EVALUATION AND MODIFICATION OF POWERTILLER OPERATED PADDY REAPER

By
SELVAN P.

THESIS
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Department of Farm Power Machinery and Energy
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING & TECHNOLOGY
Tavanur - 679 573
MALAPPURAM

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DECLARATION

I hereby declare that this thesis entitled **"Evaluation and Modification of Powertiller Operated Paddy Reaper"** 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.

Tavanur
22nd August 1995

SELVAN, P.

CERTIFICATE

Certified that this thesis entitled **"Evaluation and Modification of Powertiller Operated Paddy Reaper"** is a record of original work done independently by **Sri. Selvan, P.** 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.

Dr. M. Sivaswami
Chairman, Advisory Committee
Assistant Professor
Department of Farm Power
Machinery and Energy
KCAET, Tavanur

Tavanur
22nd August, 1995

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Sri. Selvan, P.**, a candidate for the degree of Master of Technology in Agricultural Engineering with major in Farm Power and Machinery, agree that the thesis entitled **"Evaluation and Modification of Powertiller Operated Paddy Reaper"** may be submitted by Sri. Selvan, P., in partial fulfilment of the requirement for the degree.

Dr. M. Sivaswami
(Chairman, Advisory Committee)
Assistant Professor
Department of Farm Power
Machinery and Energy
KCAET, Tavanur

Dr. K. John Thomas
Dean i/c
KCAET, Tavanur
(Member)

Sri. Jippu Jacob
Associate Professor and Head
Department of FPM&E
KCAET, Tavanur
(Member)

Er. M.R. Sankaranarayanan
Assistant Professor
Department of Agril. Engineering
College of Horticulture
Vellanikkara
(Member)

External Examiner

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SELVAN, P.

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SYMBOLS AND ABBREVIATIONS

Agric.	-	Agricultural
AICRP	-	All Indian Co-ordinated Research Project
AMA	-	Agricultural Mechanization in Asia
CAAMS	-	Chinese Academy of Agricultural Mechanization Sciences
CI	-	Cast iron
CIAE	-	Central Institute of Agricultural Engineering
cm	-	centimetre(s)
CMERI	-	Central Mechanical Engineering Research
D	-	Diameter
dia.	-	diameter
Dept.	-	Department
Engng	-	Engineering
Engr.	-	Engineer
et al.	-	and others
FAO	-	Food and Agriculture Organisation
Fig.	-	Figure
FIM	-	Farm Implements and Machinery
FPME	-	Farm Power Machinery and Energy
g	-	gram(s)
ha	-	hectare(s)
hp	-	horse power
hr	-	hour
IARI	-	Indian Agricultural Research Institute

ICAR	-	Indian Council of Agricultural Research
i.e.	-	that is
IRRI	-	International Rice Research Institute
ISI	-	Indian Standard Institutions
J	-	Journal
KAMCO	-	Kerala Agro-Machinery Co-operation
KAU	-	Kerala Agricultural University
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kg	-	kilogram
kmph	-	kilometre per hour
Kw	-	Kilowatt
L	-	length
lit	-	litre(s)
Ltd.	-	Limited
m	-	metre(s)
man-hr	-	man hour(s)
mc	-	moisture content
MF	-	Massey Ferguson
min.	-	minute(s)
mm	-	millimetre
MS	-	Mild Steel
M/s	-	Messers
No.	-	Number(s)
PAU	-	Punjab Agricultural University
pp	-	Pages
PTO	-	Power Take Off

Pvt.	-	Private
RARS	-	Regional Agricultural Research Station
RNAM	-	Regional Network for Agricultural Machinery
rpm	-	revolutions per minute
Rs.	-	Rupees
s	-	second(s)
Sci.	-	Sciences
Sec	-	Second(s)
Sq.m.	-	square metre
TNAU	-	Tamil Nadu Agricultural University
Viz.	-	namely
w	-	watt(s)
&	-	and
@	-	at the rate of
°	-	Degree
/	-	Per
%	-	per cent

Introduction

INTRODUCTION

Mechanisation of small and marginal farms is gaining importance in our country as an essential step to increase the timeliness of operation as well as to reduce the labour requirement and cost of cultivation. At present tractors and powertillers are easily available for the farmers to carry out almost all the tillage operations like ploughing, puddling, levelling as well as for transportation. But all other farm operations like sowing, transplanting, harvesting, threshing and winnowing are still done manually mostly with traditional equipments which are inefficient.

Paddy is the major crop in Kerala as the rice is the stable food for its people. Introduction of labour and time saving as well as most efficient machinery for all cultural practices of paddy cultivation has become necessary because of labour scarcity.

The state is experiencing a steady decline in the area and production of paddy during this decade (Farm Guide, 1984 and 1994). This is happening in Kerala because of the higher wage rates and unavailability of farm labours. This will be intensified as the youngsters are not willing to work in the field. To save paddy cultivation, at least the labour intensive operation in the paddy are to be appropriately mechanized.

The efficiency of manual harvesting system using sickles is considerably low. Statistics show that around 200 man hours per ha are required to harvest the paddy. The operational problems in using heavy machines are that they cannot be operated in all the fields as most of them are small in size.

For harvesting paddy, a light machine which is trivial in design with a low price tag is essential.

Kerala Agricultural University has conducted studies on a modified IRRI one metre reaper as well as a tractor operated reaper.

The 5 hp paddy reaper has to be purchased exclusively for harvesting purpose by the farmers and sometimes the power of the prime-mover may not be enough for propulsion as well as for harvesting in heavy soils in Kerala. Moreover the tractor operated reaper can be used only in big plots and approaching the paddy fields by this tractor operated paddy reaper is a problem in Kerala.

In India not much work has been done to develop a paddy harvester suitable for the commonly available commercial powertillers.

Realising the necessity of mechanising the harvesting operation of paddy improving productivity and also for relieving the farmers from the back breaking toil, a study on power tiller operated vertical conveyer reaper has been undertaken.

The development of paddy harvester suitable to the powertiller will be accepted by the farmer for paddy harvesting. The farmer has to pay only the additional cost of reaper. This will also increase the annual use of power tiller. The manoeuvrability as well as easy approach to the field is higher for the powertiller operated reaper. It is also easier to transport the unit even to small fields having undulated topography.

The introduction of a powertiller operated harvester may reduce the cost of harvesting significantly. It may also reduce the operating time considerably.

The present investigation was undertaken with the following objectives.

a. Selection of suitable powertiller operated paddy reaper and performance evaluation of its mounting and transmission systems.

b. Evaluation of balancing, steering, sinking, propulsion, paddy harvesting, conveying and windrowing operations of the reaper.

c. Evaluation of field performance to find out optimum field and crop conditions and to reduce grain losses.

d. Studies on the labour requirements and economics of operation and comparing with harvesting by manual and tractor mounted reaper.

Review of Literature

REVIEW OF LITERATURE

A brief review on the situation of food production in India and Kerala, need for paddy mechanisation in Kerala, powertiller as the power source for paddy cultivation, problems in paddy harvesting and introduction of different paddy harvesters including some prototype and engineoperated paddy harvesters is presented in this chapter.

