of crop and agro-climatic conditions. One week age per month duration of crop may be considered acceptable value for average conditions.

2.3 Soil cutting by blade type tools

Unit draft indicates a reduction in value when the depth of operation is increased from 5 to 10 cm in both sandy loam and clay soils and is higher for clay soils than sandy soils (Swain, 1982). The unit draft of a triangular tool is minimum at 60^{o} nose angle and 30^{o} tool angle (Swain, 1982).

Depth of cut, width of cut, tool shape, tool arrangement, and travel speed are factors that may affect draft and the energy utilization efficiency for a specific soil condition. The effects of these parameters vary with different types of implements and with different soil conditions. Increased forward speed increases the draft with most tillage implements (Kepner *et al.,* 1987).

The force distribution over the tillage depth was found to be linear at the shallow depth of operation in the untilled soil and nonlinear at higher depth of operation (Glancey *et al.*, 1989).

As the tool moves forward, soil metal friction, shear failure, acceleration force for block of soil and cutting resistance act on the tillage tool. As the tool continues to move, the loading increases until the soil fails in shear (Srivastava,*et al.*, 1993).

The draft requirement increases with width, depth and rake angle of the flat tillage tool. The cross sectional area of the soil disturbed did not change with rake angle, but the significant increase in draft with angle resulted in diminished soil cutting efficiency (Mckyes and Maswaure, 1997).

Durairaj and Balasubramanian (1997) found that while working in loamy sand and clay loam soils, bent leg ploughs should have a rake angle between 9° and 15° for minimum horizontal and lateral soil reactions and maximum downward suction.

The best implement design for low draft, high cutting efficiency and superior soil loosening should have a rake angle of about 30° for flat tillage tools (Mckyes and Maswaure, 1997).

Tong *et al.*, (2005) conducted a study to predict the effects of rake angle of a chisel plough and observed that the draft force decreased with the rake angle and reached its minimum value at 45° rake angle. Over 45°, the draft force increased and reached its maximum value at 75° rake angle.

Godwin (2007) demonstrated that for low draught and good penetration, implements should be designed with a low rake angle.

It can be concluded that draft of a soil working tool depends on shape of tool, width and depth of cut, tool arrangement and forward speed.

2.4 Effect of vibration on soil working tools

Shkurenko (1960) observed that a vibratory velocity of 1.4 to 1.7 m s^{-1} is required to decrease the draft by 50 to 60 %.

Smith *et al.*, (1972) reported that power requirements increased by 70 %. The increase in power was attributed to the transition in mode of soil failure from shear with no vibration to flow with vibration of the blade.

Soil flight angle, defined as the angle between line of flight of the soil and the horizontal, was between 45° and 52° for nonvibrating tool and for vibrating tool it was between 61° and 67° (Brixius and Weber, 1975)

Vibration can reduce the draught force needed to pull a blade or tine through soil (Butson and Rackham, 1981). Vibration was most likely to be effective for low speed, high draught operations, such as subsoiling (Butson and MacIntyre, 1981). Draught reduction can be achieved at the expense of an increase in the total power consumed (Butson and Rackham, 1981).

The orbital vibration theory predicted a decreasing draught force and an increased power requirement as the velocity ratio (the ratio of the vibrating blade tip velocity to the velocity of the vibratory blade carrier) increased. When the ratio was greater than 1.0, draught reductions were greater than 50% (Al-Jubouri and McNulty, 1984).

There is a reduction of 71 to 93% in draft force while applying vibratory motion in longitudinal direction (Szabo *et al.*, 1998). The mechanical power delivered to the soil is a function of frequecy (Szabo *et al.*, 1998).

Draft reduced when amplitude increased from 3.2 to 9.6 mm and when speed increased from 2.4 to 4.8 km h^{-1} (Dawelbeit and Wright, 1999).

The force reduction factors suggest that vibrating blade reduces soil strength by decreasing cohesiveness and effective stress for dry to ductile soils (Szabo *et al.*, 1998). The soil type significantly affects draft, the clay soil required higher draft than loam soil (Dawelbeit and Wright, 1999).

The horizontal force and the vertical force decreased with increase in oscillating frequency in vibratory tillage tool, when the tool was oscillated sinusoidally in the direction of soil bin travel. The peak normal pressure was found to increase with increase in oscillating frequency, oscillating amplitude and soil bin travel speed (Niyamapa and Salokhe, 2000).

From the above studies it is revealed that the draft can effectively be reduced by inducing vibratory motion to a soil working tool. The draft reduction depends on amplitude and frequency of vibration, forward speed of implement and type of soil. Since power consumption of vibratory motion is high, it can be effectively used for low speed, high draft operations.

2.5 System of Rice Intensification (SRI)

Orthy (2001) noticed that SRI, being a sustainable rice farming technology, can help small farmers to increase their rice yields up to 10 t ha^{-1} without depending on hybrid seeds, chemical fertilizers and pesticides.

Moser and Baret (2002) reported that SRI is difficult for most farmers to practice as it requires additional labour and intensive care during the crop production. SRI permits resource limited farmers to realize higher yields up to 15 t ha^{-1} of paddy in less fertile soil with reduced rates of irrigation and inputs (Stoop *et al.*, 2002).

The System of Rice Intensification (SRI) developed in Madacascar 20 years ago, is based on the insights that rice has the potential to produce more tillers, dry matter and grain yield than the conventional method when grown in optimal 7 conditions (Spacing, soil moisture, biological active and healthy soil and aerobic soil) along with early transplanting of young seedlings (Upholf and Fernandes, 2004).

The System of Rice Intensification (SRI), by changing the way that rice plants, soil, water and nutrients are managed, has its most obvious and dramatic effects on yield, generally raising yields by 50-100 per cent, and sometimes even more (Uphoff, 2005).

In SRI method of cultivation, marking of the plot is done before transplantation, to ensure proper spacing. Then labourers, preferably women workers, transplant one or two young paddy seedling in each grid of the marking. This method of planting requires careful planting on the grid which is difficult for the workers, who do not normally follow proper spacing and maintain seedling population per hill. Moreover, in the conventional method of planting, 25-30 days old seedling are transplanted, whereas in the SRI method of transplanting, 15 days old seedling are transplanted (Berkelaar, 2001 and Willem and Kassam, 2006).

Nursery prepared at recommended seed rate, transplanting single seedling, wide spacing between individual hills, ranging from 25 × 25 to 50 × 50 cm, are some of the critical factors that influence the SRI method of cultivation (Willem and Kassam, 2006).

Alagesan *et al.*, (2008) observed that the major constraints associated with the SRI were lack of skill for planting of 15 days seedlings, handling difficulty of the small seedlings in pulling and transplanting, skilled labour shortage for mat nursery preparation and coverage of planting area.

Veeramani *et al.* (2012) conducted study based on different planting pattern of hybrid rice CORH 3 using rolling marker in system of rice intensification. The field experiment was conducted in sandy clay loam soil having pH of 7.3, low available N, medium P, high available K and organic carbon content of 0.31 % at Agricultural College and Research Institute, Madurai. The experiment was laid out in a factorial randomized block design replicated thrice. Some of the modifications were tested in the triangular method, the seedlings are planted in a zig zag pattern with 25 cm spacing between seedlings and rows, while with the oblong method of planting, the seedlings were planted in an oblong pattern with 25 cm spacing between each seedling and 30 cm between the rows. Significant phenotypical changes occur not only in plant structure and function but also in yield and yield components under SRI cultivation. The zig zag and oblong methods of planting can be perfectly and economically taken up only by utilizing specially designed rolling markers, that had significance in increasing the number of productive tillers, minimize time and cost of transplanting in SRI. Through these modifications, grain yield exceeded 10.5 t ha^{-1} and 31 % greater than in square pattern of planting.

Dhananchezhiyan *et al.* (2013) conducted a study for the development of spaced mat nursery to suit the available transplanter for System of Rice

Intensification (SRI) method of cultivation. They aimed for the achievement of 100% seed germination, enough root networks to provide enough rigidity for the mat and to offer conducive growth environment through the optimization of soil medium. Nine treatment media were prepared for the testing namely vermisoil (field soil+vermicompost-1:1, 2:1 and 3:1), soil+farm yard manure (FYM) soil (field soil+farm yard manure-1:1, 2:1 and 3:1), field soil+coirpith (1:1 and 2:1) and field soil alone. Measurements such as seedling height and root length were carried out in all trays, after 14 days of sowing. Among the nine treatment media studied, the maximum nursery height and root length of 17.06 and 10.75 cm was observed in FYM soil and vermisoil, respectively prepared in 1:1 ratio. For the same treatment media, when ratio was changed to 2:1 it recorded 16.26 and 10.14 cm respectively. For the stiffness studies, field soil was mixed with decomposed sieved coir pith and fibrous coir pith each in the ratio of 1:1 and 2:1 and tested with and without base layer and measured the stiffness force. The mat stiffness was found to be high for a media mixture of field soil and coir pith at 1:1 and 2:1 ratios with a corrugated sheet base layer. From the results, the soil medium for growth and stiffness was optimized as field soil, FYM and fibrous coir pith in the ratio of 2:1:1.

2.6 Uprooting mechanism

Munde *et al.* (2009) developed a bullock drawn turmeric digger. They developed the prototype of the machine by considering spacing and varieties used in Parbhani and Nanded districts. Field performance was evaluated using different methods of the newly developed bullock drawn turmeric digger. The field trials were conducted as per IS code (11235, 1981). The machine had shown better performance for turmeric harvesting in terms of rhizomes damage percentage, digging efficiency, field efficiency, and draft requirement over existing machine and manual methods, respectively. The rhizome damage was less 10.7 % for 70° angled V blades. The digging efficiency was found about average 86-95 % for 70° angled V blades. The field efficiency was found to be 71 to 88 % for 70° angled V blades. Draft requirement of bullock drawn turmeric digger was found to be 108 kgf.

