DEVELOPMENT OF A POWER TILLER OPERATED PADDY TRANSPLANTER FOR CONVENTIONAL SEEDLINGS

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Technology
in
Agricultural Engineering

Faculty of Agricultural Engineering and Technology
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DECLARATION

I hereby declare that this Project Report entitled **"DEVELOPMENT OF A POWER TILLER OPERATED PADDY TRANSPLANTER FOR CONVENTIONAL SEEDLINGS"** is a bonafide record of work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date : 4.3.1995

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CERTIFICATE

Certified that this Project Report entitled **"DEVELOPMENT OF A POWER TILLER OPERATED PADDY TRANSPLANTER FOR CONVENTIONAL SEEDLINGS"** is a record of original work done independently by **Mr. Prakash, K.V.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Dedicated to
My Loving Parents

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Prakash, K.V.,** a candidate for the degree of Master of Technology in Agricultural Engineering with major in Farm Power and Machinery, agree that the thesis entitled **"DEVELOPMENT OF A POWER TILLER OPERATED PADDY TRANSPLANTER FOR CONVENTIONAL SEEDLINGS"** may be submitted by Mr. Prakash, K.V., in partial fulfilment of the requirement for the degree.

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ACKNOWLEDGEMENTS

I express my special appreciation and deep sense of gratitude to Dr. M. Sivaswami, Assistant Professor, Department of Farm Power Machinery and Energy, Chairman of the Advisory Committee for his able guidance and encouragement at all stages of the work. Comments and suggestions made by him were extremely helpful in the preparation of thesis.

Heartfelt thanks are due to Er. Jippu Jacob, Associate Professor and Head of Department of Farm Power Machinery and Energy; Dr. K. John Thomas, Dean i/c, KCAET, Tavanur and Er. M.R. Sankaranarayanan, Assistant Professor (Agril. Engg.), College of Horticulture, Vellanikkara, members of the Advisory Committee for their suggestions and co-operation to complete this thesis work.

I am grateful to the staff members of the All India Co-ordinated Research Project on Farm Implements and Machinery (ICAR) for their help during research work.

I must acknowledge my gratitude to the technicians Shri. Jose and Shri. Vijayan who contributed their enthusiastic help during the fabrication.

It is a pleasure to express my thanks to the friends especially Er. Selvan, Er. Sushilendra, Er. Anand Bhose and

Er. Jayarajan for their help during the evaluation and field operation of the implement done at KCAET Instructional Farm, Tavanur.

My sincere thanks were extended to the staff and friends who have helped me either directly or indirectly for the completion of thesis.

I thank Mr. O.K. Ravindran, C/o Peagles, Mannuthy for the neat typing of this manuscript.

Tavanur
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SYMBOLS AND ABBREVIATIONS

Agric.	-	Agricultural
APAU	-	Andhra Pradesh Agricultural University
ASAE	-	American Society of Agricultural Engineers
BIS	-	Bureau of Indian Standards
CFMTTC	-	Central Farm Machinery Training and Testing Centre
CIAE	-	Central Institute of Agricultural Engineering
cm	-	centimetre(s)
Dept.	-	Department
dia.	-	diameter
edn.	-	edition
et al.	-	and other people
F.C.	-	Field Capacity
Fig.	-	Figure
FIM	-	Farm Implements and Machinery
GI	-	Galvanised Iron
ha	-	hectare(s)
hp	-	horse power
hr	-	hour
ICAR	-	Indian Council of Agricultural Research
IRRI	-	International Rice Research Institute
ISAE	-	Indian Society of Agricultural Engineers
J.	-	Journal
KAU	-	Kerala Agricultural University

KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kg	-	kilogram
km/hr	-	kilometre per hour
Lit	-	Litre
m	-	metre(s)
min.	-	minute(s)
mm	-	millimetre
MJ	-	Mega Joule
MS	-	Mild Steel
M/s	-	Messers
NIAE	-	National Institute of Agricultural Engineering
No.	-	Number
PAU	-	Punjab Agricultural University
pp	-	Pages
Proc.	-	Proceedings
RNAM	-	Regional Network for Agricultural Machinery
rpm	-	revolutions per minute
Rs.	-	Rupees
Sec.	-	Seconds
TNAU	-	Tamil Nadu Agricultural University
U.K.	-	United Kingdom
var	-	variety
Wt.	-	weight
/	-	Per
%	-	per cent
°	-	Degree

Introduction

INTRODUCTION

Paddy is one of the important agricultural commodities in world trade even though it is less than five per cent of the total production of all agricultural commodities. India had never been among the rice exporting nations until it attained self-sufficiency in rice during early eighties.

Paddy is grown in high-rainfall areas or in areas where supplemental irrigation is available to ensure good yields. If the crop has to depend solely on rainfall, it requires not less than 30 cm of rainfall per month over entire growing period. India is the second largest rice producing country in the world. In 1988-89, it produced 70.67 million tonnes of rice from an area of 41.86 million ha. In 1989-90, India was able to step up its rice exports to a level of over 0.40 million tonnes. The growth since then increased gradually touching a record export of 0.75 million tonnes in 1991-92. In 1992-93, the export declined to 0.56 million tonnes due to reduction in production level.

Transplanting of paddy seedlings in puddled soil is one of the most widely accepted cultivation practices for paddy crop. Studies have shown that transplanted paddy crop

gives higher yield compared to other methods of cultivation. Manual transplanting of paddy seedlings which is very tedious and requires about 40 to 50 man-days per ha. Acute labour shortage during transplanting season and increased wages of farm labourers have compelled the paddy growing countries to think of mechanising the paddy cultivation. Efforts are on for many years to develop suitable manual, animal drawn, power tiller mounted, tractor drawn and self-propelled paddy transplanters to tackle the problem but with only limited success. The interest in research on paddy transplanter had its ups and downs in India. Though manual transplanters increase the output of the farm labourer, machine is not accepted due to the low field coverage and requirement of special (mat) type seedlings.

It has been observed in Kerala that the area of paddy cultivation is decreasing steadily over the last few decades. In 1983-84, the area under the paddy was 0.74 million hectare which has been reduced to 0.52 million hectare in 1992-93 (Farm Guide, 1986 and 1994). The area under paddy is being reclaimed for raising other crops like coconut and for construction purposes, as the paddy cultivation was reported to be under loss for farmers, because of of high labour wages. Moreover high labour scarcity is also experienced during peak seasons like transplanting, harvesting and threshing. This

necessitates the introduction of labour saving and economical farm machinery in the paddy cultivation areas of Kerala.

A transplanter with high field capacity using conventional root washed seedlings, which can be operated by commonly available power tillers will readily be accepted by the farmers in Kerala. This will reduce the cost of cultivation and as well take care of labour scarcity in paddy cultivation in addition to increasing in the annual use of power tillers.

Hence, the development work on a power tiller operated paddy transplanter for conventional root washed seedlings was taken up with the following objectives:

1. To study the different mechanical transplanters including the manually operated and self-propelled types.

2. To develop power tiller operated paddy transplanter suitable for conventional root washed seedlings.

3. To develop a suitable power transmission system for operating the transplanter with power tiller.

4. To evaluate the performances of float, seedling tray movement, a picker arm and to study the feasibility and economics of operation of transplanter in Kerala.

Review of Literature

REVIEW OF LITERATURE

This chapter deals with the research works which were carried out in India and abroad. It is a well-known fact that the transplanted paddy gives more yield than broadcast paddy. Development of paddy transplanters in various countries as well as in India and their technical details were studied in the following sections.

1. Methods of planting paddy
2. Development of paddy transplanters

2.1 Methods of planting paddy

Paddy crop can be raised by the following two systems.

2.1.1 Direct seeding

Direct seeding in dry conditions can easily be achieved by a seed drill. Problems are encountered in sowing in rows under low land wet conditions. Seeds could be uniform and germinated only slightly to avoid entangling during the metering. The flutted roller metering mechanism is found effective for uniform distribution. Controlled germination of seeds is an essential pre-requisite for a mechanical device

to work satisfactorily. A low land row seeder is usually a pull type machine for easier operation.

2.1.2 Transplanting

Transplanting of paddy seedlings in puddled soil with standing water is the most wide spread technique used throughout the Asian countries. Two to four seedlings are planted in a hill manually in rows. Row planting permits easy mechanical weed control, interculture operations and increase in yield. Transplanting has the advantage of requiring less precision in land preparation and creating the conditions for better weed control. This system permits growing the seedlings in nursery under favourable conditions.

Timeliness of transplanting was considered as very essential for optimising the yield and there has been an increase in realisation among paddy growing countries to design and develop transplanters capable of performing precise and transplanting of paddy seedlings at an acceptable cost (Kurup and Datt, 1981).

2.2 Development of paddy transplanters

A review of developments in the mechanisation of paddy production was carried out through literature search, visits and personal communication. In developed and

industrialised countries, paddy production is fully mechanised. While most of the farm operations in paddy production in developing countries are still carried out by manual labourers. Development of machinery in the appropriate technology line is currently taking place in some developing countries. Japan has developed some small motorized machines which are adequate for small scale farming in poor countries (Igbeka, 1984).

China and Japan progressed in their own way and several transplanters were developed Japan started using soil bearing seedlings in 1960 with transplanters (Quiang, 1986).

In China, the mechanisation of paddy production was carried out at different stages. Three phases of developments were described. In sixties, manually pulled transplanters were developed but not successful. In seventies, motorized and manually operated transplanters were manufactured but the techniques of raising paddy seedlings and uprooting the seedlings by machine were not efficient and moreover transplanting quality was low. The eighties saw the introduction of Japanese transplanters, techniques and adoption of these methods in China (Wang and Zhang, 1989).

In 1964, development project on a simple hand operated transplanter was initiated at National Institute of

Agricultural Engineering (NIAE) in United Kingdom (U.K) resulting in a prototype which was tested at Budni in 1966. The machine was mostly made out of wood and weighed only 20 kg. It was operated by one man and transplanted in four rows 225 mm apart at a time. The mechanical finger-set when actuated by the operator, picks the seedlings from seedling tray, returns and plants them in soil. The machine had an output rate of upto 0.08 ha per a day of 8 hr under optimum field conditions. This machine had certain limitations for its successful adoption under Indian field conditions. Loss of time during operation was observed because of washing and arranging the seedlings in the tray. Again the periodical cleaning of transplanting fingers against sticking roots reduced the rate of work substantially (Dass and Ratnam, 1989).

2.2.1 Manual transplanters

Manual transplanting is the most common method of transplanting by the way of placing the seedlings in the puddled field by the hand. This operation requires considerable labour and involves human drudgery. In many areas, manual transplanting is done in rather a casual manner and not in rows which creates problem in weeding. Transplanting in rows in one hectare area normally requires 50 man-days. The cost of operation works out to be Rs.1000 to

Rs.1500 depending on the availability of the labourers, their wages and capacity to work.

In around 1950, a hand transplanting aid was developed in Taiwan. It consisted of an iron rod with a fork forged on one end. The rod was fitted to a wooden handle. The overall length of tool was about 45 cm. During operation, the fork picked up two to four seedlings which were punched into the puddled soil. It required considerable skill but with experience, the rate of planting could be increased by about 20 per cent compared to manual transplanting. The device also reduced stooping (Stout, 1968).

Mandhar (1975) designed and developed a three-row transplanting aid for paddy. It consists of main frame, three seedlings, retainer at the bottom, three planting fingers and an actuating mechanism. The device was reported to require about 300 man-hr per ha which practically saved no labour.

International Rice Research Institute (IRRI) started research on paddy planters using Chinese transplanters and introduced the cam deflected five-row manual model for mat seedlings with field capacity of 0.20 ha per day. The improved six-row model, with inertia control mechanism, have a field capacity of 0.30 ha per day (Salzar et al., 1986).

2.2.2 Mechanical transplanters

In 1974-75, for first time in India, two different makes of Japanese transplanters have been tested at CFMTTC, Budni. Both are self-propelled (small petrol engine operated) two-row (fixed spacing) walking type. Because of the requirement of the special mat type seedlings and main field condition as per the manufacturer, further work had not been taken up (Anonymous, 1975).

It is also a needful aspect to know the relationship between the physical characteristics and the injury seedlings during mechanical transplanting. Around 10 to 42 per cent of four-leaved paddy seedlings sustained injury during mechanical transplanting. Mostly the damage appeared in the form of scratches on basal leaf sheaths and buckling of upper leaf blades. But less than 10 per cent suffered buckling or cutting of basal parts with effects on plant growth. Short seedlings with hard, elastic sheaths and erect short leaf blades suffered less damage than did other seedlings. It was recommended that seedlings transplanted mechanically should be less than 20 to 22 cm in height, less than 0.35 to 0.40 in buckling index and less than 0.15 to 0.20 in natural deflection ratio (Nishio and Fujii, 1975).

In Japan, existing mechanised paddy transplanters was controlled by a seated operator and consists of a single planting finger operated by a crank axle. Planting accuracy is affected by vibration when the speed of the drive axle exceeds 300 rpm. The new paddy transplanter has two planting fingers linked by a rotating axle operated by an eccentric system. The system allows the planting fingers to maintain a constant course with vibration and gives two plantings for each rotation of the axle. The prototype model was 2.80 m long, 2.20 m wide and 1.40 m height and weighs 437 kg. It had six-planting units at 30 cm apart. It can plant at a speed of 0.40 to 1.10 m per sec with a spacing of 14 to 18 cm. The design reduced the vibration and torque on the planting fingers, increasing the accuracy and decreasing plant damage compared with crank operated transplanters (Kikaika and Nogyo, 1986).