It is projected that with year 2000 AD Indian population would rise up to 1070 million and food requirement would increase to 230 million tonnes. In India, the area and the production of food crops had shown a decrease for the past 10 years while the population growth has increased. The rate of increase in population is 14.32 per cent.

In Kerala the present production of paddy, which is the stable food for its population, is only 1.03 million tonnes, while the actual requirement is 10.4 million tonnes. It is estimated that the requirement of paddy will be 67 million tonnes in 2000 AD (John, 1994).

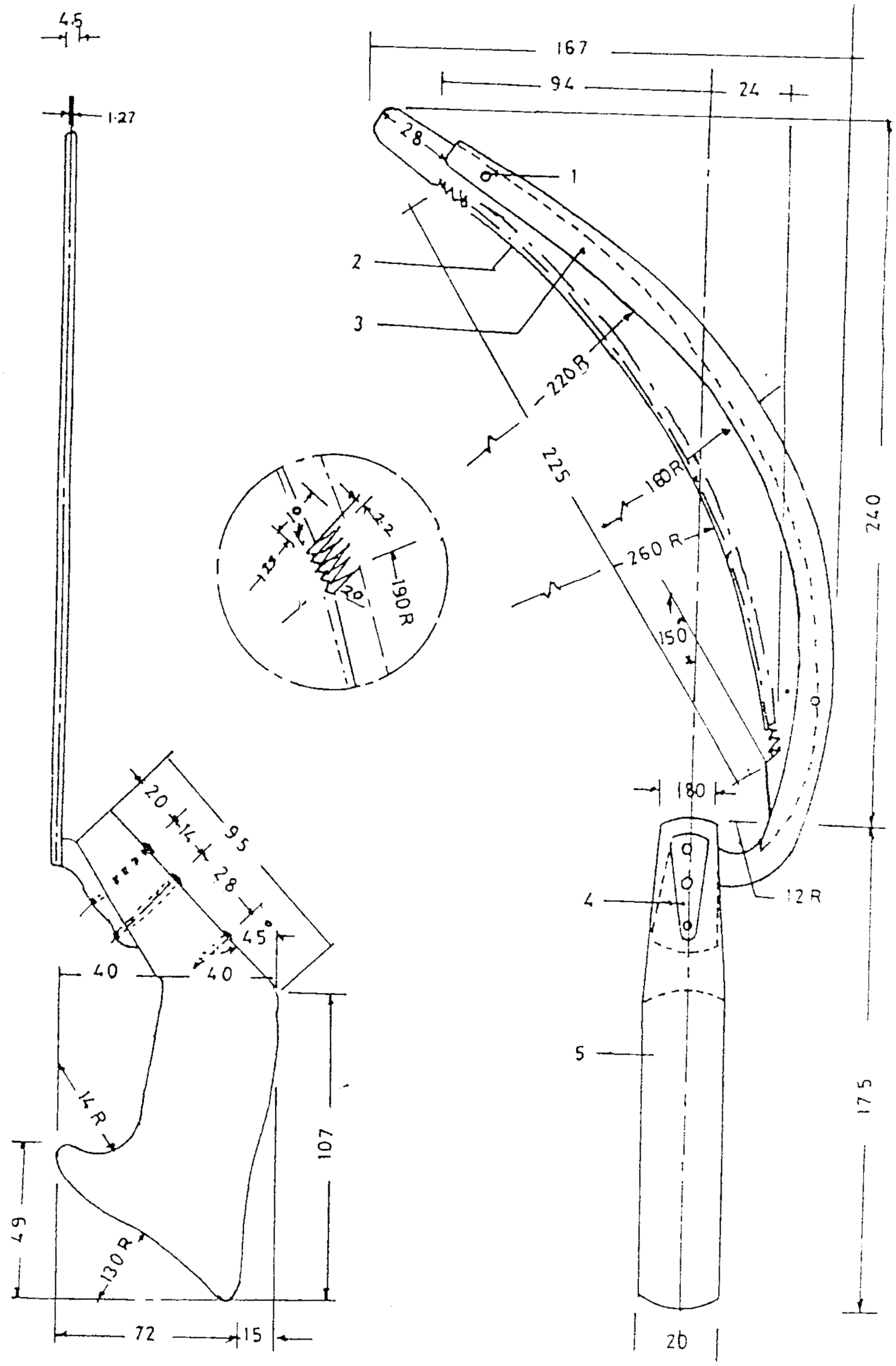
The declination in the paddy production is due to high cost of production. The increase in the labour cost, unavailability of labourers during the peak season all worsened the situation. Introduction of appropriate labour saving farm machine is the only solution to prevent the reduction in both area and production of paddy as well as the reduction in the farm labour population in Kerala.

The major labour intensive operations in paddy cultivation are transplanting, harvesting and threshing. In most cases harvesting, threshing and transplanting operation for the next crop coincide creating the scarcity of labour and the high wages as well as crop loss. The appropriate mechanisation is to be given priority for these labour intensive operations.

2.1 Methods of harvesting

Paddy harvesting is the operation of cutting the straw along with earhead in order to recover the paddy and straw. In India paddy harvesting is traditionally done by manual labours. Around 200 man-hrs are required for harvesting one hectare of paddy by using either plain or serrated sickles.

Sickles with serrated edges are light in weight and require less cutting force and need no repeated sharpening (Michael and Ojha, 1978). The new serrated sickle developed for increasing the efficiency of operation is given in Fig.1. The Naveen sickle (Appendix-I) developed at Bhopal was tested and an equation giving the relationship of the labour requirement with respect to the crop yield per hectare for the sickle was also developed (Pandey and Devnani, 1981).



1. Handle
2. Clip
3. U-shaped strip
4. Blade
5. Riveted

FIG.1 NAVEEN SICKLE

2.2 Hand dropper

The manually operated prototype harvester which is known as hand dropper was developed and used in Japan. But it was not successfully introduced in India (Michael and Ojha, 1978).

2.3 Animal drawn reapers

In England McComick and Hussey started developing horse drawn reapers during 1830's. They also fabricated horse drawn grain binders (Smith and Wikes, 1977).

A simple harvester having 1.05 m cutter bar operated by a pair of bullocks was developed in India. The power required by its different components at no load as well as at harvesting the crop were analysed (Singh *et al.*, 1977).

In Ludhiyana, an animal drawn paddy reaper was developed during 1964 (Fig.2). The specifications are given in Appendix-II. This machine was similar to McComic reaper in design with reduced weight. The major drawback of this model was the high draft requirement. In 1966-67 the PAU animal pulled engine driven reaper (Appendix-III) was developed so as to operate the harvester easily with a pair of bullocks (Fig.3).

