MODIFICATION AND PERFORMANCE EVALUATION OF SIX ROW RICE TRANSPLANTER FOR CONVENTIONAL SEEDLINGS

By

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THESIS

Submitted in partial fulfilment of
the requirement for the degree

Master of Science in Agricultural Engineering

Faculty of Agricultural Engineering
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Tavanur - Malappuram

1990

DECLARATION

I hereby declare that this thesis entitled "Modification and Performance Evaluation of Six Row Rice Transplanter for Conventional Seedlings" is a bonafide record of research 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.

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CERTIFICATE

Certified that this thesis entitled "Modification and Performance Evaluation of Six Row Rice Transplanter for Conventional Seedlings" is a record of research work done independently by **Smt. Bainu T. Kuzhively** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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SYMBOLS AND ABBREVIATIONS USED

Agric.	-	Agricultural
Agron.	-	Agronomy
Amm.	-	American
ASAE	-	American Society of Agrincultural Engineers
CIAE	-	Central Institute of Agricultural Engineering
cm	-	centimetre(s)
Dept.	-	Department
dia.	-	diameter
edn.	-	edition
et al.	-	and other people
Fig.	-	Figure
FIM	-	Farm Implements and Machinery
ha	-	hectare(s)
hp	-	horse power
hr	-	hour
ICAR	-	Indian Council of Agricultural Research
Inc.	-	Intercontinental
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
kmph	-	kilometre(s) per hour
m	-	metre(s)
m^2	-	square metre(s)
min	-	minute(s)
mm	-	millimetre(s)

MS	Mild Steel
No.	number
N.Y.	New York
pp	pages
PAU	Punjab Agricultural University
Proc.	Proceedings
Res.	Research
RNAM	Regional Network of Agricultural Machinery
rpm	revolutions per minute
Rs.	rupees
sec	second(s)
Soc.	Society
TNAU	Tamil Nadu Agricultural University
USA	United States of America
/	per
%	per cent

Introduction

INTRODUCTION

Rice is the unique major food crop of the world by virtue of the extent and variety of uses and its adaptability to a broad range of climatic and cultural conditions.

About half of the world's population is dependant on rice as their principal energy supplying food grain. Considering this importance of rice it was described as the 'Grain of Life' by the United Nations in 1966. 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 hectares. It has been observed that the area of rice cultivation in Kerala is decreasing steadily for the last few decades. In 1970-71 there were 0.874 million hectares of land under rice cultivation which reduced to 0.663 million hectares in 1988-89. The main reason for this decline in area is largely due to the high cost of labour charges prevailing in the state which makes rice cultivation unprofitable. Presently the labour charges are three to four times higher than the other parts of the country.

The rice crop can be raised either by direct seeding or by transplanting. Transplanting is done either by planting young seedlings in the puddled soil manually or by a mechanical transplanter. Transplanting is the most common method adopted in the South East Asian countries. Transplanting has got several advantages over direct seeding, method such as lower seed requirement, healthy seedlings, less sensitive to draught, and heavy raining conditions, optimum plant spacing etc. Transplanting is done manually as follows. The bunch of seedlings is held in the left hand and two or three seedlings are separated by the right hand and they are fixed in the puddled field. This method is very effective but involves more than 250 man hours per hectare. Besides labour intensiveness of the operation, it involves considerable drudgery for the labourers. There is often acute shortage of labourers also at the time of transplanting and the timely farm operations are very essential for better yield. The labour requirement in transplanting may be as high as 3.5 to 10 times in case of manual transplanting compared to direct seeding.

The introduction of suitable machines for transplanting harvesting and threshing operations is very essential in Kerala to make rice cultivation profitable. The advantages of machine transplanting are many. It provides relief from the tedious bending postures, avoids dipping of the fingares in the puddled field and reduces the human energy expenditure. Vos reported that bending postures similar to that followed in rice transplanting an extra energy expenditure of about 2 kcal per min and heart rate increases by 35 per cent.

Although power transplanters are working satisfactorily in Japan these machines can not be as such adaptable to our conditions in the state, due to the problems such as complex mechanisms, high initial cost and running cost, greater skill required in the operation of the machine etc. A feasibility study conducted by the IRRI indicated that it may be too costly for the small rice farmers to use power transplanters. So these transplanters are beyond the reach of small farmers in developing countries.

Recognising these problems the Agricultural Engineering Department of the International Rice Research Institute (IRRI) designed and developed the manually operated transplanter. This model works efficiently with mat type rice nurseries. But mat type nursery raising requires advanced agronomical and plant protection techniques. That much expertise can not be expected from ordinary farmers of the state. So this machine has to be suitably modified to use conventional rice seedlings.

Hence it is proposed to modify the existing six-row rice transplanter for conventional seedlings with the following objectives.

1. To modify the existing IRRI six-row rice transplanter to use conventional seedlings.
2. To evaluate the performance of the modified transplanter in the field.
3. To identify the problems in the performance if any, and undertake possible rectifications.

Review of Literature

REVIEW OF LITERATURE

This chapter briefly reviews the results of the investigations on various rice transplanters, carried out in India and abroad in the past. The literature survey has arranged under the following headings.

1. Different sowing methods of rice
2. Development of rice transplanters viz. transplanting aids, transplanters using non-conventional seedlings and conventional seedlings

2.1 Different sowing methods of rice

Investigations in India and abroad proved that the transplanting of rice has a series of advantages over other methods.

Clouston (1908) stated that a transplanted field could be easily detected as the tillers were numerous and the crop less weedy. In Italy rice is either drilled or broadcasted or transplanted by mechanical means. Tompany (1932) reported that transplanting induces a higher yield, gives more regular stand, facilitate weeding and reduces the amount of supply of essential nutrients. It also shortens the period of duration which the crop occupies the land.

Bennet *et al*. (1941) pointed out that in some parts of Japan and USA rice has been sown directly on the paddy field as thickly as is customary with transplanted rice, and yields have been approximately the same. Adair *et al*. (1942) in the United States proved that after over a period of years, no significant differences in average yields resulted from the direct and transplanting methods.

Experiments in the Philippines proved that transplanted rice developed faster and was more uniform, taller, and matures later than broadcasted seed. The mean yields were 3230 kg and 2150 kg per hectare for transplanted and broad casted seeds respectively (Calma *et al*., 1948). Efferson (1952) reported that the improvements in cultivation methods and change over from broadcasting to transplanting increase the average yield from 1750 kg per hectare to 4300 kg per hectare. In India the increase in yield through transplanting had been 15 to 30 per cent (Rahmiah, 1954). Experiments in Egypt showed that yield under transplanting was 20 per cent higher than direct sowing (Gad-El-Haq, 1963).

More recent work in the Philippines showed that there was only little difference in yield between broadcasted and transplanted rice but that direct sowing required the use of non-lodging and more care than the usual. Transplanting is advisable as a protection against pests, to offset the effects of low seed viability, poor water supply and control and facilitates weed control (Anon, 1976).

Timeliness of transplanting is considered as very essential for optimizing yield and there has been an increase in realization among rice growing countries to design and develop transplanters capable of performing precise and timely transplanting of rice seedlings at an acceptable cost (Kurup et al., 1981).

Experiments and experiences in all the important rice producing regions confirm that higher yield is obtained from transplanted rice than from direct broadcasting or drilling (Grist, 1985). Transplanting enables easy management, saving in time, water, weed and pest control expenditure, and maximum use of the land.

2.2 Development of rice transplanters

Hand transplanting is very labour intensive and the high labour input often results in labour shortages during the planting, season (Salazar et al., 1985). The traditional method of transplanting is painful to the labourers as there is a bending position through out the time of transplanting. Besides approximately thirty per cent of the total labour requirement for rice production is accounted for transplanting (Anon, 1978). The attempts made to evolve different transplanting mechanisms for rice have been briefly reviewed here.

2.2.1 Transplanting aids

Around 1950, a hand transplanting aid was developed and used in Taiwan (Stout, 1968). It was a simple aid consisting of an iron rod with a fork forged on one end (Fig.1). A wooden handle was mounted on the other end of the rod. It had a length of 45 cms. Two to four plants were slipped into the fork and the tool was plunged into mud and withdrawn leaving the seedlings in its place. This contributed to an increased rate of transplanting by about 20 per cent; but as it required considerable skill and experience it soon became absolute. The disadvantages of the tool that the depth of planting count not be felt by the operator, was overcome by adding a small plate at right angles, but still it did not become popular.

Mandhar (1975) designed and developed a three-row transplanting aid for rice. It consists of a mainframe, three seedlings droping tubes a spring loaded and hinged seedling retainer at the bottom, three planting fingers and an actuating mechanism. The device was reported to require about 300 man hours per hectare which practically saved no labour.

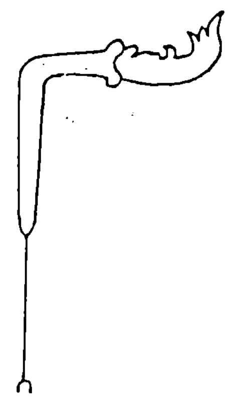


Fig.1 Hand transplanting aid (Stout, 1968)

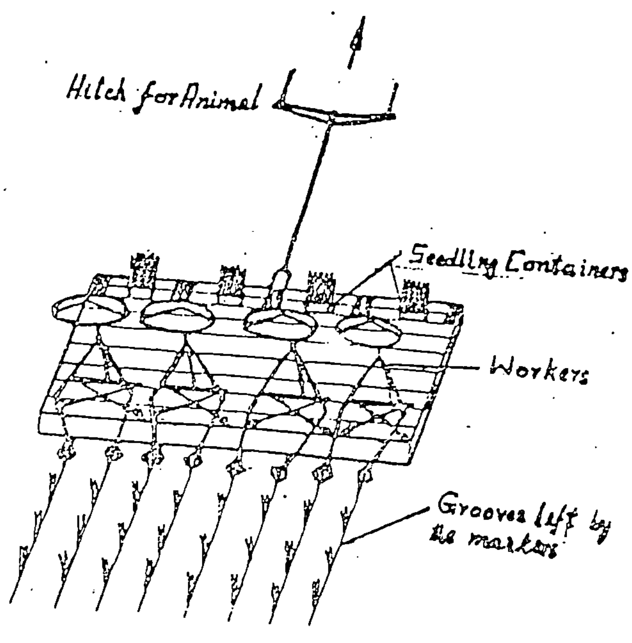


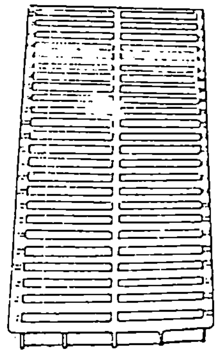
Fig.2 Wooden transplanting platform (Ben-Nun, 19‾5)

Ben-Nun (1975) reported the design of a wooden rice transplanter platform that could be drawn over the rice field by a single animal (Fig.2). It had 240 cm length, 70 cm width and 12 cm height with eight adjustable pegs for making underneath. The persons sat on the platform in cross legged posture. A worker picked up 6 to 8 seedlings from the bunch kept on his lap, divided them into two halves and then transplanted them by both hands in two adjacent markings left by the pegs. It was claimed that four trained workers and a driver could do the work of fifteen labours.

2.2.2 Transplanters using non-conventional and conventional seedlings

Non conventional seedlings are those which raised in a special nursery using frames such as band type or continuous band type, pot type or mat type seedlings. 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 (Fig.3a). In continuous band type the partitions did not span from edge to edge, so that the seedlings when grown took the shape of a continuous band extending from one cover of the box to the diagonally opposite corner. This was also to be cut into

(a)



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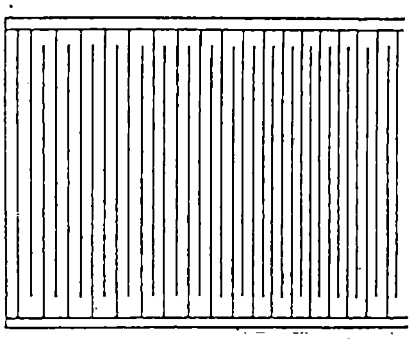

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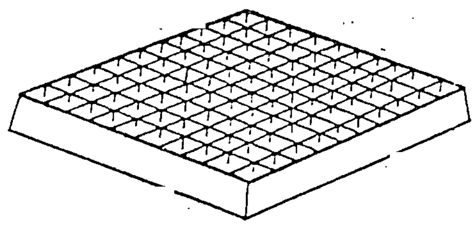


Fig.3 Types of Non-conventional seedling nursery frames (Biswas, 1981)

a. Band type nursery box

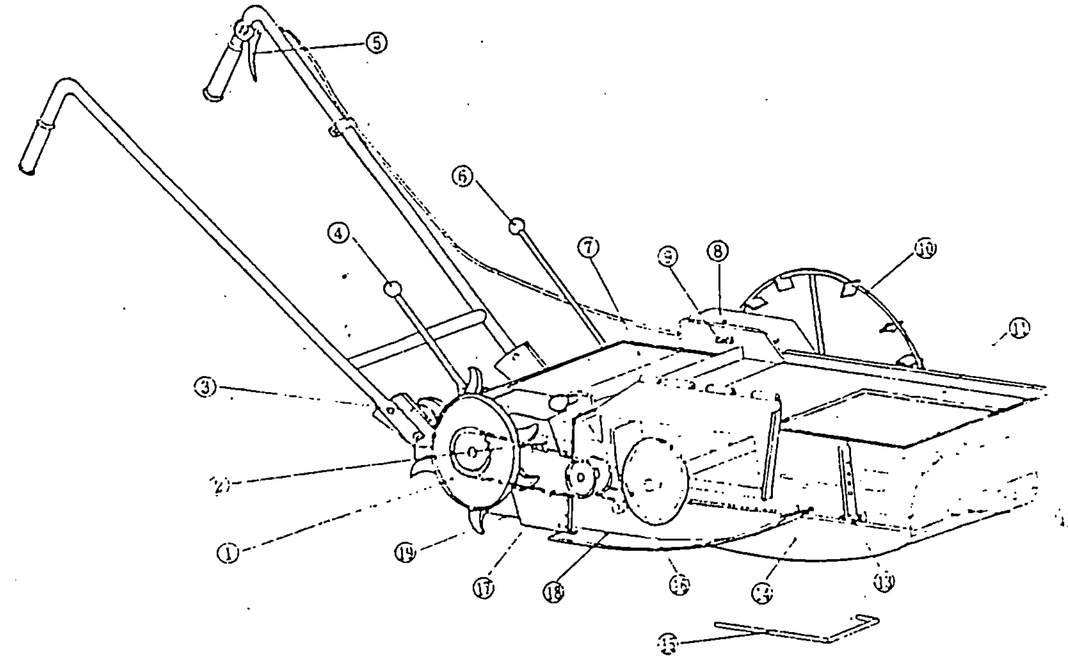
b. Continucus band type nursery box

c. Pot-type nursery box

blocks at the time of transplanting (Fig.3b). In the pot-type, the box was divided into blocks or pots by lattice like partitions. The seedlings grown in this were ready to use without cutting (Fig.3c) (Biswas, 1981).

In mat type two methods were adopted. One is single frame method and the other is double frame method. In single frame method, frames were kept side by side and the seedlings grow like a mat, with their roots inter woven. The frames could be removed one week after sowing. In double frame method another frame positioned on the top of the first one. The top frame could be removed a week after sowing. The lower frame could be removed with the removal of seedlings only. The top surface of the lower frame serve as guide for the knife while removing the seedling mat. The transplanting unit was able to cut and slice out block of seedlings from the mat.

The transplanters for non-washed seedlings appeared in Japan in 1966 for the first time (Miura, 1966). Seedlings for this type of machines (Fig.4) were grown in a box and had a corrugated polythelene sheet below it (Band type). Though transplanters using seedlings 5 to 6 leaf stage were introduced those using young seedlings of 2-3 leaf stages were more popular as these seedlings had less soil thickness, seedling band of about 7 mm width pulled out from a seedling holder and cut to about 1 cm by a blade and star wheel. The

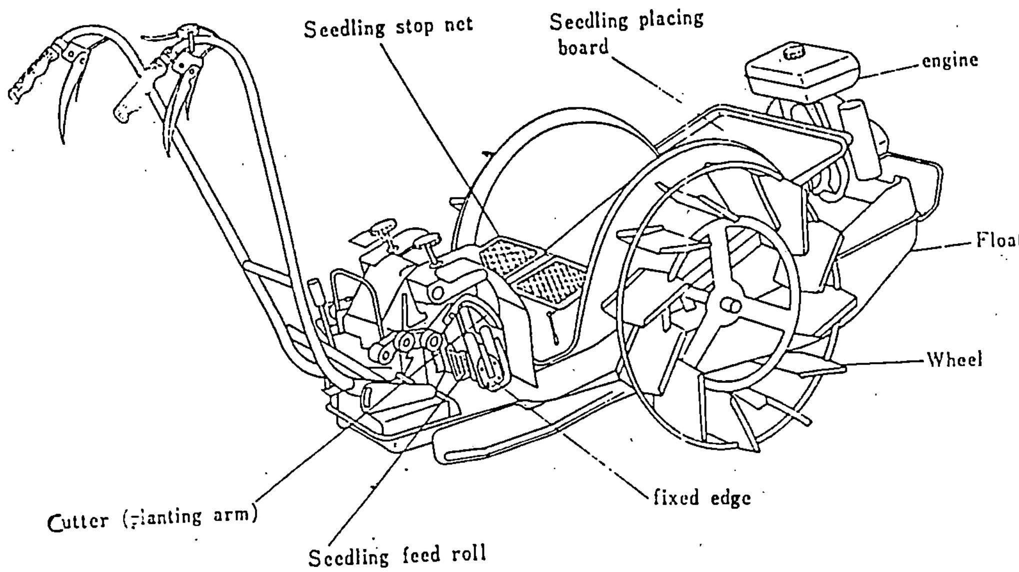


① Star wheel : to cut and plant seedlings
② Conveyor belt : to carry seedlings
③ Handle-bar controller : to adjust the angle of handle-bar to the machine body
④ Float controller for vertical direction
⑤ Seedlings flow control lever : to control seedlings flowing out from the seedling box
⑥ Wheel adjuster : to adjust sinking of the wheels so as to run machine smoothly
⑦ Seedlings guiding board
⑧ Device for carrying out seedlings
⑨ Fixer of roller
⑩ Wheel : to drive other rotating parts
⑪ Seedling box holder
⑫ Handle-bar
⑬ Marker(1) : to adjust the spacing between rows on which seedlings are planted. (Holes from bottom upward on the guide board show those of marker respectively for the spacings of 24, 27, 30, 33, and 36 cm
⑭ Float
⑮ Marker(2) : to be fixed to Marker(1)
⑯ Gear-box
⑰ Chain
⑱ Levelling board : to level the surface of field where rice seedlings are to be transplanted.
⑲ Blade

Fig.4 Transplanting machine for soil bearing seedlings (Miura, 1966) claw, then planted these seedlings by pushing into the soil. Under ideal conditions, the machine transplanted to a depth of 2 to 3 cm at a rate of one hectare in thirty hours with missing hills of less than ten per cent.

Hoshino (1969) reported about a two row self-propelled machine which had a float and it used continuous band type seedlings (Fig.5a). The end of the band was carried to the fixed edge of the roll. Here a cutter, sliced the band into blocks which were then planted into the field. A seedling top net controlled the movements of the seedlings by pushing the leaf-tips of the seedlings and helped the seedlings to move into the planting system regularly. The height of the net was adjustable to suit the seedlings height. The slicing and planting operations are shown in Fig.5b.