Sanjay *et al.* (2015) designed and developed a ginger harvester. It consists of screeners which not only separate ginger from soil but also protect ginger without any harm. This machine was having an auto front petrol-engine with rotation speed 20 to 25 rpm approximately with the aid of gear reduction. The cost of the machine is about Rs. 26,000 and if the farmer buys this machine, he can recover the invested money back by harvesting two and half acres. It has advantages such as simple in design and construction; it can be easily fabricated at village level. Machine makes the process faster than manual harvesting and hence reduces most of the harvesting time and labours required to operate the machine so reduces the labour cost.

In order to increase the productivity in rice cultivation, SRI method is the most promising. However, due to monotonous manual uprooting of rice seedlings restricting the farmers to adopt this method. In India and abroad very few attempts have been made so far towards mechanising such laborious operations. In present time there is no mechanical equipment developed nor commercially available, for uprooting the rice seedlings. Therefore, the present study was proposed and carried out to develop seedling uprooting machine for SRI method.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

In the present study, a seedling uprooting unit for system of rice intensification (SRI) was developed and field tested at instructional farm of K.C.A.E.T. In SRI, seedlings are raised on the ordinary nursery bed. The seedlings are pulled off when they become 8 to 12 days old and washed well to remove the soil from the roots for next transplanting operation. A large amount of human hours are consumed to accomplish this seedling uprooting practice for the given seedling nursery area. Since it is a laborious and monotonous work, a seedling uprooting unit was developed and field tested; so as to overcome these problems and to save time of operation. In this chapter, concept, factors influencing the design of seedling uprooting unit, design of functional components, constructional features and field tests for the developed seedling uprooting unit for SRI are explained in detail.

3.1 Concept and development of seedling uprooting unit for SRI

The International Rice Research Institute (IRRI) has identified and categorized four rice agro ecosystems as, irrigated rice ecosystems, rainfed lowland rice ecosystems, upland rice ecosystems, and deepwater rice ecosystems. In irrigated rice system, crop establishment is commonly carried out by transplanting the seedlings. (Thiyagarajan and Gujja, 2013)

Transplanting is done either manually or mechanically. Considering the acute shortage in agricultural labourers, mechanical transplanting is deployed in major rice cultivating regions. The mechanical transplanters may be broadly categorized to the following types; depending on the type of nursery used.

- Non soil seedling type transplanter (Root washed seedling type)
- Soil bearing seedling type transplanter (Seedling mat type)

In conventional rice cultivation, either direct method (broadcasting or drum seeder type) or indirect method (manual or mechanical transplanting) is being used.

The System of Rice Intensification involves cultivating rice with as much organic manure as possible, starting with young seedlings planted singly at wider spacing in a square pattern and with intermittent irrigation that keeps the soil moist but not inundated, and frequent intercultivation with weeder, that actively aerates the soil. Since, single seedlings are planted on each hill, the planting is done manually in SRI method. Manual transplanting is laborious and time consuming. Now a days modification of existing machine transplanters to suit SRI are also being undertaken.

In order to minimize the labour and time for uprooting seedlings, the need for a machine which can uproot the seedling from nursery was keenly felt. Thus the concept of development of seedling uprooting machine was evolved.

3.2 Factors influencing the development of seedling uprooting unit

3.2.1 Physical properties of soil

The physical property of the soil directly or indirectly affects the soil-tool interface as well as the growth of the crop. The three properties, *viz*, moisture content, bulk density and penetration resistance of the soil were determined. Soil samples from different parts of the experimental plot were collected in clean and closed containers to determine the present status of the soil. The tests were conducted in the Soil and Water Laboratory at K.C.A.E.T, Tavanur.

3.2.1.1 Soil type and texture

The field with good drainage and sunlight without any shade was selected for the study. The analysis of grain size distribution of soil was carried out by sieving method. Dry sieve analysis was carried out using 4.75mm, 2mm, 1mm, 600μm, 425μm, 300μm, 212μm, 150μm, and 75μm size sieves. Sieving was done using sieve shaker and weight of soil retained in each sieves were noted.

3.2.1.2 Moisture content

It is the percentage of water in a given soil sample. It can be found out by standard test procedures and using the equation,

$$\text{Soil moisture content (wb)} = \frac{W_i - W_f}{W_i} \times 100$$

..... Eq. (i)

where,

W_i = initial weight of the soil, gm

W_f = final weight of the soil, gm

Oven drying method was used to determine the moisture content of the soil sample. In this study, a soil sample of 50 g was collected in a clean container and placed in an oven under controlled temperature between 105°C to 110°C for a time period of 24 hours. The experiment was replicated for six samples from different parts of the field and the mean value was calculated.

3.2.1.3 Bulk density

The bulk density of the soil was found out by using the formula,

$$\rho = \frac{M}{V}$$

..... Eq. (ii)

where,

ρ – Bulk density, g cm^{-3}

M – Mass of the soil, g

V – Volume of the soil, cm^3

3.2.1.4 Penetration resistance

Soil cone penetrometer (Proving ring type) was used to measure the penetration resistance of the soil. Penetrometer was positioned in the field and slightly pressed on the handle. A uniform force was placed on the handle and the deflection of dial gauge was noted for 1 cm in depth. The solid stem penetrated into the soil and force was measured from the deflection of the needle of proving ring corresponding to the insertion of 30^0 cone. The penetrometer resistance was measured for each increment of one cm and recorded manually. The same procedure was repeated to measure penetration resistances at various location of the study area.

3.2.2 Biometric observation

The crop parameters which indicate the germination and growth of the rice such as plant height, number of leaves and root length are described as follows.

3.2.2.1 Plant height

It is the height of the plant measured 12 days after planting and at the time of uprooting on the same plant. It is expressed in cm. Plant height was measured with the help of a meter scale from the base of the plant to the tip of top most leaf at 12 days interval of time after the date of planting and also at the time uprooting stage from ten randomly selected and labelled plants of plots.

3.2.2.2 Number of leaves

It is the count of number of leaves present in a seedling after 12 days. Readings were taken from ten randomly selected and labeled plants.

3.2.2.3 Root length

It is the measured length of root of seedling after uprooting. Readings were taken from ten randomly selected and labeled plants.

Plate 3.1 Stages of field preparation

Plate 3.2 Field - 12 Days after sowing

3.3 Functional components of seedling uprooting system

3.3.1 Bed cutting tool

In order to cut the required thickness of soil bed, cutting tool was developed and fabricated with MS flat sheet of 2 mm thickness. It consisted of rectangular base plate (25 × 30 cm) placed horizontally beneath the cutting blade. The cutting blade has nominal pointed soil engaging face for better penetration with less draft, placed over the base plate in an inclined position maintained with adjustable guides and set screw. The horizontal reciprocating stroke of 2cm motion was provided to the cutting unit (cutting blade and base plate) by dual cam, spring loaded, and horizontal stroke mechanism.

3.3.2 Conveyor unit

The slatted belt type conveyor was fabricated with two adjacent roller chains interlinked with MS flat linkages giving overall belt width of 25 cm and 155 cm belt length. Sprockets with 14 teeth and 6.5 cm diameter were used at picking side and bigger sprocket of 16 cm diameter with 34 teeth were used at dropping side of the conveyor. The MS flat sheet guides on the sides of conveyor were provided to avoid off-movement or skidding out of cut bed from conveyor.

3.3.3 Main frame

According to the geometry of power unit a suitable frame was fabricated using MS angles (3 × 3 cm) to attach the cutting and conveying unit. The main frame was fixed to the power unit with nut-bolt fasteners on the left side. As the power output shaft was on the left side, it was helpful to transmit drive to conveyor and stoke mechanism. Also, for safe delivery of cut seedling bed, it was essential to keep the developed system on either side of the power unit.

3.3.4 Power unit

In order to drive the conveyor belt, stroke mechanism and for forward motion, a power unit from the existing vertical conveyor reaper was chosen. It consisted of 4 hp SHRIRAM HONDA-GK200 gasoline engine with the specifications provided in Appendix-VI.

3.3.5 Speed reduction unit

In order to reduce the revolutions per minute of the final conveyor driver pulley and to limit the conveyor belt speed to 1 to 1.5 ms^{-1}, speed reduction unit with required diameter of pulleys was designed and fabricated. Also to increase the torque at final drive, an intermediate shaft with bigger pulley (40 cm diameter) driven by smaller engine pulley (7.5 cm diameter) by an open belt was introduced. On the other side of the intermediate shaft, smaller pulley (5 cm diameter) was installed to transfer drive to the conveyor shaft with pulley diameter of 25 cm.

Speed reduction ratios between different size of pulleys and input revolutions and the rotational speed at final shaft can be calculated by following equations,

$$N_1D_1 = N_2D_2$$

..... Eq. (iii)

and

$$N_3D_3 = N_4D_4$$

..... Eq. (iv)

D_1 = driver pulley on engine shaft,

D_2 = driven pulley on intermediate shaft,

D_3 = driving pulley on either side of intermediate shaft,

D_4 = driven pulley on conveyor shaft,

N_1, N_2, N_3 and N_4 are respective shaft speeds (rpm),

From engine to intermediate pulley

$$N_1D_1 = N_2\,D_2$$

..... Eq. (v)

From intermediate shaft to conveyor pulley

$$N_3D_3 = N_4\,D_4$$

..... Eq. (vi)

But, $N_3 = N_2$, as D_2 and D_3 pulleys are same on the same shaft,

$$N_2D_3 = N_4\,D_4$$

..... Eq. (vii)

Conveyor belt speed

Linear velocity of conveyor belt (V_b) can be calculated by,

$$V_b = \pi \mathrm{D} \mathrm{N}_4$$

..... Eq. (viii)

3.4 Design considerations

The power requirement of the equipment was determined by calculating the sum of specific power requirements of different functional units, such as draft requirement of cutting tool, power requirement of conveyor system and power requirement for self propulsion and transmission system. The total power requirement obtained from the calculations was then multiplied with a suitable factor of safety (F.O.S.) to derive the design value of the power requirement for an efficient working of the developed equipment.