1. Swath divider
2. Platform
3. Frame
4. Gear box
5. Land wheel
6. Pitman wheel
7. Cutterbar

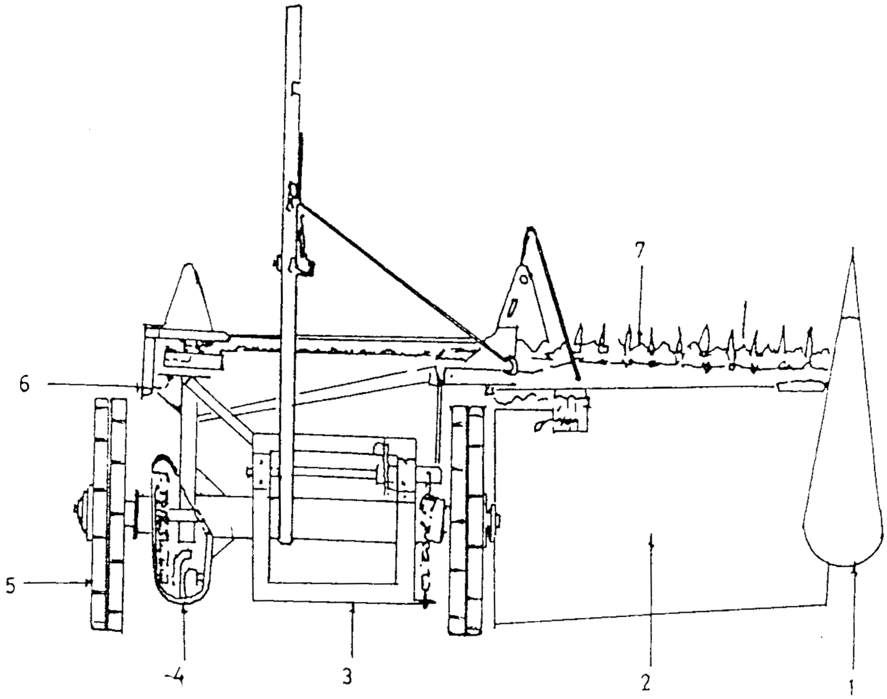


FIG.2 P.A.U. ANIMAL DRAWN REAPER

1. Cutterbar
2. Swath divider
3. Platform
4. Counter shaft
5. Pitman wheel Drive shaft
6. Engine platform
7. Engine pulley
8. Land wheel
9. Pitman wheel
10. Beam

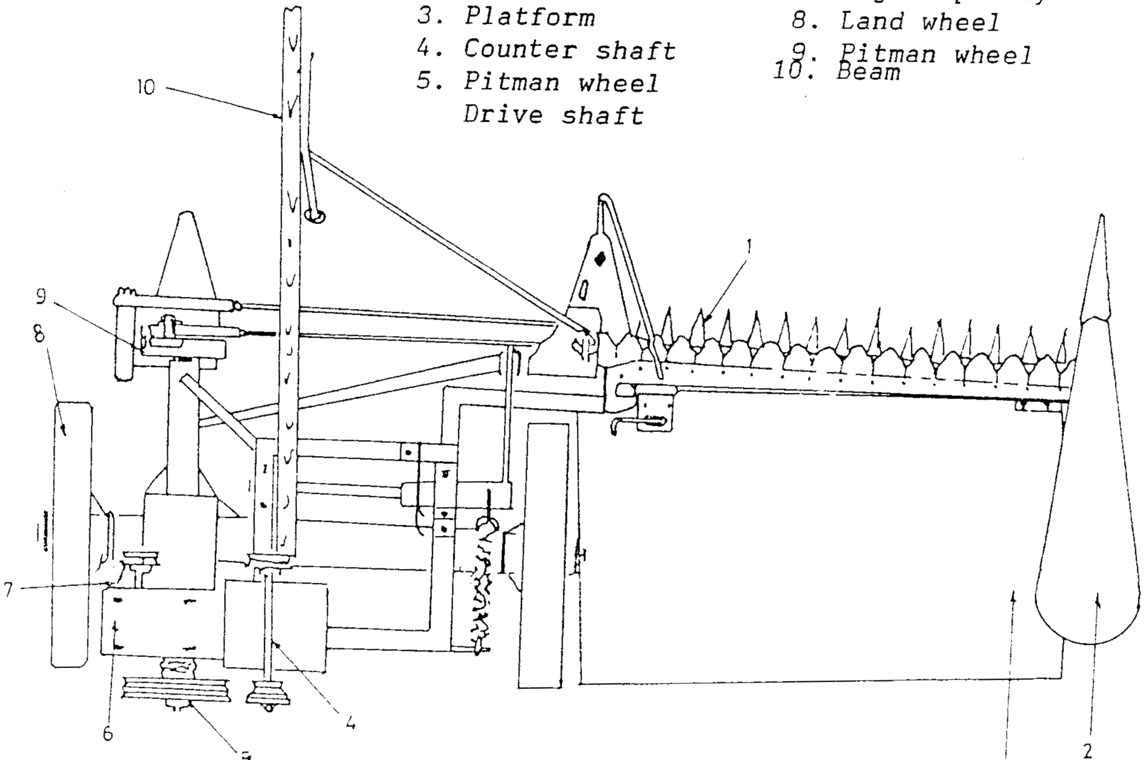


FIG.3 P.A.U. ANIMAL DRAWN ENGINE

The quality of windrow formed was not found satisfactorily (Yadav, 1988).

In 1968, similar work was started at New Delhi, with the introduction of horizontal endless belt conveyer windrower behind the cutter bar. This provision was made to windrow the harvested crop to a side to ensure immediate clearing of swath for the subsequent runs of the machine (Yadav, 1988). Bhatnagar (1969) studied the field performance of the animal drawn engine driven reaper. Similar work was also carried out at Jabalpur during 1970 and at Pantnagar during 1981 (Singh and Singh, 1987).

Efforts were taken to develop animal drawn reapers in Australia, China and many other countries. The Australian reaper with single wheel was a single animal operated machine with a conventional cutter bar. The animal drawn reaper designed in China has a cutter bar for cutting plants, a reel for gathering of harvested crop and a crop board for collecting harvested crop. It also had a provision of hook through which animals are harnessed by chain or rope (Yadav, 1988).

During 1980's an animal drawn reaper was developed at Bhopal as an attachment to a tool-frame with two transport wheels. Power transmission from the friction wheel was done through a set of sprocket, chain and bevel gears. Rotary motion is converted into reciprocating motion by introducing a lever mechanism, which helped in improving the force developed by the friction wheel for cutting. Because of this feature of the machine the draft requirement was reduced (Yadav, 1988).

The comparative specifications of PAU, IARI and CIAE animal drawn reapers are given in Appendix IV.

Verma and Bhatnagar (1970) have developed a bullock drawn reaper with engine operated cutter bar of length 1.37 m.A four stroke 2 Hp engine was used as a power source with a cutter bar speed of 150 metre per minute.

Khanna (1972) made a reaper pulled by a pair of bullocks. The power for operating the cutting mechanism and conveyer belts were provided by a 3 hp engine. The cutter bar operates at 800 strokes per minute.

Rahman *et al.* (1980) have worked on a push type harvester using human power. During the forward motion the power from the traction wheel is transmitted through suitable mechanism to operate the cutter bar knife. The speed of the operation was approximately one metre per hour, while that of the cutting knife was 200 to 225 rpm.

It is found that considerable efforts have been made at various places for the development of animal drawn reapers. But, not a single design could become popular in our country.

In Kerala use of animals for agricultural operation is reducing day by day and the size and draft capacity of the animals are also limited. So use of any heavy equipment like reaper is unthinkable. Only a power operated harvester will solve the harvesting problems in Kerala.

2.4 Power operated harvesters

Power operated harvesters are classified into three major types such as self propelled, powertiller operated and tractor mounted harvesters.