It has been reported that in Japan the required and expenditure incurred in raising mat type nursery were less than other types. Transplanters for the type of nursery were introduced in Japan in the seventies. All the Japanese transplanters which had passed the National tests were engine driven machines of walking type with floats using non-washed seedlings (Yoshiakimori, 1975). They were two row or four row transplanters. The engines were four stroke gasoline engines in the range of 1.6 to 2.5 hp. The floats and wheel system were adjustable which provided excellent right direction



(a)

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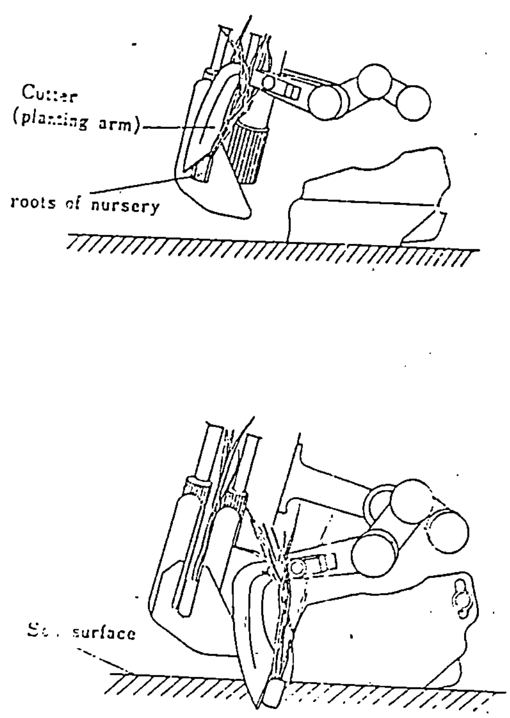


Fig.5 Transplanting machine (Hoshino, 1969)

a. Machine with float

b. Cutting and planting of band type nursery mobility of machine under all swampy conditions and a constant planting of seedlings were made by the planting fork. The planting fork was attached on a planting arm and the blocks were transplanted along a straight line. The planting fork was provided with a pair of claws which held the out blocks of the seedlings, between them and carried them to the transplanting position in the field and released the seedlings. Different arrangements were of the planting forks to cut and release the seedlings could be seen in different models but all of them worked by a link mechanism driven by a crank arm mounted on a shaft that was powered by an engine as shown in Fig.6a. Releasing of the seedlings from the planting fork were arranged in two ways (Hoshino, 1974). In one system the clearance between the two claws was changed by shifting claws (Fig.6b). In the other system planting fork rotated through certain angle to widen the gap between them and thereby release the seedlings, while a third arrangement employed a supplementary fork to push out the seedlings from the claw of the planting fork.

Singh and Garg (1977) reported the development of a six row rice transplanter using mat-type seedlings in Punjab. It had three units and each unit had been given separate power drive. The average row spacing was 300 mm and the plant distance could be varied from 140 mm to 160 mm. The working of this machine was found quite satisfactory, with coverage only 0.1 hectare per hour and was not economical in comparison to hand transplanting. This unit was modified into a 10 row transplanter which increased the field capacity upto 0.17 hectares per hour at a working speed of 12.4 kmph. It planted seedlings at a row spacing of 26.6 and hill distance of 14 cm with 12 per cent missing hills. It required 28 man hours per hectare for driving the tractor and feeding the seedling.

Development and evaluation of a tractor mounted rice transplanter was started in 1974 as a co-operative project between Malaysia and Japan. After modifying the initial 8 row transplanters named Tanima and Granti tractor mounted Sandai (Fig.7) version was reported to have missing hills of only 10 per cent. It was capable of operating in 10 cm standing water at a speed of 0.3 metre per second. The machine could cover one hectare area in 4.2 hours and field efficiency was about 73.5 per cent. Preparation of mat type seedling was the only problem for the success of such transplanters (Biswas, 1981). He has also reported that a 4 row manual transplanter for soil bearing seedlings had been developed at IRRI (Fig.8a). The major components of the machine were feeding frame ejector fingure, ejector holder, ejector lever and handle. A prawl and rachet mechanism causes the tray to move laterally when a lever was actuated by the planting frame. The downward stroke of the handle picked the seedlings and planted them and upward strokes released them.

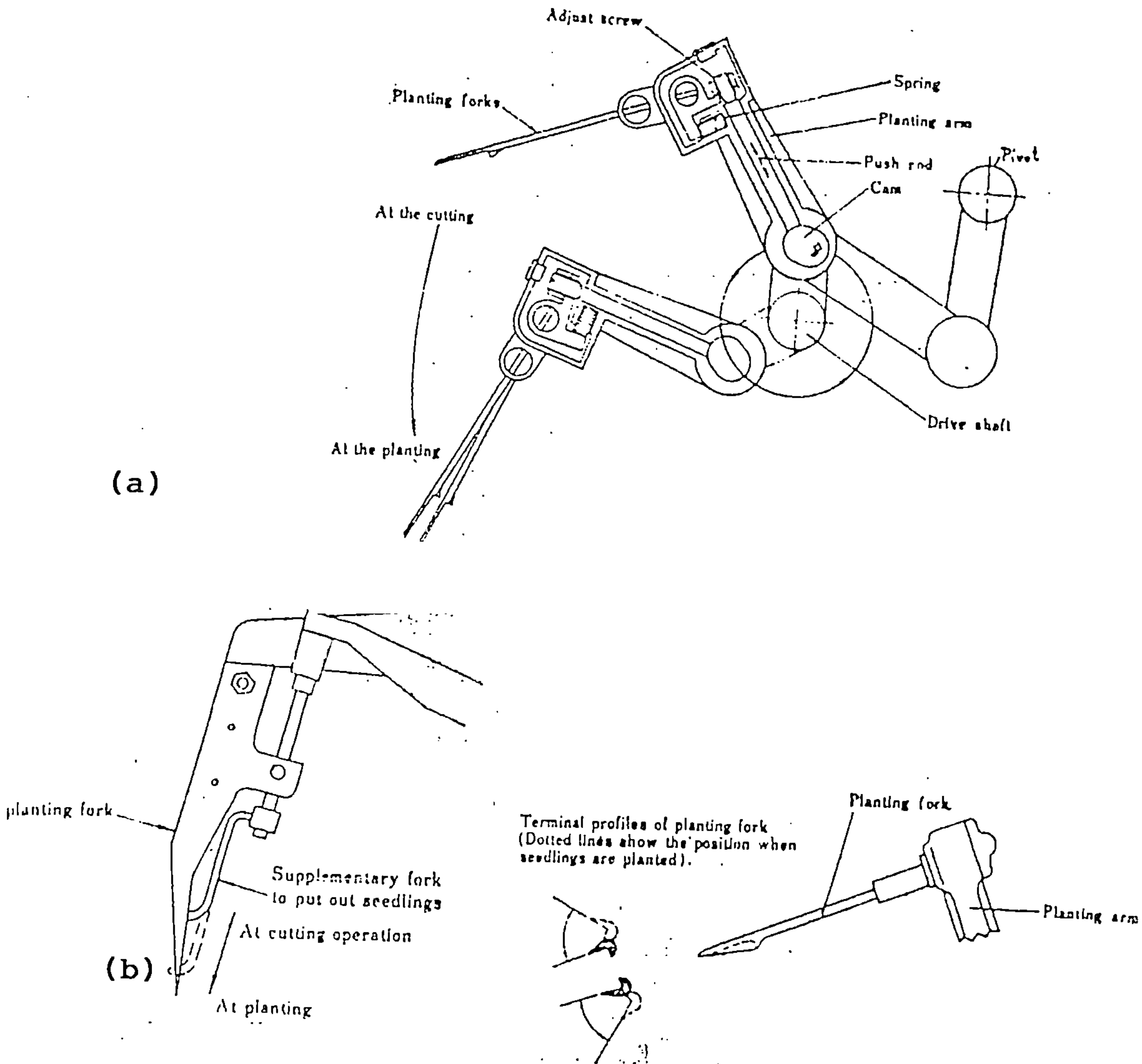


Fig.6 Planting forks for mat type nursery (Hoshino, 1969)

a. Line requirements of the planting fork

b. Types of planting fork

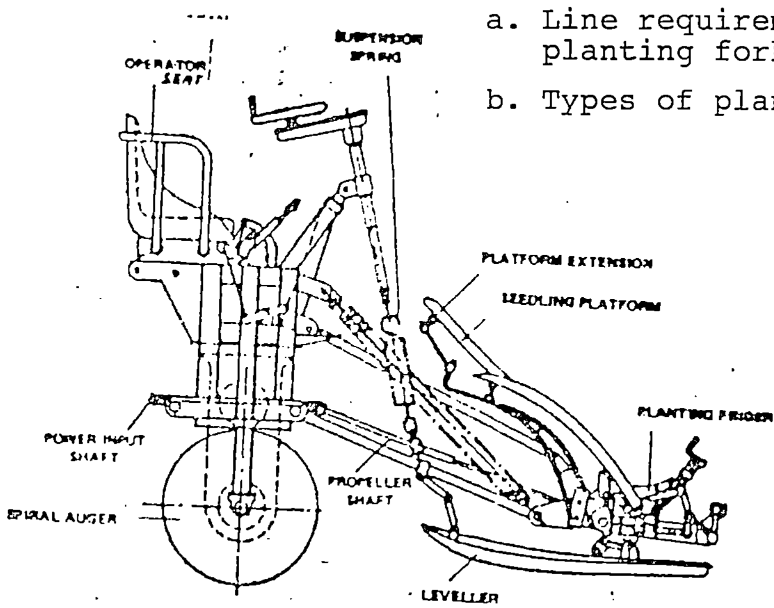


Fig.7 Tractor mounted transplanter (Handai, 1974)

The 5 row and 6 row were developed in the lines of 4 row unit by the IRRI. The operation of the 5 row transplanter was similar to 4 row rice transplanter (Fig.8b). Karunanithi et al. (1983) evaluated the five row manually operated rice transplanter. They studied the different methods of preparation of mat type nursery and the performance of the manually operated rice transplanter. They found that the capacity of the machine was 0.1 ha/day. There was 40 per cent saving in labour cost and 9 per cent saving in total cost of transplanting including nursery preparation as compared to the traditional method. They also found that the usage of the machine over and above 3.24 hectare per year yielded benefits.

Improvements of the five row rice transplanters which began in 1982, produced the six row rice transplanter model (Fig.9). Changing the five row to six row version increased the capacity to 0.35 ha/day and reduced the floating hills since the operators foot prints fell between third and fourth rows of the transplanted seedlings. The weight of the machine was reduced to 20 kg (Salazar et al., 1985).

Grarg and Sharma (1985) reported that under the auspices of the Indian Council of Agricultural Research (ICAR) developments were carried out on rice transplanters at Bhopal, Ludhiana, Coimbatore and Hydrabad. It has been reported that all these centres started their work with the IRRI rice

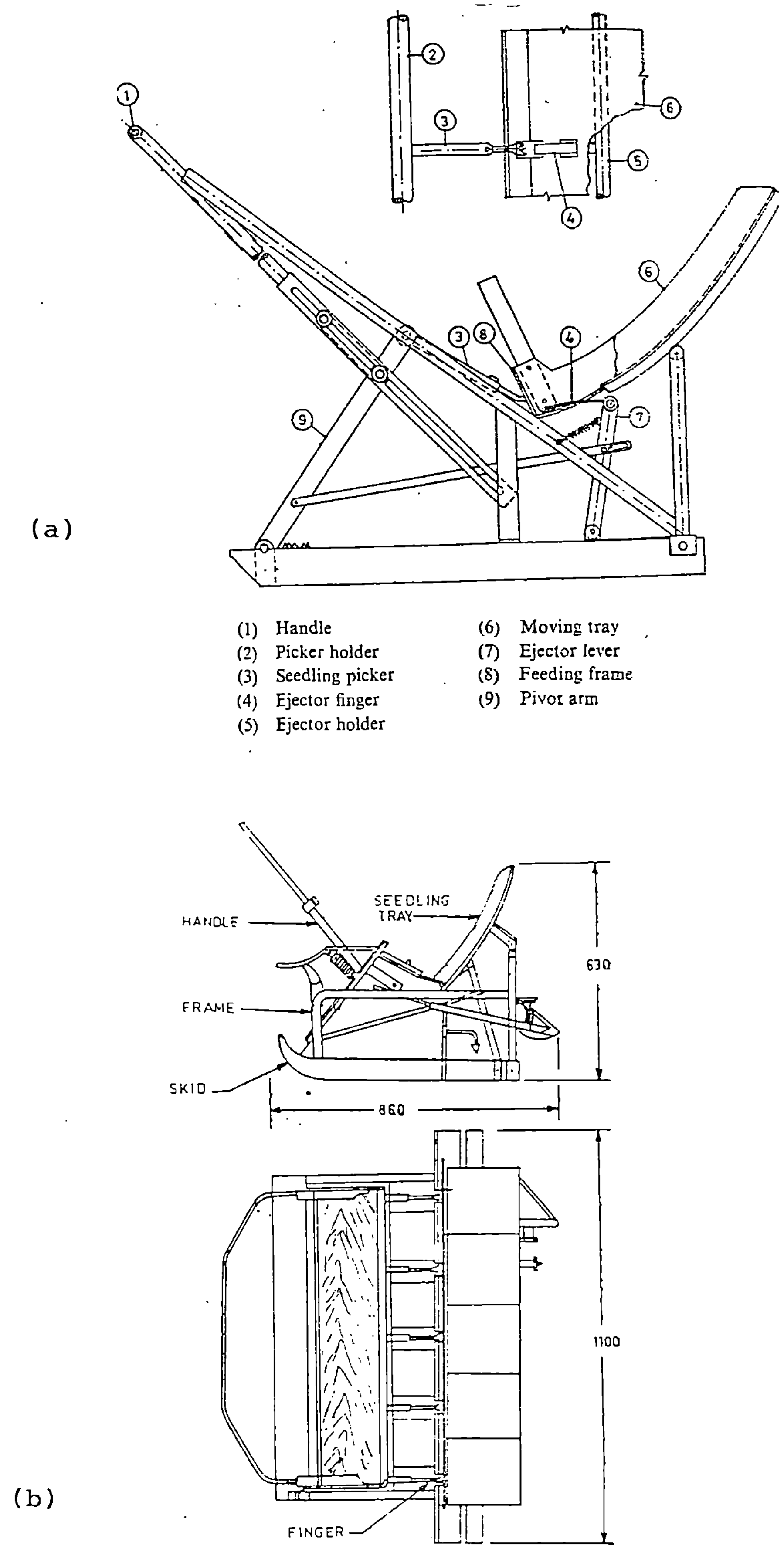


Fig.8 IRRI manual rice transplanters (Salazar, 1985)

a. Four row rice transplanter

b. Five row rice transplanter

transplanter as the base model. The six row Korean riding type transplanter with mat type seedlings was modified at Ludhiana and they found that it saved around five per cent labour and thirty five per cent cost. The net labour saving was about 145 man hours per hectare and net financial saving was Rs.154 per hectare over the traditional hand transplanting. The field capacity was 1.2 to 1.5 hectare per day.

A self propelled rice transplanter of PAU design was fabricated and tested at Coimbatore (Anon, 1987). It consisted of a 4.8hp diesel engine, power transmission system, float etc. as shown in Fig.10b. It was reported that the transplanter was working satisfactorily but the floating ability and traction capacity had to be improved. It was reported that the machine required further modifications for matching the field conditions.

In Kerala Agricultural University, the IRRI 5 row and six row rice transplanters were intensively tested from 1982 onwards. Minor modifications and adjustments were carried out. After conducting preliminary field trials with the six row rice transplanters the unit was found to give satisfactory performance. But raising of mat type nurseries as per the specifications was found difficult in the actual field conditions. Even with the help of agronomists, the raising of mat type nursery posed many problems in the initial stages (Anon, 1990).

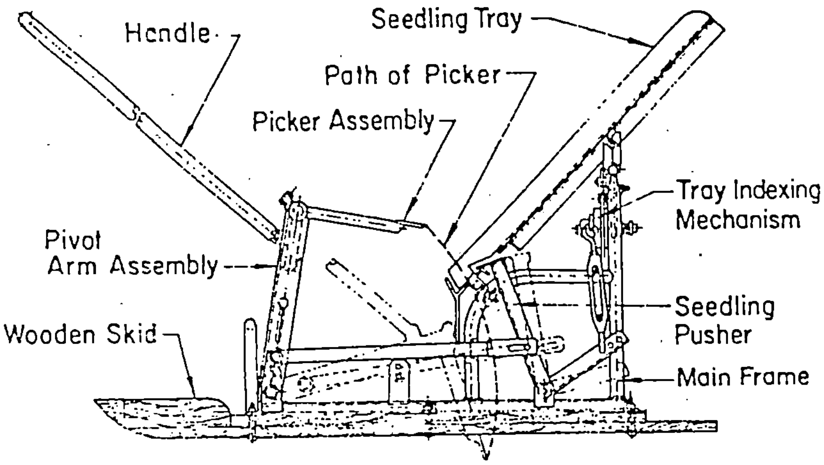


Fig.9 Side elevation of six row rice transplanter (Salazar, 1985)

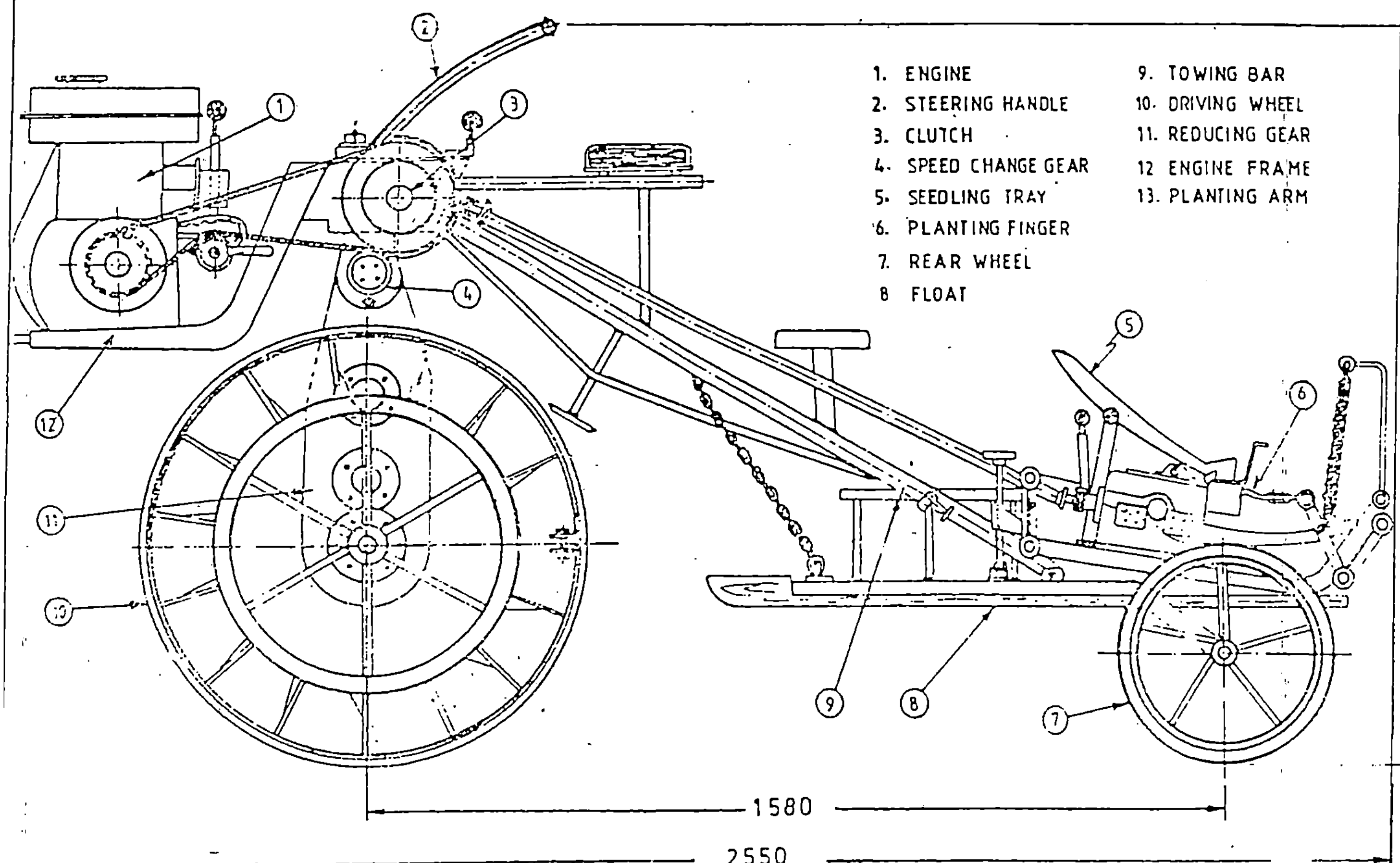


Fig.10 Side elevation of self propelled transplanter (Anon, 1987

2.2.3 Transplanters using conventional seedlings

A manually operated transplanting mechanism was tried at Coimbatore as early as in 1962. It had two rows with eight pickers. The working was found similar to the Chinese hand operated transplanter. The performance was reported to be not satisfactory (Anon, 1978).