The picking performance of a four-row self-propelled riding type paddy transplanter was evaluated under two different field conditions. The first field was prepared using a rotary cultivator attached to a 22 kilo watt four-wheel tractor for both first ploughing and puddling. The second field was ploughed using conventional mould board plough and puddling was carried out using a raker attached to the two-wheel walking type tractor. Planting accuracy of the

transplanter was measured in these fields. The missing hills and floating hills in the first field were measured to be 6.33 per cent and 1.33 per cent respectively with no observed buried hills. In the second field the missing and buried hills were measured to be 2.33 per cent and 2.00 per cent respectively with no observed floating hills. The mechanical properties of soil which affected the transplanter performance were also measured and were discussed (Earmopas et al., 1988).

The Sri Lankan version of IRRI paddy transplanter (Mark II) was used experimentally in Philippines. It was very well suited to paddy farmings in South-East Asia and in several regions of Philippines. The successful adoption of Mark II transplanter was achieved by the training given to farmers in techniques and in repair and maintenance (Anonymous, 1991).

2.3 Transplanters using non-conventional seedlings

Non-conventional seedlings are usually raised in special nursery trays (frames). Broadly, non-conventional seedlings can be classified as pot type, band type, continuous band type and mat type. In pot type, 30 to 35 day old paper pot seedlings of paddy are used. Paper pots of 1.50 x 1.50 cm section and 3.00 cm height were filled with soil and seeds planted. The paper pots were arranged in

blocks. Each block contained 760 pots in 38 rows of 20 pots. To cover one hectare area, 350 blocks of seedlings were necessary. These pots were filled with loam or clay loam soil manually or power packing machine. After 30 to 35 day of growth in the nursery, the paper pots with seedlings were separated by gently beating. The separated seedlings were carried to the field. The seedlings were manually broadcast with 10 to 15 pots at a time which require only 10 to 12 man-hr per ha.

In band type, the box was divided by partitions to provide bands of seedlings which were 7 to 10 mm wide. The bands were cut at the time of transplanting into blocks of 10 to 15 mm length. In continuous band type, seedlings are grown in continuous bands in a box between plastic folded partitions. The seedlings are taken out of the box and fed into machine. To increase the tensile strength of the band, a film of porous artificial fibre is laid in the bottom of boxes.

In mat type, there are two methods. In single frame method, frames were kept side by side and paddy seedlings grow like a mat. The frames can be removed one week after sowing. In double frame method, another frame is positioned on the top of the first one. The top frame could be removed with the

removal of seedlings only. The transplanting unit was able to cut and slice out blocks of seedlings from the mat.

Five-row and six-row transplanters were developed on the lines of four-row unit by IRRI. The operation of the five-row transplanter was similar to the four-row paddy transplanter. Karunanithi et al. (1983) evaluated the five-row manually operated paddy transplanter. They studied the different methods of preparation of mat type nursery and performance of the manually operated paddy transplanter. They found that the capacity of the machine was 0.10 ha per day. There was 40 per cent saving.

Reddy (1984) designed and developed a ground wheel driven manually pulled paddy transplanter. The principle of four-bar mechanism was used for operating the planting fingers. The drive was taken from the ground wheel and transmitted through chain and sprocket as well as through geared wheels. The seedling tray frame was fabricated similar to that of IRRI five-row transplanter. The planting fingers at a distance of 20 cm, each fixed on an angle iron bar, was assembled on a four-bar mechanism. The motion of the intermediate shaft was transmitted to operate the tray movement and nursery pushing mechanism. During the initial trials, the machine gave a field capacity of 0.30 to 0.40 ha per day.

IRRI paddy transplanter was evaluated in clay-loam soil conditions of Tamil Nadu to find out its adaptability. The mat type nursery raising technique was studied in detail with respect to soil base and seed rate. In case the soil contains more than 50 per cent of clay or farm yard manure soil has was recommended for the base. The force required at the handle to operate the unit was analysed and found to be within the range of human effort for continuous operation. An area of 0.13 ha can be covered by the unit in a day of eight-hour. There was a labour saving of 43.60 per cent and financial saving of 15.80 per cent (Manian et al., 1987).

A ten row manually operated paddy transplanter using mat type seedlings was evaluated to optimize the seedling mat parameters. The influence of mat moisture content and seedling age on the number of seedlings planted per hill was studied for soil mats. Seedlings of four different ages at five different moisture contents were considered at an average seedling density of seven plants per square cm. The desired three to four seedlings per hill were obtained at 20 to 25 per cent moisture content of mat with 25 to 30 day old seedlings (Swain and Maity, 1989).

A self-propelled riding type paddy transplanter using mat type seedlings was developed at Ludhiana. It had a field capacity of 0.20 ha per hr and costs around Rs 25,000.

The performance of the machine was very good when seedlings were properly prepared and are 20 to 28 day old. The mechanical transplanting of paddy was possible only in the regions where there was control in the fields and also where the farmers were ready to adopt raising of mat type seedlings for successful operation of the machine (Devnani, 1990).

The five-row and the six-row IRRI manually operated paddy transplanters were evaluated in Kerala between 1984 and 1990 after standardizing the method of raising mat type seedlings. It was observed that six-row paddy transplanter gave a field capacity of 0.017 ha per hr with field efficiency of 85 per cent with a saving of Rs.600 per ha. A need for development of higher field capacity transplanter was observed (Sivaswami, 1985 and Sivaswami, 1990).

2.4 Transplanters using conventional seedlings

Hoshino (1974) reported of a power tiller operated paddy transplanter which was commercially available during sixties in Japan. The seedlings were root washed, arranged and then transferred to the seedling box. Only two or four seedlings were taken out by a claw. The holding claws made of rubber held the seedling at lower part and carried them above the seedling receiving springs.

Sandhu (1975) reported the development of a bullock drawn paddy transplanter for conventional seedlings. A wooden circular disc of 75 cm diameter with 12 spring loaded fingers of 15 cm length each arranged serially at the periphery of the disc was the main part of the machine. The disc was driven by a ground wheel by means of a chain and sprocket. The seedlings were arranged in a box after cleaning and proper sizing, which were gripped and planted in the soil by the fingers. The opening and closing of the fingers were caused by a pair of stationary wooden cams. It was also observed that the performance of the machine was not satisfactory.

An experimental power operated paddy transplanter having two mechanical fingers was developed and evaluated in the laboratory. The transplanter consists of (i) a tray which holds and feeds the seedlings, (ii) a finger mechanism to pick up and release the seedlings, (iii) a mechanism to oscillate the finger assembly between the point of pick up and release. The tray is rectangular box of 92 cm x 22 cm x 15 cm. By means of screw feeding system, seedlings were pushed continuously towards the tray opening by means of a cam and follower assembly and a gear box. The seedling tray moves forward when the seedlings are to be picked up by the fingers after which the tray returns to its original position (Parida and Das, 1977).

In Tavanur, IRRI six-row paddy transplanter designed for mat type nursery seedlings was modified and tested for conventional seedlings. The test results showed that the field capacity was improved from 0.013 ha per hr to 0.016 ha per hr. The field efficiency was also improved from 48.26 per cent to 56.87 per cent (Bainu, 1990).

Andhra Pradesh Agricultural University (APAU) power tiller operated paddy transplanter was evaluated in Kerala. Problems in mounting the transplanter, assembling auxillary gear box, worm and pinion gear, alignment of the picker arm, reciprocating movement of seedling tray were noted. The defects were rectified and again field evaluation was carried out. The percentage of missing hills, floating hills and buried hills were 8.20, 10.50 and 3.00 respectively. An actual field capacity of 0.10 ha per hr with a field efficiency of 66.70 per cent was achieved. A saving of an amount Rs.560 per ha and 235 man-hr per ha were also observed compared to the manual transplanting. Need for improvements to float, picker arm, seedling tray movement and power transmission system was observed (Sivaswami, 1993).

In India, for the last 25 years, research on paddy transplanters were on progress with only limited success. Manual transplanters are not accepted by farmers as they are drudgery to operate and have only less field coverage. The

need for development of a power operated was felt to face the labour shortage during transplanting seasons. The use of mechanical transplanter increases the efficiency of an operator as well as productivity of the farm. The power tiller operated paddy transplanter for conventional seedlings will be best suited and will be acceptable to farmers of Kerala. Hence, the present research work has been undertaken to fabricate and to test a power tiller operated paddy transplanter for conventional root washed seedlings.

Materials and Methods

MATERIALS AND METHODS

This chapter deals with the description of various components, their functional parameters, procedure adopted for the field test, critical evaluation and practical utility of the newly fabricated power tiller operated eight-row paddy transplanter for conventional seedlings.

The latest manually operated IRRI six-row paddy transplanter which was extensively field tested in India was also evaluated in different field conditions in Kerala for several years. This paddy transplanter was not accepted by the farmers because of the lower field capacity, drudgery in usage and lack of experienced field labourers as well as difficulties in raising suitable mat type nursery. The farmers desire was to have a power operated transplanter which will use the conventional seedlings, which were pulled from the nursery and used in transplanter after washing the roots.

The power tiller is more suitable in paddy growing areas for different field operations. The power tillers are used for an extensive range of operation embracing tilling, puddling, levelling the fields and hauling as well as pumping the water. Because of their adaptability to different field and soil conditions such as narrow tracts, soft or sloping

lands, they have a very wide range of applications. In India where paddy is grown mostly in low lying areas with high rainfall, by the small and marginal farms sharing the major portion, the power tillers are found best suited and are in use in large numbers. Considering this fact the power tiller was selected as the prime mover for operating the paddy transplanter.

The 8 to 10 hp air cooled diesel engine mounted power tiller (Mitsubishi Make, CT85 Model) was used for the research purpose. The detail specifications of the power tiller is given in Appendix 1.

3.1 Studies on the APAU eight-row paddy transplanter

At APAU, Hyderabad a eight-row paddy transplanter was developed to be mounted on a power tiller. One prototype of the transplanter was got fabricated by M/s Andhra Pradesh State Agro Industries Development Corporation Limited, Hyderabad. Detail studies on the components and working of the transplanter was carried out with the Mitsubishi power tiller for evaluation in laboratory conditions.

3.1.1 Laboratory study

Several problems were observed in mounting the paddy transplanter with the power tiller, in assembling the

auxillary gear box with power tiller rotary gear unit, slipping of worm and pinion gear set, the problems in reciprocating movement in nursery feeding tray as well as in picker arm assembly.

The auxillary gear box was subjected to several improvements by the way of finishing the surfaces and using two rubbers and one metal packing to avoid any oil leak from the power tiller gear box. The gears were aligned and correctly set in. To avoid the oil leak along the output shaft of the auxillary gear box, an oil seal assembly was additionally provided.

The problems in the hitching limbs, connecting pins and vertical hitch adjustment lever were rectified to bring the float parallel to the puddled soil. The main shaft of the paddy transplanter was re-aligned and slippage and other problems observed in the worm and pinion gear set were rectified. The problems in the power transmission system to the reciprocating tray movement was partly rectified. Maximum care was taken in adjusting the four-bar mechanism, picker arm assembly and planting fingers to give satisfactory results in the laboratory conditions. The special type of cage wheels suitable to the paddy transplanter were fitted and long duration laboratory trials on paddy transplanter, running to

three weeks duration, were carried out in the laboratory conditions.

3.1.2 Field evaluation

After these minor adjustments, the unit was evaluated at Kelappaji College of Agricultural Engineering and Technology (KCAET) farm during September and October, 1993. The main field was puddled with tractor and levelled. After 24 hour the excess water was drained and a thin layer of water was maintained in the main field. Without seedlings the transplanter was evaluated in the field for its smooth operation. The following problems were observed:

1. The puddled soil accumulated in front of the float and started forming a pair of small ridges at both the sides of the float.

2. In the field, the alignment of the picker arm assembly and fingers were again disturbed due the variation in the levels between the power tiller and transplanter in the puddled land.

3. It was found that some of the fingers were touching the mouths of the feeding frame assembly. The fixtures of the fingers with picker arm assembly were found to be weak.

4. In the field conditions, the reciprocating tray movement assembly was not functioning properly.

The above problems were temporarily rectified and the unit was again field evaluated. The seedlings (Var:Red Triveni) which was 20 days old and pulled, root washed and bundled by the labourers for their usual manual transplanting was used. The following field problems were observed:

1. The nursery feeding tray used to bend backward when the tray is full and tilt forward when the nursery feeding tray became empty.

2. The nursery feeding tray was in curve shape and placed at an angle of 40 degrees to the horizontal plane. This made the paddy seedlings to move down at slower rate to the feeding frame assembly.

3. The nursery feeding tray was not uniform due to slippage in worm and pinion gear set. The seedlings were not continuously fed to the planting fingers for uniform picking.

4. The seedling mouth of the feeding frame assembly has dimension of 16 mm x 135 mm compared to planting finger size 10 mm x 10 mm. This caused falling of seedlings from both the sides of the mouth. This increased the percentage of floating hills.

5. The alignment of the picker arm assembly was not parallel causing damage to the feeding frame assembly.

The above field problems were rectified to carry out preliminary field tests. The major problems such as seedling tray movement, wooden float design and alignment of the picker arm assembly cannot be rectified permanently. Considering all these problems and based on field experiences, it was decided to develop and fabricate a new version of paddy transplanter suitable for conventional seedlings, which traditionally prepared, pulled and root washed manually.