2.4.1 Self propelled reaper windrower

The first vertical windrowing reaper was developed in China during 1976. The prototype has a cutting width of 1.85 m with a rear windrowing mechanism mounted on a two wheel walking tractor. The operation was blocked by the change in the direction of the conveyed crop through right angles and hence was not got popularised. The machine was modified on a side windrowing reaper. A new series was introduced in 1977 with cutting width of 0.7, 1.0, 1.3, 1.6, 1.9 and 2.5 m. The following improvements in the design were incorporated with reapers during 1979-80.

(i) The clearance between the ledger plate and the knife section was improved.

(ii) Wrapping of straw around the star wheel was prevented.

(iii) The susceptibility of the frame to deformation was rectified.

IRRI improved the original Chinese reaper so as to suit better for agricultural and industrial conditions of developing countries in South and South East Asia.

In 1980, three Chinese engineers worked at IRRI, in Philippines to develop a simplified reaper. It was light, less expensive and easy to fabricate. The design eliminated the lugged v-belts and simplified the power take-off, conveyer drive and cutter bar mechanisms. Another self propelled harvesting machine for paddy was also developed by CMFRI, Durgapur (Appendix V). Its power requirement was 4-5 hp (Devnani, 1980).

The CAAMS-IRRI reaper was having a cutter bar width of 1.0 m and field capacity of 2.4 ha per day with 3 hp petrol engine (Bockhop et al., 1986).

Under CIAE-IRRI Industrial Extension Project at Coimbatore, the IRRI reaper was again modified to suit the local conditions with the incorporation of light weight diesel engine.

The unit consisted of reciprocating cutter bar of 1 m width, crop dividers, star wheels, horizontal conveyer for taking the crops in vertical position, 5 hp Lombardini diesel engine, speed reduction unit and a pair of pneumatic or cage wheels (Devnani, 1988a).

Another series of reapers were designed in 1984 with cutting width of 1.2, 1.5 and 1.8 m and many manufacturers in Philippines have taken up the production, having yearly output of 2000 to 5000 (Ling, 1986).

In Kerala, the one metre vertical conveyer reaper was tested at farmers fields as well as at research stations from 1989 onwards. Several successful demonstration were conducted in Kerala after incorporating many modifications. It was found to provide side clutches to facilitate easy turning in muddy fields. Hence a new model with a pair of clutches was designed and fabricated and field trials were conducted successfully. The average field capacity was 0.14 ha per hour (KAU, 1990 and 1991; Sivaswami, 1991, 1992 and 1993). This unit was exclusively used for harvesting paddy and was found suitable for both dry and wet paddy fields. It can be used only for a few days in a year. But if a powertiller or tractor operated paddy reaper are developed, the annual use of tiller or tractor will also be increased. So the owners of tiller or tractor will readily accept the reaper attachment.

A self propelled reaper binder of 10 hp with a cutting width of 1.24 m was developed at Hissar (Devnani, 1988b).

Ranganna (1986) has developed a push type vertical conveyer reaper. The power for operating the cutting mechanism and conveyer belts were provided by a petrol engine of 1.7 hp with speed reduction kit. The field capacity was 0.095 ha/hr and the cutter bar width of 0.62 m was adopted with forward travel speed of the machine was 0.44 m/sec.

Palanimuthu (1989) has developed a low cost paddy reaper with cutter bar having width of 0.30 m and a forward speed of 30 m/minute.

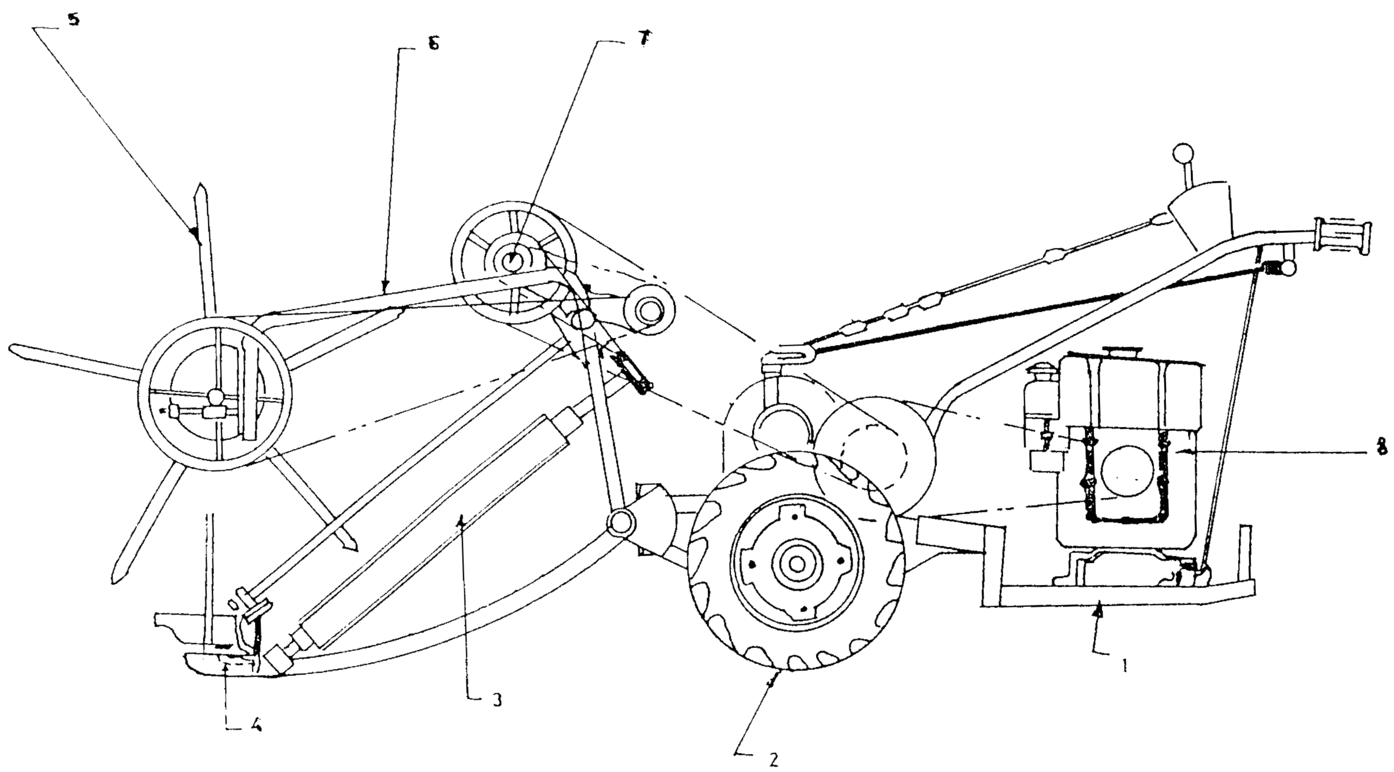
Kubota Power Reaper (AR 120) has been developed by M/s KAMCO in Kerala. It is a self propelled paddy reaper windrower based on Kubota reapers of Japan. This reaper is reported to be suitable for paddy and wheat (Indian Express 1994).

The improved version of the IRRI one metre paddy reaper was extensively field tested in various field conditions in Kerala (Sivaswami, 1993). The unit also had the advantage of using it as a mini tiller after interchanging with special rotavator with the reaper. A saving of an amount of Rs.800 per ha and saving of 128 man-hrs per ha, compared to the manual harvesting is achieved.