A wooden rice transplanter was developed in Britain in 1964 by the Ministry of Overseas Development in collaboration with the National Institute of Agricultural Engineering. It was hand operated and consisted of a tray to carry the seedlings. A finger mechanism was used to carry the seedlings and it placed them in the soil by a single lever action. The transplanter rested on two wooden floats for smooth movement in puddled field.

Two wheel tractor mounted root washed seedling type rice transplanters appeared in Japan in 1965 (Miura, 1966). The conventional seedlings are kept in an upright position in the seedling box (Fig.11). The conventional seedlings were kept in an upright position in the seedling box. The planting unit was attached to a two-wheel tractor and was driven from the P.T.O. through a belt pulley. The planting claw moved to the seedling box and grasped a hill of seedlings which was pulled then out and transferred to the ground. Then the claw opened again and moved to its original position to repeat the operation. The claw opened at the upper end to pick up the seedlings and again at the lower end for planting. The machine was provided with a device to check the extra seedlings to be grapsed by the fingers. The tray was moved transversely after every picking to enable to grasp from fresh place. The depth of planting was adjustable by moving up and down the levelling board. The row to row spacing was 30 cm and hill distance was adjustable from 12 cm to 18 cm by changing the belt pulley. The major problem was the significant variation in number of seedlings per hill.

Stout (1968) described a Chinese hand operated transplanter. It consisted of a box for holding seedlings mounted on a sledge platform. The seedlings were pushed to the rear end of the box by a movable position and they were grasped by a remotely controlled set of seven pincers and forced into the puddled soil. He has also reported that another manually operated rice transplanter was developed in the Philippines. This transplanter was 125 cm wide equipped with five adjustable picking fingers at 18 cm spacing and seedling rests on a wooden float. By a simple lever mechanism the seedlings were picked up by the fingers from the tray and picking mechanism releasing the seedlings to the field.

Hoshino (1974) reported a power tiller operated transplanter which was commercially available during the sixties in Japan (Fig.12a). The seedlings were washed,

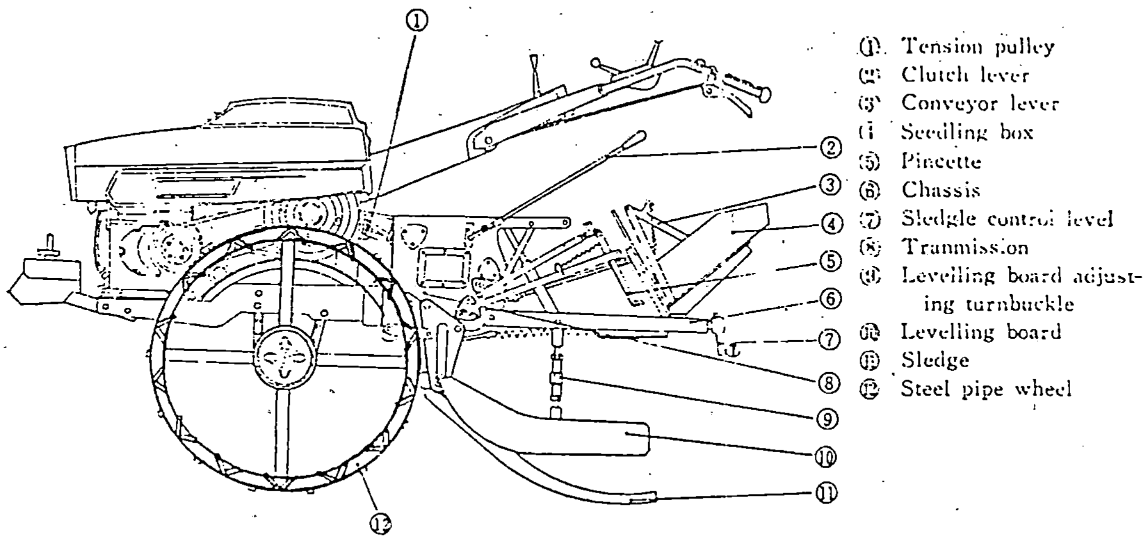
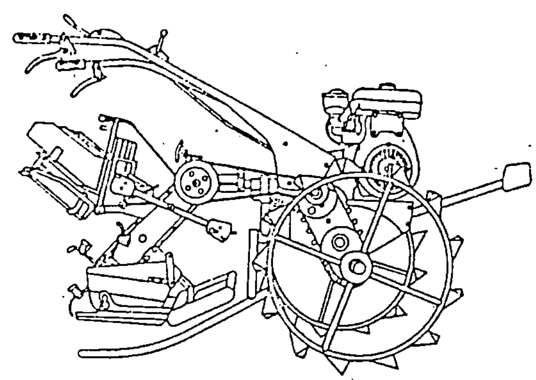
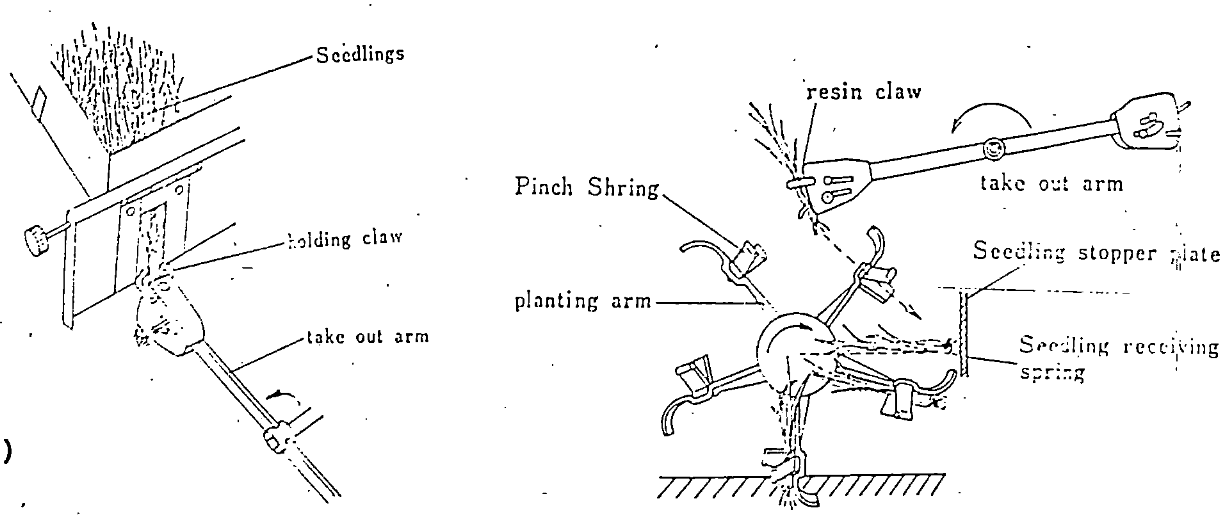


Fig.11 Power tiller attached transplanter (Miura, 1966)

(a)



(b)



Take out motion.

Planting motion.

Fig.12 Power tiller attached improved rice transplanter (Hoshino, 1969)

a. Rice transplanter
b. Take out and planting motions in the improved rice transplanter

arranged and then transferred to the seedling box of the machine. Two to four seedlings were taken out by a resin claw. The holding claws made of rubber held them at the lower part of the seedlings and carried them above the seedlings receiving spring (Fig.12b). The seedlings which were discharged travelled forward by inertia. The lower parts of the seedlings were brought to the same level during the course of falling on the receiving spring. The spring in turn grasped the seedlings and then planted them into the soil by rotation of planting arm.

Sandhu (1975) reported about a bullock drawn rice transplanting mechanism for conventional seedlings (Fig.13). A wooden circular disc of 75 cm diameter with twelve spring loaded fingers of 15 cm length each arranged racially 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 that were opened and closed by a pair of stationary wooden cams. It was observed that the performance of the machine was not satisfactory.

Mahapatra (1976) developed an indigenous rice transplanter named Annapurna in Orissa. It had ten rows, made use of root washed, pruned seedlings. The major component of the machine were body handle, finger set handle, finger opening lever, seedling tray, marker, float, clamp type fingers and finger guide channel. When the finger opening lever was pressed, all fingers opened for gripping the seedlings. The seedlings were pressed into the puddled soil and released. The machine was pushed back to repeat the operation. Seedlings were planted to 2 to 4 cm deep into the soil, and coverage of the machine was about 0.16 hectares per day.

Parida and Das (1977) developed an automatic rice transplanting mechanism at Kharagpur (FIg.14). It consisted of a tray to hold feed seedlings, a finger mechanism to pick up and release the seedlings and an oscillating mechanism for fingers. Laboratory tests showed that the number of seedlings in a hill varied from 1 to 8 and planting was done at 60 degrees to 90 degrees from horizontal with 12.5 to 21.0 percentage of missing hills.

It has been reported from China that a self-propelled, riding type, 12 row rice transplanter was developed for seedlings of 20 to 30 cm height with washed and trimmed root (Fig.15). Working width of the machine was 210 cm. Row spacing varied from 10 to 20 cm and planting depth varied from 3.5 to 7.0 cm. The output of the machine at different row spacing varied from 0.14 to 0.23 hectare per hour (Biswas, 1981). The above Chinese machine was tested in South Korea.

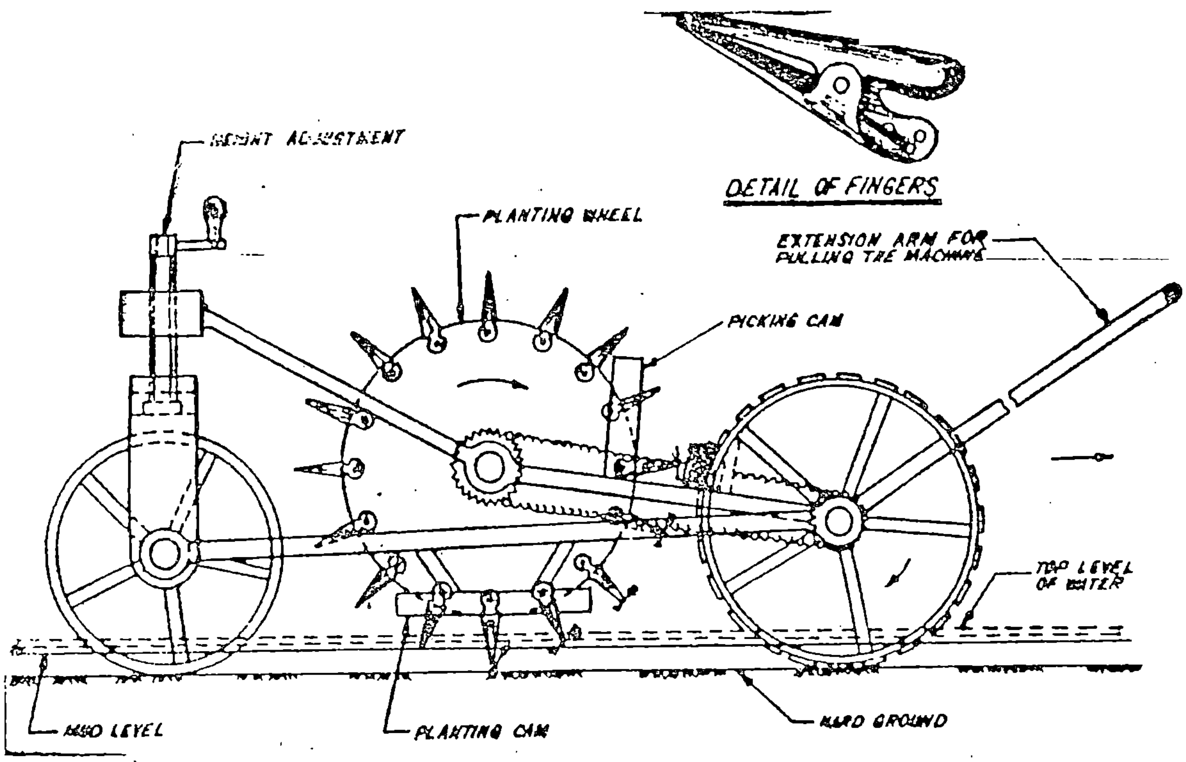


Fig.13 Bullock drawn rice transplanter (Sandhu, 1975)

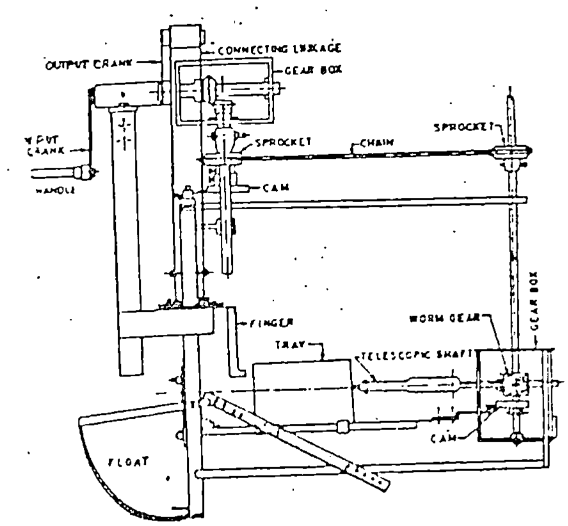


Fig.14 The experimental automatic transplanter
(Parida & Das, 1977)

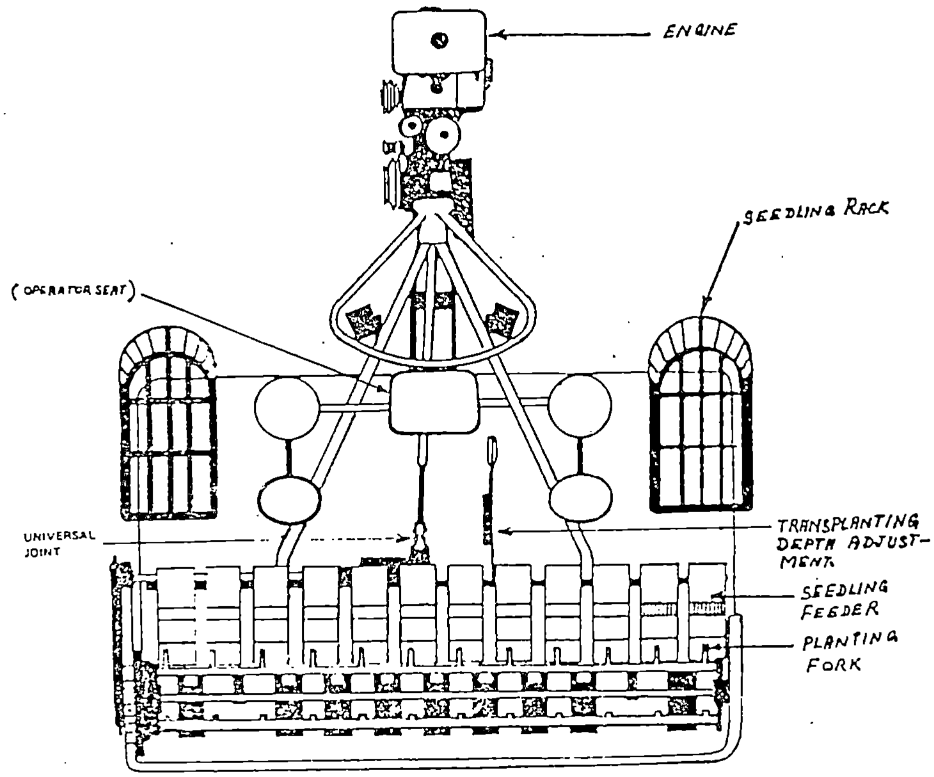


Fig.15 A self propelled 12-row Chinese type transplanter (Biswas, 1981)

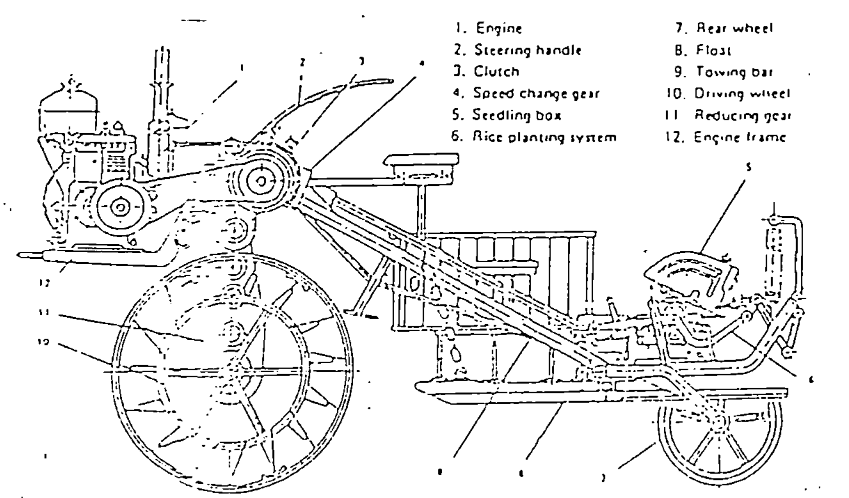


Fig.16 The Korean rice transplanter (Anon, 1978)

With these experience a six row, self-propelled transplanter was developed there (Fig.16). With the working speeds of 0.36 to 0.50 metre per second, it covered a maximum of one hectare in eight hours. The row spacing of the unit was 13 to 14 cm.

Khan and Gunkel (1987) tried to improve the designs of both the transplanting and feeding mechanisms of the Korean transplanter to improve its seedling distribution pattern in Pakistan. It was reported that a better seedling distribution was found with a planting speed of 40 cm per second with rice seedlings having 2 cm root length.

Though there were many attempts for developing a transplanter using conventional seedlings, there is not much success reported so far. But the development of a transplanter for conventional seedlings is very essential for reducing the drudgery of labours and cost of transplanting and making rice cultivation more profitable. Hence an attempt has been undertaken to modify the IRRI six row rice transplanter for using conventional seedlings.

Materials and Methods

MATERIALS AND METHODS

The critical evaluation of the IRRI six row rice transplanter the details of the modifications of the transplanter and the experimental procedure adopted are presented in this chapter.

3.1 Critical evaluation of the IRRI six row rice transplanter for conventional seedlings

Experiments were conducted at the Instructional Farm of the Kelappaji College of Agricultural Engineering & Technology, Tavanur to evaluate the field performance of the IRRI six row rice transplanter. The specifications of the machine is given in the Appendix I. The rice variety 'Triveni' was selected for the test. The seedlings were of 19 days old. The average length of the root, and the average height of the seedlings were measured before the start of the field experiment. A plot of 15 x 8 m^2 was selected for the test. The time loss, average depth of planting, number of seedlings per hill, percentages of missing hills, floating hills, damaged hills, buried hills and average speed of operation were determined. The theoretical field capacity, actual field capacity and field efficiency were also determined for the existing IRRI six row rice transplanter. The six row rice transplanter before modification is shown in Plate I.

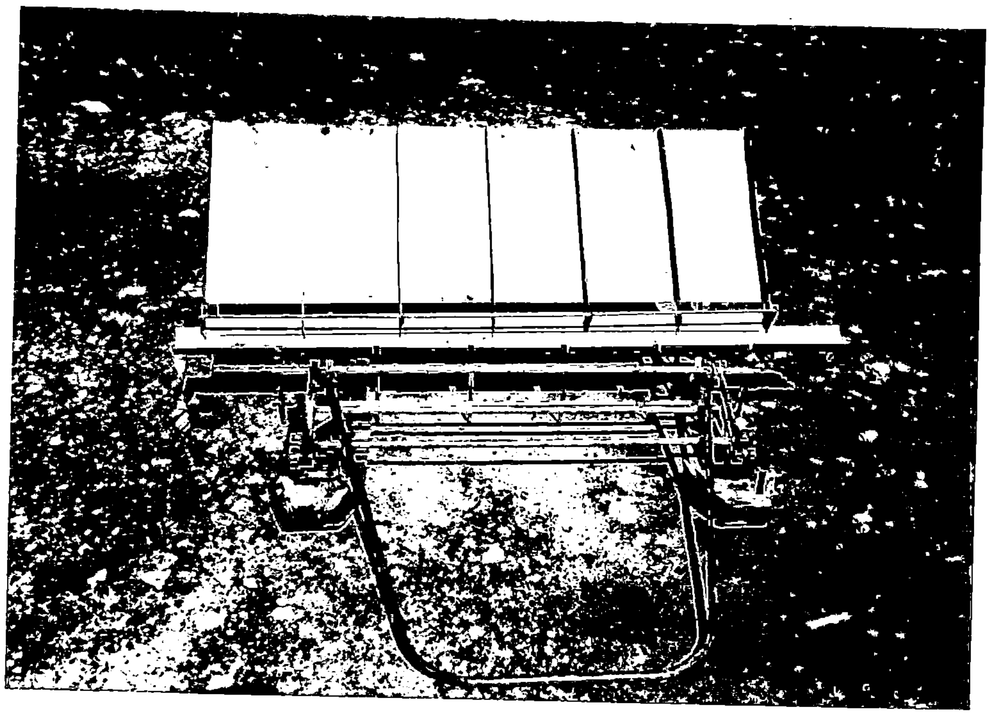


Plate I Six row rice transplanter before modification

3.1.1 Drawbacks of the machine when conventional seedlings were used

1. When all the compartments of the tray were filled with conventional seedlings the feeding tray had tilted backwards.

2. The number of seedlings in each hill varied considerably.

3. In stead of the optimum of 3 seedlings per hill, an average six seedlings were picked up by the picker arm.

4. The conventional seedlings were not held firmly as that of the mat type seedling. Keeping the conventional seedlings erect in the seedling tray was difficult. This allowed the seedling to slip backward or to turn sideways.