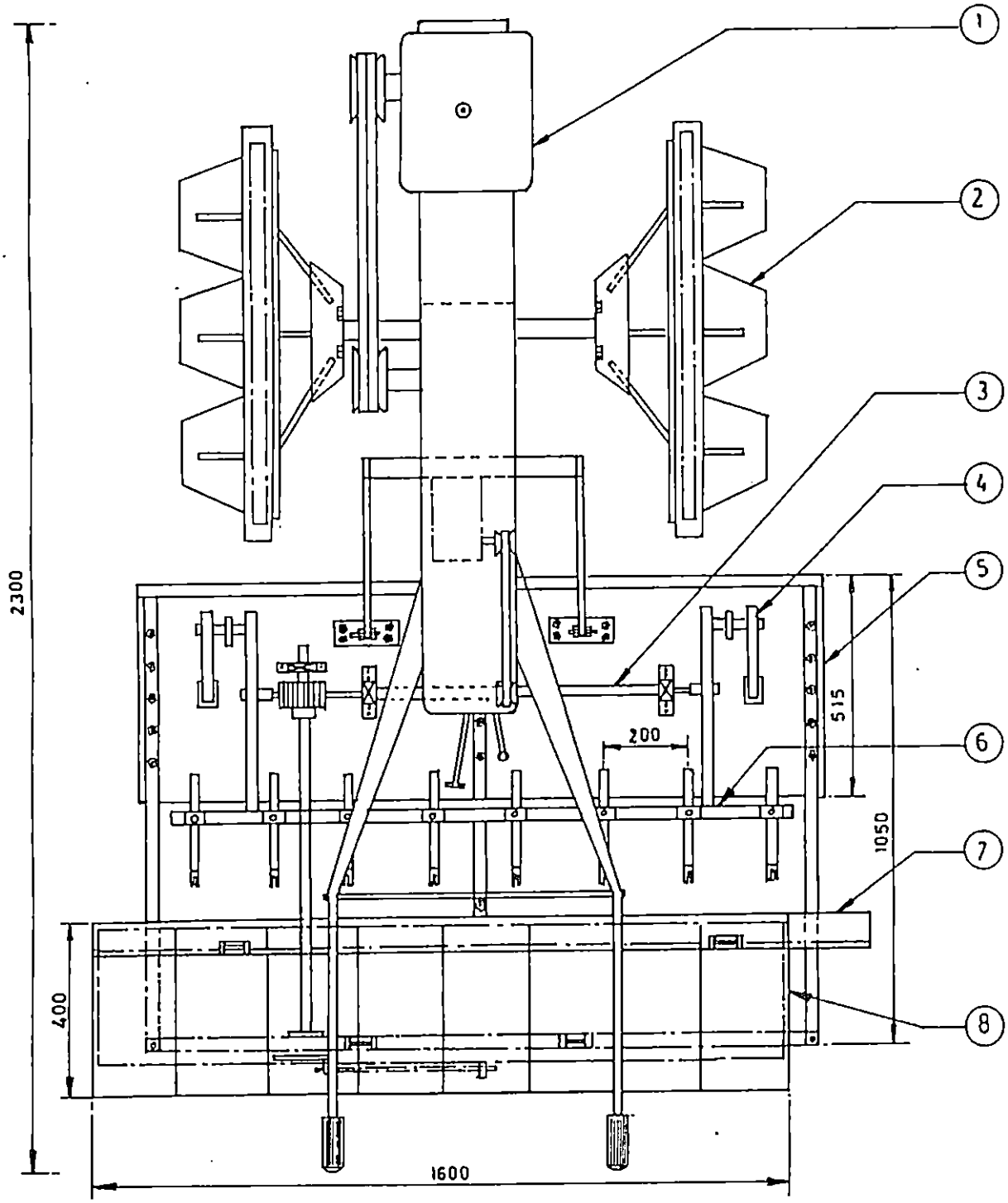
3.2 Description of new version of paddy transplanter

The overall dimensions of 1600 mm, 1050 mm and 550 mm were determined by considering the dimensions of the power tiller as well as the ergonomical requirements of the operator. By keeping the four-bar mechanism and worm and pinion gear set as such, modifications and improvements were incorporated in all other components and systems. The dimensions and constructional details of the top view of power tiller mounted paddy transplanter is given in Fig.1.

3.2.1 Auxillary gear box

For giving the proper power for operation of the paddy transplanter as well as to improve the balancing of the

All dimensions in mm
Scale 1:15



1. *Diesel engine*
2. *Special cage wheels*
3. *Main shaft*
4. *Four-bar mechanism*
5. *Wooden float*
6. *Picker arm assembly*
7. *Feeding frame assembly*
8. *Nursery feeding tray*

FIG.1 TOP VIEW OF POWER TILLER MOUNTED IMPROVED PADDY TRANSPLANTER

power tiller operated transplanter, the rotovator assembly of the power tiller was removed. In its place an auxillary gear box was assembled. The auxillary gear box consists of two shafts, four-bearings and a pair of spur gear sets, which meshes with each other in vertical position. The 36 teeth 11.20 cm dia gear meshes with power tiller gear box when rotovator gear lever is engaged in second position. The 26 teeth 8.10 cm dia gear receives the power and transmits through its shaft and double groove V-pulley to the paddy transplanter. The main purpose of the spur gear set is to reduce the speed and to supply required power to the paddy transplanter. It also gets lubrication from the gear box oil of the power tiller.

The assembling of the auxillary gear box was improved by finishing the faces, aligning the fastioner grooves and providing rigid double rubber and one metal packing in between. This also improved the meshing of the power tiller rotary gear along with auxillary gear box. The output shaft of the auxillary gear box was provided with oil seal with a suitable housing to avoid oil leak. When the engine is operated at normal speed, the auxillary gear box is to give 360 rpm through 100 mm double groove V-pulley. The auxillary gear box was also provided with the facility to fit

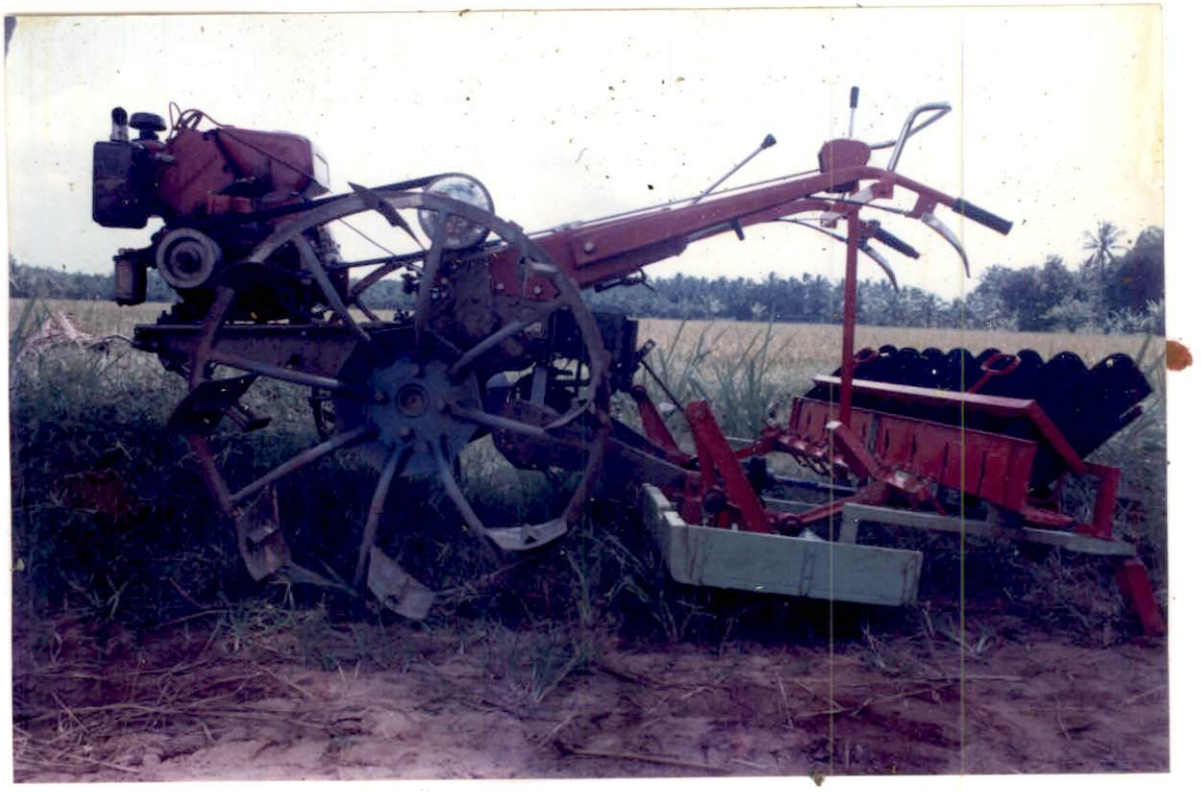
the hitching limbs to the transplanter as well as providing the tension pulley to V-pulley.

3.2.2 Wooden float

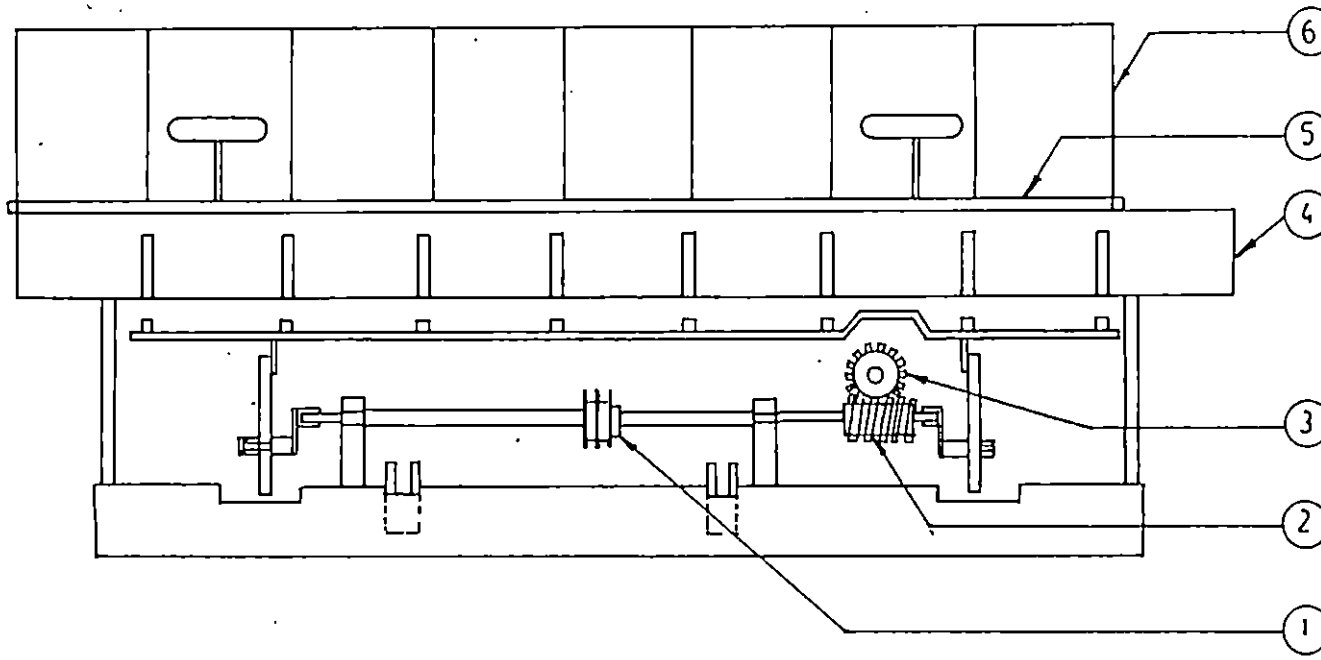
The earlier design of the wooden float used to collect the soil in front of the float without allowing the soil to pass its beneath. The accumulated soil used to form ridges at both the sides. This problem was rectified by newly fabricating a wooden float made of jack wood and has given enough curvature like a bottom of boat to allow the soil to pass freely beneath without giving any resistance. Various components of the paddy transplanter such as main shaft, transmission shaft, nursery feeding tray, picker arm assembly and four-bar mechanism were fixed on the wooden float (Plate I). The main purpose of the wooden float is to support all the components,to float freely over the puddled soil and to level the puddled soil before transplanting. Front view of paddy transplanter is given in Fig.2. The corners of the wooden float were made curve shape in order to avoid the soil thrust force during the operation. The wooden float is hitched to the power tiller by three-point hitch system. The side view of power tiller operated improved paddy transplanter is shown in Plate II.