3.4.1Selection of prime mover

3.4.1.1 Draft requirement for cutting tool

$$\text{Force } (F) = w \times d \times R$$

..... Eq. (ix)

Where,

w = width of cutting tool, cm

d = depth of cut, cm

R = soil resistance, $kg.cm^{-2}$

$$\text{Power requirement for cutting tool } (\mathbf{P}) = \text{draft (kgf)} \times \text{speed} (m.s^{-1})$$

3.4.1.2 Power requirement of conveyor system

$$Q = \frac{w \times t \times V_b \times \rho \times 100 \times 60}{1000}$$

..... Eq. (xi)

Where,

Q = Capacity of belt conveyor, $kg.h^{-1}$

w = Width of belt, cm

t = Thickness of soil bed, cm

V_b = Belt speed, $m.s^{-1}$

ρ = Bulk density of soil, $g.cm^{-3}$

Therefore the power requirement,

$$P = F_e \times V_b \times 10^{-3} \quad kW$$

..... Eq. (xii)

Where,

P = Power requirement, kW

F_e = Effective force, N

V_b = Belt speed, $m.s^{-1}$

Effective force is calculated by multiplying the weight of components on the conveyor (material, conveyor belt and drum pulley) with the gravity and coefficient of friction.

$$F_e = (M + M_b + M_r) \times g \times \mu_R$$

..... Eq. (xiii)

Where,

μ_R = coefficient of friction

g = acceleration due to gravity ($m.s^{-2}$)

M = material weight, kg

M_b = belt weight, kg

M_r = drum pulley weight, kg

3.4.1.3 Power requirement for self propulsion and transmission system

Power required for transmission,

$$P_T = \frac{\text{vehicle weight (N)} \times \text{speed } (m.s^{-1})}{1000}$$

..... Eq. (xiv)

Therefore, total power requirement of the machine can be calculated by,

$$\text{Total power required (P)} = P_d + P_T + P_c$$

3.4.2 Selection of the operational parameters for field tests

3.4.2.1 Selection of speed of operation

The speed of operation was selected on the basis of the rated engine speed (rpm) of the prime mover. Considering the rated engine speed of 3000 rpm as the upper limit, the three engine speeds were selected as 1000, 2000 and 3000 rpm for safe working of prime mover.

3.4.2.2 Selection of Angle of cutting

The angle of cutting (α) was selected on the basis of previous studies related to soil cutting tools and root crop harvesters. As suggested by Swain (1982) the unit draft of a triangular tool have minimum at 30° tool angle. For optimizing the angle of cutting three different cutting angles viz. 20°, 30° and 40° were selected.

3.5 Field evaluation

3.5.1 Thickness of the bed

The thickness of bed after cutting seedlings, with respect to speed of machine and angle of cutting blade, was measured using steel rule and the results were analysed.

3.5.2 Time of operation

The time taken to uproot the seedlings with respect to speed of machine and angle of cutting blade was observed by using a stop watch. The results were analyzed.

3.5.3 Wheel slip

It is the relative movement of the wheel in the direction of travel for a given distance under load and at no load condition. The wheel slippage was determined by measuring distance travelled by developed machine in five revolutions of cage wheels at no load and with load. A mark on the rim of cage wheel was made to observe the wheel revolutions. The distance travelled at working speed in load and no load condition within selected time was noted down. The wheel slippage was calculated as follows,

$$S_L = \frac{L_1 - L_2}{L_1} \times 100$$

..... Eq. (xv)

S_L = wheel slippage, %

L_1 = distance travelled at no load, m

L_2 = distance travelled with load, m

3.5.4 Seedling root damage

The quality of work carried out by different engine speed and cutting angle used was evaluated in terms of damage to the roots of rice seedlings while in operation. Root damage was taken as the ratio of number of damaged plants to the total number of plants in 5 cm × 5 cm size of seedling bed after uprooting. Three bed samples were taken randomly for every engine speed - cutting angle observations were made for each combination of engine speed and cutting angle. The bed soil was gently washed off to quantify the root damaged plants. Plant damage was calculated by using following equation:

$$\text{Plant damage, \%} = \frac{Q_2}{Q_1} \times 100$$

.... Eq. (xvi)

where,

Q_1 = total no. of plants in 5 cm × 5 cm seedling bed after uprooting operation.

Q_2 = total no. of damaged plants in 5 cm × 5 cm seedling bed

3.6 Performance characteristics of final prototype

3.6.1 Theoretical Field capacity

It is the theoretical area covered per hour by an implement at rated speed. Width of the implement and operating speed were measured as explained earlier. Theoretical field capacity in ha hr^{-1} is calculated using the formula.

Theoretical field capacity = $\frac{W \times S}{10}$

..... Eq. (xvii)

Where,

W – Implement width, m

S – Operating speed, km h^{-1}

3.6.2 Actual Field capacity

The actual field capacity was determined by observing the actual area covered per hour with standard test procedures.

3.6.3 Field efficiency

Field efficiency was calculated from theoretical and effective field capacity using the formula,

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

..... Eq. (xviii)

3.6.4 Fuel consumption

Fuel consumption of the machine is the amount of fuel required to cover a known distance with implement. An external fuel tank was attached with the machine to determine the fuel consumption of the machine. The tank was filled to full capacity before and after each test trial. The volume of fuel refilled after the test is the fuel consumption for the operation.

3.6.5 Cost economics

The field capacity of the seedling uprooting machine and the cost of operation were calculated. The saving in cost in the field operation with seedling uprooting machine was worked out with the conventional method of seedling uprooting.

Manual seedling uprooting was carried out by hand. The capacity of the manual labourers for the seedling uprooting (man-hours/ha) was determined by recording total time (seconds) taken to uproot the seedlings.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The present study is undertaken to develop a seedling uprooting unit for SRI system. This chapter deals with the details of the field experiments done to evaluate the performance of seedling uprooting unit. The relevant physical properties of soil and field performance of the seedling uprooting unit are determined and summarized.

4.1 Development of seedling uprooting unit.

Based on the functional components as discussed in section 3.3, an initial model (Model - I) followed by modified Model II of uprooting unit was fabricated and tested for its functionality. This model was refined and redesigned to get final model (Model - III) as a sequential development. Details of various models are discussed in the following sub sections.

4.1.1 Model - I

At the earliest stage of development of seedling uprooting machine was fabricated using prime mover (self propelled) from a garden tiller. The bed cutting mechanism was consisted of inclined cutting blade with extended carrier tray behind. The drive was taken from the output shaft of the prime mover to provide horizontal reciprocating motion to the cutting tool, using crank mechanism with chain drive.

The major constraints faced during the operation of this model were difficulty in conveying the seed bed due to the accumulation of seed bed on the extended tray itself. Since, the seedling bed was continuously accumulating on the carrier tray, severe splitting of bed was observed, which was damaging the seedlings and bed geometry. Also the vibrations of cutting tool were transferred to entire machine through the extended tray and main frame which may result in operator's fatigue.

4.1.2 Model - II

In order to minimize seedling bed damage and excessive vibrations major modifications were done in the reciprocating cutting tool mechanism. A rubber belt conveyor was provided for conveying the seedling bed formed during the cutting phase. In this model, even though both conveyor and cutting tool reciprocating mechanism were taking drive from the same shaft, the belt conveyor system was exclusive of any reciprocation or was stationary on the main frame.

The major problem associated with this model was the slippage of conveyor belt, as the rubber belt mounted on the final shaft was losing the grip on bed loading. Also, the existing traction device i.e. tyres were engaging with excessive slippage under operating conditions, ensuing the reduction in forward motion and skidding-off from the line of operation.

Plate 4.1 Model - I

Plate 4.2 Model - II

4.1.3 Model - III

In order to overcome the drawbacks of the first and second models, a new modified seedling uprooting unit was developed and tested in the field. For this model a gasoline powered prime mover was selected as power source and chain and sprocket mechanism were used for conveyance of seedling with minimum slippage. The Model - III was fitted with a pair of cage wheels for eliminating excessive slippage and better traction during field operation.

Since, the development of the rice seedling uprooting machine was a sequential process, the Model – III was selected as final prototype for subsequent field testing and evaluation study.

Plate 4.3 Seedling uprooting unit – Model III

4.2 Physical and mechanical properties of soil

Physical properties such as the soil texture, moisture content, bulk density and penetration resistance of the soil, which influence the performance of the seedling uprooting unit were determined.

4.2.1 Soil type and texture

Soil samples from the experimental plots were analyzed for particle size distribution using sieve analysis and the results are given in Appendix I. Soil texture of all the samples was sandy loam with 60% sand, 30% silt and 10% clay.

4.2.2 Moisture content

Moisture content was determined as percentage by weight, by oven drying method. Soil samples from six different locations in the study area at specified intervals were determined. The average moisture content found out was 21.7 %. The results are given in Appendix II.

4.2.3 Bulk density

The bulk density of the soil in the experimental field was found out by core cutter method. The mean bulk density of the soil was found to be 1.95 g cm^{-3}. The recorded values and its calculations are given in Appendix III.

4.2.4 Penetration resistance

The cone penetrometer test was conducted to find the cone index. Appendix IV shows the soil penetration resistance with respect to depth and soil moisture at the selected sites. It was observed that the penetration resistance increased with increasing depth and moisture content for all trial sites. Ploughing the soil generally reduced penetration resistance. At the time of operation, penetration resistance was in the range from 0.21- 1.19 MPa.

4.2.5 Biometric observation

The crop parameter such as plant height, number of leaves and root length were observed at 12^{th} days after planting. Average height of the plant was observed to be 9 cm with an average of 3 leaves per plant. Average root length of 2.5 cm was noticed.