5. The transplanted seedlings were pressed by the feeding frame during the forward motion of the machine, as the conventional seedlings are normally taller.

3.2 The functional requirements of the six row transplanter for conventional seedlings

1. As per the recommendations from the Package of Practises of the Kerala Agricultural University, the number of seedlings per hill should be 2 to 3 seedlings per hill. Hence the modified rice transplanter should plant only 2 to 3 seedlings per hill.

2. The machine should not damage the transplanted seedlings while being moved over the plants after transplanting.

3. The picker arm and the feeding frame mouth should not damage the seedlings while picking.

4. There should be a seedling guard mechanism to hold the seedlings in position.

5. Missing and floating hills and damage of seedlings should be low.

6. High field capacity is preferable.

7. The number of components should be minimum so that the machine can be modified by village artisans.

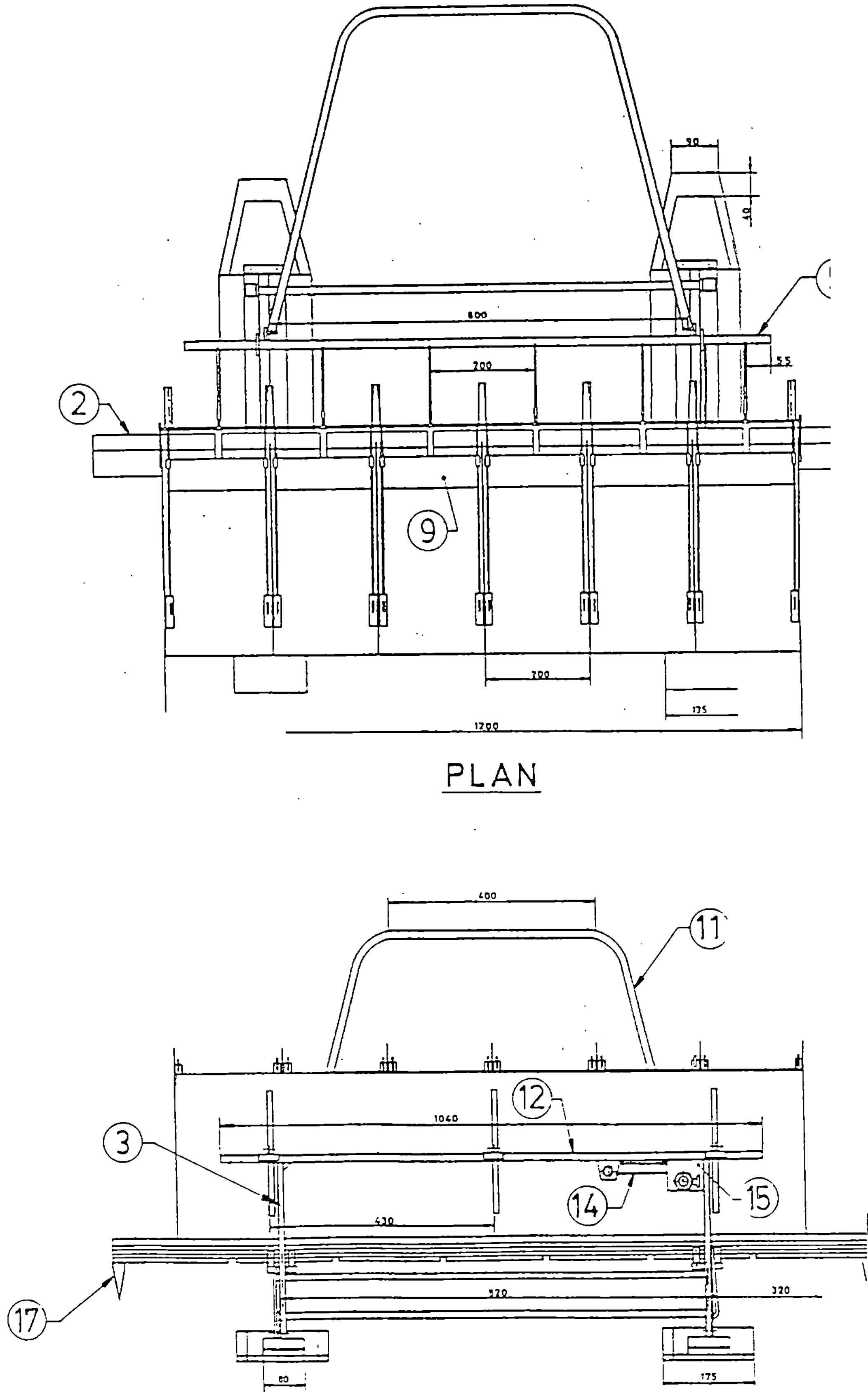
8. The weight of the machine should be less so that it can be carried by two persons.

3.3 Components identified for modification

In order to achieve these functional requirements, the following four components were identified for modification.

1. Feeding frame assembly
2. Picker arm assembly
3. Tray assembly
4. Seedling pusher assembly

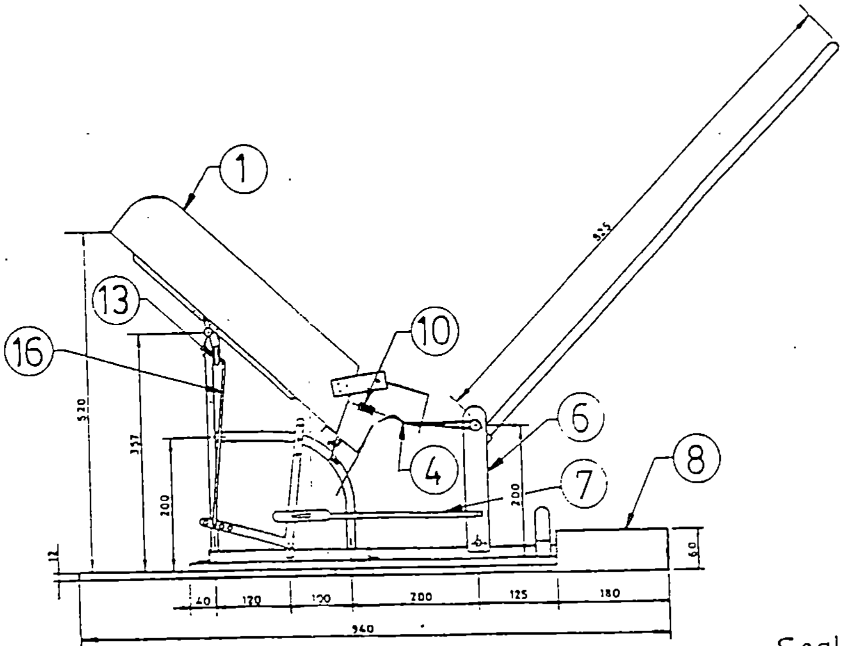
The modified six row rice transplanter is shown in Fig.17.



All dimensions in mm.

Fig. 17 MODIFIED

1 SEEDLING FEED TRAY ASSEMBLY
2 FEEDING FRAME ASSEMBLY
3 MAIN FRAME ASSEMBLY
4 PICKER ARM ASSEMBLY
5 PICKER HOLDER MECHANISM ASSY.
6 PIVOT ARM ASSEMBLY
7 FEEDER LINK ASSEMBLY
8 SKID ASSEMBLY
9 PRESSURE PLATE ASSEMBLY
10 SPRING
11 HANDLE ASSEMBLY
12 CARRIAGE BAR ASSEMBLY
13 SPROCKET
14 CHAIN
15 CHAIN DRIVE COVER
16 CONNECTING ROD
17 ROW GUIDE



SIDE VIEW

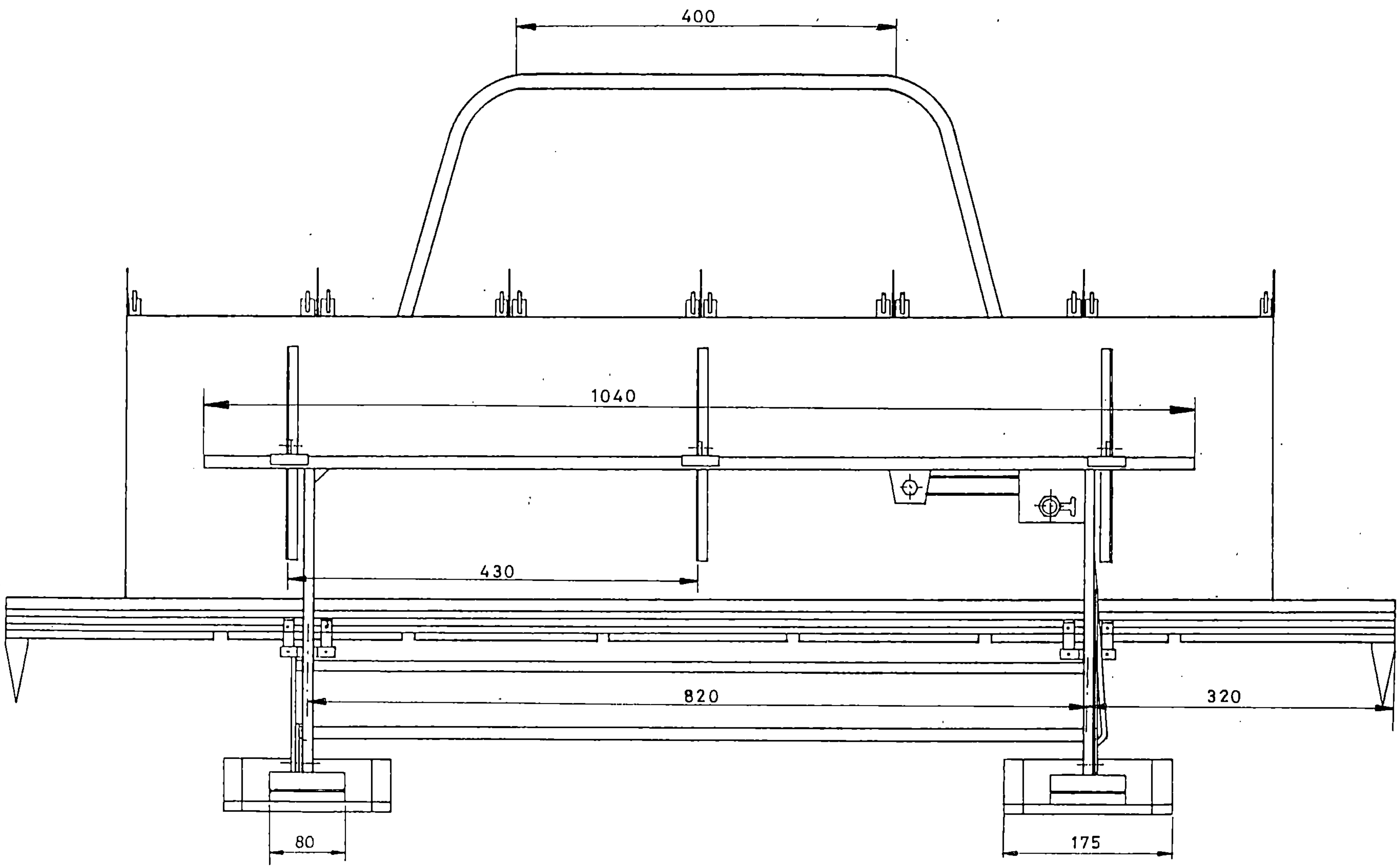
Scale - 1 : 11.8

CE TRANSPLANTER

Scale - 1:6.4

All dimensions in mm.

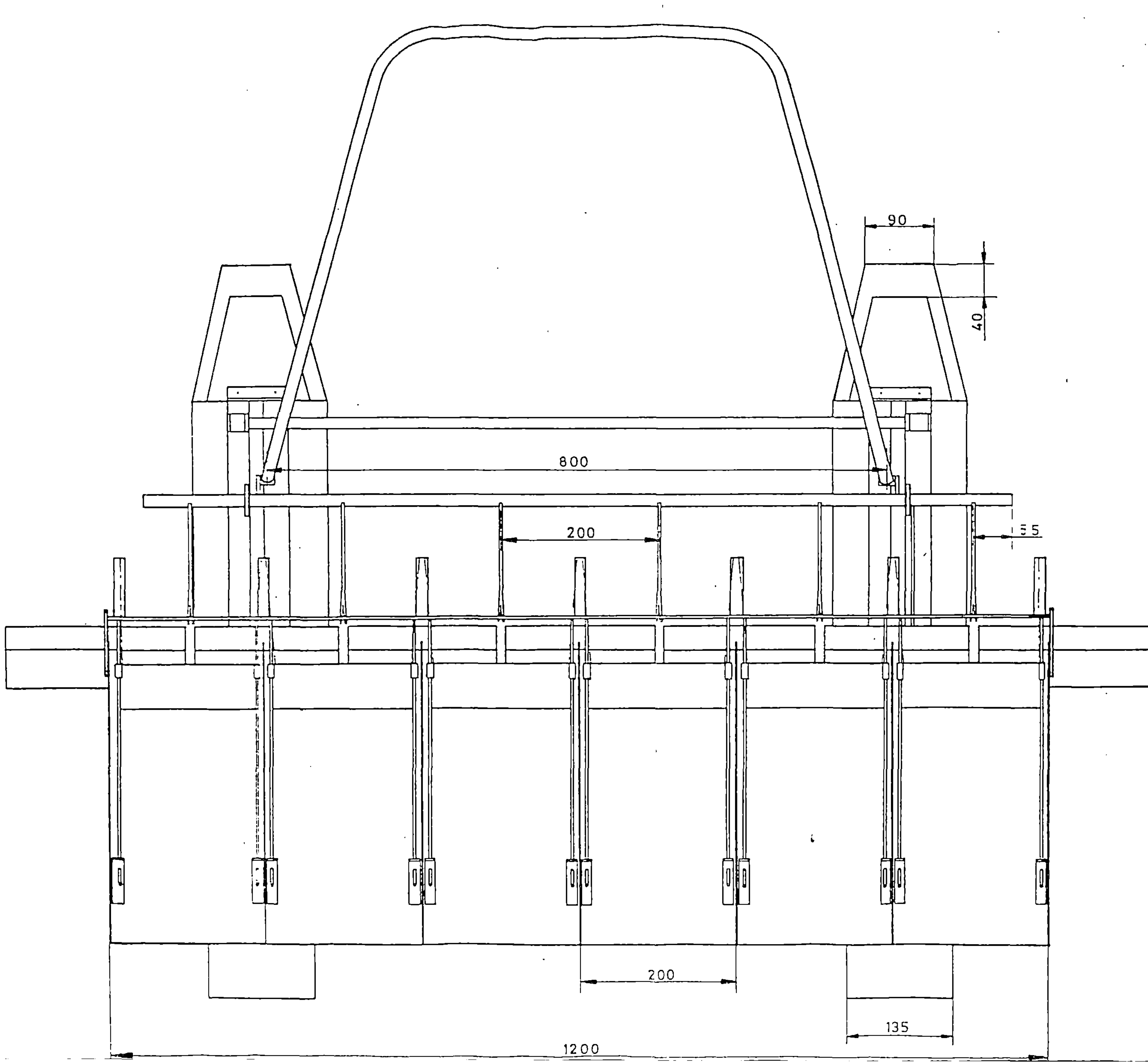
Fig. 17a PLAN

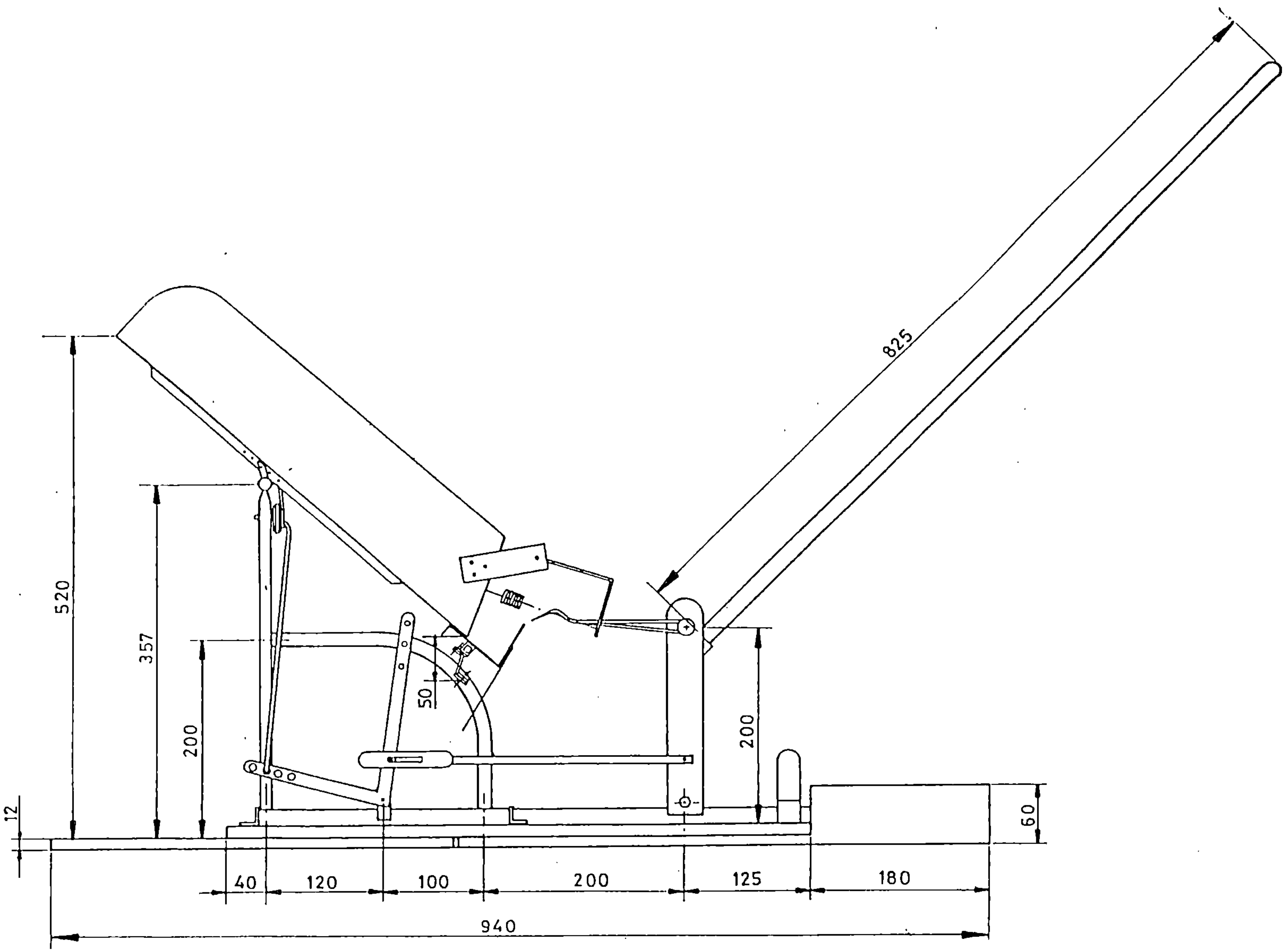


Scale - 1 : 6.4

All dimensions in mm.

Fig. 17b ELEVATION


90
40
800
200
55
200
135
1200



Scale - 1:6.4

All dimensions in mm.