Plate I Top view of power tiller operated improved paddy transplanter

Plate II Side view of power tiller operated improved paddy transplanter



All dimensions in mm
Scale 1:12



1. V-Pulley
2. Worm Gear
3. Pinion Gear
4. Feeding frame assembly
5. Nursery pressing unit
6. Nursery feeding tray

FIG.2 FRONT VIEW OF IMPROVED PADDY TRANSPLANTER

All dimensions in mm
Scale 1:12

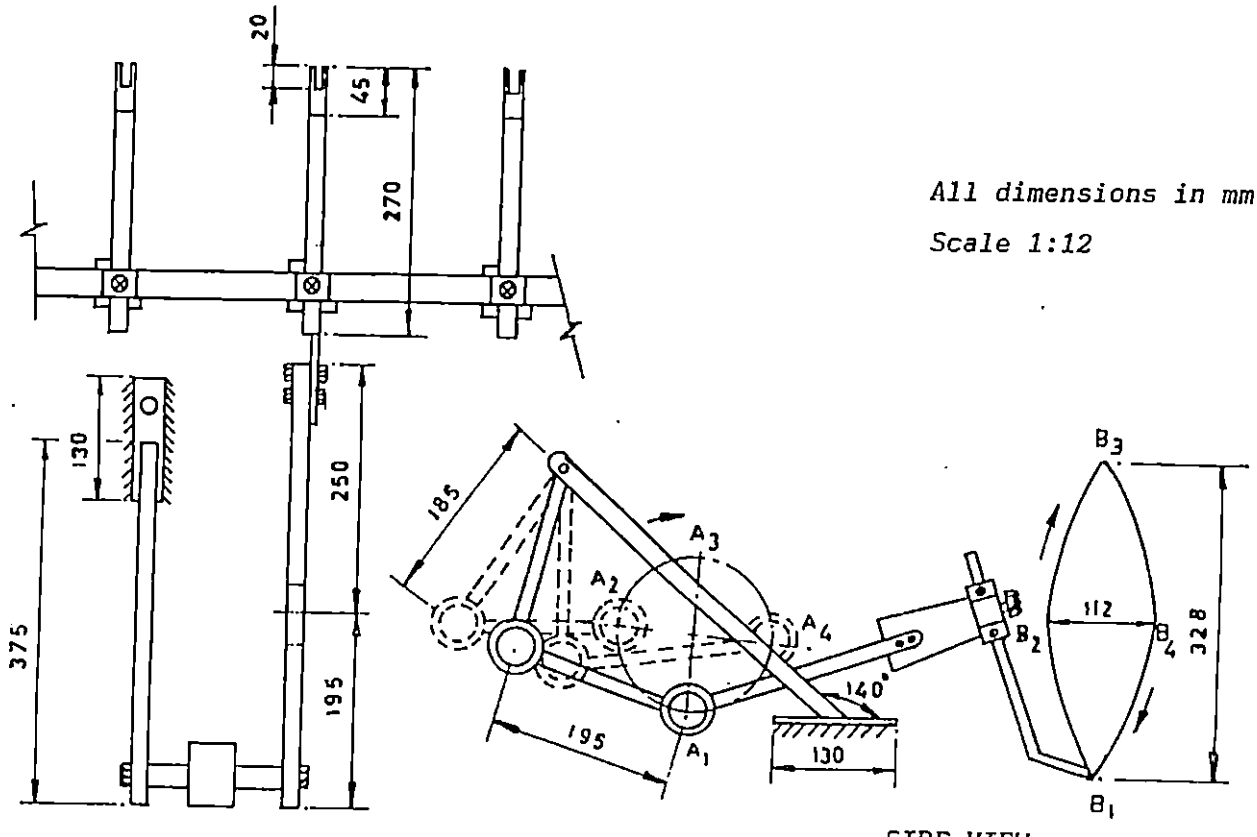


FIG.3 FOUR-BAR MECHANISM FOR PICKER ARM ASSEMBLY

3.2.3 Main shaft

The main shaft is fixed rigidly over the wooden float by means of a pair of bearing and bearing support at both the ends. The main shaft receives the power from auxillary gear box through a double groove V-pulley and belt system. The power received by main shaft is diverted into two sections, one to operate the picker arm assembly through four-bar mechanism and another through a crank for the movement of nursery feeding tray. Both the ends of the main shaft are fixed to four-bar mechanism through a crank connection to operate the picker arm assembly. At one end of the main shaft, worm and pinion gear set of 11:1 gear ratio is fitted. This gear set is used to transmit the power in perpendicular from the main shaft to the transmission shaft for the tray movement. The dia and length of the main shaft is 25 mm and 1000 mm respectively.

3.2.4 Four-bar mechanism

To make replica of the manual transplanting of paddy seedlings, the best way is to utilise the locus of the expanded lever of the four-bar mechanism. The details of the specification and dimensions along with the orientation of locus are given in Fig.3. It mainly consists of four-bars with ball bearing connections in which one-bar is fixed and other

three are movable parts. The fixed bar is rigidly fitted over the wooden float. The four-bar mechanism is connected to crank which inturn is connected to the main shaft. The main purpose of the four-bar mechanism is to give the motion to the picker arm assembly in an elliptical shape. The locus which is an elliptical shape is transmitted to picker arm assembly, which covers the minimum distance to take-out the seedlings from the nursery feeding tray, keep the seedlings in the puddled soil and will come back to the original position in a different path.

3.2.5 Picker arm assembly

The picker arm assembly consists of a set of eight-planting fingers fitted in special type of sockets and gets power from the main shaft through a crank and four-bar mechanism. Both the ends of the arms are connected to the extended lever of the four-bar mechanism to achieve desired locus. During its operation the planting fingers collect the seedlings by its fixed fork arrangement and transplants in the soil at desired depths. The picker arm assembly was fabricated by 25 mm hallow square tube of length 1500 mm with a provision to allow the transmission shaft without any hindrance. A set of eight-special type of 10 mm x 10 mm x 25 mm sockets were fabricated and fitted at 200 mm spacing on the picker arm for receiving the planting fingers of size 10 mm x 10 mm section.

Additionally three-finer adjustment knobs were provided on all the three sides of the socket to achieve maximum perfection in aligning the planting fingers. This also provided enough strength to take care of any unexpected friction in separating and receiving the seedlings from the nursery feeding tray and transplanting in puddled land. It prevented any minor misalignments in the planting finger and hence prevented any damage to the mouth of the feeding frame assembly.

3.2.6 Feeding frame assembly

The planting finger was found to touch the walls of feeding frame assembly in the earlier prototype. It was modified and improved so that the planting finger move very accurately inside the mouth to take the seedlings without touching any of the side walls of the mouth. This unit is a fixed part which rests on a platform and is supported at three points in order to avoid any bending. This assembly is made of Galvanised Iron (GI) sheet of 22 gauge. It consists of eight-seedling mouths of width 10 mm, vertical 100 mm and length 35 mm made at 200 mm spacing. The planting fingers enter through the mouths of feeding frame assembly to catch the seedlings from the nursery feeding tray. The planting finger should not touch the walls, should not damage the unit and should only enter through the opening to pick up the seedlings.

3.2.7 Transmission shaft

Transmission shaft is mainly used to transmit the power to the nursery feeding tray through a crank connection. The one end of this shaft is attached in right angle to the main shaft through a worm and pinion gear set and the other end to the crank in rear end of the float for converting the rotary motion into a reciprocating motion. In the earlier design, the one end of the transmission shaft was supported by one bearing and its bearing support. The bearing support was fixed by a separate hollow square tube of 1.60 m length. For supporting the nursery feeding tray assembly, another hollow square tube of same length was provided. In the present design the former square tube for supporting the bearing has been discorded and bearing support was on the latter hollow square tube by suitably altering the frame design.

3.2.8 Nursery feeding tray assembly

In the earlier design the nursery feeding tray assembly was made of 22 gauge Aluminium sheet consisting of eight-compartments and was curved in shape. The tray was fitted at an angle of 40 degrees and supported by bush rollers for reciprocating motion. When the power was transmitted from

transmission shaft to the nursery feeding tray through the crank, the following problems were observed:

1. Horizontal to and fro motion of the tray movement was not perfect due to its various design problems and improper fabrication.

2. Tilting of the tray was observed backward and forward when the seedling in the tray was full and empty respectively.

3. The upper end of the tray was supported by bush rollers and lower end was completely rested on the feeding frame assembly. Due to this arrangement, the friction was observed high during the reciprocating tray movements.

4. Owing to curve shape of nursery feeding tray, the seedling moved down at slower rate to supply the seedling to the feeding frame assembly.

The above problems were rectified by the improvements and modifications carried out on the new nursery feeding tray assembly. This unit was made of 22 gauge GI sheet consisting of eight-compartments at 200 mm spacing. In order to get proper horizontal to and fro movement of the tray, the various types of guides for tray movement were studied. The rail and roller assembly was found best suited to get proper

functioning of tray movements. The total capacity of 7.60 kg of seedling were stored in all eight-compartments of the nursery feeding tray. The following improvements and modifications were made:

1. The nursery feeding tray was fitted with special type of rail and roller assembly to avoid friction as well as to improve the accuracy of its horizontal movement. Two-set of rail and roller were fitted at the beneath of the tray in all the four-corners. To match the rollers, four pieces of rails of length 960 mm were fitted on the hollow square tube suitably. This prevented any type of tilting of the tray other than to and fro movement in horizontal way. The energy required for the operation of the nursery feeding tray was also reduced. The smooth movement of the tray on the rails, reduced the friction and improved the overall efficiency of the paddy transplanter. The provision of total four-set of rollers and 960 mm length of rail increased the total weight only to 0.560 kg. The details of the rail and roller assembly is given in Fig.4.

The specifications of rail and roller were given:

A. Rail

a. Width, mm : 5

b. Height, mm : 4

c. Material of construction : MS rod

B. Roller

a. Diameter, mm : 20

b. Groove, mm : 3

c. Length, mm : 50

d. Width, mm : 10

e. Weight, gm : 18

f. Material of construction : MS wheel

2. In the first prototype of IRRI five-row transplanter, the nursery feeding tray was only in curve shape. But it was subsequently improved by a straight nursery feeding tray for IRRI six-row transplanter, because of its uniformity in feeding the seedlings. The curve nursery feeding tray of the earlier prototype was substituted with an improved straight nursery feeding tray.

3. Tray angle of the nursery feeding tray was increased to 45 degrees from its earlier value of 40 degrees to the horizontal.

4. The power for the operation of nursery feeding tray was taken from the transmission shaft through crank arrangement. It was improved by way of providing a disc with provision of achieving various crank radii, to optimize the crank radius. One pair of needle bearings were also provided one at the crank pin of the disc and another at the tray connection.

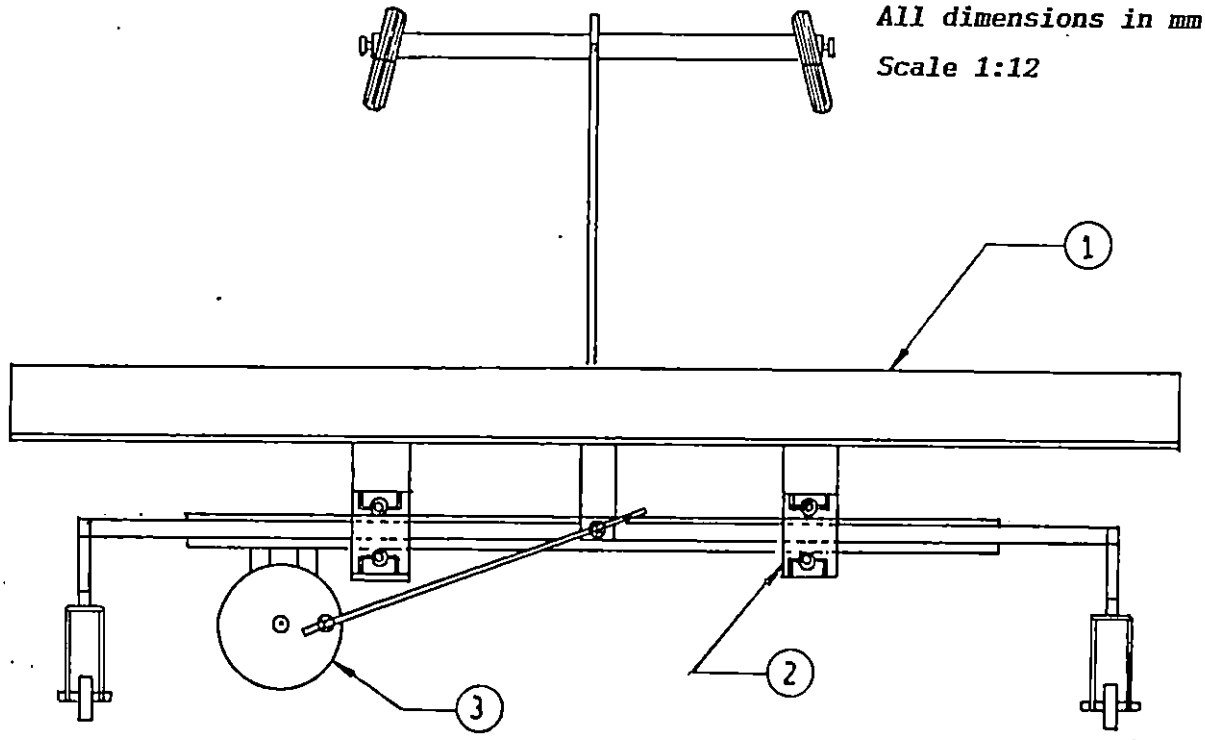
3.2.9 Nursery pressing unit

Without the nursery pressing unit, the loose root washed seedling will not come to the end of the tray in a compact form to supply the seedling continuously to the planting fingers. When the nursery pressing unit was fixed to the tray by a pair of springs, it is able to hold the seedlings in a pressed condition so that all the seedlings are in vertical position and correct number of seedlings were taken out by the fingers regularly. This unit makes the loose root washed seedling in almost identical condition of the mat type seedlings.

3.3 Power transmission of paddy transplanter

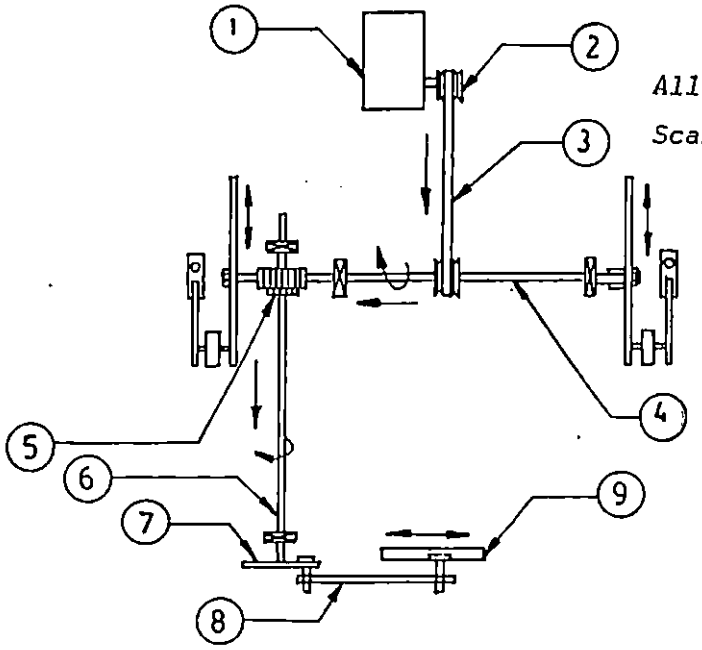
3.3.1 Mounting of transplanter with power tiller

The Mitsubishi power tiller has three-forward and one-reverse gears in low speed as well as in high speed. In



1. Nursery feeding tray
2. Rail and roller assembly
3. Tray movement control disc

FIG.4 RAIL AND ROLLER ASSEMBLY TO THE NURSERY FEEDING TRAY OF THE PADDY TRANSPLANTER



All dimensions in mm
Scale 1:20

1. Auxillary gear box
2. V-Pulley
3. V-Belt
4. Main shaft
5. Worm and pinion gear assembly
6. Transmission shaft
7. Tray movement control dis
8. Connecting rod
9. Nursery feeding tray

FIG.5 POWER TRANSMISSION OF THE PADDY TRANSPLANTER

addition to this, it contains first, second and neutral positions of gear for rotovator operation. The entire rotovator assembly was dismantled from the rear side of the power tiller and in its place, the auxillary gear box was fitted. The engagement of rotovator gear box in second gear position allows the power from tiller gear box to the auxillary gear box of the transplanter. Proper care was taken for alignment of the auxillary gear during its engagement. Completely out of the meshing was ensured when the rotovator gear lever was in neutral position. Proper seating was ensured by pair of rubber packing and one metal packing.