4.3 Selection of prime mover

4.3.1 Draft requirement for cutting tool

Since the soil type under the study was sandy loam, the soil resistance was taken as 0.4 $kg.cm^{-2}$ and the effective force required for cutting was calculated by,

$$\text{Force } (\text{F}) = \text{w} \times \text{d} \times \text{R}$$

$$\text{F} = 25 \times 3 \times 0.4$$

Power requirement for cutting tool (P),

$$\text{P} = \text{draft (kgf)} \times \text{speed}(\text{m.s}^{-1})$$

$$P = \frac{30 \times 0.25 \times 9.81}{1000}$$

$$P = 0.0745\ kW$$

4.3.2 Power requirement of conveyor system

$$Q = \frac{w \times t \times V_b \times \rho \times 100 \times 60}{1000}$$

Where,

Q = Capacity of belt conveyor, $kg.h^{-1}$

w = Width of belt, cm

t = Thickness of soil bed, cm

V_b = Belt speed, $m.s^{-1}$

ρ = Bulk density of soil, $g.cm^{-3}$

$$Q = \frac{25 \times 3 \times 0.94 \times 1.95 \times 100 \times 60}{1000}$$

$$Q = 826.61 \ kg.h^{-1}$$

Therefore the power requirement,

$$P = F_e \times V_b \times 10^{-3} \quad kW$$

and

$$F_e = (M + M_b + M_r) \times g \times \mu_R$$

Where,

P = Power requirement, kW

F_e = Effective force, N

V_b = Belt speed, $m.s^{-1}$

μ_R = coefficient of friction

g = acceleration due to gravity ($m.s^{-2}$)

M = material weight, kg

M_b = belt weight, kg

M_r = drum pulley weight, kg

$$F_e = (8 + 5.5 + 1.5) \times 9.81 \times 0.033$$

$$F_e = 4.8570\ \text{N}$$

Power requirement,

$$P = F_e \times V_b \times 10^{-3} \quad \text{kW}$$

$$P = 4.8570 \times 0.94 \times 10^{-3}$$

$$P = 4.5655 \times 10^{-3}\ \text{kW}$$

4.3.3 Power requirement for self propulsion and transmission system

Power required for transmission,

$$P_T = \frac{\text{vehicle weight (N)} \times \text{speed } (\text{m.s}^{-1})}{1000}$$

$$P_T = \frac{248 \times 9.81 \times 0.25}{1000}$$

$$P_T = 0.611 + 10\% \text{ belt drive transmission}$$

$$P_T = 0.669\ \text{kW}$$

Therefore,

$$\text{Total power required (P)} = P_d + P_T + P_c$$

$$P = 0.0745 + 4.5655 \times 10^{-3} + 0.669$$

$$P = 0.748\ \text{kW}$$

Considering factor of safety $= 3$

$$P = 0.748 \times 3$$

$$P = 2.244\ \text{kW}$$

Since, the selected prime mover has power output of 3.0 kW, which is higher than the design power requirement. Hence, selected power source is sufficient for the operation of the developed machine.

4.4 Design features and specifications of final prototype

- The self-propelled rice seedling uprooting unit was developed in compliance with System of Rice Intensification.
- The power unit with cage wheel type self-propelling mechanism gives drive to the machine.
- Dual cam horizontal stroke mechanism takes drive from intermediate shaft and actuates the cutting tool in to and fro motion.
- Cutting blade with 25 cm cutting width cut the seedling bed and continuous reciprocating motion helps to reduce the draft.
- Speed reduction from engine output shaft to conveyor mechanism was accomplished by speed reduction unit consisting intermediate shaft-pulley.
- Cross belt transmission was used at final drive to reverse the rotational direction of conveyor system.
- Finally with the forward motion, seedling bed was taken up by the conveyor belt and laid behind on left side of the machine.

Table 4.1 Specifications of developed seedling uprooting machine

Sl. No.	Particulars	Values
1	**Overall dimensions**	
	i. Length (mm)	2350
	ii. Width (mm)	1000
	iii. Height (mm)	850
2	**Weight (kg)**	148
3	**Implement type and power source**	
	i. Implement type	Self-propelled, walk behind
	ii. Source of power	Gasoline engine prime mover
	iii. Power output	4.0 hp or 3 kW
4	**Tractive element**	
	i. Type	Cage wheel (2 Nos.)
	ii. Diameter (mm)	460
	iii. Width (mm)	140
	iv. No. of lug	12
5	**Bed cutting tool**	
	i. Cutting blade width (mm)	250
	ii. Cutting angle	0° to 45°

	iii. Base plate size (width x length)	250 mm x 300 mm
6	**Cutting tool reciprocating mechanism** i. Type ii. Stroke length (mm)	 Spring loaded dual cam horizontal stroke type 20
7	**Conveyor unit** i. Type ii. Sprocket size iii. Centre to centre distance (mm) iv. Length (mm) v. Belt speed (ms^{-1}) – Maximum Minimum	 Roller chain slatted belt Driver : 34 teeth Driven : 14 teeth 600 1550 0.942 0.314