Fig. 17c SIDE VIEW

The modifications were completed in three stages.

3.3.1 Modification stage one

a. Feeding frame assembly modification

The IRRI six row rice transplanter has been designed for mat type nursery seedlings of 15 to 20 days age with 170 mm to 200 mm height. But in the case of conventional seedlings the minimum height of the seedlings of that age is 225 mm (Appendix II). The increase in the height of conventional seedlings caused a serious problem while transplanting with this machine. The seedlings were brought to almost horizontal position to the field while pulling the machine forward. This problem was rectified by raising the height of the feeding frame by 50 mm. The feeding frame mouth was also reduced to 12 mm from 18 mm (Fig.18).

b. Modification of the picker arm

In the IRRI six row rice transplanter, the finger size was 8 mm. This size of the finger was good for picking the mat type nursery seedlings. But the diameter of the seedlings varied considerably when they were grown in the conventional nurseries. Moreover the conventional seedlings were in a compacted state while they were set for transplanting operation. In order to overcome this problem, the transplanter fingers were modified based on the average

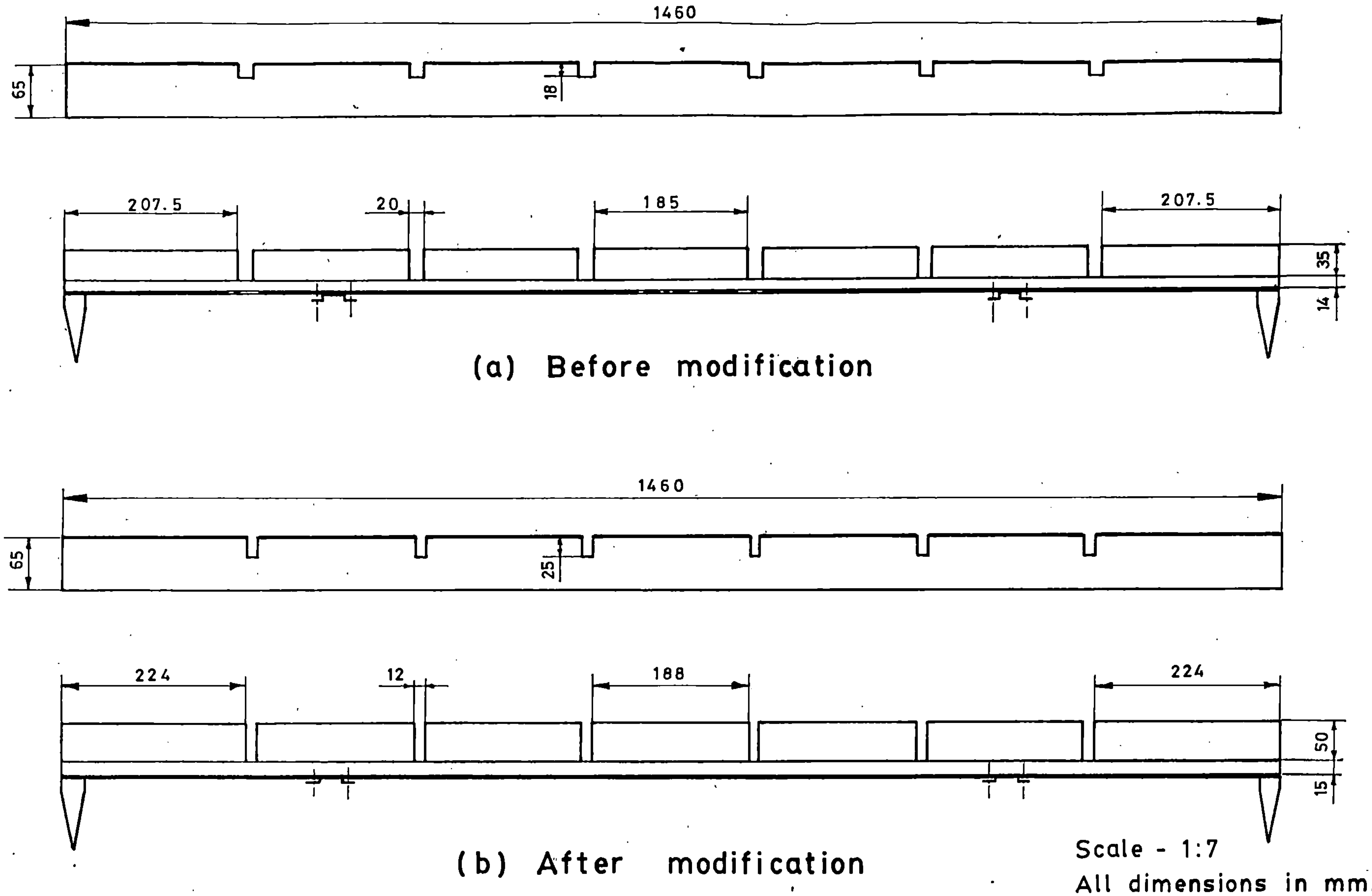


Fig. 18 FEEDING FRAME ASSEMBLY

diameters of the conventional seedlings. Diameter of randomly selected seedlings were taken for determining the average diameter per seedling. It is given in Appendix II. The finger gap of 5.4 mm was obtained considering the optimum number seedling per hill as 2 to 3 and the average diameter of the seedling as 1.77 mm (Fig.19).

3.3.2 Modification stage two

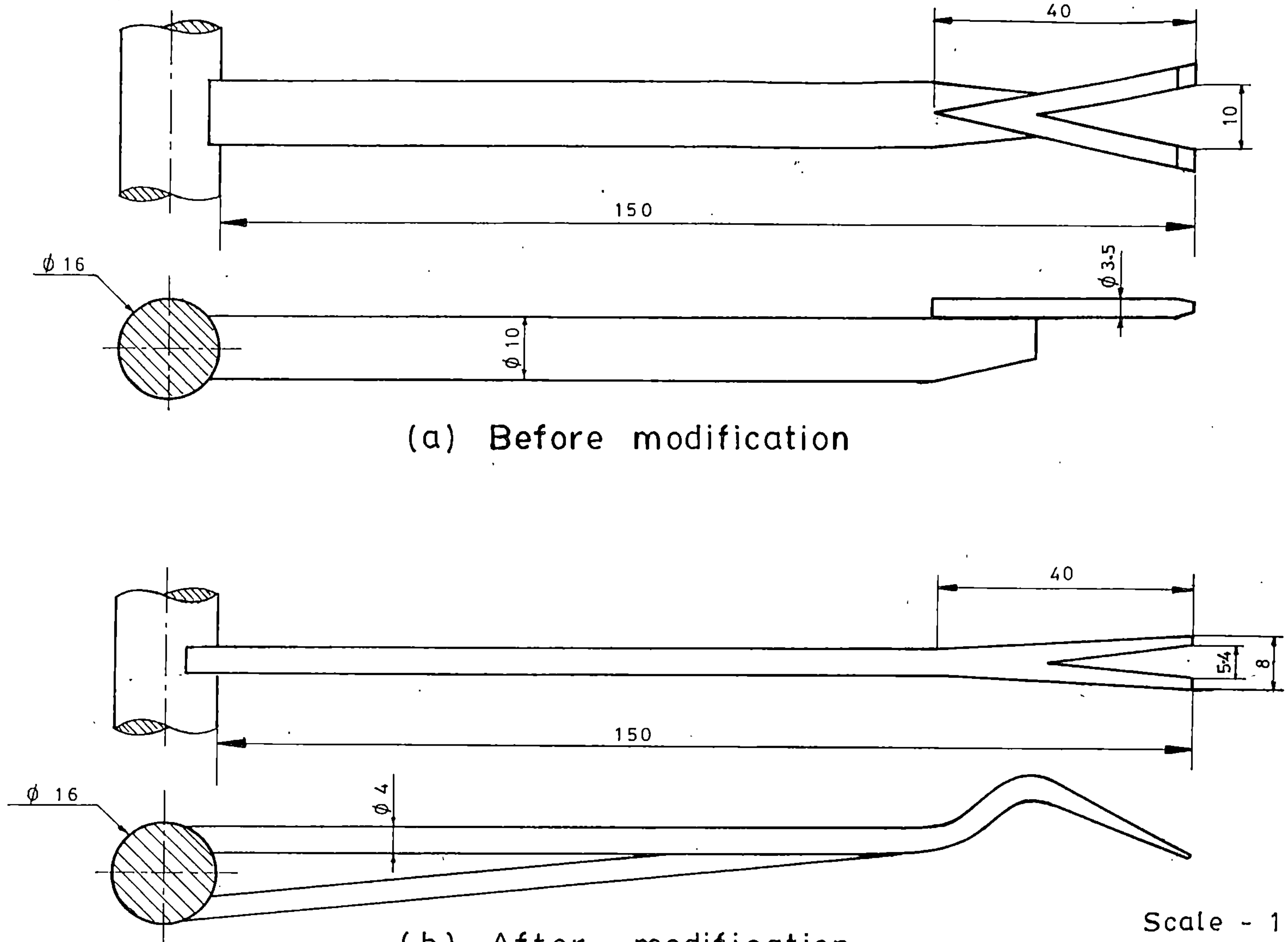
a. Modification of tray assembly

The IRRI six row rice transplanter has no provision for holding the conventional seedlings together for them to the picker arm unit (Fig.20a). The problem was mainly due to insufficient height of the partition walls of the trays. Hence the height of the partition walls of the trays was increased from 40 mm to 100 mm (Fig.20b). In the original model there was a gap between the feed trays and the feeding frame. This caused falling of the conventional seedlings while operating the machine. The gap was also eliminated in the modification.

3.3.3 Modification stage three

a. Introduction of a seedling pusher mechanism

In the original IRRI six row rice transplanter the entire seed mat moved downward as a whole whenever the



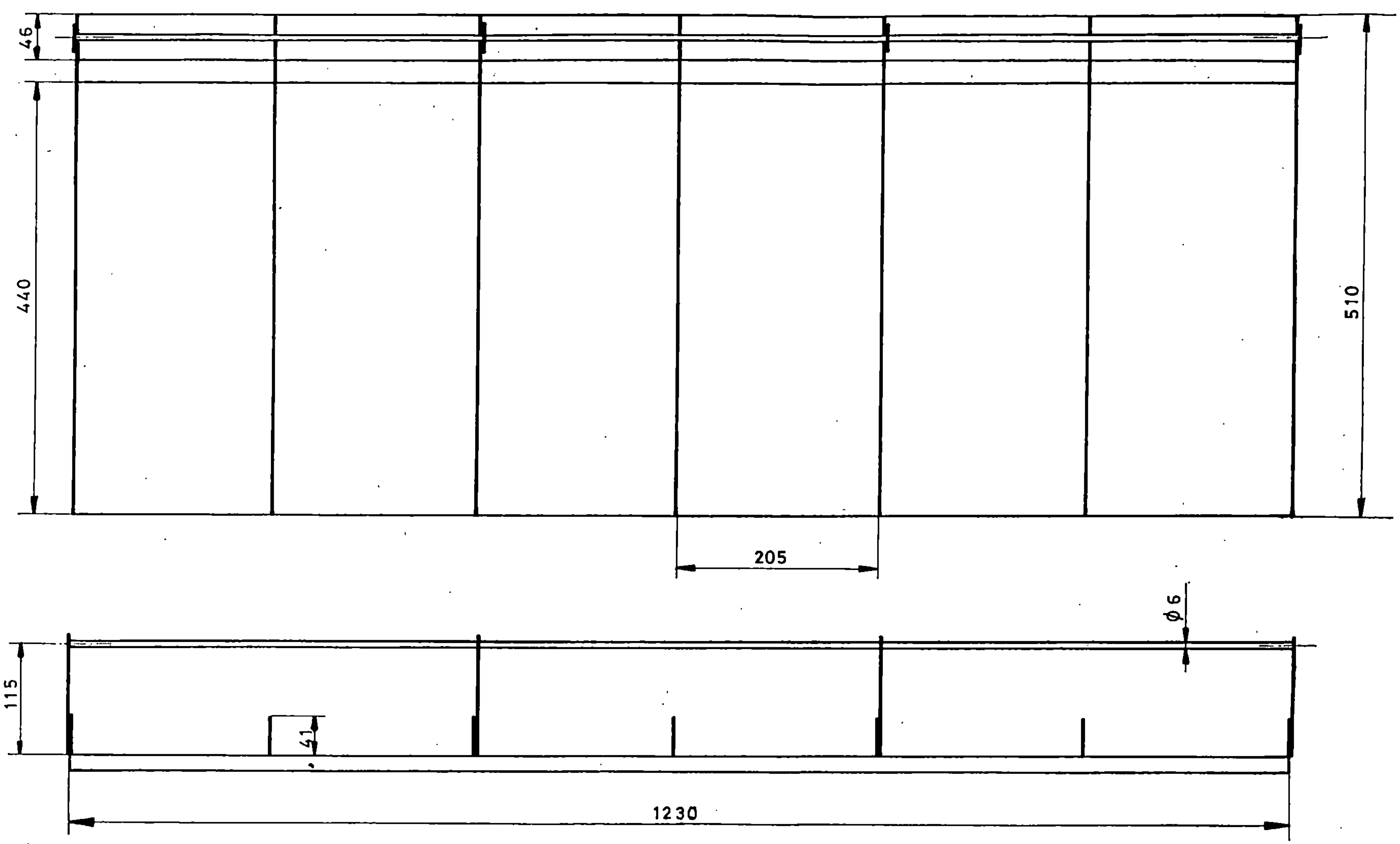
Scale - 1:1
All dimensions in mm.

Fig. 19 PICKER ARM ASSEMBLY

seedlings were picked away at the feeding frame mouth. But in the case of conventional seedlings the downward movement of the seedlings were not uniform. This created missing hills and damages due to the tilting of the seedlings. In order to rectify these defects, a pressure plate with the help of a pair of coiled springs are used (Fig.20b). The modified six row rice transplanter is shown in Plate II.

3.4 Experimental programme

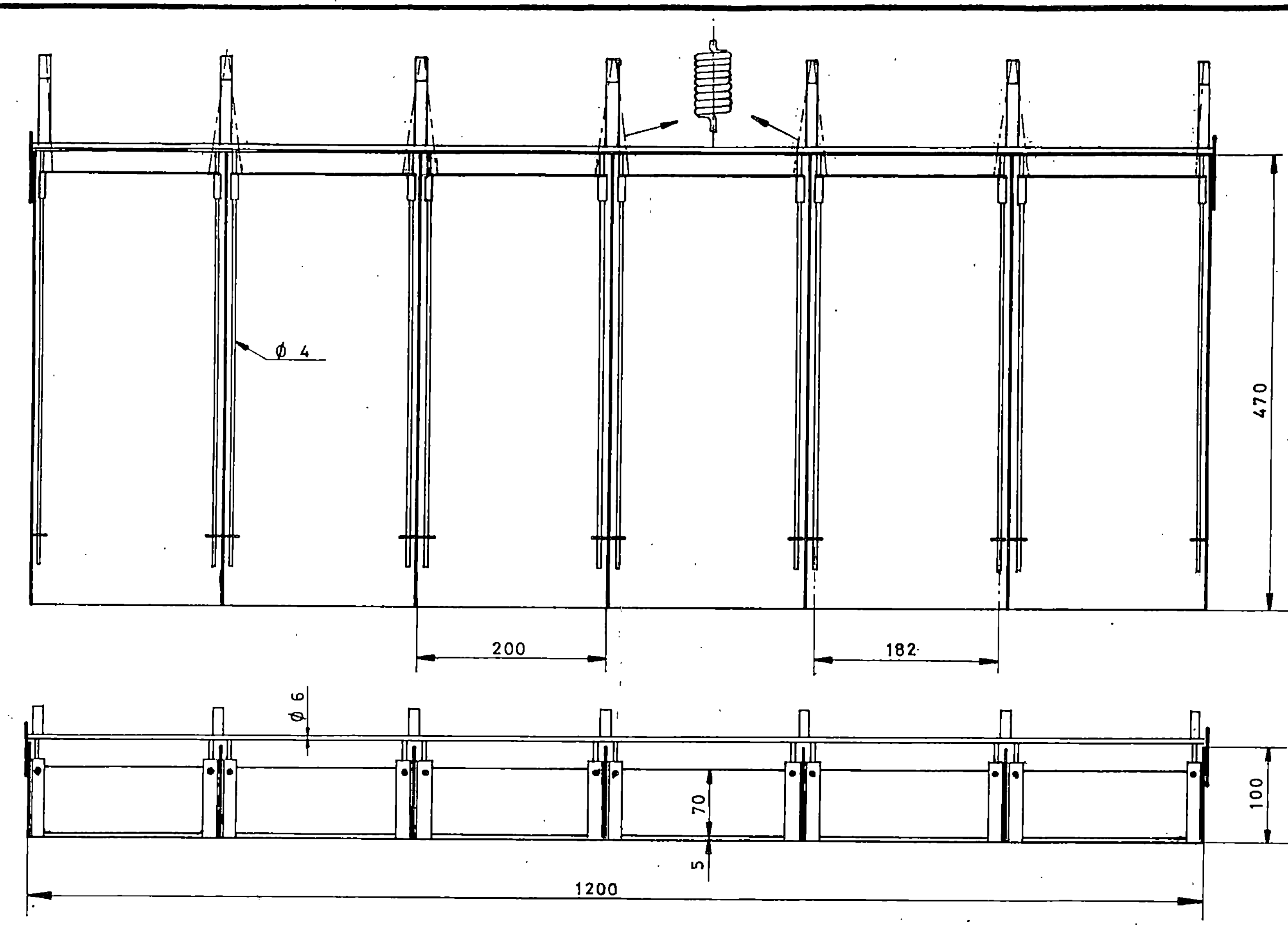
The modified six row rice transplanter was tested at the KCAET farm to evaluate the field performance of the machine. Three tests were conducted after each stage of modifications. The rice variety 'Triveni' was used for raising the seedlings. The seedlings of 19 to 22 days of old were used for testing. Field size varied from 160 m^2 to 400 m^2. The field was ploughed and levelled well and allowed to settle for 24 hours. The depth of water in the field was 15 mm to 20 mm during transplanting. The seedlings were picked up from the nursery and roots were washed and arranged in the feeding trays (Plate III). The services of the experienced operator from the FIM Scheme of the Department was available and hence the machine was operated at normal speeds.



Scale - 1:6

All dimensions in mm.

Fig. 2(a) SEEDLING FEED TRAY ASSEMBLY BEFORE MODIFICATION



Scale - 1:6

All dimensions in mm.

Fig. 20(b) SEEDLING FEED TRAY ASSEMBLY AFTER MODIFICATION

Plate II Modified six row rice transplanter

Plate III Filling the feeding trays with conventional seedlings

Plate IV Modified six row rice transplanter under operation

The modified six row rice transplanter under operation in the field is shown in Plate IV.

3.4.1 Seedling distribution, missing hills, floating hills and damaged hills determination

The number of seedlings per hill in an experimental plot was counted for 30 continuous plantings and the average values were found. The experiments were repeated for different speeds 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 in each experiment and the percentages were calculated.

3.4.2 Speed of operation

The experienced operator of the FIM Scheme of the College helped in the actual field operations. The average speed of the transplanting in each test was noted down. The time taken to cover a distance of ten metres was measured. The experiment was repeated to get average speed of operation. The speed in kilometres per hour was calculated from the following expression.

$$\text{Speed (kmph)} = \frac{\text{Distance in metres x 3600}}{\text{Time in seconds x 1000}}$$

3.4.3 Field capacity

Theoretical field capacity was observed by noting the time, speed operation and the width of planting.

$$T_{FC} = \frac{W \times S}{1000}$$

T_{FC} - Theoretical field capacity (ha/hr)

W - Width of planting in centimetres

S - Speed of operation in kilometres per hour

The actual field capacity was measured by observing the time required to cover a known area.

$$\text{Actual field capacity (ha/hr)} = \frac{\text{Area covered (hectares)}}{\text{Time (hours)}}$$

3.4.4 Field efficiency

The percentage of field efficiency was determined by the following expression

$$\text{Field efficiency \%} = \frac{\text{Actual field capacity}}{\text{Theoretical field capacity}} \times 100$$

3.4.5 Economic analysis

3.4.5.1 Break even analysis

The break even point of the machine was determined both analytically and graphically. In the graphical method the annual transplanted area in hectares was taken in the X axis and total cost of operation per hectare was taken in the Y axis. The graph was plotted for both man and machine and the intersection was taken as the break even point of the machine.