One pair of hitching limb was extended from auxillary gear box to connect the paddy transplanter. According to the level of sinkage of power tiller cage wheels in the puddled soil, the horizontal level was maintained by adjusting the hitching limbs in the suitable position provided at the auxillary gear box. The paddy transplanter was also provided support from the handle through a pipe structure called vertical adjustment lever.

3.3.2 Power train

The power transmission from power tiller engine to operate the paddy transplanter is given in Fig.5. The power train of paddy transplanter consists of the auxillary gear

box, pulleys and belts, main shaft, four-bar mechanism, worm and pinion gear set, transmission shaft, crank connection, rail and reciprocating rollers of the nursery feeding tray. The power tiller is found to move at walking speed with transplanter when power tiller is operated in first and second gears of low speed selections. When the power tiller engine is operated at 1400 rpm, the output shaft of the auxillary gear box supply the power at 470 rpm and main shaft at 430 rpm. By the crank of four-bar mechanism the picker arm assembly has 142 strokes per minute and totally 1136 number of hills are planted per minute. The power tiller moves at theoretical forward speed of 15.62 m per min. By worm and pinion arrangement, the transmission shaft is operated at 43 rpm to transmit reciprocating movement of the tray through the crank.

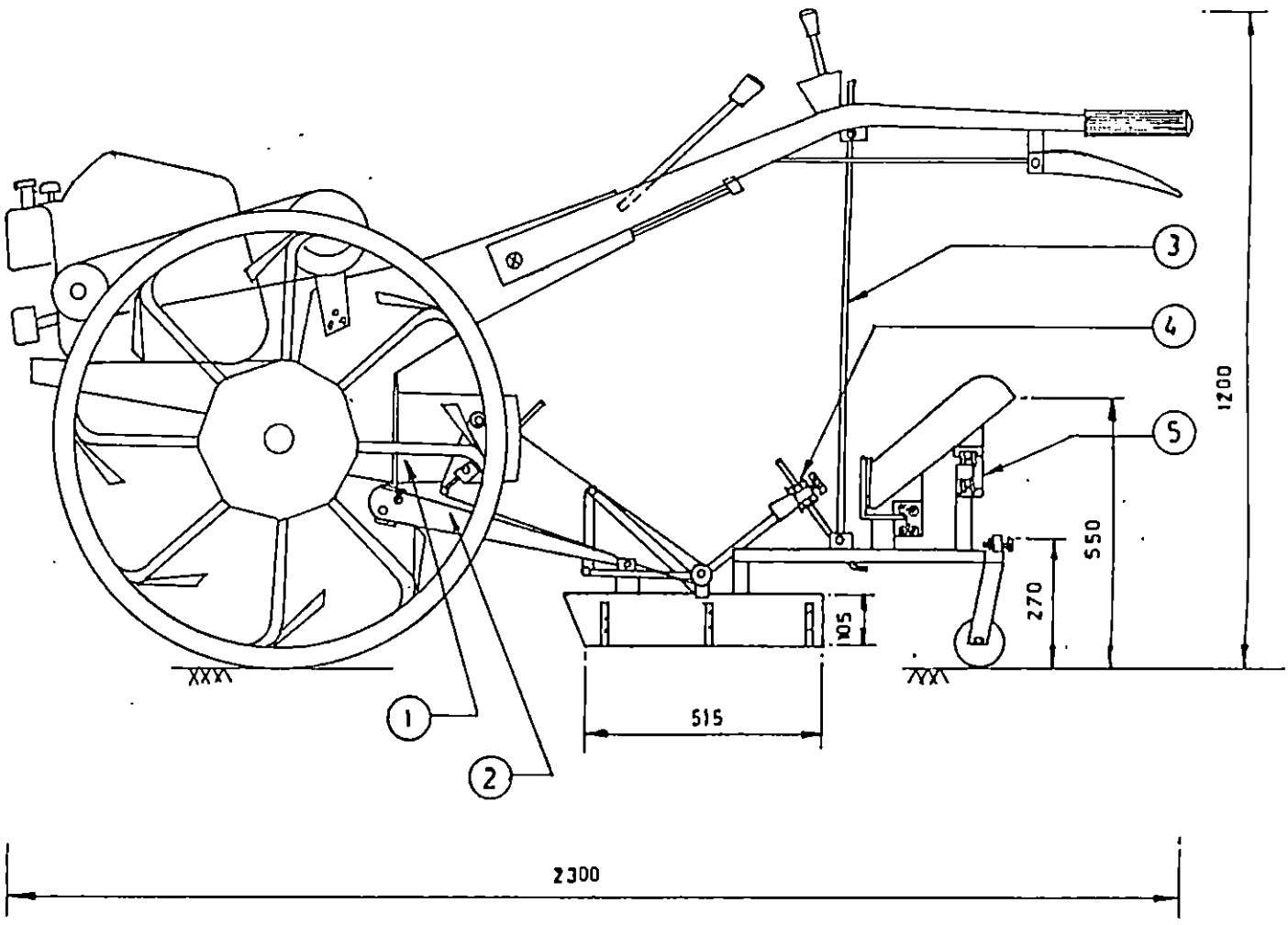
Four-bar mechanism actuates the picker arm assembly when the rotovator gear lever is engaged in the second gear position. The power from tiller gear box transmitted to the main shaft of the paddy transplanter through the auxillary gear box, pulleys and belts. The worm and pinion gear set reduce the speed of the main shaft in 11:1 gear ratio to convey the power to the tray. Each compartment in the tray is at a width of 20 cm. It is expected that the nursery feeding tray assembly is to move theoretically 20 cm for every crank, but practically it is enough to restrict the movement to 18 cm

so that the planting finger will not touch the partition wall of the tray but will take the seedlings from the tray. Hence to and fro movement of the tray is restricted to 36 cm. This is achieved by selecting 72 mm as the crank radius. The picker arm assembly will operate six-time for the nursery feeding tray to move from one end to other end. There exists a linear relationship between the picker arm assembly and tray movement. The side view of the power tiller operated improved paddy transplanter is given in Fig.6.

3.4 Nursery preparation for transplanter

The performance of a transplanter to a large extent depends on the type of nursery fed into it. Almost all the mechanical transplanters successfully operated in foreign countries used specially prepared mat type seedlings. The introduction of the new transplanter requiring special mat type seedling is not accepted by the farmers in India. The different parameters affecting the successful preparation of mat type of nursery are not able to be under controlled by the Indian farmers. Unsuccessful preparation of mat type seedlings greatly affects the performance of the transplanters. The transplanters using the conventional seedlings are only accepted by the farmers in country.

All dimensions in mm
Scale 1:15



1. *Auxillary gear box*
2. *Hitching limb*
3. *Vertical hitching adjustment lever*
4. *Fine adjustment knob*
5. *Rail and roller assembly*

FIG.6 SIDE VIEW OF POWER TILLER MOUNTED IMPROVED PADDY TRANSPLANTER

In this study, the special emphasis is given to develop the transplanter which will use only the conventional paddy seedlings.

The conventionally grown seedlings are manually pulled, root washed and as usual and are bundled. The uprooting, washing the roots and bundling methods are same as followed locally. The bundled seedlings will be loaded in the nursery feeding tray after spreading the seedlings.

3.5 Main land preparation

The main land should be puddled and is to be perfectly levelled. About five to eight cm of water is to be allowed to stand over the soil. Enough time is to be given for settling the coagulated particles so as to have a firm soil for operating the transplanter. When the soil is settled, the water is to be drained and with only a thin layer of water the power tiller with transplanter can be taken to the field for operation.

3.6 Critical evaluation of improved eight-row paddy transplanter for conventional seedlings

The improved eight-row paddy transplanter for conventional seedlings was developed and fabricated at KCAET Tavanur and trials were conducted at KCAET Instructional farm,

Tavanur to evaluate the field performance of the paddy transplanter. The paddy seedlings (Var: Red Triveni, Hraswa) which were 20 days old were selected for the field tests.

The preliminary trials of the paddy transplanter were taken up in the laboratory. After adjusting the minor operating defects, the unit was operated in the satisfactory position for 15 hr in the laboratory. During preliminary testings in the laboratory, the individual components of the transplanter were observed. Again the machine was taken on the road and was operated for 10 hr to find out any defects in the maneuverability of the transplanter. A plot of 29 x 16.5 square metre was selected for evaluation purpose. The paddy transplanter was operated for 10 hr in the puddled land without any seedlings to study the working of components in detail. The rear view of power tiller operated improved paddy transplanter is shown in Plate III.

In the perfectly levelled land suitable for transplanting, the transplanter was evaluated after loading the seedlings. The observations such as time loss, average depth of planting, number of hills per square metre, damaged hills, buried hills and average speed of operation were noted. The theoretical field capacity, actual field capacity and field efficiency were also determined. Field evaluation of power tiller operated paddy transplanter is shown in Plate IV.

Plate III Rear view of power tiller operated improved paddy transplanter

Plate IV Field evaluation of power tiller operated paddy transplanter

During testing, the problems encountered were noted and rectified for further field evaluation.

3.7 Practical utility

The subject of paddy transplanter is becoming globally important. The green revolution has no doubt provided very scope in the production of food crops but this trend in agricultural productivity can be enhanced only through mechanisation of agriculture. The use of farm implements such as mechanical transplanter not only saved the cost of transplanting but increased the timeliness of operation and productivity of labour.

Improvements on paddy transplanters is a continuous process. The mechanical transplanter is well suited for small and medium farmers. The power tiller operated improved paddy transplanter can be used as a supplementary unit in farms facing from shortage of farm labourer. The farmers would however be able to command more area under cultivation within a short period. Keeping in view the high wages for paddy transplantation, the adoption of these types of mechanical transplanters would be justified.

Results and Discussion

RESULTS AND DISCUSSION

The original eight-row power tiller operated paddy transplanter developed at APAU, Hyderabad was taken up initially for its evaluation. This transplanter has been extensively tested at KCAET, Tavanur in different field conditions. The details of the power tiller operated APAU paddy transplanter were given.

4.1 Specifications of APAU paddy transplanter

1.	Type of machine	:	Power tiller mounted Paddy transplanter
2.	Transplanter price, Rs.	:	16,000
3.	Operating width, mm	:	1600
4.	Weight of the machine without seedlings, kg	:	83
5.	Crop for which machine suitable	:	All varieties of paddy
6.	Source of power	:	Mitsubishi power tiller fitted with 10 hp diesel engine
7.	No. of planting fingers	:	8
8.	Row to row spacing, mm	:	200
9.	Provision for adjusting row to row spacing	:	Nil
10.	Plant to plant spacing, mm	:	100 to 120

11.	Arrangement for changing plant to plant distance	:	By changing the forward speed
12.	Provision for changing the number of plants per hill	:	By changing finger fork gap
13.	Size of the compartments in the nursery feeding tray, mm	:	200 x 400
14.	No. of compartments in the nursery feeding tray	:	8
15.	Angle of nursery feeding tray with reference to horizontal float, degrees	:	40
16.	Planting fingers		
	(i) Type	:	Fixed fork
	(ii) Size of opening between the finger fork, mm	:	4
17.	Expected forward speed of travel, km per hr	:	1.20
18.	Theoretical field capacity, ha per hr	:	0.10
19.	No. of persons required		
	(i) Operating the power tiller	:	1
	(ii) Nursery transporting and filling tray	:	1
	(iii) Gap fillings	:	1
20.	Materials of construction of important components		
	(i) Gears	:	Hardened steel
	(ii) Pulley	:	Cast iron

(iii)	Belt	:	Non elastic fibre
(iv)	Nursery feeding tray	:	Aluminium sheet, 22 gauge
(v)	Feeding frame assembly	:	Aluminium sheet, 22 gauge
(vi)	Wooden float	:	Teak wood and GI sheet
(vii)	Hitching limbs	:	MS plates, two limbs fixed and one adjustable

4.2 Performance results of APAU paddy transplanter

Test conditions

A. Condition of seedlings

1.	Paddy variety	:	Red Triveni
2	Average number of leaves per plant	:	3
3.	Age of seedlings, day	:	25
4.	Average length of root, mm	:	40
5.	Average height of seedling, mm	:	250

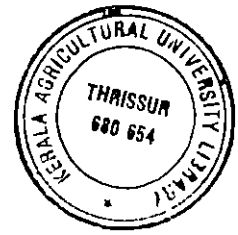
B.	Location	:	KCAET Instructional Farm, Tavanur
C.	Area of plot, sq.m.	:	1200
D.	Type of soil	:	Sandy-loam

E. Field performance and transplanting in first gear of power tiller

1.	Date of test	:	28.09.1993 to 15.10.1993

2.	Average depth of transplanting, mm	:	45
3.	Average number of seedlings per hill	:	4
4.	No. of hills per sq. m	:	45
5.	Distance between hills, mm	:	120
6.	Missing hills, %	:	6.00
7.	Floating hills, %	:	12.30
8.	Damaged hills, %	:	2.30
9.	Average speed of operation km per hr	:	1.20
10.	Depth of water at the time of planting, mm	:	20 to 30
11.	No. of labourers used	:	3
12.	Row to row spacing, mm	:	200
13.	Actual field capacity	:	0.12
14.	Theoretical field capacity, ha per hr	:	0.19
15.	Field efficiency, %	:	63

The improved version of power tiller operated eight-row paddy transplanter for conventional seedlings was developed at KCAET Tavanur and tested in different field conditions. The tests were conducted in accordance with the procedure and guidelines provided by Bureau of Indian Standards (BIS) and Regional Network of Agricultural Machinery (RNAM) test codes. The details of the material and dimensions



of the improved version of paddy transplanter were discussed. Field evaluation of the improved version of paddy transplanter at the experimental plot is shown in Plate V.