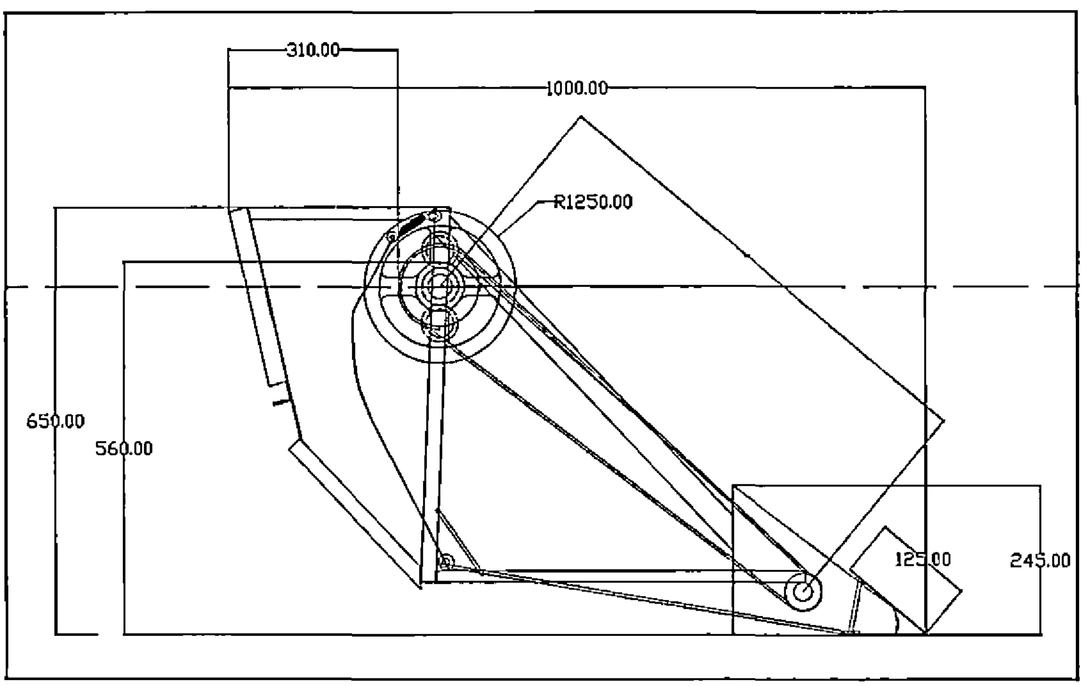

Fig 4.1 Side view of seedling uprooting unit

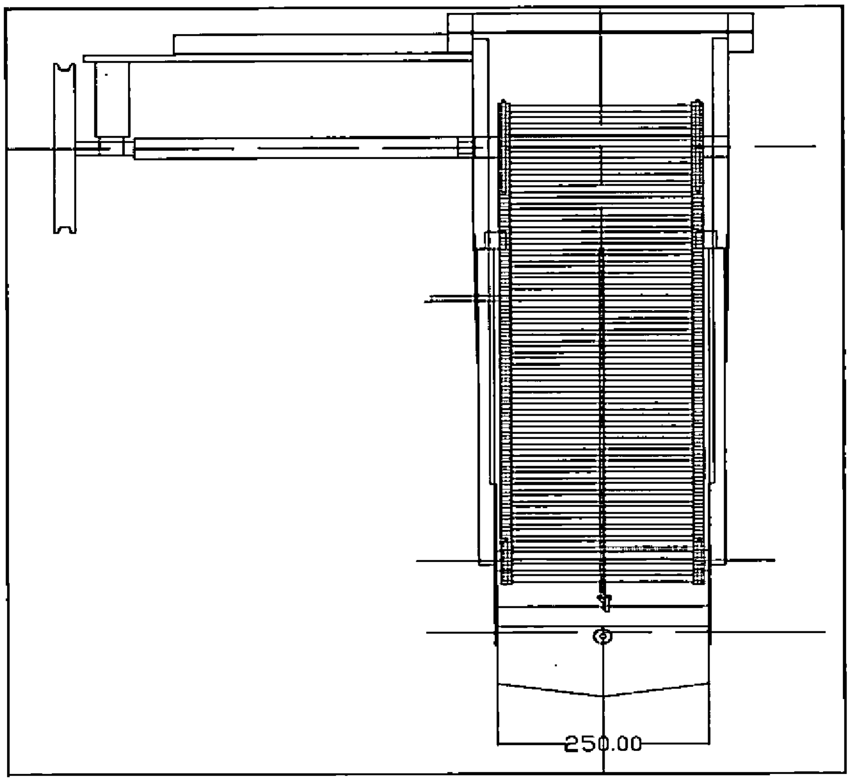

Fig 4.2 Top view of seedling uprooting unit

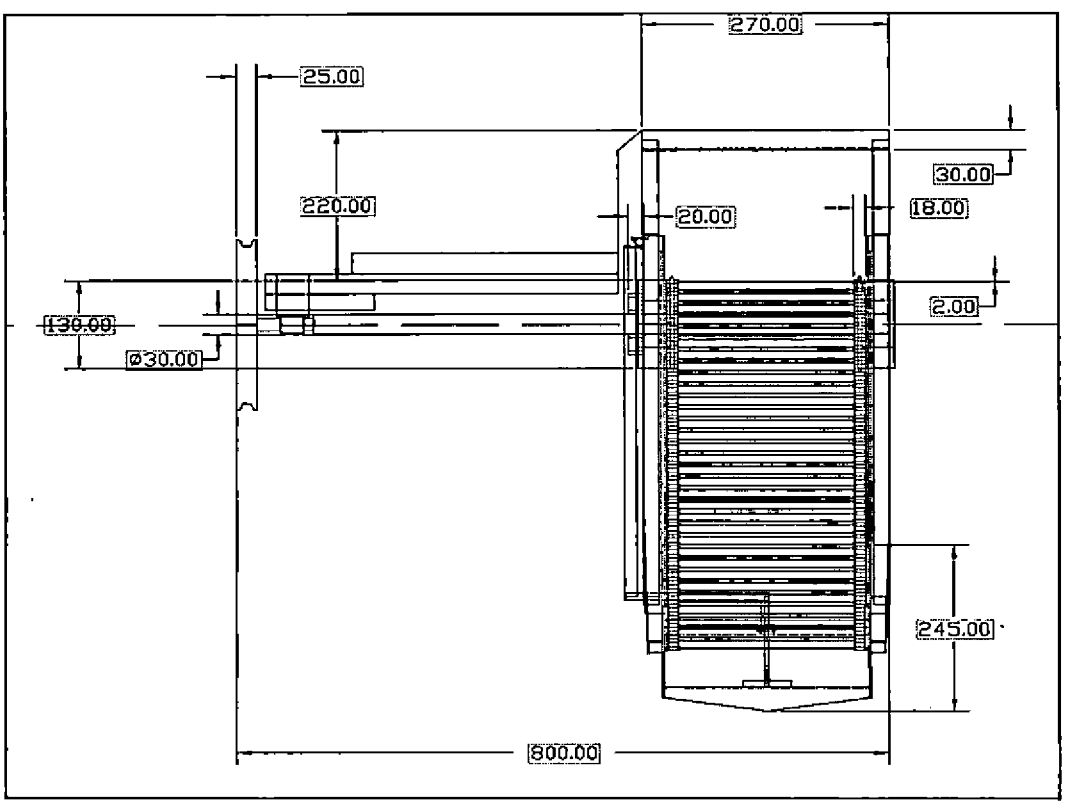

Fig 4.3 Front view of seedling uprooting unit

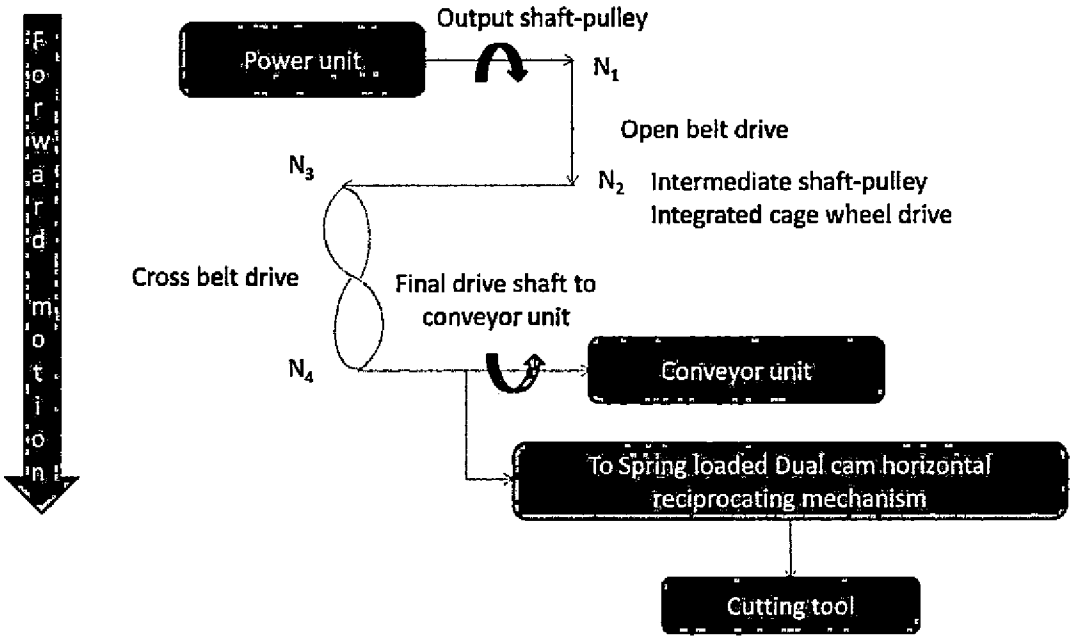

Fig. 4.4 Power transmission in the seedling uprooting unit

Power transmission in the seedling uprooting unit

Speed reduction ratios between different size of pulleys and input revolutions and the rotational speed at final shaft can be calculated by following parameters,

D_1 = 7.5 cm, driver pulley on engine shaft,

D_2 = 40 cm, driven pulley on intermediate shaft,

D_3 = 5 cm, driving pulley on either side of intermediate shaft,

D_4 = 25 cm, driven pulley on conveyor shaft,

N_1, N_2, N_3 and N_4 are respective shaft speeds (rpm),

From engine to intermediate pulley,

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} = \frac{40}{7.5} = 5.33$$

Therefore,

$$N_1 = 5.33N_2$$

and

$$N_4 = \frac{N_2 D_3}{D_4}$$

$$N_4 = \frac{N_1}{5.33} \times \frac{5}{25}$$

$$N_4 = \frac{N_1}{26.65}$$

Conveyor belt speed

Linear velocity of conveyor belt (V_b) can be calculated by,

$$V_b = \pi \times 16 \times \frac{\mathrm{N_1}}{26.65}$$

and

$$V_b = 1.885 \text{ cm.min}^{-1}$$

The linear velocities of conveyor belt corresponding to various engine speeds are tabulated below.

Table 4.2 Linear velocities of conveyor belt corresponding to various engine speeds

Sl.No	Engine speed (rpm)	Linear velocity (ms^{-1})
1	1000	0.314
2	2000	0.628
3	3000	0.942

4.5 Field evaluation

The machine performance was evaluated in the field, and time of operation, fuel consumption and field capacity were found out.

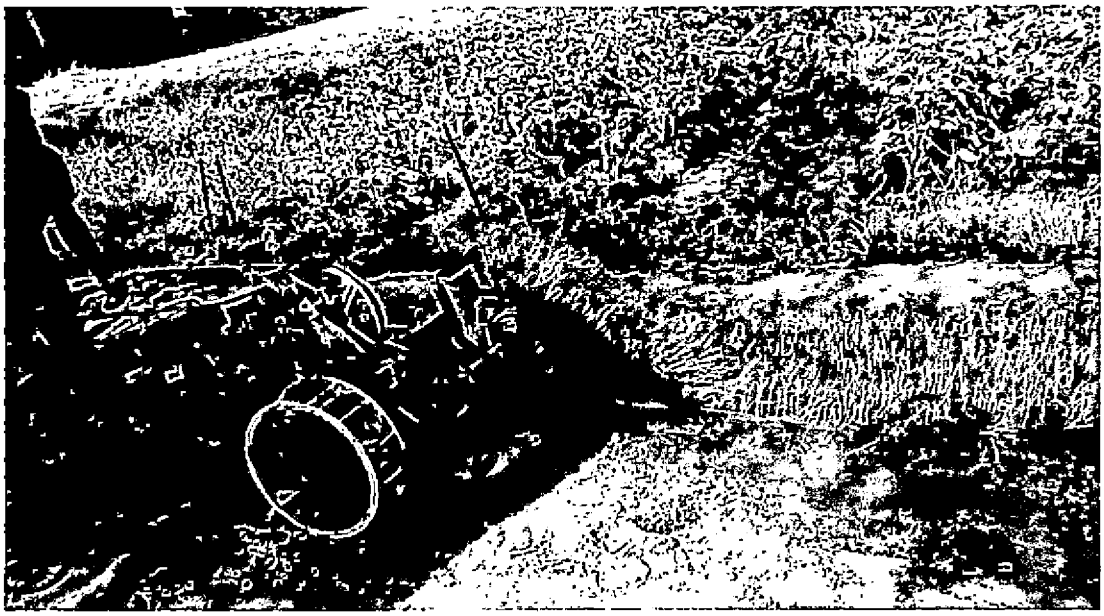

Plate 4.4 Working of machine

4.5.1 Thickness of the bed

The bed thickness after cutting with respect to three different engine speeds and three cutting angles of blade are shown in the Table 4.3, Fig. 4.6.