A side mounted self propelled harvester was developed at Udaipur during 1970. Attempts were made at Coimbatore and Durgapur to develop powertiller operated paddy reaper during 1971-74. The reel type low cost reaper (Fig.4) which was fabricated at Coimbatore was selected for evaluation at different countries for its regional acceptance by RNAM during 1978-80 (Devnani, 1988a).

Garg *et al.* (1986) conducted a study in Punjab with informations on harvester price, salient features of the machine, total area of harvested, labour engaged for crop collection and bundling and over all saving in terms of labour and money. The study also indicated the nature and frequency of breakdowns, farmers response towards the use of machine and speed at which the machine was operated.

An analysis has been done on a vertical conveyer cereal reaper to establish the relationship between different widths of cut and man hours required to gather the crop during harvesting itself and the grain yield, to find out the width of cut for which the costs of complete machine reaping with manual gathering would be equal to those of manual harvesting (Devnani, 1981).



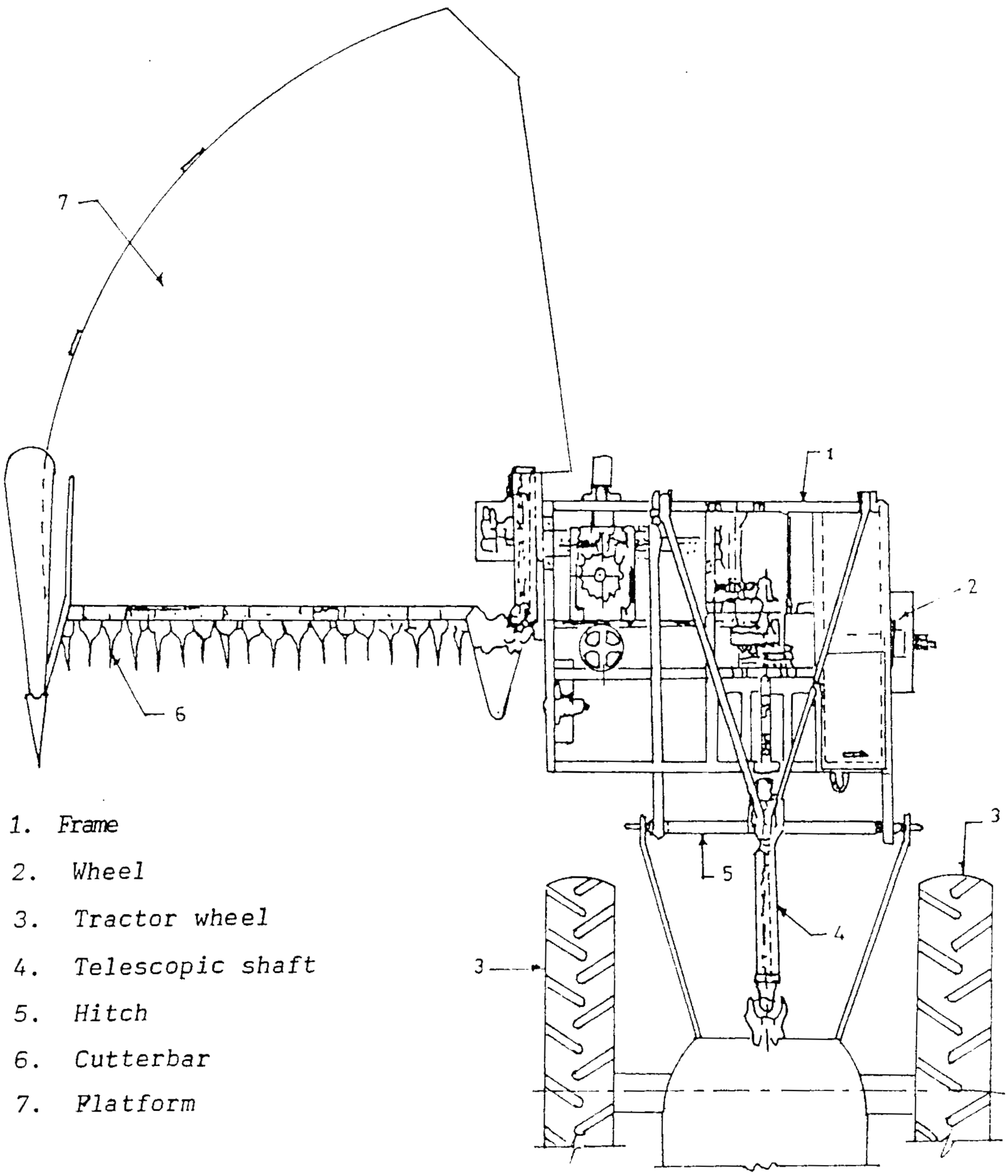
1. **Engine Chasis**	3. Conveyer	5. Reel assembly	7. Main shaft
2. Ground wheel	4. Cutterbar	6. Mainframe	8. Engine

FIG.4 REEL TYPE LOW COST PADDY HARVESTER DEVELOPED AT COIMBATORE

2.4.2 Tractor mounted reapers

During 1968-69 the tractor rear mounted PTO operated self raking type reaper was developed at Ludhiyana (Fig.5), Appendix-VI. This machine was operated with a 30 Hp tractor at a speed of 3 kmph. The field capacity was 0.37 ha per hr. The area to be manually cleared before the reach of machine for harvesting was found to be very high. Another tractor rear mounted reaper binder was developed and evaluated mainly for harvesting wheat (Chauhan and Kalkat, 1976).

During 1960-70, the tractor front mounted reaper using cutter bar, reel and canvas conveyer was developed at Ludhiyana. The field capacity was 0.29 ha per hr. Limited units were marketed around 1971-72. The work was continued on the development of the machine during 1974-79 and was evaluated at Ludhiyana and Bhopal (Devnani, 1980). Development of an another type of tractor operated cereal harvester was reported by C.M.F.R.I., Durgapur (Appendix-VII). The Tractor Testing and Training Centres at Budhini and Hissar also conducted testing and evaluations of reapers and reaper binders. The tractor mounted PTO driven cereal reaper binder with 1.65 m cutter bar was developed. The field capacity of the machine was 0.28 ha/hr with grain loss in the range of 2.0 to 2.3 per cent. A tractor mounted reaper was also developed at I.A.R.I., New Delhi. It was known as 'Pusa reaper' (Fig.6, Appendix-VIII).



1. Frame
2. Wheel
3. Tractor wheel
4. Telescopic shaft
5. Hitch
6. Cutterbar
7. Platform

FIG.5 TRACTOR REAR MOUNTED SELF RANKING TYPE REAPER

During 1978 at Ludhiyana, tractor mounted reaper binder was developed. The cutter bar had a width of 3.27 m and a field capacity of 0.2 to 0.3 ha/hr. The weight of bundles was 3 to 6 kg. At Bhopal a tractor operated reaper with a cutting width of 2.05 m was developed (Devnani, 1988b).