4.3 Specifications of improved version of paddy transplanter

1.	Type of machine	:	Power tiller mounted paddy transplanter
2.	Transplanter price, Rs.	:	10,000
3.	Dimensions		
	(i) Length, mm	:	1600
	(ii) Width, mm	:	1050
	(iii) Height, mm	:	550
4.	Operating width, mm	:	1600
5.	Weight of the machine without seedlings, kg	:	87
6.	Crop for which machine suitable	:	All varieties of paddy
7.	Source of power	:	Mitsubishi power tiller fitted with 10 hp diesel engine
8.	No. of planting fingers	:	8
9.	Row to row spacing, mm	:	200
10.	Provision for adjusting row to row spacing	:	Nil
11.	Plant to plant spacing, mm	:	100 to 120
12.	Arrangement for changing plant to plant distance	: :	By changing the forward speed
13.	Provision for changing the number of plants per hill	: :	By changing finger fork gap

14.	Size of the compartments in the nursery feeding tray, mm	:	200 x 400
15.	No. of compartments in the nursery feeding tray	:	8
16.	Angle of nursery feeding tray with reference to horizontal float, degrees	:	45
17.	Planting fingers		
	(i) Type	:	Fixed fork
	(ii) Size of opening between the finger, mm	:	4
18.	Expected forward speed of travel, km per hr	:	1.20
19.	Theoretical field capacity, ha per hr	:	0.19
20.	No. of persons required		
	(i) Operating the power tiller mounted paddy transplanter	:	1
	(ii) Nursery transporting and filling tray	:	1
	(iii) Gap fillings	:	1
21.	Materials of construction of important components		
	(i) Gears	:	Hardened steel
	(ii) Pulley	:	Cast iron
	(iii) Belt	:	Non elastic fibre
	(iv) Nursery feeding tray	:	GI sheet, 22 gauge
	(v) Feeding frame assembly	:	GI sheet, 22 gauge
	(vi) Wooden float	:	Jack wood

Plate V Field evaluation of improved paddy transplanter at the experimental plot

Plate VI Working of paddy transplanter at KCAET Instructional Farm

(vii)	Frame	:	Hollow square tube MS pipe
(viii)	Hitching limbs	:	MS plates, two limbs fixed and one adjustable
(ix)	Rail and roller assembly	:	MS rod and MS wheel
(x)	Picker arm	:	MS square rod
(xi)	Tray movement control disc	:	MS plate

4.4 Field experiments with improved version of paddy transplanter

4.4.1 Seedling distribution, missing hills, floating hills, damaged hills determination

The paddy transplanter was extensively tested at KCAET Instructional Farm, Tavanur. The number of seedlings per hill in an experimental plot was counted and the average values were found. The experiments were repeated for number of times and the average number of seedlings per hill was determined for each case. Similarly the number of missing hills, floating hills and damaged hills were counted and percentages were calculated. Working of paddy transplanter at KCAET Instructional Farm, Tavanur is shown in Plate VI.

In each case the number of seedlings per hill was not constant. This is mainly because of using conventional type of nursery. The number of seedlings picked up by planting

finger mainly depends on the thickness of stem and density of seedlings in the nursery feeding tray. Hence the variation occurred. The results are summarised in Table 1.

Table 1. Average number of seedlings per hill, percentages of missing hills, floating hills and damaged hills

Sl. No.	No. of seedlings per hill	Missing hills, %	Floating hills, %	Damaged hills, %
1.	3	6.20	3.10	3.62
2.	2	7.45	1.25	2.52
3.	4	8.31	1.63	3.86
4.	3	4.12	2.10	3.92
5.	4	5.84	2.36	4.35
6.	2	8.52	2.62	3.63
7.	4	5.36	2.52	4.82
8.	3	7.94	3.20	3.35
Average	3.12	6.72	2.34	3.76

The number of seedlings per hill was found to vary from 2 to 4. These values are not the extreme values and are found to be within range of acceptable limits. The number of seedlings per hill in manual transplanting is also found to be

from 2 to 4 seedlings. But in 6.72 per cent hills, seedlings were not transplanted, this was only because of the loose conventional seedlings, were not picked by the fingers. This missing hill percentage can be minimised by improving the condition of the seedlings and planting fingers.

It is also observed that a very less number of hills were floated. This was mostly due to the poorer capacity of the soil to receive the seedlings taken up by the fingers. The number of floating hills can be minimised by operating the transplanter in slow speed. The average value of the floating hills was found to be only 2.34. The total hills to be transplanted by manual operation as gap filling is calculated to be 9.06 per cent. This should be minimised by improving the system in the transplanter.

Damage to the seedlings happened between the mouths of the feeding frame assembly which are of rectangular in shape and the moving tray. Some seedlings which are not laid up vertical, are subjected to crushing by the moving tray. The percentage of damaged hills was obtained to be 3.76. Damage to the roots of the seedlings are also happened due to shearing action of the fingers, but these seedlings are found to establish in the soil without any problem. When the speed of the operation of picker arm assembly is increased, the percentage of damaged seedlings are also increased.

4.4.2 Speed of operation

Speed of operation of paddy transplanter for various trials were given in Table 2. The speed of operation mainly

Tale 2. Speed of operation of paddy transplanter observed from 16.50 m length of row in first gear

Sl. No.	Time, sec	Speed, km per hr
1.	45	1.32
2.	48	1.24
3.	49	1.21
4.	45	1.32
5.	51	1.16
6.	47	1.26
7.	49	1.21
8.	48	1.24
Average	47.75	1.24

determines the field capacity and field efficiency. When the speed of operation is increased then the picker arm assembly operates at a faster rate to take out the seedlings from the nursery feeding tray. This causes the considerable damages to the seedlings and seedlings are not properly transplanted in

the soil. The average speed of operation was found to be 1.24 km per hr.

4.5 Performance results of improved version of power tiller mounted eight-row paddy transplanter

Test conditions 1

A. Condition of seedlings

1.	Paddy variety	: Hraswa
2.	Average number of leaves per plant	: 4
3.	Age of seedlings, day	: 20
4.	Average length of root, mm	: 45
5.	Average height of seedlings, mm	: 240
6.	No. of seedlings in one bundle before transplanting	: 238
7.	Weight of one bundle of seedlings, gm	: 129.10

B. Condition of test fields for transplanter

1.	Location	: KCAET Instructional Farm, Tavanur
2.	Area of field, sq.m.	: 478.50
3.	Type of soil	: Sandy-loam

C. Field performance and transplanting in first gear of power tiller

1.	Date of test	:	22.09.1994
2.	Average depth of transplanting, mm	:	42
3.	Average number of seedlings per hill	:	3
4.	No. of hills per sq.m	:	55
5.	Distance between hills, mm	:	123
6.	Missing hills, %	:	6.72
7.	Floating hills, %	:	2.34
8.	Damaged hills, %	:	3.76
9.	Average time taken for transplanting, min	:	22
10.	Average time lost in operation, min	:	7
11.	Average speed of operation, km per hr	:	1.20
12.	Standing angle of nursery after transplanting, degrees	:	70
13.	Fuel consumption		
	(i) Per hr, lit	:	1.05
	(ii) Per ha, lit	:	8.10
14.	Theoretical field capacity, ha per hr	:	0.19
15.	Actual field capacity ha per hr	:	0.13
16.	Field efficiency, %	:	68.42

Test conditions 2

A. Condition of seedlings

1.	Paddy variety	: Hraswa
2	Average number of leaves per plant	: 4
3.	Age of seedlings, day	: 20
4.	Average length of root, mm	: 45
5.	Average height of seedlings, mm	: 240
6.	No. of seedlings in one bundle before trans-planting	: 238
7.	Weight of one bundle of seedlings, gm	: 129.10

B. Condition of test fields for transplanter

1.	Location	: KCAET Instructional Farm, Tavanur
2.	Area of field, sq.m	: 478.50
3.	Type of soil	: Sandy-loam

C. Field performance and transplanting in second gear of power tiller

1.	Date of test	: 27.09.1994
2.	Average depth of transplanting, mm	: 42
3.	Average number of seedlings per hill	: 3
4.	No. of hills per sq.m	: 40
5.	Distance between hills, mm	: 154

6.	Missing hills, %	:	10.40
7.	Floating hills, %	:	4.80
8.	Damaged hills, %	:	7.60
9.	Average time taken for transplanting, min	:	26.10
10.	Average time lost in operation, min	:	13.10
11.	Average speed of operation, km per hr	:	1.40
12.	Standing angle of nursery after transplanting, degrees	:	70
13.	Fuel consumption		
	(i) Per hr, lit	:	0.90
	(ii) Per ha, lit	:	8.20
14.	Theoretical field capacity, ha per hr	:	0.22
15.	Actual field capacity ha per hr	:	0.11
16.	Field efficiency, %	:	50

It was observed that when the transplanter was operated in second gear of the power tiller then there are considerable damages to the seedlings and problems were also encountered in the nursery feeding tray movement.

4.6 Operating conditions of paddy transplanter

The power tiller operated eight row paddy transplanter was operated in the puddled field with and without paddy

seedlings to find out its performance. In the power tiller mounted paddy transplanter, the operator should find enough space to walk freely behind the transplanter and also should have good control over the handles to operate the unit with maximum care even during turnings at corners and at head lands. The optimum width for a transplanter to be mounted with power tiller is decided by taking the following considerations:

1. Width of transplanter should at least cover the track width of the power tiller with cage wheels.

2. For easy maneuverability and easy control during turning at the head lands, the width of the transplanter is to be restricted less than 170 cm.

Based on the experiences in the field operations as well as to achieve optimum field coverage for power tiller operated paddy transplanter, the number of row is decided to be eight. Hence the actual width of the transplanter has become 160 cm.

4.6.1 Machine aspect

Ease of handling, adjustments, maintenance and durability of the paddy transplanter were discussed under this section. The different components for transmitting the power

and to operate different parts were distributed almost uniformly over the float to get uniform weight distribution over the float. This facilitated the balancing of the unit as the transplanter is hinged to the power tiller through a pair of limbs.

The paddy transplanter was operated in laboratory as well as on the road for several hours to find out its various problems. The handling and driving of paddy transplanter was quite easy and the power transmission system was found satisfactory. The wooden float was perfectly balanced on both the sides of the cage wheels of the power tiller. A pair of wheel is used to transport the unit to the field. No difficulty was found to turn the unit at corners with the help of steering clutches of the power tiller.

The four-bar mechanism actuates the picker arm assembly to take out the seedlings from the nursery feeding tray. In order to get the smooth to and fro motion of the tray, the special roller assemblies were fixed to the tray and suitable rails were fixed on the top and bottom of the hollow square tubes. The roller assemblies were fixed to all the four corners of the tray so that the load coming from the tray to the transplanter frame was more uniform. By this arrangement, the tray was found moving smoothly over the rail without any friction. There is a provision to remove the

nursery feeding tray for its repair and maintenance easily. The rail and roller assembl. es arrested the tilting movements of the tray either in backward or forward when the tray is full of seedlings or when it is empty.

The paddy transplanter was well suited to the light and medium soils. The machine will find difficulty to perform better in heavy soils as the power tiller could not move forward and will stuck up in soil.

4.6.2 Crop aspect

The suitability for different paddy varieties, damages to the nursery, crop spacing were discussed under this section. The paddy transplanter was well suited to all varieties of root washed conventional paddy seedlings. A skilled labourer is required to operate the paddy transplanter in the puddled soil. The operator should take care to walk only in between the rows, already transplanted by the machine. The percentages of missing hills, floating hills and damaged hills were found to be 6.72, 2.34 and 3.76 respectively. Two women labourers were required for transporting the seedlings as well as to gap fill the missed hills. The number of seedlings per hill was not constant and varied between 3 to 4. The row to row crop spacing is fixed to 200 mm.

4.6.3 Field operation aspect

The paddy transplanter is to be operated in first gear of power tiller, any increase in the forward speed results in more damages to the seedlings. The average depth of planting was found to be 42 mm. However depth of planting can be kept at desired level by suitably adjusting the planting fingers. The actual field capacity of the paddy transplanter was found to be 0.13 ha per hr in first gear of power tiller and cover one hectare area of field in eight-hour duration. The theoretical field capacity of the transplanter is calculated as 0.19 ha per hr. The average speed of operation in puddled field was noted and found to be 1.20 km per hr. The field efficiency of the transplanter is thus found to be 68.42 per cent. The fuel consumption for the power tiller to operate the paddy transplanter is 1.05 lit per hr and it consumed on an average of 8.10 lit per ha.

4.7 Cost of operation for the paddy transplanter

The detail calculation of cost of operation for the paddy transplanter is given in Appendix 2. The cost indicators for eight-row paddy transplanter as well as for manual transplanting were given in Tables 3 and 4 respectively.