Table 4.3 Thickness of bed w.r.t. speed of operation and cutting angle (mean values, in cm)

Speed of operation (rpm)	Angle of blade		
	20°	30°	40°
1000	1.9	2.8	5.9
2000	1.9	2.7	5.8
3000	1.1	2.4	6.0

The thickness of bed after cutting was in the range of 1.1 cm to 6.0 cm with respect to different speeds and cutting angles of the blade. The minimum thickness of bed (1.1 cm) was observed in case of 3000 rpm engine speed and cutting angle of 20°, since the cutting angle was unable to penetrate the blade more than 1.90 cm in the bed. The maximum thickness of 6.0 cm was noticed with engine speed of 3000 rpm and cutting angle of 40°. However, due to larger cutting angle, the blade was getting deep penetration than the required one. This also caused reduction in the forward speed of the equipment, which was affecting

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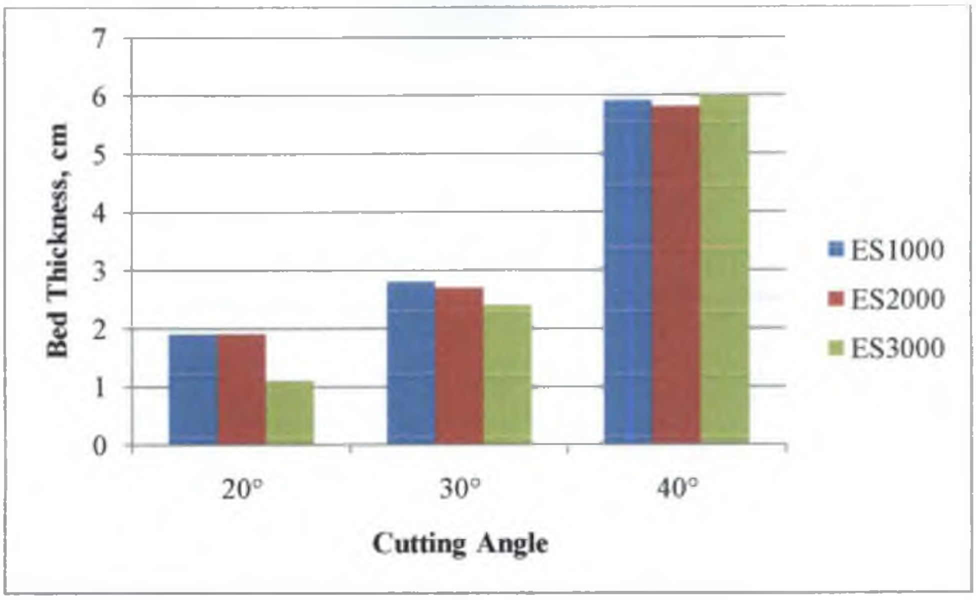

Fig. 4.5 Thickness of bed Vs. Cutting angles w.r.t. three engine speeds

From the field observations it was clear that cutting angle of 30° with engine speed of 2000 rpm was satisfying the requirements (in terms of minimum seedling root damage) for successful seedling uprooting without excess root injuries and with optimum time of operation. Since the cutting angle of 20° with all the three engine speeds resulted in excessive root damage and on other hand, cutting angle of 40° with three engine speeds was engaging with the difficulty in forward motion due to excessive penetration of cutting blade; combination of engine speed of 2000 rpm with 30° cutting angle has proved to be best suited for the successful operation of the machine.

4.5.2 Time of operation

The actual time of operation of rice seedling uprooting unit with respect to three different engine speeds and three cutting angles of blade are shown in the Table 4.4, Fig. 4.7 respectively.

Table 4.4 Time (seconds) elapsed in seedling uprooting with respect to engine speed and cutting angle of blade.

Engine speed (rpm)	Angle of blade		
	20°	30°	40°
1000	133.9	143.9	195.9
2000	49.9	55.1	80.1
3000	25.3	45.3	81.2

Field observations showed that the engine speed and cutting angle of blade has great influence on the time requirement and quality of operation for 10 m of running seedling bed length for each combination of engine speed and cutting angle. A minimum time of operation of 25.3 seconds was observed for the engine speed of 3000 rpm and cutting angle 20°.But at this speed of operation and angle of cutting, the thickness of bed cut was only 1.1 cm, which was found with excessive root damages resulting in loss of viability of seedlings. For the best combination in terms of bed thickness (engine speed 2000 rpm and cutting angle 30°) the elapsed time of operation noticed was 55.1 seconds for 10 m of running seedling bed length. This gave required bed thickness (2.7 cm) in order to avoid root damage and an optimum time of operation as compared to the other combinations of engine speed and cutting angle.

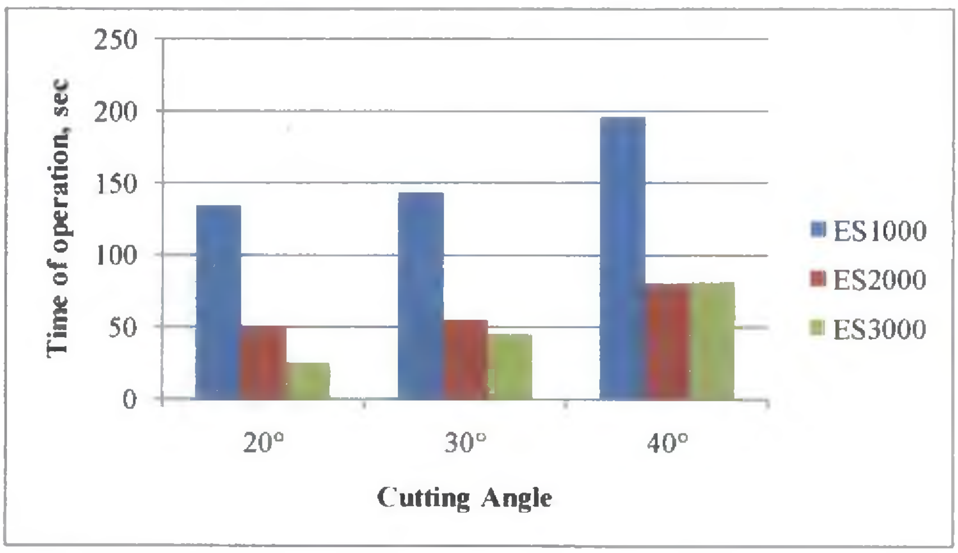

Fig.4.6 Time of operation Vs. Cutting angles w.r.t. three engine speeds

Hence, the cutting angle of 30° with engine speed of 2000 rpm was the most satisfying and best suited for the requirements both in terms of bed thickness and speed of operation. Similar findings were noticed by Swain in 1982, as reported that the draft was minimum for cutting angle of 30° with triangular cutting tool.

4.5.3 Wheel slip

The wheel slip during the operation of rice seedling uprooting unit with respect to three different engine speeds and three cutting angles of blade are shown in the Table 4.5, Fig. 4.8 respectively.

Table 4.5 Wheel slip w.r.t. speed of operation and cutting angle (mean values in %)

Engine Speed (rpm)	Angle of blade		
	20°	30°	40°
1000	26.8	21.6	23.9
2000	30.9	25.4	31.9
3000	32.1	34.1	35.2

Wheel slip during the operation was measured with load and no load conditions of the machine for a 10 m run. The measured wheel slip was in the range of 21.6 % to 35.2 % with respect to three different engine speeds and three cutting angles of the blade.

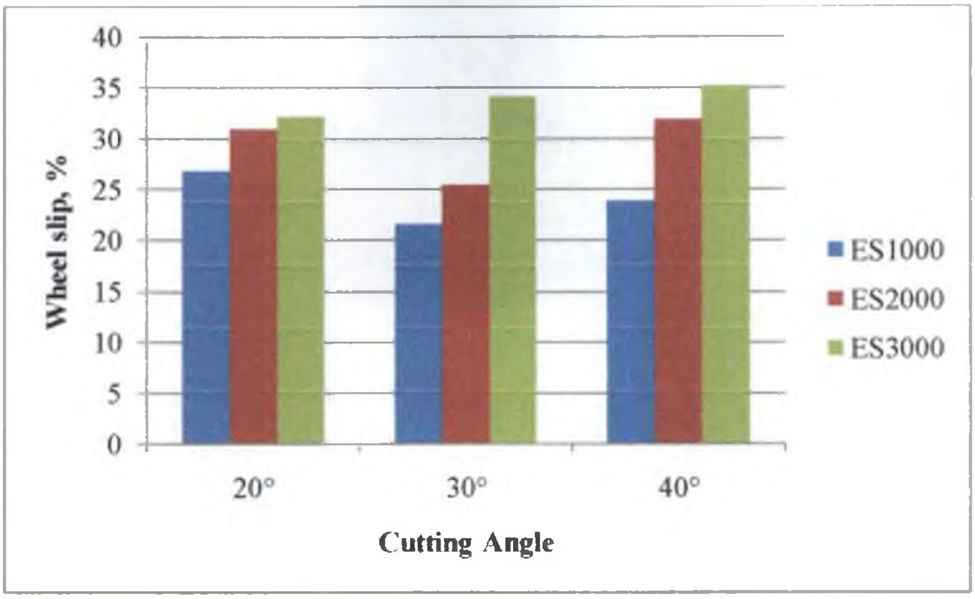

Fig. 4.7 Wheel slip Vs. Cutting angles w.r.t. three engine speeds

The maximum wheel slip of 35.2 % was observed for the cutting angle 40° with engine speed of 3000 rpm, followed by 32.1 per cent wheel slip with 30° cutting angle and 3000 rpm engine speed. Minimum wheel slippage of 21.6 per cent was observed for the cutting angle 30° with engine speed of 1000 rpm, followed by 25.4 per cent wheel slip with 30° cutting angle and 2000 engine rpm. Hence in case of wheel slippage also, the cutting angle of 30° with engine speed of 2000 rpm has been proved to be the best suited for operation of the machine.

4.5.4 Root damage

The damage caused to the root system after the seedling uprooting operation are observed and shown in Table 4.6, Fig. 4.9 respectively.

Table 4.6 Root damage w.r.t. speed of operation and angle of blade on root damage (mean values, in %)

Engine speed (rpm)	Angle of blade		
	20°	30°	40°
1000	93.5	2.1	1.2
2000	96.6	3.3	1.1
3000	97.3	4.1	1.3

From the table it is inferred that maximum damage of 97.3 % occurred with cutting angle 20° and engine speed at 3000 rpm. When the cutting angle is 20° damage were found to be high with all engine speed. This happened because the thickness of bed after cutting at this angle was in the range of 1.1 to 1.9 cm, so that the roots of seedling of about 2.5 cm length may be cut while uprooting. Minimum damage were noticed when the cutting angle is 40° because the bed thickness after cutting were maximum (5.9 to 6 cm) at this angle. Reasonable root damage encountered with cutting angle 30° at different engine speed. When considering other parameters like time of operation and wheel slip also it is evident that the cutting angle of 30° with engine speed of 2000 rpm is the best suited for operation of the machine with less damage.