In the analytical method the break even point was obtained by the following formula.

$$F_{c1} + (V_{c1} \times X \text{ ha}) = F_{c2} + (V_{c2} \times X \text{ ha})$$

where,

F_{c} - Fixed cost for the transplanter

V_{c} - Variable cost per hectare for the transplanter

F_{c2} - Fixed cost for hand transplanting

V_{c2} - Variable cost per hectare for manual transplanting

X - Break even hectares

3.4.5.2 Cost analysis

The cost of the machine was taken as Rs.1750/-. The number of hours the machine could be successfully operated was taken as 300 hours per annum. The interest rate was taken as

12 per cent and the repair and maintenance rate was taken as 5 per cent of the machine cost. The insurance and housing charges are negligible and hence they were not taken into account. The labour cost was taken as Rs.35/day of 8 hours. The cost of operation of the machine was calculated from the following expression.

Total cost of operation per hour

= Fixed cost per hr + variable cost per hr

3.4.5.3 Pay back period

Pay back period is the time needed to recoup the money invested. It is calculated from the following expression.

$$\text{Pay back period (PBP)} = \frac{\text{Total investment}}{\text{Total annual benefits - total annual cost}}$$

Results & Discussion

RESULTS AND DISCUSSION

The modified rice transplanter was intensively tested under varying field conditions and with different parameters. Three stages of modifications were undertaken for the machine and the test results obtained after the modifications are presented in this chapter. The field after transplanting with the modified six row rice transplanter is given in Plate V.

4.1 Critical evaluation of the IRRI six row rice transplanter

The results of the critical evaluation of the IRRI six row rice transplanter using conventional seedlings are as follows:

Average number of leaves/plant	= 3
Average length of roots	= 40 mm
Average height of seedlings	= 220 mm
Area of plot	= 120 m^2
Time lost in operation	= 15 min & 23 seconds
Water level at the time of planting	= 30 mm
Total time taken for transplanting	= 51 min & 40 seconds
Average depth of planting	= 48 mm
Average number of seedlings per hill	= 6
Percentage of missing hills	20.55%

Plate-V. The field transplanted with Modified Six Row Rice Transplanter

Percentage of floating hills	= 10%
Percentage of buried hills	= 6.11%
Percentage of damaged hills	= 23.33%
Average speed of operation	= 4.06 m/min
	= 0.243 km/hr
Theoretical field capacity	= 0.0288 ha/hr
Actual field capacity	= 0.0139 ha/hr
Field efficiency	= 48.38%

It was found that the percentages of missing hills, floating hills, buried hills and damaged hills were very high. Field capacity and field efficiency were also low.

4.2 Field experiments with the modified machine

4.2.1 Seedling distribution

The uneven distribution of seedlings per hill was one of the major problems with the original model of the six row rice transplanter.

The results of the test conducted after each stage of modification is given in Appendix III to XI. The results are summarised in Table I and plotted in Fig.21.

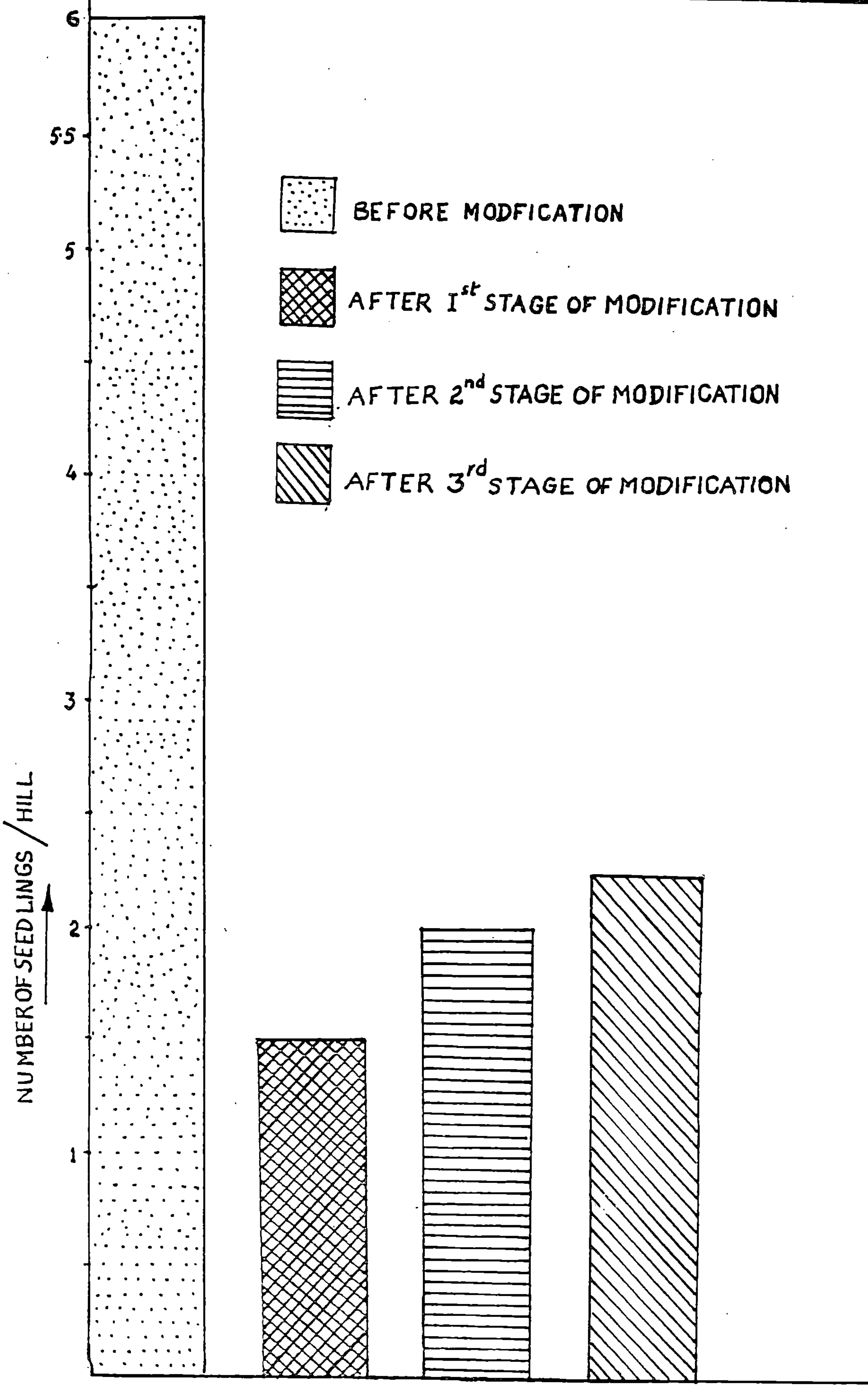


TABLE-21: EFFECT OF MODIFICATION ON THE DISTRIBUTION OF SEED LINGS / HILL

Table 1. Average number of seedlings per hill

Test No.	Modification stage one	Modification stage two	Modification stage three
1	1.77	1.73	2.16
2	1.40	2.20	2.38
3	1.33	1.97	2.26
Average	1.50	1.97	2.27

The picker arm assembly was modified in the first stage reducing the gap in the fingers. The finger gap has got a major impact on the number of seedlings per hill. After the first modification, the average number of seedlings per hill dropped to 1.5 from an average of six seedlings per hill before modification. This low value may be due to the low packing density of the seedlings in the trays, as the seedlings were in non compacted from in the trays. Improvements in the tray assembly resulted in higher values in the second and third stages.

As the three stage of modifications were over an average of 2.27 seedlings per hill was obtained. Before the modification the average value was six seedlings per hill. The new value closely resumbles with the desired value of 2 to 3 seedlings per hills which is the recommended rate by the Kerala Agricultural University.

4.2.2 Missing hills

The performance evaluation of the machine after each stage of modification is given in the Appendix III to XI and the summarised results are given in Table 2. The results are plotted in Fig.22.

Table 2. Percentage of missing hills

Test No.	Modification stage one (%)	Modification stage two (%)	Modification stage three (%)
1	12.77	11.11	6.11
2	12.22	6.66	4.44
3	16.11	8.88	6.11
Average	13.70	8.88	5.55

The feeding frame modification rectified the alignment problems and hence the number of missing hills were reduced after the first stage of modification. The tray modifications undertaken in the second and third stages of modifications resulted in keeping the seedlings steady in the feeding trays and then is decrease in the percentage of missing hills after the second and third stages of modifications. The critical evaluation of the original six row rice transplanter gave a very high value which was 20.83 per cent. This could be brought down to an average value of 5.55 per cent after the modifications.

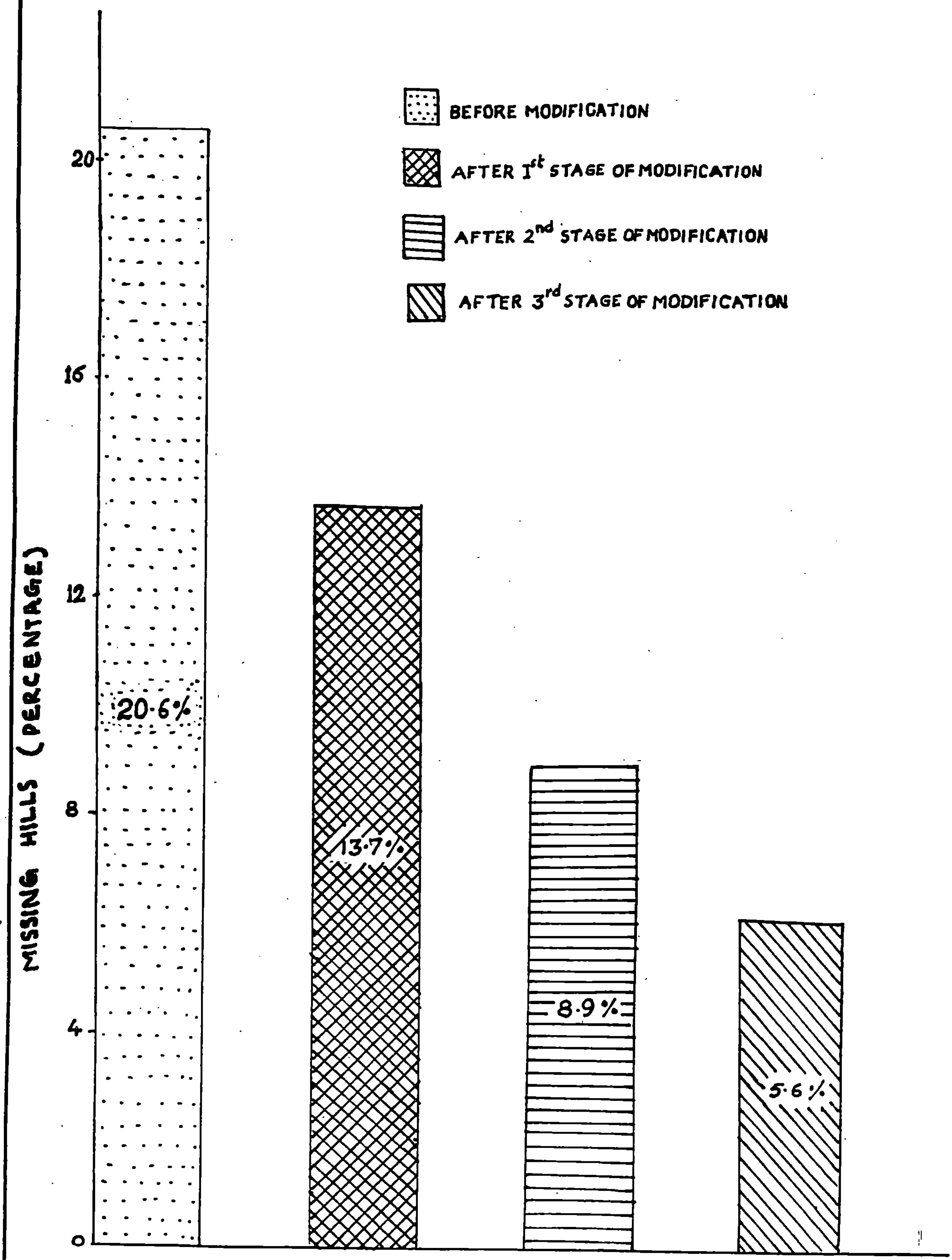


FIG:22 EFFECT OF MODIFICATIONS ON MISSING HILLS

4.2.3 Floating hills

The percentage of floating hills occurred during the performance evaluation is given in Table 3.

Table 3. Percentage of floating hills

Test No.	Modification stage one (%)	Modification stage two (%)	Modification stage three (%)
1	6.67	6.11	5.50
2	8.88	5.55	6.11
3	5.56	5.55	5.55
Average	7.03	5.70	5.73

The conditions of the field, speed of operation and the picking mechanism are the three important factors deciding the number of floating hills. The improved fingers of the picker arm held the seedlings tightly and placed them into the soil reducing the missing hills in the first stage. In the second and third stages of modification the feeding trays were modified, so the seedlings could be held properly in the feeding trays. There is not much difference in the values for the last two modifications. This may be due to the fact that the field conditions are moreover similar in both occasions and the picker arm was modified in the first stage itself.

4.2.4 Damaged hills

The percentage of damaged hills after each modification is summarised in Table 4 and are plotted in Fig.23.

Table 4. Percentage of damaged hills

Test No.	Modification stage one (%)	Modification stage two (%)	Modification stage three (%)
1	15.55	9.44	3.33
2	11.66	9.44	3.33
3	12.77	7.77	3.33
Average	13.30	8.90	3.33

The damage of the seedlings in the transplanter were mainly due to the alignment problems, low height of the feeding frame and the improper holding of seedlings in the trays. The height of the feeding frame was increased and the alignment problem was rectified in the first stage of modification. Hence there was improvement after the first stage. When the seedlings are kept in loose from there was the chance of damage by the picker arm fingers. This was checked in the second and third stages of modification.

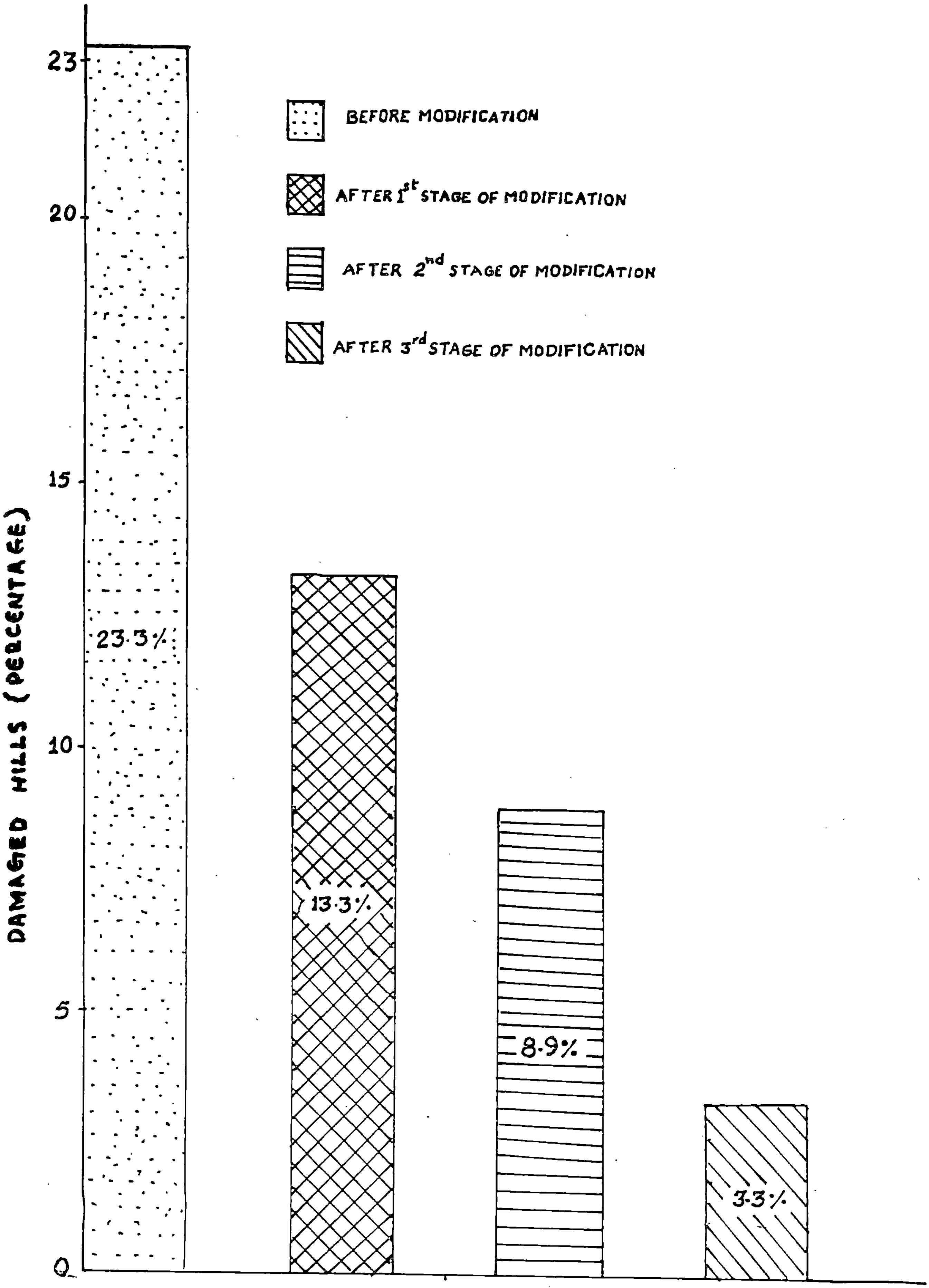


FIG:23-EFFECT OF MODIFICATIONS ON DAMAGED HILLS

4.2.5 Speed of operation

The speed of operation of the machine for various trials are given in Table 5. The speed of operation has got a decisive role in the field capacity and the total losses.

When the speed of operation is increased the seedlings are not fixed in the soil but are found to come alone with the picker arm finger. The causes the increase in the floating hills.

Table 5. Speed of operation of the machine

Test No.	Modification stage one (km/hr)	Modification stage two (km/hr)	Modification stage three (km/hr)
1	0.2196	0.2310	0.2238
2	0.2172	0.2478	0.2490
3	0.2238	0.2580	0.2280
Average	0.22	0.245	0.233

4.2.6 Field capacities

The field capacity of the machine for various trials after each modification are given in Table 6. The values are plotted in Fig.24.