Table 3. Cost indicators for eight-row paddy transplanter

Sl. No.	Item	Observations
1.	Power tiller	
	a. Cost of machine, Rs.	: 70,000
	b. Useful life, years	: 10
	c. Hours of use per year	: 10
	d. Fixed cost	
	(i) Depreciation per year, Rs.	: 6,300
	(ii) Repair and maintenance per year, Rs.	: 3,500
	(iii) Interest on investment per year, Rs.	: 9,625
	(iv) Insurance and shelter per year, Rs.	: 1,400
	(v) Total fixed cost per year, Rs.	: 20,825
	(vi) Total fixed cost per hour, Rs.	: 30
	e. Variable cost	
	(i) Labour cost per hr, Rs.	: 25
	(ii) Fuel cost pr hr, Rs.	: 10
	(iii) Total variable cost per hr, Rs.	: 35
	f. Total cost of power tiller per hr, Rs.	: 65
2.	Paddy transplanter	
	a. Cost of machine, Rs.	: 10,000
	b. Useful life, years	: 5

Contd.

c.	Hours of use per year	:	300
d.	Fixed cost		
	(i) Depreciation per year, Rs.	:	1,800
	(ii) Repair and maintenance per year, Rs.	:	500
	(iii) Interest on investment per year, Rs.	:	1,375
	(iv) Insurance and shelter per year, Rs.	:	200
	(v) Total fixed cost per year, Rs.	:	3,875
	(vi) Total fixed cost per hour, Rs.	:	15
e.	Variable cost		
	(i) Labour cost per hr, Rs.	:	20
f.	Total cost of paddy transplanter per hr, Rs.	:	35
3.	Total cost per hr for power tiller and paddy transplanter, Rs.	:	100
4.	Actual field capacity, ha per hr	:	0.13
5.	Operating cost, Rs. per ha	:	800

The power tiller operated paddy transplanter is using only the conventionally raised root washed type paddy seedlings. The cost of preparation of nursery, pulling, root washing and bundling are one and the same for both manual transplanting and power tiller operated transplanting. Hence, in the comparative study of the manual and power tiller

operated transplanter the cost of preparation, pulling and root washing and transportation of paddy seedlings are not separately considered.

Table 4. Cost indicators for manual transplanting

Sl. No.	Item	Observations
1.	Labour required for only transplating, woman-days per ha	40
2.	Labour wages, Rs. per day	40
3.	Total work hour per day	8
4.	Total labourers for transplanting, woman-hr per ha	320
5.	Cost for only transplanting, Rs. per ha	1600

It is found that 320 man-hr are required for completing the transplanting operation in one ha. The total cost of transplanting by using power tiller operated paddy transplanter includes depreciation, insurance and taxes. The total operating cost of paddy transplanter was found to be Rs.800 per ha. The cost of manual transplanting in Kerala was found to be Rs.1600 per ha. Thus there was a financial saving of Rs.800 per ha. A saving of 50 per cent in the cost of transplanting operation alone can be achieved by the

introduction of power tiller operated paddy transplanter. Moreover the labour shortage felt during transplanting season which often coincides with harvesting and threshing operations will also be reduced.

A power tiller with its transplanter attachment, its male operator, two female labourers are expected to work for eight-hour for completing the transplanting of one ha. An attempt of the comparative energy utilization of the power tiller operated paddy transplanter with manually transplanting was made. The energy conversion factors for male labourers, female labourers and power tillers were taken as 1.96 MJ per hr, 1.5 MJ per hr and 56.31 MJ per hr respectively (Mittal et al., 1985). It is found a total of 502.40 MJ of energy is consumed for transplanting one ha by manual labourers as compared to 491.08 MJ of energy consumed by a power tiller with its operator along with two women labourers to assist the transplanting. Graphical representation of cost of operation as well as the energy utilization is shown in Fig.7. There is no much energy utilization levels in these two systems of operations but saving of Rs.800 which is 50 per cent of the cost of transplanting is considered to be a much relevant contribution to the problem faced in Kerala.

The solution for the problem of non-availability of labourers for paddy cultivation is also partly given by

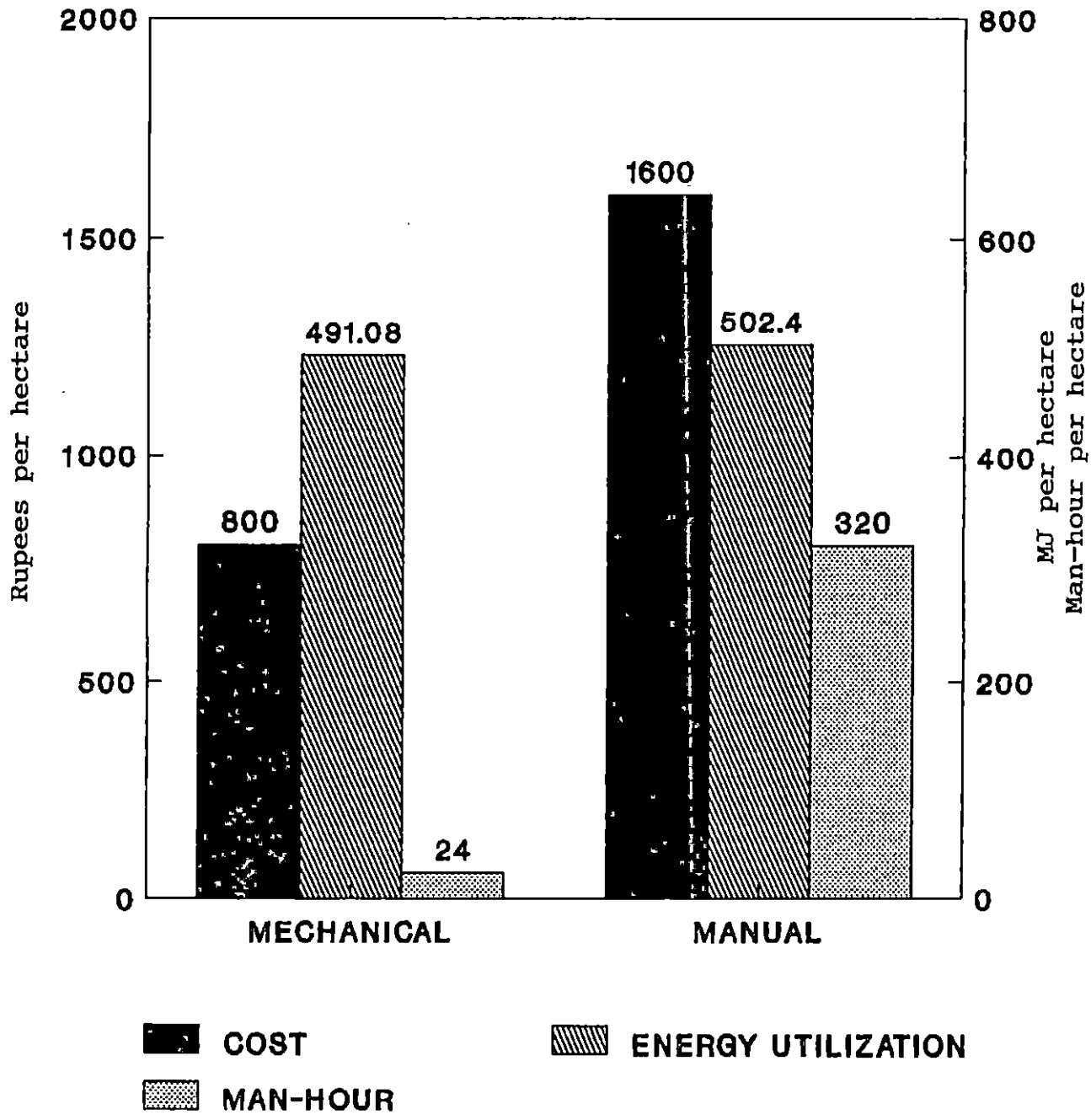


FIG. 7. COST AND ENERGY IN TRANSPLANTING OPERATIONS

introduction of these transplanters. In the place where 320 man-hr are needed for transplanting one ha, it is enough to spend only 24 man-hr to transplant one ha with saving of 296 man-hr per ha.

The comparison of the performance of two paddy transplanters are shown in Appendix 3. As discussed earlier the power tiller operated improved version of paddy transplanter is definitely increase the actual field capacity from 0.017 ha to 0.130 ha per hr, which was actually the demand of farmers.

4.8 Appropriate paddy mechanisation technology

Paddy cultivation in Kerala is confronting a crisis today. Total cultivated area is decreasing at a frightening rate in every year. Major reason for this gloomy situation is that paddy cultivation has nowadays become uneconomical owing to the high cost of cultivation and low yield per hectare. Labour wages is comparatively higher and labour shortage is often felt especially during the peak seasons of agricultural operations. The significance of mechanisation and the introduction of labour saving and appropriate farm machinery like power tiller operated paddy transplanters, self-propelled paddy reapers and rasp-bar paddy threshers will definitely reduce the cost of cultivation and man power requirement and

solve the major problems faced by farmers to a certain level. The appropriate mechanisation does not mean the replacement of a vast labour force involved in agriculture but will reduce peak requirement and drudgery of the labourers and thereby increasing the work output of the labourers.

The analysis of comparative cost of cultivation and man-hr saved per ha for the operations like

(i) transplanting the paddy seedlings which are pulled, root washed and transported to the main land by
   a. manual method and
   b. Mitsubishi power tiller operated improved paddy transplanter

(ii) harvesting the standing paddy crop and leaving on the field itself as windrows by
   a. manual method by sickle and
   b. self-propelled 5 hp paddy reaper windrover and

(iii) threshing and winnowing the harvested paddy crop at the threshing yard by
   a. manual method by crushing under foot or beating against the ground and
   b. using 7.5 hp flow through rasp-bar paddy thresher winnower are given in the Table 5.

It is well understood from Table 5 that introduction of a power tiller operated transplanter, 5 hp self-propelled reaper and 7.5 hp rasp-bar paddy thresher for the basic three operations could reduce the total labour required by an extent upto 90.60 per cent by bringing man-power requirement from 690 man-hr per ha to only 65 man-hr per ha. This is considered to be a promising result in the strategy of reducing the labour input in paddy cultivation. The reduction of labour for the above major operations which constitutes the major labour investments, will pay the way for reviving the uneconomical situation in the paddy cultivation owing to these

Table 5. Cost and man-power saving per hectare by introduction of appropriate machinery for paddy cultivation

Sl. No.	Operations	Conventional		Appropriate machinery		Saving	
		Man-hr	Rs.	Man.hr	Rs.	Man-hr	Rs.
1.	Transplanting	320	1600	24	800	296 (92.5%)	800 (50.0%)
2.	Harvesting	200	1800	21	860	179 (89.5%)	940 (52.2%)
3.	Threshing	170	1700	20	800	150 (88.2%)	900 (52.9%)
	Total	690	5100	65	2460	625 (90.6%)	2646 (51.8%)

reduction in the human labour requirement. The cost for carrying out the above three operations are reduced from Rs.5100 to Rs.2460 by the introduction of these simple farm machinery. The saving of Rs.2640 which is 51.8 per cent when compared to conventional method will be of interest to the paddy growing farmers. This analysis was taken by keeping all other operations like ploughing, puddling, pulling and transportation of seedlings, irrigation, application of chemicals, bundling and transportation of harvested crop, drying and storage as well as all other management operations are same for the farm following conventional method and the farm using the above three appropriate machinery.

The introduction of paddy transplanter will not make any unemployment situations as at present labour scarcity is faced widely for the farm operations. Moreover all other jobs like seedbed and nursery preparations, pulling and transportation of seedlings are done in the conventional way involving the human labourers. In addition, the establishment of manufacture, service, repair and maintenance facilities for the power tiller operated paddy transplanter will actually increase the employment opportunities and income among the skilled hands.

Summary

SUMMARY

Paddy is the major food crop in India and is cultivated both in dry and wet lands. For dry land paddy, the seeds are either drilled or broadcast on well prepared friable soilbed. However, the yield of dry land paddy is lower than that of wetland conditions.

The preparation of the seedbed and transplanting accounts for over 23 per cent of the total working hour for paddy cultivation. The transplanting job which is a major labour intensive and strenuous often coincides with harvesting and threshing operations creating labour scarcity. In Kerala, labour wages are very high and paddy area and production was gradually decreasing for the last ten years due to high cost of cultivation. The introduction of suitable and appropriate machinery for transplanting, harvesting and threshing operations are very essential to make paddy cultivation profitable.

The IRRI manually operated paddy transplanter was evaluated in Kerala. Due to low field coverage and requirement of special (mat) type seedling, the manual transplanters were not accepted by the farmers. A transplanter with high field capacity using conventional root

washed seedlings, which can be operated by the commonly available power tiller will readily be accepted by the farmers. This will reduce the cost of cultivation as well as labour scarcity in paddy cultivation and will also increase the annual use of power tiller.

Studies on the eight-row APAU paddy transplanter were carriedout with 8 to 10 hp Mitsubishi power tiller. Several problems including the mounting the transplanter with power tiller, auxillary gear box, slipping of worm and pinion gear set, reciprocating tray movement, planting fingers were observed. Further field studies were carriedout after rectifying all the above defects.

Based on the field experiences and considering all the problems in APAU paddy transplanter, an improved version of paddy transplanter was fabricated at KCAET Tavanur. The wooden float was made in a curve shape in order to avoid the formation of soil bunds on both the sides of the float. The main shaft and transmission shaft were placed at right angle through worm and pinion gear set arrangement. The picker arm assembly was fitted to the extended arm of the four-bar mechanism assembly. The picker arm assembly operates in an elleptical shape to take out the paddy seedlings from the nursery feeding tray through the mouths of the feeding frame assembly. The angle of nursery feeding tray was increased to

45 degrees and it was made to a straight one in stead of curve shape. The nursery feeding tray consists of eight compartments of size 200 mm x 400 mm making the width of operation as 1600 mm. The various types of tray movements were studied and to get the smooth and frictionless movement, the special type of rail and roller assemblies were incorporated. The four set of rollers and rails having one pair of roller for each set was fitted at all the four corners of the tray. This prevented any forward or backward tilting of tray. The entire weight was thus transmitted to both the top and bottom frame of the main structure. Care was taken to restrict the tray movement to only 180 mm in one way, so as to get a free board of 10 mm at both the ends of compartment, thus ensuring the complete collection of seedlings as well as no physical contact by the planting fingers with other metal parts. The uniform distribution of all the components over the float avoided the tilting of transplanter during the field operation.