A tractor mounted PTO operated self raking type reaper (Appendix-VI) was evaluated for its performance at Ludhiyana (Verma and Garg, 1970, 1971). Later the design, development and field evaluation of a tractor front mounted vertical conveyer reaper windrower was conducted at Ludhiyana (Appendix-IX). It also included the popularization, performance, production status and usage of reapers in Punjab (Garg *et al.*, 1983, 1984 and 1986; Garg and Sharma, 1991).

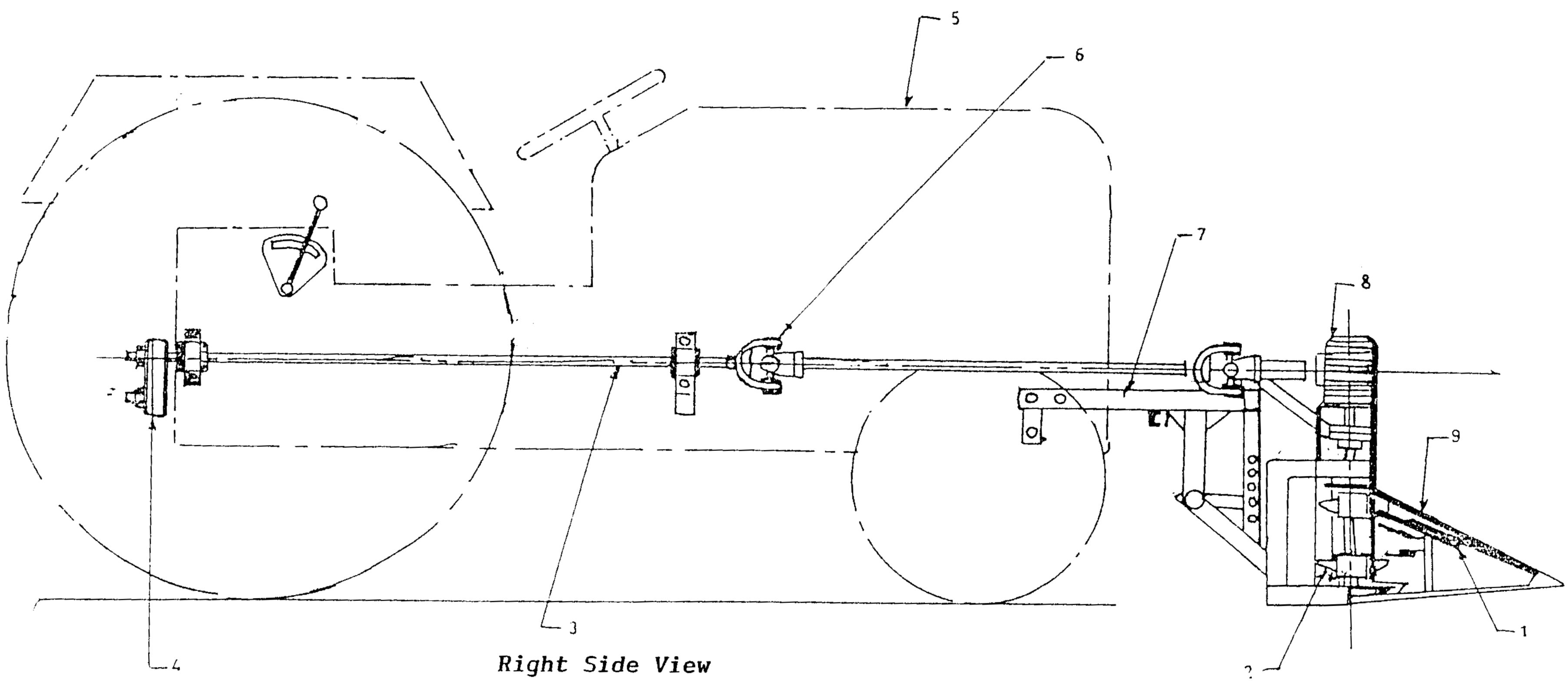
Garg and Sharma (1985) have adopted IRRI model VCR design for harvesting wheat and paddy crops with a 2.2 m cutter bar. It is a tractor front mounted type with a field capacity of 3.0 ha/day (Appendix-X).

2.4.3 Powertiller operated reapers

2.4.3.1 Powertillers

Powertillers are very useful for small land holdings and small fields where the tractors cannot reach easily. Total number of tillers used in India is about 56500 presently and day

1. *Star wheel*
2. *Lugs*
3. *Drive shaft*
4. *PTO shaft pulley*
5. *Tractor*
6. *Universal joint*
7. *Mounting frame*
8. *Gear box*
9. *Crop divider*



Right Side View

FIG.6 TRACTOR OPERATED VERTICAL CONVEYER REAPER by day its demand is increasing. The use of powertillers is confined only to dry ploughing, wet puddling, levelling, ridging, forming furrows and bunds and transporting. They are also be used to operate pump sprayers, thresher and huller.

Many special type of agricultural equipments and machinery for different operation with the powertiller as a prime-mover, were developed in different regions.

A powertiller operated bed former was developed at TNAU, Coimbatore (Pandey *et al.*, 1983).

A telescopic ladder that can be mounted on the powertiller had been developed for plucking fruits (Rajalingam, 1988).

A single row basin lister as an attachment to Mitsubishi powertiller had been developed (Nagarajan, 1988).

Comparative study on the field evaluation of powertiller and animal drawn equipment indicated that the time required for three blade harrowing was 82 per cent higher than powertiller rototilling (Varshney *et al.*, 1989).