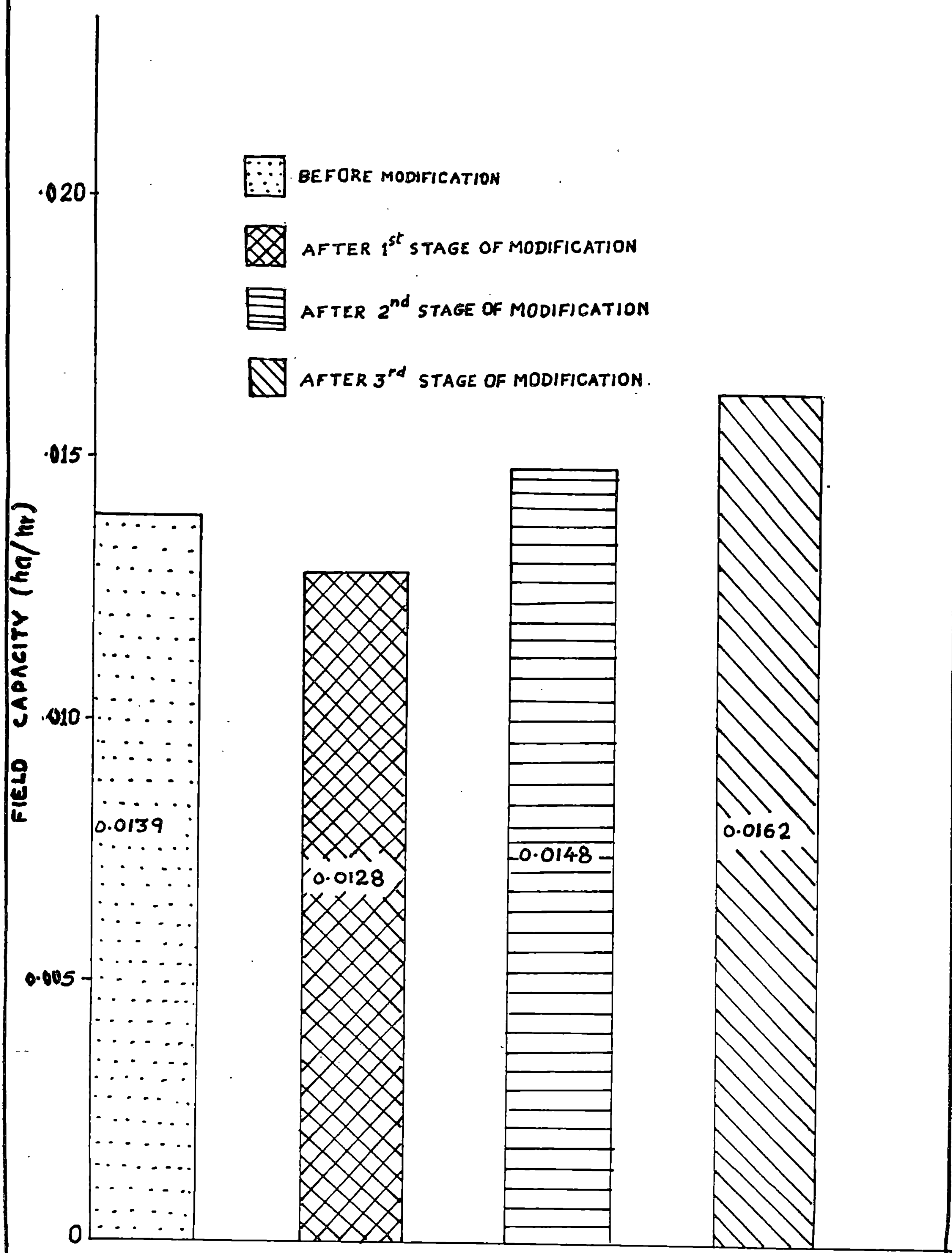


FIG:24- EFFECT OF MODIFICATIONS ON FIELD CAPACITY

Table 6. Field capacities of the transplanter

Test No.	Modification stage one (ha/hr)	Modification stage two (ha/hr)	Modification stage three (ha/hr)
1	0.0123	0.0137	0.0152
2	0.0132	0.0155	0.0185
3	0.0128	0.0152	0.0150
Average	0.0128	0.0148	0.0162

Improvement in the field capacities of the transplanter is one of the most desirable results. High field capacity means the machine can cover more areas.

When the picker arm and feeding frame were modified, the alignment problem of the machine was rectified resulting the smooth movement of the machine as a result the field capacity improved. In the second stage the feeding trays were modified reducing the losses and operational difficulties. In the third stage the pressure plate held the seedling together which resulted smoother operations, avoided tilting of the seedlings in the feeding trays. The original six row rice transplanter had a field capacity of 0.0139 ha/hr which could be improved to 0.0162 ha/hr after the modifications. The field capacity was improved by minimising the operational troubles and thereby saving the time of operation as the width of the machine was not changed.

4.2.7 Field efficiency

The field efficiencies for various stages of modifications are summarised in Table 7 and are plotted in Fig.25.

Table 7. Field efficiencies after each stage of modification

Test No.	Modification stage one (%)	Modification stage two (%)	Modification stage three (%)
1	46.80	49.42	55.55
2	40.86	52.20	60.05
3	47.76	50.87	55.01
Average	48.46	50.80	57.90

The field efficiency depends on the actual field capacity of the machine and the speed of operation of the machine. The field capacity were improved in each stages of the modification, hence there is improvement in field efficiencies in each case.

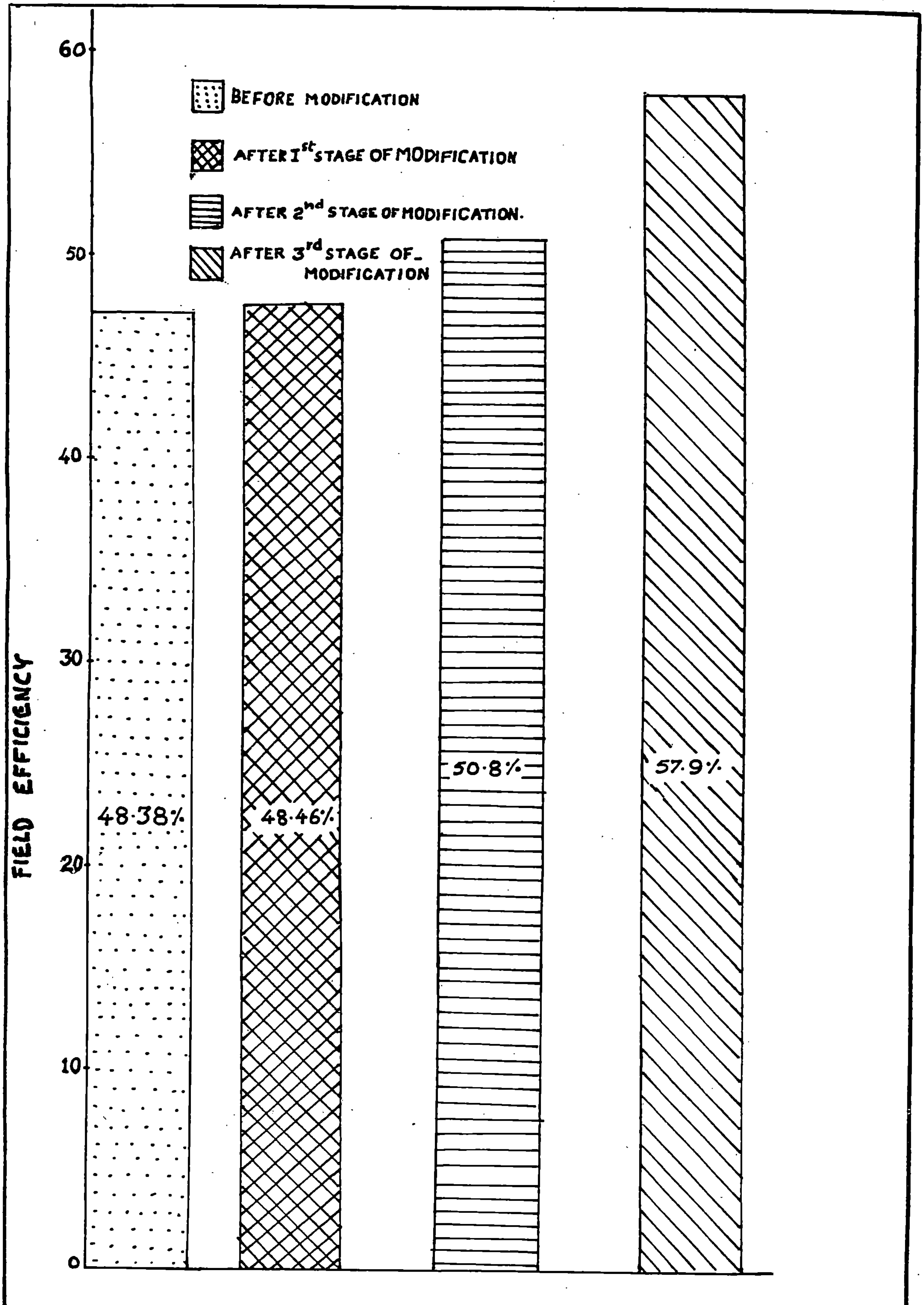


FIG 25. EFFECT OF MODIFICATIONS ON FIELD EFFICIENCY

4.3 Economic analysis

4.3.1 Break even point analysis

The annual transplanted area in hectares and the total cost per hectare is given in Table 8.

Table 8. Total cost per hectare for modified six row rice transplanter and hand transplanting at different annual transplanted area

Annual transplanted area (hectares)	Total cost/hectare (Rs.)	
	Modified six row transplanter	Hand transplanting
0.5	1823	1050
1.0	1047	1050
1.5	788	1050
2.0	659	1050
2.5	581	1050
3.0	529	1050

The break even point is determined by plotting the annual transplanted area in hectares in the X axis and the total cost per hectare in the Y axis for both machine and manual transplanting. The graph is plotted in Fig.26.

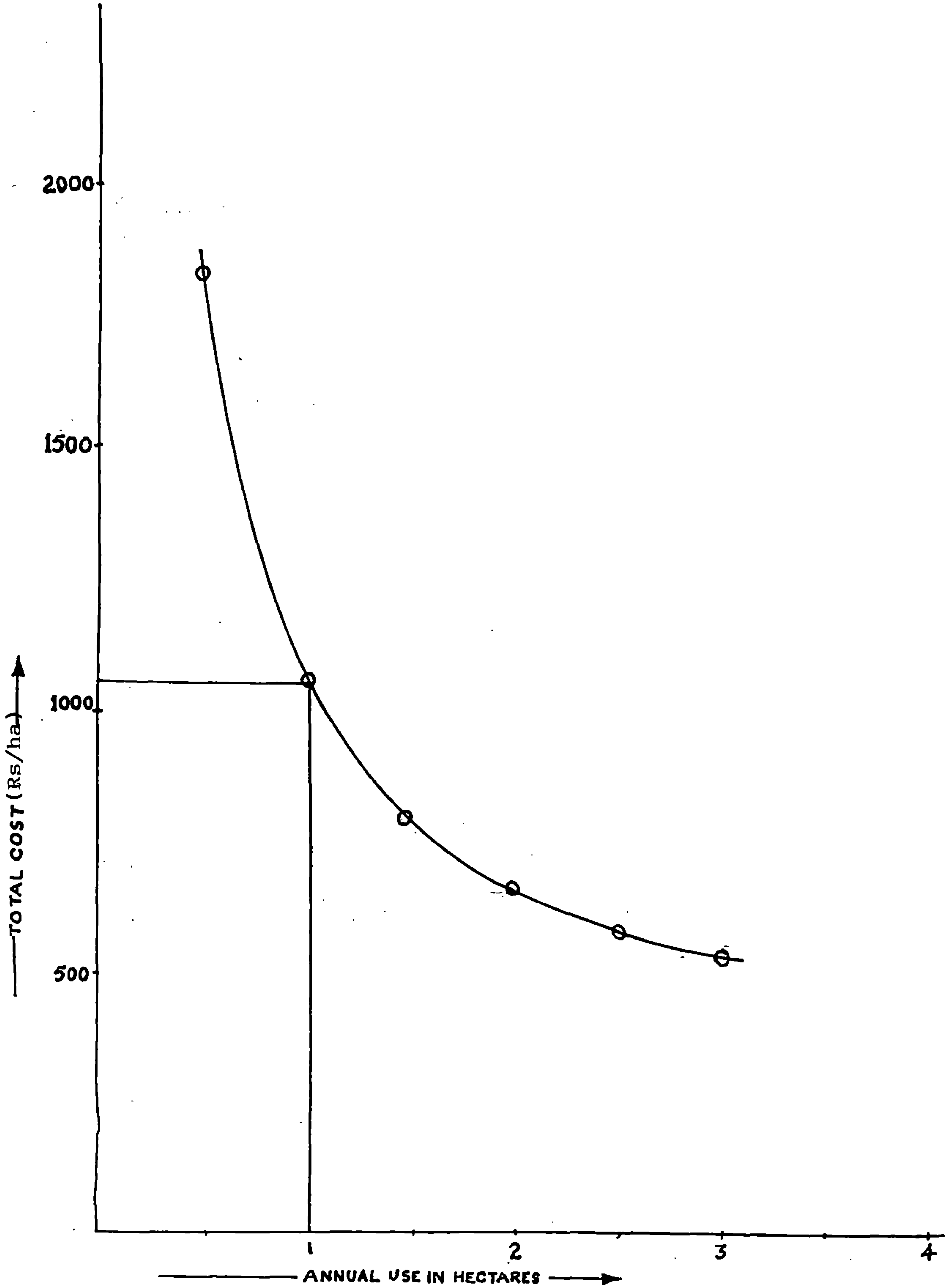


FIG:26. BREAK EVEN POINT ANALYSIS

The break even analysis of the modified six row rice transplanter was calculated analytically and it is given in the Appendix XII. It was found that the usage of the machine over and above one hectare per year yielded profits.

4.3.2 Cost of operation

The operating cost of the modified six row rice transplanter is given in the Appendix XIII. The cost of operation of the transplanter was obtained as Rs.6.97 per hour. The actual field capacity of the machine is 0.0162 ha/hr and hence the cost of transplanting one hectare of land is Rs.432.00 per hectare.

Cost of manual transplanting is Rs.1050 per hectare. Thus there is a saving of Rs.618 per hectare, if the modified six row rice transplanter is used for transplanting.

4.3.3 Pay back period

The pay back period for the transplanter for different areas of annual use is given in Table 9.

Table 9. Pay back period for the transplanter for different areas of annual use

Annual use in hectares	Fixed cost	Variable cost	Total cost	Total benefits	Net benefits	Pay back period
1	776	271.25	1047.25	1050	--	--
2	776	542.50	1318.50	2100	781.50	2.24
3	776	823.75	1599.75	3150	1550.25	1.13

The pay back period is 2.24 years when annual utilization is 2 hectares per annum and it is 1.13 years when the annual utilization is 3 hectares per annum.

Summary

SUMMARY

About half of the world's population is dependant on rice as their principal energy supplying food grain. Transplanting is the most common method of raising rice crop in the South East Asian countries as tranaplanting has got several advantages over the different seeding method. Manual transplanting is very effective but it is labour intensive. There is often acute shortage of labourers also at the time of transplanting and the timely farm operations are very essential for getting better yield. The introduction of suitable machines for transplanting, harvesting, and threshing operations is very essential in Kerala to make rice cultivation profitable. The IRRI six row rice transplanter, designed for mat type nursery seedlings was modified and tested at Kelappaji College of Agricultural Engineering and Technology, Tavanur for conventional seedlings. The modifications were conducted in three stages. After each stage intensive field experiments were conducted for finding out the suitability of the modification. In the first stage the feeding frame assembly and the picker arm assembly were modified. The conventional type seedlings are taller than the mat type seedlings nursery seedlings and hence when the machine was operated with conventional seedlings, the

transplanted seedlings were brought almost horizontal position. This problem was rectified by raising the height of the feeding frame of the transplanter by 50 mm. The mouth of the feeding frame was also changed from 8 mm to 5.4 mm in order to hold 3 seedling in each picking as per the recommendations in the Package of Practises of Kerala Agricultural University.

In the second stage the tray assembly was modified as there was no provision for holding the conventional seedlings together for feedig the picker arm unit. The height of the partition walls of the tray was increased from 40 mm to 100 mm.

In the final stage a pressure plate with the help of a pair of coiled springs were introduced in order to rectify the problem of falling of the seedlings from the trays which caused excessive missing and damaged hills.

The test results are summarised as follows:

1. The average number of seedlings per hill was obtained as 2.27 which closely resembled the desired value of 2 to 3 seedlings as recommended by the University.

2. The missing hills percentage was reduced from 20.83 per cent to 5.55 per cent.

3. The floating hills percentage was brought down to 5.55 per cent from 10 per cent.

4. Damaged hills percentage was reduced from 23.3 per cent to 8.8 per cent.

5. The field capacity of the machine was improved from 0.0139 ha/hr to 0.162 ha/hr.

6. The field efficiency was improved from 48.26 per cent to 56.87 per cent.

7. It was found by break even analysis that the machine was profitable for transplanting an area beyond one hectare per annum compared to the hand transplanting.

8. Cost analysis of the transplanter showed that there is a saving of Rs.618.00 per hectare.

9. The pay back period is 2.24 years when the annual utilization of the transplanter is 2 hectares per annum and 1.13 years when the annual utilization is 3 hectares per annum.

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Appendices

Appendix I

Specification of the IRRI six row rice transplante_

Power	-	One person
Field capacity	-	0.3 to 0.4 ha/day
Planting depth	-	3 to 5 cm
Tray displacement per stroke adjustment	-	1.0/1.3 cm
Standing water depth in the field	-	1 to 5 cm
Weight	-	20 kg
Length	-	85 cm
Width	-	125 cm
Materials used for construction	-	Steel and wood
Size of seedling mat	-	20 x 50 cm
Number of seedling mat per hectare	-	400-450
Size of seed bed per hectare	-	1.2 M x 45 M
Seed requirement per hectare	-	30 to 40 kgs

Appendix II

Diameter and height of seedlings in a conventional nursery of of 19 days age

Sl. No.	Diameter of seedlings			Height of seedlings
	I	II	Average	
1	1.32	2.22	1.770	231
2	1.27	2.32	1.795	227
3	0.98	2.23	1.605	210
4	0.95	2.48	1.715	212
5	1.01	2.17	1.590	225
6	1.03	1.66	1.345	215
7	1.27	3.12	2.195	253
8	1.09	2.55	1.820	235
9	1.21	2.69	1.900	221
Average			1.770	225.4

Average size of seedlings = 1.77 mm

Appendix III

Modification - Stage one

Test 1

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	3	[illegible]	3	3	2	2
2	3	[illegible]	F	3	2	2
3	4	[illegible]	0	2	5	3
4	D	[illegible]	D	D	D	D
5	1	[illegible]	0	4	3	F
6	D	[illegible]	D	4	3	2
7	3	[illegible]	5	2	3	0
8	0	[illegible]	2	0	2	0
9	0	[illegible]	0	5	4	6
10	0	[illegible]	4	4	3	3
11	1	[illegible]	2	2	0	3
12	F	F	2	4	4	2
13	0	[illegible]	1	4	3	4
14	3	[illegible]	D	0	2	3
15	D	[illegible]	2	5	3	4
16	0	[illegible]	D	3	4	2
17	D	[illegible]	0	F	3	3
18	2	[illegible]	3	4	3	4
19	0	[illegible]	F	3	1	3
20	1	[illegible]	3	B	4	6
21	1	F	F	D	3	4
22	3	[illegible]	D	D	D	D
23	D	[illegible]	3	3	4	1
24	2	F	2	0	3	3
25	F	[illegible]	3	0	2	2
26	3	[illegible]	2	3	3	4
27	0	[illegible]	D	2	B	1
28	2	[illegible]	3	2	D	3
29	D	F	2	D	D	3
30	2	[illegible]	2	2	3	2

Variety of seeds - Triveni

Date of sowing - 26.5.1989

Date of transplanting - 15.6.1989

Age of seedlings - 19 days

Type of seedlings - Conventional

Leaf stage - 2 to 3 leaves

Percentage of Damaged hills = 16.11%

Average number of seedlings per hill = 319/180 : 1.77

Percentage of missed hills = 23/180 x 100 = 12.77%

Percentage of floating hills = 12/180 x 100 = 6.67%

Percentage of buried hills = 2/180 x 100 = 1.11%

Total area covered = 20 x 8 = 160 m^2

Average speed of operation = 3.66 m per min
0.219 kmph

Average depth of planting = 35 mm

Total time taken = 78 min

Theoretical field capacity = W x S /100

= 120 x 0.219 /1000

= 0.0263 ha/hr

Actual field capacity = 0.0123 ha/hr

Field efficiency = 0.0123 /0.0263 x 100

= 46.8%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix IV

Modification - Stage one

Test 2

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	2	2	2	1	1	2
2	1	0	2	2	1	3
3	0	0	0	1	2	3
4	2	2	1	2	0	2
5	1	0	3	2	2	D
6	0	0	2	4	0	3
7	F	1	1	0	3	4
8	D	2	1	D	D	D
9	2	1	0	1	F	F
10	2	4	1	1	1	3
11	2	2	3	2	3	5
12	F	F	2	3	2	1
13	1	2	3	3	3	1
14	1	D	2	3	2	2
15	0	0	2	0	1	0
16	D	D	D	D	D	D
17	F	F	F	1	2	3
18	1	D	2	1	1	4
19	2	3	2	2	1	2
20	0	0	2	1	2	1
21	4	0	1	2	2	4
22	2	3	3	3	2	4
23	2	D	D	D	D	D
24	F	F	F	2	1	D
25	1	2	2	3	2	1
26	2	4	3	0	1	2
27	D	D	2	1	2	2
28	2	1	2	2	1	3
29	1	1	1	3	3	4
30	F	F	F	F	F	0

Variety of seeds - Triveni

Date of sowing - 26.5.1989

Date of transplanting - 16.6.1989

Age of seedling - 20 days

Leaf stage - 2 to 3 leaves

Total no. of seedlings = 252

Average number of seedlings per hill $= \frac{252}{180} = 1.4$

Percentage of missed hills $= \frac{20}{180} = 11.11\%$

Percentage of damaged hills $= \frac{21}{180} \times 100 = 11.66\%$

Percentage of buried hills = 0

Percentage of floating hills $= \frac{16}{180} \times 100 = 8.88\%$

Actual area covered $= 200\ m^2$

Average speed of operation = 3.62 m/min

$= \frac{3.62 \times 60}{1000} = 0.2172$ km/hr

= 90.[illegible] min [illegible] secs.