The improved version of paddy transplanter was operated in laboratory as well as on road for many hours for finding its alignment and maneuverability. When the unit was found satisfactory after several adjustments, it was operated without paddy seedlings in the puddled field. The minor

problems were again rectified and the necessary adjustments in alignment were carried out.

The power from the power tiller gear box is taken through special auxillary gear box to the paddy transplanter. The power through auxillary gear box is transmitted to the main shaft of the transplanter. The transplanter consists of a wooden float on which all the components were assembled. The main shaft of the transplanter was fixed on the wooden float with a pair of bearing support and it transmits the power to the picker arm assembly through a pair of four-bar mechanism. The reciprocating tray movement was obtained by means of a worm and pinion gear set, transmission shaft, tray movement control disc and crank. As the four-bar mechanism actuates the picker arm assembly, the planting fingers take the seedlings through the mouths of the feeding frame assembly from the nursery feeding tray to transplant them in the puddled soil. To and fro motion of the nursery feeding tray supply the seedling continuously to the planting fingers.

The main land was puddled and perfectly levelled. Enough time was given for settling the coagulated particles so as to have a firm soil. When the soil is settled, the water is to be drained and a only thin sheet of water is maintained for the proper operation of the paddy transplanter.

The ordinary paddy seedlings (Var: Hraswa, Red Triveni) having 20 day of age were pulled, root washed and bundled and ready for manual transplanting were actually used for the improved version of paddy transplanter. The unit was operated to transplant the seedlings at KCAET instructional farm, Tavanur during September-October 1994. The power tiller was operated in the field at a forward speed of 1.20 km per hr in the first gear so that 2 to 4 seedlings were transplanted at a spacing of 100 to 120 mm.

All the field observations, machine conditions, seedling observations and field performances were noted and analysed.

The test results are summarised as follows:

1. The power tiller operated improved eight-row paddy transplanter was developed and fabricated. It has an average field capacity of 0.13 ha per hr and field efficiency of 68.42 per cent.

2. An average of 55 hills per sq m and 3 seedlings per hill was obtained which are found in the acceptable range.

3. The missing hills, floating hills and damaged hills were found to be 6.72 per cent, 2.34 per cent and 3.76 per cent respectively.

4. The paddy transplanter has some pre-requisites like good quality nursery, well puddled, settled and levelled field with a a thin sheet of water for its better performance.

5. Cost analysis of the paddy transplanter showed that there was a financial saving of Rs.800 per ha for transplanting operation alone compared to the manual transplanting.

6. It is found that a total of 502.40 MJ of energy is consumed for transplanting one ha by manual labourers as compared to 491.08 MJ of energy consumed by a power tiller. Energy utilization levels in these two systems of operations saved about 50 per cent of the cost of transplanting.

7. The introduction of appropriate machinery for paddy cultivation which include the newly developed power tiller operated improved paddy transplanter, self-propelled paddy reaper and rasp-bar paddy thresher were revealed that there was a labour saving of 625 man-hr per ha and financial saving of Rs.2640 per ha compared to the manual method for the transplanting, harvesting, threshing and winnowing operations alone. This accounts for a saving of 90.6 per cent in man-hr per ha and 51.8 per cent in the cost of operation per ha for the same three operations.

8. The achievements in reducing the man-power and cost and required in paddy cultivation shows a definite solution, bring more area under paddy in Kerala and more paddy production is thus ensured.

References

REFERENCES

Anonymous (1975). Mechanical Transplanting of Paddy Series-2. Report of Tractor Training and Testing Station. Ministry of Agriculture and Irrigation, Tractor Nagar, Budni.

Anonymous (1991). Sri Lankan rice transplanter in Philippines. Farm Equipment International. 12 (1): 24.

Bainu, T.K. (1990). Modification and performance evaluation of six-row rice transplanter for conventional seedlings. Unpublished M.Tech Thesis submitted to KAU, Vellanikkara.

Dass, R.S. and Ratnam, N.V. (1989). Performance Evaluation of Rice Production Equipment. Agric. Engg. Today. 13 (6): 15-23.

Devnani, R.S. (1990). New Implements for Farm Jobs. Indian Farming. 40 (6): 5-7.

Eamopas, K., Munthumkaran, V., Ounkong, N., Goto, Y. and Yamauchi, T. (1988). Performance of a self-propelleed riding type rice transplanter. J. Kasetsart. 22 (5): 78-87.

Hoshino, S. (1974). Further progress of the paddy rice seedling transplanting machine in Japan. JARQ. 4 (1): 19-22.

Igbeka, J.C. (1984). Development in rice prouction mechanisation. Agric. Mech. Asia. 15 (1): 27-32.

Karunanithi, R., Chinnan Chetty, G. and Shanmughan, A. (1983). Annual report. All India Co-ordinated Research Project on Farm Implements and Machinery (ICAR), TNAU, Coimbatore: 55-68.

Kikaika and Nogyo. (1986). A high speed rice planter from the Institute of Agricultural Machinery, increased efficiency through a rotating planting mechanism. Farming Mechanisation. 1: 39-40.

Kurup, G.T. and Datt, P. (1981). Rice Transplanters. Tech. Bulletin. Central Rice Research Institute, Cuttack. 1: 2-14.

Mandhar, S.C. (1975). Design of Paddy Transplanter. Unpublished M.Tech thesis. Dept. of Applied mechanics, Indian Institute of Technology, New Delhi.

Manian, R., Natrajanmoorthy, K., Chinnanchetty, G. and Kumar, V.J.F. (1987). Evaluation of IRRI Rice Transplanter in clay loam soil. J. Agric. Engg. ISAE. 24 (2): 127-136.

Mittal, V.K., Mittal, J.P., Dhawan, K.C., Panesar, B.S. and Sodhi, K.S. (1985). Management data on farm power, energy and machinery. All India Co-ordinated Research Project on energy requirements in agricultural sector. PAU, Ludhiana: 5.14-5.17.

Nishio T. and Fujii, S. (1975). Relationship between the physical characteristics and the injury of seedlings on mechanical transplanting. Proceedings crop science society of Japan, Saitama. 44 (4): 471-476.

Parida, B.C. and Das, H. (1977). Development and performance of an experimental automatic paddy transplanter. J. Agric. Engg. 14 (2): 74-76.

Quiang, D.Z. (1986). Rice seedling transplanting in China. Proceedings. International Conference on Small Farm Equipments to Developing Countries, Manila: 207-211.

Reddy, S. (1984). Annual report. All India Co-ordinated Research Project on Farm Implements and Machinery (ICAR), Pantnagar. pp.18-130.

Salazar, G., Ebran, L., Icatio, H., Duff, B. and Sickney, R.E. (1986). Rice seedling transplanters in Philippines. Proceedings. International Conference of Small Farm Equipments to Developing Countries, Manila: 213-298.

Sandhu, B.S. (1975). Attempts in the development of a new machine for transplanting paddy. The Agric. Engineer. 17: 25-30.

Sivaswami, M. (1985 and 1990). Feasibility trials of IRRI five-row and six-row rice transplanter. Annual reports. All India Co-ordinated Research Project on Farm Implements and Machinery (ICAR), KCAET, Tavanur.

Sivaswami, M. (1993). Evaluation of power tiller operated paddy transplanter. Annual report. All India Co-ordinated Research Project on Farm Implements and Machinery (ICAR), KCAET, Tavanur.

Stout, B.A. (1968). Equipment for Rice Production, FAO, Rome.

Swain, S. and Maity, S.P. (1989). Influence of seedling mat parameters on performance of manually operated rice transplanter. J. Agric. Engg. 26 (2): 173-181.

Wang, D.S. and Zhang, C.H. (1989). The development of rice transplanting mechanisation in China. Proceedings. International symposium on agricultural engineering, Beijing: 12-15.

Appendices

APPENDIX I

Specification of power tiller

Brand name	:	Mitsubishi Sakthi
Model	:	CT 85
Type	:	4 cycle air cooled, inclined, 1 cylinder, overhead valve type diesel engine fitted with walking type tractor
Chasis No.	:	V9C-33573
Engine No.	:	V9C-23873
Combustion chamber type	:	Special swirl combustion chamber type
Bore x stroke	:	80 x 90 mm
Swept volume	:	452 CC
Compression ratio	:	20:1
Rated output/crankshaft rpm	:	8 hp/3000 rpm
Maximum output/crankshaft rpm	:	10 hp/3200 rpm
Dry weight of engine	:	115 kgs
Capacity of lubricating oil	:	2.7 litre
Using fuel	:	Diesel oil
Tank capacity	:	8 litre
Air cleaner	:	Oil bath type
Tilling system	:	Side drive rotary 4 speed tilling system
Transmission	:	6 forward, 2 reverse speed, 4 rotary speed
Clutch	:	Multiple plate dry disc

Brake	:	Hand operated internal metallic shoe type
Lubrication	:	Grade box SAE 90
Length of power tiller	:	230 cm
Width of power tiller	:	67 cm
Height of power tiller	:	120 cm
Weight without engine	:	230 kg
Fuel consumption	:	1 to 1.2 ltr per hr

Speed, km per hr :

	Low speed	High speed
1st gear	1.2	4.8
2nd "	1.9	7.6
3rd "	3.3	14.6
Reverse "	0.9	2.8

APPENDIX II

Cost of operation of improved version of eight-row paddy transplanter

1. Power tiller

A. Basic information

(i)	Cost of the machine, Rs.	:	70,000
(ii)	Useful life, years	:	10
(iii)	Hours of use per year	:	800
(iv)	No. of skilled labour requirement	:	1
(v)	No. of unskilled labour requirement	:	2
(vi)	Skilled labour wage per day, Rs.	:	75
(vii)	Unskilled labour wage per day, Rs.	:	40
(viii)	Repair and maintenance	:	5% of cost of machine
(ix)	Interest on investment	:	25% per year
(x)	Salvage value	:	10% of cost of machine
(xi)	Insurance and shelter	:	2% per year

B. Cost items

I Fixed cost

(i) Depreciation cost per year, Rs. : $\frac{\text{Initial cost-salvage value}}{\text{Useful life}}$

$$= \frac{70000 - 7000}{10}$$

$$= 6,300$$

(ii) Repair and maintenance per year, Rs. : Cost of machine x 0.05

= 70000 x 0.05

= 3,500

(iii) Interest on investment per year, Rs. : (Cost of machine + salvage value)/2 x Interest rate

$= \frac{(70000 + 7000)}{2} \times 0.25$

= 9,625

(iv) Insurance and shelter per year, Rs. : Cost of machine x 0.02

= 70000 x 0.02

= 1,400

Total fixed cost per year, Rs. = 6300+3500+9623+1400

= 20,825

Total fixed cost per hr, Rs. = 26.10

Rounded to the value, Rs. = 30

II Variable costs

(i) Labour cost per hr, Rs. : $\frac{75 \times 1}{5}$

= 25

(ii) Fuel cost per hr : 10

Total variable cost per hr : 35

Total cost of power tiller per hr, Rs. = 65

2. Paddy transplanter

A. Basic information

(i) Cost of machine, Rs. : 10,000

(ii) Useful life, years : 5

(iii) Hours of use per year : 300

B. Cost items

I Fixed costs

(i) Depreciation cost per year, Rs. : $\frac{(10000 - 100)}{5}$

= 1800

(ii) Repair and maintenance per year, Rs. : 1000 x 0.05

= 500

(iii) Interest on investment per year, Rs. : $\frac{(10000+1000)}{2}$ x 0.25

= 1375

(iv) Insurance and shelter Per year, Rs. : 1000 x 0.02

= 200

Total fixed cost per year, Rs. : 1800 + 500 + 1375 + 200

= 3875

Total fixed cost per hr, Rs. = 12.90

Rounded to the value, Rs. = 15

II Variable cost

(i) Labour cost per hr : $\frac{40 \times 2}{5}$

= 16

Rounded to the value, Rs. = 20

Total cost of paddy transplanter per hr, Rs. : 35

Total cost per hr for power tiller and paddy transplanter, Rs. : 100

Cost of operation per ha : $\frac{100}{0.13}$

= 769.25

Round to the value, Rs. = 800

APPENDIX III

Comparison of performance of two paddy transplanters

Sl. No.	Particulars	Power tiller eight-row paddy transplanter	IRRI six-row paddy transplanter
1.	Speed of machine, km per hr	1.20	0.17
2.	Effective transplanter width, mm	1600	1200
3.	Distance between rows, mm	200	200
4.	Distance between hills, mm	100 to 120	140
5.	Actual field capacity ha per hr	0.130	0.017
6.	Fuel consumption		
	Per hr, lit	1.05	Not applicable
	Per ha, lit	8.10	Not applicable
7.	No. of seedlings per hill	3 to 4	3 to 5
8.	Depth of transplanting, mm	42	20

ABSTRACT

Transplanting of paddy seedlings is a very tiresome and labour consuming operation and labour shortage is experienced during planting. As a solution to reduce the high cost of cultivation and labour shortage in paddy transplanting, a power tiller operated paddy transplanter is an essential need of hour. The APAU paddy transplanter was evaluated after rectifying the defects at KCAET instructional farm, Tavanur.

Based on the field experiences and considering the all problems in APAU paddy transplanter, an improved version of power tiller operated paddy transplanter was developed and fabricated at KCAET Tavanur and tested during September-October 1994. The conventional root washed paddy seedlings ready for manual transplanting were used. When the power tiller is operated at a forward speed of 1.20 km per hr, the transplanter could transplant 2 to 4 seedlings per hill at a spacing of 100 to 120 mm. The average field capacity was found to be 0.13 ha per hr. A saving of Rs.800 per ha which is 50 per cent and reduction of 296 man-hr per ha which is 92.5 per cent was achieved for transplanting operation alone compared to manual transplanting.