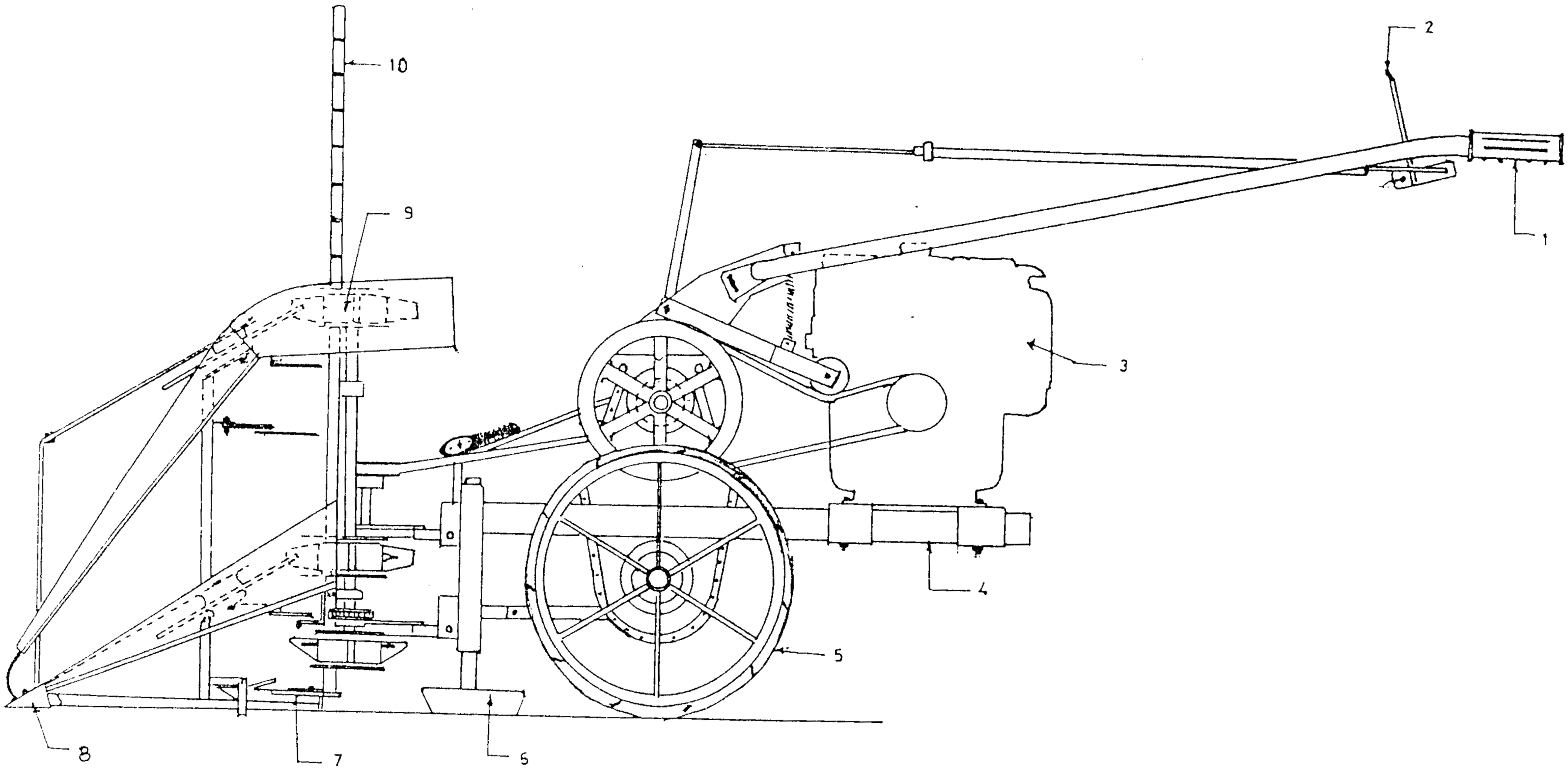
A powertiller operated turmeric digger had been designed and developed based on the needs of mechanisation of harvesting turmeric and in view of growing use of power tillers (Subramanian, 1992).

Another model of self propeller reaper windrower (Appendix-XI) for sorghum was developed during 1970-72 at Ludhiyana (Fig.7). The 5 hp engine was mounted at the rear to achieve proper balancing (Devnani, 1980).

Chauhan (1973) reported that a prototype of powertiller front mounted reaper was developed and tested at Ludhiyana. Harvesting losses were observed and their causes were reported (Appendix-XII).

Tiangco and Dietrio (1982) had observed that the vertical conveyer type of reapers carry out the simulated action of manual harvesting, i.e., holding, cutting, conveying and finally laying the crop neatly in the form of windrows.

Garg *et al.* (1984) have adopted a vertical conveyer reaper windrower with 1.6 m cutter bar to a powertiller. The machine was operated with 5 hp diesel engine and used for harvesting wheat. They further reported that the shattering losses were very minimum and it requires about 8 people for its continuous operation.



1. Handle
2. Clutch lever
3. Engine
4. Chasis
5. Cage wheel
6. Skid
7. Cutter bar
8. Header point
9. Conveyer
10. Vertical cross support

FIG.7 SELF PROPELLED SORGHOM HARVESTER

The design and development of a powertiller operated vertical conveyer reaper was started at Bhopal and first prototype was fabricated during 1981 (Devnani, 1981).

From the earlier studies conducted in other states as well as the studies undertaken at KAU reveal that the vertical conveyer reaper-windrower concept is found satisfactory for harvesting wheat as well as paddy.

It is noted that paddy or wheat reapers were developed recently at different institutions used the following two models.

(i) The self propelled model which is operated by a 5 hp diesel engine.

(ii) The tractor front mounted model

But not enough studies have seen reported on the development of a reaper suitable for the commonly available commercial 8 to 12 hp powertillers manufactured in India viz. Kubota and Mitsubishi .

A preliminary work has been attempted to develop and evaluate paddy reaper suitable for a commercially available powertiller.

Materials and Methods

MATERIALS AND METHODS

In this chapter the various considerations while selecting the powertiller mounted paddy reaper windrower, its components and the laboratory and field trials carried out to evaluate the reaper-windrower are discussed. The modifications undertaken to improve the performance of the unit, economic analysis and comparison with other types of paddy reaper and its feasibility in Kerala are also discussed.

3.1 Selection of prime mover

The powertiller is chosen for attaching a paddy harvesting unit to fulfil the following requirements

(i) The prime mover should provide sufficient power required for traction, to cut the crop at desired height and to windrow the cut crop at desired pattern.

(ii) It should require only minimum maintenance and adjustments.

(iii) The size and weight of the prime mover should be minimum so as to facilitate easy handling and operation of the harvester.

a. Power required for cutting the crop

The force or load required for cutting the crop was measured experimentally in the laboratory itself by fabricating a simple device. This device consists of an actual size cutter bar hinged at one end and a weight pan was attached to the other free end weights were gradually added at the pan and the cutterbar was suddenly released so as to simulate the actual dynamic cutting of the cutterbar during working. During laboratory trials, the following observation were taken.

Dia of each stem = 5 mm

Cross sectional area of each stem = $\frac{\pi}{4} \times 5 \times 5$

= 19.63 mm^2

Weight added to cause cutting one stem = 2.61 kg

Hence shear stress = $\frac{2.61}{19.63}$ = 0.133 kg/mm^2

No. of knives in the cutter bar = 20

As per the experimental results, two stems are taken by each knife

Shearforce for cutting the crop = 0.133x20x2x19.63 kgf

Total cutting force at the cutterbar = 104.43 kgf

The stroke length of cutterbar = 75 mm

Therefore sliding length per stroke = 150 mm

The speed of cutterbar	= 350 strokes/min
Hence average velocity of the blade	= 0.88 m/sec
Therefore power required for cutting	= $\frac{\text{Cutting force x linear velocity}}{75}$ hp
	$\frac{104.43 \times 0.88}{75}$
	= 1.23 hp

The efficiency of the power transmission from the engine to the gear box of the powertiller was assumed as 75 per cent.

b. Power required for conveyer belt

Speed of conveyer belt	= 60 m/min
Linear velocity of belt	= 1 m/s
Weight of single star wheel	= 0.70 kg
Load on the conveyer belt	= 0.70x25 = 17.5 kg
Self weight of conveyer belts	= 5.4 kg
Hence total load on the belt including self weight	= 22.9 kg
Assumed factor of safety	= 2
Hence, power required	= 22.9x2x1.00 kg.m/sec
	= 45.8 kg.m/sec
Power required for conveyance of crop	= $\frac{45.8}{75}$ = 0.61 hp
Taking 25% frictional loss Hp required	= 0.76 hp

c. Power required for traction

Power of engine	=	8 hp
Weight of whole unit	=	386.5 kg
Coefficient of traction	=	0.8
Traction force	=	386.5 x 0.8
	=	309.2 kgf
Forward speed while working	=	1.5 kmph

The efficiency (η) of power transmission from engine to traction wheels taken as 98 per cent.