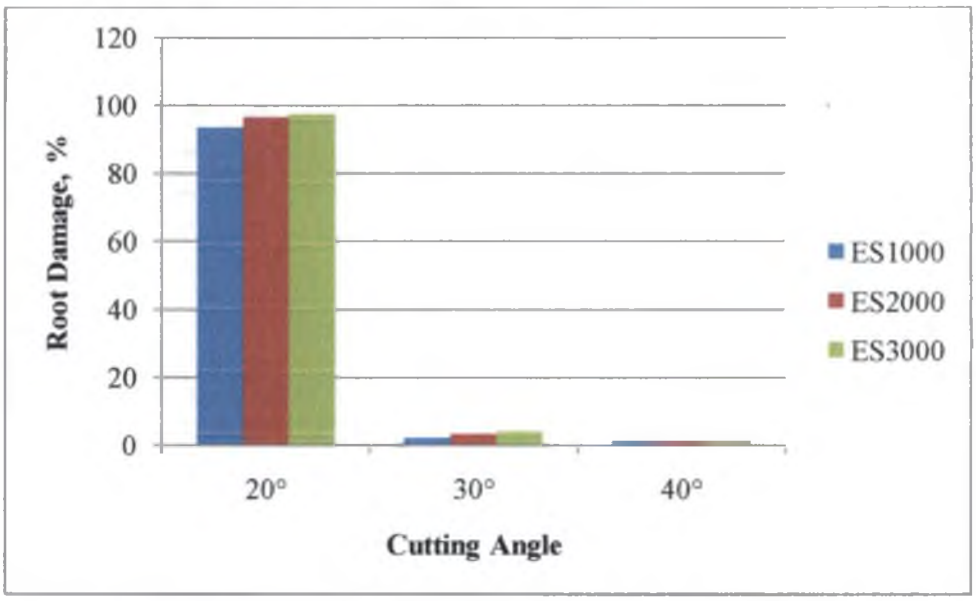

Fig. 4.8 Root damage Vs. Cutting angles w.r.t. three engine speeds

4.6 Performance characteristics of final prototype

The field evaluation of seedling uprooting machine on thickness of bed after cutting, elapsed time of operation, wheel slip and percentage of root damage w.r.t. three engine speeds and three cutting angles was done. It was evident that the 30° cutting angle with 2000 rpm engine speed is the most promising combination for effective seedling uprooting. For this final prototype field performance characteristics like field capacity, field efficiency and fuel consumption were assessed.

4.6.1 Field capacity

The theoretical field capacity was calculated on the basis of width of cutting blade and theoretical speed of machine without considering losses, which was 163.33 m^2h^{-1}. While the actual field capacity was obtained by actual width of bed cut and measured speed of machine with turning losses, which was 132.7 m^2h^{-1}.

4.6.2 Field efficiency

Field efficiency was obtained by the ratio of effective field capacity and theoretic field capacity, which was found to be 81.2 %.

4.6.3 Fuel consumption

The observed fuel consumption for the final prototype was in the range of 0.51 to 0.53 l h^{-1}.

4.6.4 Cost of operation

The field capacity of the developed seedling uprooting machine is 0.0163 ha h^{-1}. Manual uprooting of rice seedling requires 4 x 10^{-3} ha h^{-1}. At the present wage rate of Rs. 300 per day, the total cost of operation by manual method is about Rs. 750 per hectare. By the developed uprooting machine, the total cost of operation is Rs. 250 per hectare. Hence the savings over conventional method is Rs. 500 per hectare. The details of the cost analysis and the field coverage by manual method are given in Appendix V.

SUMMARY AND CONCLUSIONS

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study was conducted to develop a seedling uprooting machine for System of Rice Intensification (SRI). System of Rice Intensification is a method developed in Madagascar in the early 1980's, where, it has been shown that yields can be enhanced by suitably modifying certain management practices such as controlled supply of water, planting of younger seedlings and providing wider spacing In this method 12 to 15 days old root washed seedlings are transplanted on the well puddled field. Only one younger seedling is transplanted per hill with row to row and hill to hill spacing of 25 cm. In this circumstance, there is a need for the mechanization in the uprooting, washing and feeding the seedling to root washed transplanter. On this ground a seedling uprooting unit for system of rice intensification was developed and field tested at instructional farm of K.C.A.E.T.

The seedling uprooting unit was consists of four major components namely bed cutting tool, conveyor unit, main frame and power unit. In order to cut the required thickness of soil bed, cutting tool was developed and fabricated with MS flat sheet of 2mm thickness. It consisted of rectangular base plate (25×30 cm) placed horizontally beneath the cutting blade. The cut seedling beds were conveyed through a slatted belt type conveyor having two adjacent roller chains inter linked with MS flat linkages giving overall belt width of 25 cm and 155 cm belt length. In order to drive the conveyor belt, stoke mechanism and forward motion a power unit from the existing vertical conveyor reaper was chosen. It consisted of 4 hp gasoline engine. According to the geometry of power unit a suitable frame was fabricated using MS angles (3×3 cm) to attach the cutting and conveying unit.

The developed seedling uprooting unit was tested in the field in order to optimize the speed of operation and angle of cutting. Three levels of angle of blade viz., 20, 30 and 40 degrees and three levels of engine speed viz., 1000, 2000 and 3000 rpm were selected for the study. The thickness of bed, time of operation, wheel slip and plant damage were tested with respect to the above selected cutting angles and engine speeds.

The thickness of bed after cutting was in the range of 1.1 cm to 6.0 cm with respect to different speeds and cutting angles of the blade. The minimum thickness of bed (1.1 cm) was observed in case of 3000 rpm engine speed and cutting angle of 20°. The maximum thickness of 6.0 cm was noticed with engine speed of 3000 rpm and cutting angle of 40°. Cutting angle of 30° with engine speed of 2000 rpm was satisfying the requirements (2.7 cm bed thickness) for the successful seedling uprooting without excess root injuries and with optimum time of operation.

A minimum time of operation of 25.3 seconds was observed for the engine speed of 3000 rpm and cutting angle 20°. For the best combination in terms of bed thickness (engine speed 2000 rpm and cutting angle 30°) the elapsed time of operation noticed was 55.1 seconds.

The measured wheel slip was in the range of 21.6 per cent to 35.2 per cent with respect to three different engine speeds and three cutting angles of the blade. The maximum wheel slip of 35.2 per cent was observed for the cutting angle 40° with engine speed of 3000 rpm and minimum wheel slippage of 21.6 per cent was observed for the cutting angle 30° with engine speed of 1000 rpm. In case of wheel slippage also, the cutting angle of 30° with engine speed of 2000 rpm has been proved to be the best suited for operation of the machine.

From the table it is inferred that maximum damage of 97.3 % occurred with cutting angle 20° and engine speed at 3000 rpm. Minimum damage were noticed when the cutting angle is 40° because the bed thickness after cutting were maximum (5.9 to 6 cm) at this angle. Reasonable root damage encountered with cutting angle 30° at different engine speed.

From the field observations it can be concluded that cutting angle of 30° with engine speed of 2000 rpm is best for the effective seedling uprooting in terms of bed thickness, time of operation, wheel slip and plant damage. For this final prototype field performance characteristics like field capacity, field efficiency and fuel consumption were assessed. The theoretical field capacity was computed as 163.33 m^2h^{-1} and field efficiency was found to be 81.2 per cent. The observed fuel consumption for the final prototype was in the range of 0.51 to 0.53 $l.h^{-1}$.

At the present wage rate of Rs 300 per day, the total cost of uprooting and washing of seedlings for cultivating an area of one hectare by manual method is about Rs. 750. While the total cost for uprooting and washing of seedlings for cultivating an area of one hectare by using developed machine was Rs. 250. Hence the savings over conventional method is Rs. 500 for the same operation.

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DEVELOPMENT OF SEEDLING UPROOTING UNIT FOR SYSTEM OF RICE INTENSIFICATION

By

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(2013-18-113)

Abstract

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in

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Kerala Agricultural University, Vellanikkara, Thrissur

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Kerala

2016

ABSTRACT

The present study was conducted to develop a seedling uprooting machine for System of Rice Intensification (SRI). System of Rice Intensification is a method developed in Madagascar in the early 1980's, where, it has been shown that yields can be enhanced by suitably modifying certain management practices such as controlled supply of water, planting of younger seedlings and providing wider spacing. In this method 12 to 15 days old root washed seedlings are transplanted on the well puddled field. Only one younger seedling is transplanted per hill with row to row and hill to hill spacing of 25 cm. The preparation of seedlings for this method involves uprooting from nursery and washing the roots. This is done manually and no mechanical device for uprooting seedlings is available at present. In this circumstance, there is a need for the mechanization in the uprooting, washing and feeding the seedling to root washed transplanter. On this ground a seedling uprooting unit for system of rice intensification was developed and field tested.

The seedling uprooting unit was consists of four major components namely bed cutting tool, conveyor unit, main frame and power unit. In order to cut the required thickness of soil bed, cutting tool was developed and fabricated with MS flat sheet of 2mm thickness. It consists of a rectangular base plate (25×30 cm) placed horizontally beneath the cutting blade. The cut seedling beds were conveyed through a slatted belt type conveyor having two adjacent roller chains inter linked with MS flat linkages giving overall belt width of 25 cm and 155 cm belt length. In order to drive the conveyor belt, a power unit from the existing vertical conveyor reaper was chosen. It consisted of 4 hp gasoline engine. According to the geometry of power unit a suitable frame was fabricated using MS angles (3×3 cm) to attach the cutting and conveying unit.