Average depth of planting = 37 mm

Theoretical field capacity $= \frac{W \times S}{1000} = \frac{120 \times 0.2172}{1000}$

= 0.02606 ha/hr

Actual field capacity $= \frac{200 \times 60}{90.54 \times 10000}$

= 0.01325 ha/hr

Field efficiency $= \frac{0.01325}{0.02606} \times 100$

= 50.86%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix V

Modification - Stage one

- Test 3

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	1	0	1	2	3	3
2	D	1	D	D	D	1
3	2	2	0	1	1	2
4	1	0	1	2	2	3
5	F	F	2	0	2	F
6	2	1	3	2	1	4
7	1	D	0	3	2	1
8	1	2	0	F	F	2
9	D	D	D	1	2	2
10	1	2	2.	3	2	3
11	0	1	2	0	3	4
12	0	1	F	D	2	4
13	2	0	F	2	3	2
14	2	2	3	1	D	D
15	3	0	0	3	1	2
16	0	1	2	0	0	4
17	2	2	2	2	D	0
18	2	1	2	3	4	5
19	D	2	4	2	3	2
20	2	0	0	D	D	1
21	1	2	D	2	3	2
22	2	2	1	2	3	2
23	D	D	D	D	D	D
24	1	1	1	F	0	0
25	0	0	0	1	1	2
26	0	0	0	2	2	3
27	F	F	1	2	2	3
28	0	1	2	4	5	5
29	2	1	1	1	2	1
30	2	D	D	2	2	2

Variety of seeds - Triveni

Date of sowing - 26.5.1989

Date of transplanting - 17.6.1989

Age of seedling - 21 days

Leaf stage - 2 to 3 leaves

Total number of seedlings - 240

Average number of seedlings per hill $= \frac{240}{180} = 1.33$

Percentage of missed hills $= \frac{28}{180} \times 100 = 15.55\%$

Percentage of damaged hills $= \frac{23}{180} \times 100 = 12.77\%$

Percentage of floating hills $= \frac{10}{180} \times 100 = 5.55\%$

Area covered $= 20 \times 8 = 160\ m^2$

Average speed of operation $= 3.73$ m/min

$= \frac{3.73 \times 60}{1000}$

$= 0.2238$ km/hr

$= 75$ min

Average depth of planting = 40 mm

Theoretical field capacity $= \frac{W \times S}{1000} = \frac{120 \times 0.2238}{1000}$

$= 0.0268$ ha/hr

Actual field capacity $= \frac{160 \times 60}{75 \times 10,000}$

$= 0.0128$ ha/hr

Field efficiency $= \frac{0.0128}{0.0268} \times 100$

$= 47.76\%$

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix VI

Modification - Stage two

Test 1

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	1	2	2	4	3	2
2	2	0	1	2	2	3
3	2	1	F	3	4	4
4	0	0	4	D	D	2
5	D	D	F	2	2	3
6	3	2	1	3	3	4
7	3	3	3	2	4	6
8	2	F	2	F	3	2
9	D	0	2	3	F	3
10	0	0	0	D	D	3
11	1	0	2	3	2	0
12	3	0	0	D	2	3
13	2	2	D	F	1	2
14	1	D	0	D	0	D
15	2	2	D	3	2	4
16	F	F	2	4	3	5
17	1	2	3	2	D	1
18	2	2	D	2	3	2
19	1	4	2	2	1	2
20	0	3	2	2	3	1
21	2	0	1	4	2	3
22	2	2	2	1	2	3
23	0	2	3	1	3	2
24	3	2	0	2	2	F
25	0	1	2	4	F	5
26	0	2	2	0	2	2
27	2	0	2	1	1	2
28	3	D	3	2	3	4
29	2	1	3	1	2	4
30	2	2	F	2	2	F

Date of sowing the seeds - 8.9.1989

Date of transplanting - 29.9.1989

Age of seedling - 20 days

Leaf stage - 2 to 3 leaves

Total number of seedlings = 312

Average number of seedlings per hill $= \frac{312}{180} = 1.73$

Percentage of missed hills $= \frac{20}{180} \doteq 11.11\%$

Percentage of damaged hills $= \frac{17}{180} \times 100 = 9.4$

Percentage of floating hills $= \frac{12}{180} \times 100 = 6.6$

Area covered $= 20 \times 8 = 160$ m

Average speed of operation = 3.85 m/min

$= \frac{3.85 \times 60}{1000}$

= 0.231 km/hr

Total time taken = 70 min

Average depth of planting = 37 mm

Theoretical field capacity $= \frac{W \times S}{1000}$

$= \frac{120 \times 0.231}{1000}$

= 0.0277 ha/hr

Actual field capacity $= \frac{160 \times 60}{10 \times 10000}$

= 0.0131 ha/hr

Field efficiency $= \frac{0.0137}{0.0277} \times 100$

= 49.45%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix VII

Modification – Stage two

Test 2

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	4	0	4	3	3	4
2	3	4	3	2	D	4
3	2	2	1	3	5	3
4	3	0	2	2	4	3
5	0	3	3	3	4	4
6	4	D	2	4	3	2
7	D	3	4	4	2	0
8	3	4	4	1	2	5
9	4	2	D	3	0	2
10	2	2	3	2	3	4
11	2	D	0	3	3	2
12	4	2	3	2	D	2
13	4	D	4	3	3	4
14	F	F	F	2	2	D
15	0	2	3	2	4	0
16	D	2	F	2	2	3
17	3	3	2	F	2	2
18	3	3	3	4	3	1
19	4	D	D	2	D	2
20	2	3	2	D	2	3
21	3	5	3	2	3	3
22	D	3	0	0	4	3
23	2	0	2	3	2	F
24	1	2	F	F	F	2
25	3	0	2	F	3	3
26	3	2	4	3	3	3
27	2	4	4	3	2	2
28	1	3	3	3	2	1
29	3	3	D	D	2	2
30	2	2	4	4	3	3

Date of sowing – 8.9.1989

Date of transplanting – 30.9.1989

Age of seedling – 21 days

Leaf stage – 2 to 3 leaves

Total number of seedlings = 396

Average number of seedlings = $\frac{396}{180}$ = 2.2

Percentage of nursing hills = $\frac{12}{180}$ x 100 = 6.66%

Percentage of damaged hills = $\frac{17}{180}$ x 100 = 9.44%

Percentage of floating hills = $\frac{10}{180}$ x 100 = 5.55%

Area covered = 400 m^2

Average speed of operation = 4.13 m/min

= $\frac{4.13 \times 60}{1000}$

= 0.2478 km/hr

Total time taken = 154. min, 43 secs.

Average depth of planting = 35 mm

Theoretical field capacity = $\frac{W \times S}{1000}$

= $\frac{120 \times 0.2478}{1000}$

= 0.0297 ha/hr

Actual field capacity = $\frac{400 \times 60}{154.8 \times 10000}$

= 0.0155 ha/hr

Field efficiency = $\frac{0.0155}{0.0297}$ x 100

= 52.20%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix VIII

Modification - Stage two

Test 3

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	2	1	3	2	2	2
2	3	0	2	2	3	4
3	1	2	0	0	3	2
4	2	2	2	3	2	1
5	0	0	F	2	3	2
6	2	3	F	F	F	1
7	3	3	2	2	3	4
8	2	2	3	4	2	4
9	F	2	3	4	3	3
10	2	F	2	3	4	4
11	2	2	3	2	0	1
12	2	0	3	2	D	2
13	3	D	D	D	2	0
14	0	2	0	2	3	3
15	4	3	4	2	3	2
16	D	D	F	D	2	2
17	2	2	3	2	2	1
18	D	D	F	2	D	D
19	3	4	2	0	0	4
20	0	3	2	2	3	D
21	3	0	3	3	2	2
22	2	0	3	3	4	4
23	3	4	D	3	3	4
24	2	2	3	1	2	2
25	2	F	4	4	1	2
26	1	3	2	0	2	2
27	2	2	0	3	3	2
28	2	2	3	4	2	2
29	2	D	2	4	2	5
30	3	2	2	2	3	4

Date of sowing - 13.9.1989

Date of transplanting - 4.10.1989

Age of seedling - 20 days

Leaf stage - 2 to 3 leaves

Total number of seedlings = 355

Average number of seedlings per hill $= \frac{355}{180} = 1.97$

Percentage of missed hills $= \frac{17}{180} \times 100 = 9.44\%$

Percentage of damaged hills $= \frac{14}{180} \times 100 = 1.77\%$

Percentage of floating hills $= \frac{9}{180} \times 100 = 5\%$

Area covered $= 20 \times 8 = 160\ m^2$

Average speed of operation = 4.15 m/min

$= \frac{4.15 \times 60}{1000}$

= 0.249 km/hr

Average depth of planting = 38 mm

Total time taken = 62.9 min

Theoretical field capacity $= \frac{W \times S}{1000} = \frac{120 \times 0.249}{1000}$

= 0.02988 ha/hr

Actual field capacity $= \frac{160 \times 60}{62.94 \times 10000}$

= 0.0152 ha/hr

Field efficiency $= \frac{0.0152}{0.02988} \times 100$

= 50.87%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix IX

Modification - Stage three

Test 1

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	1	2	1	2	2	3
2	0	3	2	2	2	4
3	2	2	0	2	4	1
4	F	F	2	3	3	2
5	D	D	D	3	2	3
6	2	1	2	2	3	3
7	0	2	3	2	0	2
8	3	3	2	2	2	4
9	1	2	1	3	3	3
10	2	2	2	2	4	1
11	2	3	2	2	2	4
12	F	F	F	1	2	3
13	3	1	4	1	2	3
14	4	2	2	0	0	1
15	2	0	3	4	2	3
16	3	1	3	F	3	3
17	2	5	4	3	2	2
18	4	0	2	3	2	4
19	4	0	3	2	1	2
20	F	F	2	1	F	F
21	2	2	2	1	3	2
22	2	4	4	3	2	2
23	4	2	3	4	2	3
24	D	D	D	2	1	3
25	4	3	3	2	4	6
26	0	4	0	2	3	1
27	3	2	3	4	4	3
28	2	2	1	2	3	4
29	4	3	4	1	2	3
30	2	3	1	2	6	4

Variety of seed - Jyoti

Date of sowing - 20.12.1989

Date of transplanting - 11.1.1990

Age of seedling - 21 days

Leaf stage - 2 to 3 leaves

Total number of seedlings = 390

Average of seedlings per hill $= \frac{390}{180} = 2.16$

Percentage of missed hills $= \frac{11}{180} \times 100 = 6.11\%$

Percentage of damaged hills $= \frac{6}{180} \times 100 = 3.33\%$

Percentage of floating hills $= \frac{10}{180} \times 100 = 5.55\%$

Area covered $= 170\ m^2$

Average speed of operation $= 3.80$ m/min

$= \frac{3.80 \times 60}{1000}$

$= 0.228$ km/hr

Total time taken = 67 min.6 secs

Average depth of planting = 36 mm

Theoretical field capacity $= \frac{W \times S}{1000} = \frac{120 \times 0.228}{1000}$

$= 0.02736$ ha/hr

Actual field capacity $= \frac{170 \times 60}{67.1 \times 10000}$

$= 0.0152$ ha/hr

Field efficiency $= \frac{0.0152}{0.02736} \times 100$

$= 55.55\%$

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix X

Modification - Stage three

Test. 2

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	2	2	4	3	2	4
2	4	1	3	2	3	2
3	4	3	2	3	3	3
4	2	3	2	4	5	3
5	1	0	2	1	3	3
6	2	1	4	3	2	1
7	2	2	0	0	3	4
8	4	3	3	1	2	2
9	0	2	3	2	3	3
10	3	1	4	3	2	3
11	F	F	F	F	F	2
12	3	2	3	3	4	5
13	3	2	3	1	2	3
14	4	4	2	4	3	2
15	2	2	3	F	F	F
16	3	D	D	D	D	D
17	3	2	1	2	D	3
18	2	0	2	5	3	3
19	4	3	3	2	4	4
20	3	2	3	4	2	5
21	F	F	F	4	2	2
22	2	2	2	1	2	0
23	3	4	2	2	3	2
24	1	3	3	4	2	1
25	0	3	4	2	2	2
26	3	3	2	2	2	3
27	2	2	4	2	2	4
28	4	2	3	3	2	3
29	2	2	3	3	1	4
30	3	0	4	4	2	4

Variety of seed - Jyoti

Date of sowing - 20.12.1989

Date of transplanting - 12.1.1990

Age of seedling - ~~22 days~~

Leaf stage - 2 to 3 leaves

Total number of seedling = 429

Average number of seedlings per hill = $\frac{429}{180}$ = 2.38

Percentage of missed hills = $\frac{8}{180}$ x 100 = 4.44%

Percentage of damaged hills = $\frac{6}{180}$ x 100 = 3.33%

Percentage of floating hills = $\frac{11}{180}$ x 100 = 6.11%

Area covered = 400 m^2

Average speed of operation = 4.3 m/min

= $\frac{4.3 \times 60}{1000}$

= 0.258 km/hr

Total time taken = 129min. 5 secs

Average depth of planting = 33 mm

Theoretical field capacity = $\frac{120 \times 0.258}{1000}$

= 0.03096 ha/hr

Actual field capacity = $\frac{400 \times 60}{129.08 \times 10000}$

= 0.0185 ha/hr

Field efficiency = $\frac{0.0185}{0.0309}$ x 100

= 59.87%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix XI

Modification - Stage three

Test 3

	No. of seedlings in each picker arm of the modified transplanter					
	1	2	3	4	5	6
1	3	2	1	3	4	3
2	2	3	2	2	4	4
3	0	0	3	3	2	5
4	2	1	2	2	4	3
5	F	F	F	3	3	3
6	2	0	0	3	3	2
7	3	2	2	1	4	3
8	2	1	2	2	F	3
9	3	4	3	3	2	4
10	2	3	2	2	2	3
11	0	3	3	3	2	4
12	2	2	2	2	3	1
13	3	0	3	4	2	3
14	3	3	3	2	4	3
15	2	3	2	2	4	6
16	3	3	3	2	3	2
17	F	2	0	F	2	2
18	2	3	4	D	F	F
19	2	2	2	4	D	D
20	3	4	2	2	4	D
21	2	1	3	2	0	2
22	3	2	D	D	4	3
23	3	4	4	2	D	2
24	2	2	2	3	3	5
25	4	3	2	F	2	0
26	2	2	4	3	F	3
27	2	0	3	2	2	2
28	2	2	4	4	0	6
29	2	1	3	4	2	2
30	2	2	3	1	4	3

Variety of seed - Triveni

Date of sowing - 24.12.1989

Date of transplanting - 13.1.1990

Age of seedling - 19 days

Leaf stage - 2 to 3 leaves

Total number of seedlings = 407

Average number of seedlings per hill = $\frac{407}{180} = 2.26$

Percentage of missed hills = $\frac{11}{180} \times 100 = 6.11\%$

Percentage of damaged hills = $\frac{7}{180} \times 100 = 3.88\%$

Percentage of floating hills = $\frac{10}{180} \times 100 = 5.55\%$

Area covered = 400 m^2

Average speed of operation = 3.8 m/min

$= \frac{3.8 \times 60}{1000}$

= 0.228 km/hr

Average depth of planting = 35 mm

Total time taken = 159 min. 27 secs

Theoretical field capacity = $\frac{120 \times 0.228}{1000}$

= 0.02736 ha/hr

Actual field capacity = $\frac{400 \times 60}{159.4545 \times 10000}$

= 0.01505

Field efficiency = $\frac{0.01505}{0.02736} \times 100$

= 55.01%

B = Buried hills; F = Floating hills; D = Damaged hills; 0 = Missing hills

Appendix XII

Calculation of the break even point of the modified six row rice transplanter

Basic informations

1. Machine cost - Rs.1750/-
2. Machine life - 3 years
3. Repair and maintenance - 5% of machine cost
4. Interest on investment - 12%
5. Machine capacity - 0.0162 ha/hr
6. Labour requirement - One man
7. Operational wages - Rs.35/day of 8 hours

A. Manual method

30 man-days are required for transplanting one hectare of rice.

Cost of transplanting one hectare = 30 x 35 = 1050

B. Machine transplanting

Fixed costs

1. Depreciation $= \frac{\text{Initial cost - Salvage value}}{\text{Machine life}} = \frac{1750 - 0}{3}$

$= 583.33$

Contd.

Appendix XII (contd.)

2. Repair and maintenance = Machine cost x 0.05

= Rs.87.5

3. Interest = $\frac{\text{Machine cost + Savlage value}}{2}$ x 0.12

= Rs.105/-

Total fixed cost = Rs.775.83

= Rs.776/-

Variable cost

One-man hour is required to cover 0.0162 ha/hr

$\therefore$ Man hours required to cover one hectare = 62

Cost of operating the machine in one hectare

= 62 x 35/8 = Rs.271.25

Break even point was obtained by the following formula

$$F_{c1} + (V_{c1} \times X \text{ ha}) = F_{c2} + (V_{c2} \times X \text{ ha})$$

where,

F_{c1} = Rs.776/ha

V_{c1} = Rs.271/ha

F_{c2} = 0 (In this case this is zero)

V_{c2} = Rs.1050

$$X \text{ ha} = \frac{F_{c1}}{V_{c2} - V_{c1}} = \frac{776}{1050-271} \quad 1 \text{ hectare}$$

Appendix XIII

Calculation of the operating cost of the modified six row rice transplanter

Fixed costs (Annual use of the machine as 300 hours)	=	Rs.776/annum = Rs.2.59/hr
Variable cost (Wages of the operator as Rs.3 /8 hr day)	=	35/8 = 4.38/hr
Total cost	=	Rs.6.97/hr
Field capacity of the machine	=	0.0162 ha/hr
Number of hours required to cover one hectare	=	62 hours
Cost of operating one hectare	=	62 x 6.97
	=	Rs.432 per ha

30 man days are required for hand transplanting one hectare land. Therefore cost of hand transplanting one hectare land = 30 x 35 = 1050 per hectare.

Appendix XIV

Specifications of the modified six row rice transplanter

Model	-	Modified six row rice transplanter
Type	-	Manually operated
Power	-	One person
Seedling type	-	Conventional
Materials of construction	-	Steel and wood
Working width	-	1200 mm
Row spacing	-	200 mm
Depth of planting	-	30 to 60 mm
Length	-	940 mm
Width	-	1460 mm
Height	-	532 mm
Weight	-	27.4 kg
Field capacity	-	0.0162 ha/hr

MODIFICATION AND PERFORMANCE EVALUATION OF SIX ROW RICE TRANSPLANTER FOR CONVENTIONAL SEEDLINGS

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of
the requirement for the degree

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1990

ABSTRACT

The six-row rice transplanter was originally designed for mat type seedlings. Considering the importance of a transplanter using conventional type seedlings, the above transplanter was modified. The work was carried out at the Kelappaji College of Agricultural Engineering and Technology, Tavanur. The modifications were completed in three stages.

The performance evaluation of the modified six row rice transplanter was conducted after each stage of modification. The average number of seedlings per hill could be reduced from the average value of six seedlings per hill before modification to 2.27 seedlings per hill after the modifications. The missing hills percentage was brought down from 20.83 per cent to 5.55 per cent and the floating hills percentage was reduced from 10 per cent to 5.55 per cent. Percentage of damaged hills was reduced from 23.3 per cent to 8.8 per cent. The field capacity of the machine was improved from 0.0139 ha/hr to 0.0162 ha/hr and field efficiency from 48.26 per cent to 56.87 per cent. The use of the modified transplanter is profitable if it is operated beyond one hectare per annum. It gives a saving of Rs.618.00 per hectare compared to the conventional hand transplanting giving a a 2.4 times reduction in total cost. The pay back period of the modified transplanter is 2.24 years when the annual utilization is 2 hectares per annum and 1.13 years when the annual utilization is 3 hectares per annum.