The developed seedling uprooting unit was tested in the field to optimize the speed of operation and angle of cutting. Three levels of angle of blade viz., 20, 30 and 40 degrees and three levels of engine speed viz., 1000, 2000 and 3000 rpm were selected for the study. The thickness of bed, time of operation, wheel slip

and plant damage were tested with respect to the above selected cutting angles and engine speeds. From the field observations it was found that cutting angle of 30° with engine speed of 2000 rpm was best for the effective seedling uprooting in terms of bed thickness, time of operation, wheel slip and plant damage. For this final prototype field performance characteristics like field capacity, field efficiency and fuel consumption were assessed. The theoretical field capacity was computed as 163.33 m^2h^{-1} and field efficiency was found to be 81.2 per cent. The observed fuel consumption for the final prototype was in the range of 0.51 to 0.53 $l.h^{-1}$. At the present wage rate of Rs 300 per day, the total cost for uprooting and washing of seedlings for cultivating an area of one hectare by manual method is about Rs 750. The total cost for uprooting and washing of seedlings for cultivating an area of one hectare by using machine is Rs 250. Hence a saving of Rs 500 can be expected by using the developed machine for preparing the seedlings required for cultivating one hectare.

APPENDICES

Appendix I

Particle size distribution of soil in the field

Mass of dry soil sample = 1620 g

IS Sieve	Particle size(mm)	Mass retained(g)	% retained	cumulative % retained	cumulative % finer
4.75mm	4.75	326.048	20.126	20.126	79.874
2mm	2	361.475	22.313	42.440	57.560
1mm	1	242.422	14.964	57.404	42.596
600	0.6	184.255	11.374	68.778	31.222
425	0.425	71.111	4.390	73.167	26.833
300	0.3	73.177	4.517	77.684	22.316
212	0.212	234.324	14.464	92.149	7.851
150	0.15	27.368	1.689	93.838	6.162
75	0.075	49.123	3.032	93.838	6.162
Tray		50.525			

Appendix II

Determination of moisture content

Mass of container m_1	Mass of container + wet soil m_2	Mass of container + dry soil m_3	Moisture content $(m_2-m_3)/(m_3-m_1)$	Moisture content in percent
23	55.3	48.1	0.25	25
33	68.4	60	0.2	20
38	76	67.9	0.18	18
23.5	60	52	0.23	23
36	76	67.8	0.2	20
30	77.2	66.4	0.23	23

Sample calculations :

Mass of container, m_1 (g) = 23.00

Mass of container + wet soil, m_2 (g) = 55.30

Mass of container + dry soil, m_3 (g) = 48.1

Moisture content, % = $[(m_2-m_3)/(m_3-m_1)] \times 100$

= (55.3- 48.1)/(48.1-23.00)

=0.25 x 100

Moisture content (%) = 25.00

Appendix III

Determination of bulk density

Mass of core cutter (gm)	Mass of core cutter + wet soil, (gm)	Mass of wet soil (gm)	Height of core cutter (cm)	Internal diameter (cm)	Volume (cm^3)	Bulk density (g/cm^3)	Bulk unit weight (kN/m^3)
1000	2800	1800	13	10	1020.5	1.714	16.822
900	2750	1850	12.6	10	989.1	1.769	17.356
900	2620	1720	12.6	9.5	892.66	1.904	18.682
750	1450	700	11	6.5	364.82	2.055	20.166
550	1250	700	11	6.5	364.82	2.329	22.855
550	1230	680	11	6.7	387.62	1.934	18.98

Sample calculations:

Mass of core cutter, gm = 1000

Mass of core cutter + wet soil, gm = 2800

Mass of wet soil, gm) = 1800

Height of core cutter, cm = 13

Internal diameter, cm = 10

Volume, cm^3 = 1020.5

Bulk density, g/cm^3 = Mass/ volume

= 1.714

Appendix IV

Determination of penetration resistance

Depth (cm)	Force (Kg)	Force (N)	Cone area (m^2)	CI (N/m^2)	CI (MPa) ($N/m^2 X10^{-6}$)
0	0	0	0.00032	0	0
1	0	68.67	0.00032	214593.75	0.215
2	7	147.15	0.00032	459843.75	0.46
3	15	264.87	0.00032	827718.75	0.828
4	27	294.3	0.00032	919687.5	0.92
5	30	323.73	0.00032	1011656.25	1.012
6	33	382.59	0.00032	1195593.75	1.196
7	39	68.67	0.00032	214593.75	0.215

Sample calculations:

Depth of penetration, cm = 2

Force applied, kg = 7

= 147.15 N

Cone area ,m^2 = 0.00032

Cone index = Force/ Cone area

= 459843.75 Nm^{-2}

= 0.46 MPa

APPENDIX V

Calculation of operational cost of seedling uprooting machine

The initial cost of seeding uprooting machine has been calculated by adding up the cost of individual components involved in the fabrication at the prevalent market price. These were then added to a reasonable percentage for fabrication cost and marginal profit of manufacture.

The unit cost was calculated by adding the fixed cost and variable costs.

Initial cost of machine

The initial cost of the uprooting machine was calculated on the basis of total materials used in fabrication and the detail account given in appendix. Cost of operation as25% of the total cost was assumed

The fabrication cost of seedling uprooting machine is

$$= (21690 \times 25)/100 = 5422.5$$

Hence the total cost of the uprooting machine $= (21690 + 5422.5)$

$$= 27{,}125.5 \sim 27000$$

Economic analysis

Following assumptions was made for economic analysis of seedling uprooting machine.

1. Expected life of uprooting machine = 8years
2. Annual use of machine can be calculated as follows

   Uprooting period for paddy crop/year = 60 days

   Total annual used = 480h per year, when working hour is 8h/day

   Salvage value of the uprooting machine = 10% of the initial cost.

Fixed Cost

1. Annual depreciation (by straight line method)

$$D = \frac{c - s}{L}$$

$$D = \frac{27000 - 2700}{8}$$

= ` 3075.5/ year

2. Interest on investment at 10% of initial cost

$$I = \frac{c + s}{2} \times \frac{i}{100}$$

$$I = \frac{27000 + 2700}{2} \times \frac{10}{100}$$

= ` 1485/ year

3. Shelter, insurance and tax cost @ 2% of initial cost

= (27000 × 2)/100 = ` 540/ year

Therefore, Total Fixed cost per year = 3075.5 + 1485+ 540= ` 30615/ year

Hence, total fixed cost per hour = ` 10.62/ hour

Variable Cost

1. Repair and maintenance cost @2.5% of initial cost

= (2.5 × 27000)/100 = ` 675/ year

Cost per hour = 675/480 = ` 1.40/ hour

2. Fuel consumption = 0.53 l /h

Cost of fuel per litre = ` 70

Fuel cost = 70 × 0.53 = ` 37.1/ hour

3. Lubrication cost = 1.5 % of fuel cost = 0.556/ hour

4. Wages of operator = ` 300 per day

Wages per hour = 300/8 = ` 37.5/ hour

Total operating cost = 1.40+ 37.1 + 0.556 + 37.5 = ` 76.55/ hour

Therefore, total cost of uprooting of seedling with developed uprooting machine per hour

= Fixed cost + Variable cost

= 10.62 + 76.55= ` 87.17/hour

Average effective field capacity of uprooting machine was taken from the experimental data.

Hence the operational cost of uprooting machine per hectare

= (Total cost of uprooting per hour)/ Effective field capacity

= (87.17/0.0163) = ` 5347/ ha

The seedlings needed for transplanting 1 hectare required 2.5 cent

= 5347/100

= Rs 53.47

For manual operation, the cost for preparing seedlings required for 1 hectare

Cost for manual uprooting of seedling = 37.5Rs/hour

Cost for manual uprooting of seedling per cent = 300Rs

Materials used for various parts of the seedling uprooting unit.

Sl. No	Name of the component	Material used
1	frame	MS angle
2	shaft	MS rod
3	Supporting frame	MS flat
4	Cutting blade	MS sheet
5	sprocket	Cast iron
6	chain	Alloy steel
7	Bearings (balls)	Chrome alloy steel
8	wheel	MS rod

Energy Calculation

Energy Equivalents for different inputs

Human = 1.96 MJ/ man- hours

Fuel (Kerosene) = 48.23 MJ/l

Iron = 60 MJ/Kg

Human Energy = Time of operation (h/ha) × Energy equivalent × Number of persons required

= 4.1 × 1.96 × 1 = 8.036

Machine energy $M_e = \frac{60 \times Wmc \times Tr}{AWH \times L}$

Where,

Me = Machine Energy (MJ/ha)

Wmc = Weight of the machinery (Kg)

Tr = Time required (h/ha)

AWH = Annual working hours (h)

L = Useful life (years)

Me = (148 × 4.1 × 60)/(480 x 8) = 9.48

Fuel Energy

Fuel consumption = 0.53 l/h

Fuel consumption for 4.1 h/ha = 4.1 × 0.53 = 2.173 l/ha

Fuel energy = Fuel consumption × Energy equivalent of fuel

= 2.173 × 48.23 = 104.803

Total energy for uprooting machine = Human energy + Machine energy + Fuel energy

= 8.036 + 9.48 + 104.803 = 122.319 MJ/h

Human energy required for manual operation

Seedling uprooting by manual operation requires 15.4 h/ha

Energy required for manual uprooting = 15.4×1.96

= 30.184 MJ/h

Abstract of cost of seedling uprooting unit.

Sl.No	particular	No of units	Market rate	Total cost
1	Prime mover- engine	1	14,000	14,000
2	Gear box	1	6,000	6,000
3	Sprocket	4	175	750
4	Chain	2	280	560
5	Bearing	2	150	300
6	Bush	2	15	30
7	Nut, bolt and washer	750 g	67	50

Total cost = 21690

APPENDIX VI

Specification of prime mover

Rated output, kW	:	3.0
Fuel used	:	Petrol
Model and Make	:	SHRIRAM-HONDA GK200
Overall dimension (length × width × height) mm	:	2370×1500×1070
Weight, kg	:	126.5
Engine Details	:	197 cc
Type	:	Single cylinder, 4-stroke, air cooled,
Maximum horse power, HP	:	4.0
Rated speed, rpm	:	3000
Fuel tank capacity,	:	2.5 l
Starting system	:	Recoil start