Then the hp required for traction

$$= \frac{\text{Traction force x Forward speed}}{0.98^2 \times 75 \times 0.85}$$

$$= \frac{309.2 \times 0.417}{0.98^2 \times 75 \times 0.85}$$

$$= 2.1 \text{ hp}$$

Power required for cutting, conveying and traction = 4.09 hp

Power for frictional losses:

The power required for frictional losses is taken as 50 per cent of the sum of the power for cutting, conveying and traction.

Hence, power for friction = 2.05 hp

Total power required for the prime mover = power for cutting + power for conveyance + power for traction + power for frictional losses

= 1.23 + 0.76 + 2.1 + 2.05

= 6.14 hp

In India the air-cooled 8-10 hp and water cooled 10-12 hp powertillers in the brand name of Mitsubishi are manufactured by M/s VST Tillers and Tractors, Bangalore and the water cooled 9-12hp powertiller in the brand name of Kubota are manufactured by M/s KAMCO Ltd., Athani, Aluva.

The estimated power required for the prime mover is 6.14 hp. The air cooled Mitsubishi powertiller has rated power of 8-10 hp and hence the selection of the prime mover justifies the required power for the harvester under consideration. Taking into consideration the mechanical efficiency of the system the power is found to be enough for harvesting paddy.

3.2 Selection of reaper

Selection of a suitable reaper for harvesting paddy was based upon the studies on different types of reapers. From the studies it is found that the vertical conveyer reaper-system was suitable for paddy harvesting compared to other systems. The following points are noted while selecting the vertical conveyer reaper:

1. The size and dimensions of the reaper should match the powertiller, the field conditions and the operator.

2. The cutting and conveying is to be carriedout without any loss or damage to paddy and straw.

3. It should have provision to adjust the height of cutting and to operate both in the water submerged and dry fields.

4. It should contain minimum moving parts to reduce wear and tear.

5. The crop dividing, gathering, cutting, conveying and windrowing components should be simple and efficient.

6. The power transmission from the powertiller to the reaper should be simple in design.

7. The mounting and dismantling of reaper unit with the powertiller should be easier.

With the above considerations, the specifications of the reaper unit was decided and a 1.6 m reaper-windrower was got fabricated from M/s Swathi Industries, Coimbatore. Table 1 shows the specifications of the vertical conveyer reaper for Mitsubishi powertiller.

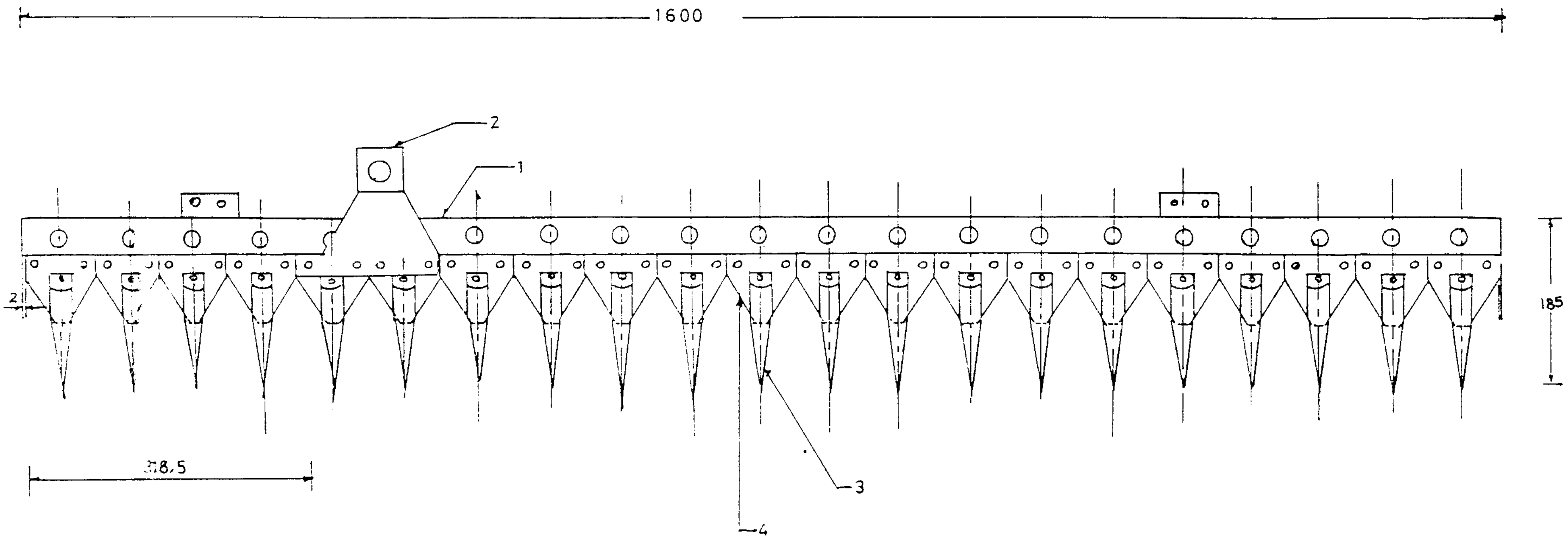
3.3 Study of components of the reaper

Cutter bar assembly

The important part in a harvester is the cutter bar assembly (Fig.8), consisting of the cutter bar, knife sections and knife guards.

Table 1. Specifications of 1.6 m Vertical Conveyer Reaper for Mitsubishi powertiller

Suitability of crop	:	Paddy
Suitable crop height	:	50-100 cms
Cutting width	:	160 cms
Minimum cutting height	:	8 cms
Weight of the reaper unit	:	100 kg
Weight of engine chasis	:	21.50 kg
Weight of auxiliary gear box	:	21.75 kg
Number of crop row dividers	:	5
Number of star wheels	:	5
Number of knife sections	:	20
Number of knife guards	:	21
Stroke length	:	75 mm
Number of pressure springs	:	5
Pitch of knife sections	:	75 mm
Crank radius	:	37.5 mm
Width of conveyor belts	:	6 cm
Lug spacing	:	13 cms
Spacing between belts	:	10 cms
Angle of star swheels from horizontal	:	20°
Recommended forward speed	:	1 m/s



1. Cutterbar frame
2. Knife bar
3. Knife guard
4. Knife section
5. Bracket

FIG.8 CUTTERBAR ASSEMBLY

Scale 1:7

Cutterbar frame - It is a metal bar having a length of 1.6 m on which 20 knife sections are mounted by rivets.

Knife section - It is a flat steel plate of triangular shape with two serrated cutting edges (Fig.9). A set of 20 knife sections are riveted on the cutterbar without any gap between the knife sections. The centre to centre distance is 75 mm. The knife sections and the ledger plates together effect the scissor like cutting action.

Knife guard - The guards protect the knife and act as a stationary shearing edge for the moving knife section. The guard also divides the standing crops and guides them into knife sections. Each knife section starts the reciprocating motion from the centre of the guard and reach the centre of the adjacent guard on each stroke of 75 mm and returns back to the original position at the next stroke. Lip is the top portion of the guard which along with ledger plate holds the crop during cutting. The ledger plate is a hardened and polished metal plate riveted over the finger of the guard which perform the cutting action during the movement of knife sections. The details of knife guard is shown in Fig.10. Finger is the projecting part of the guard which protects the knife from damage when the reaper comes across any obstruction.

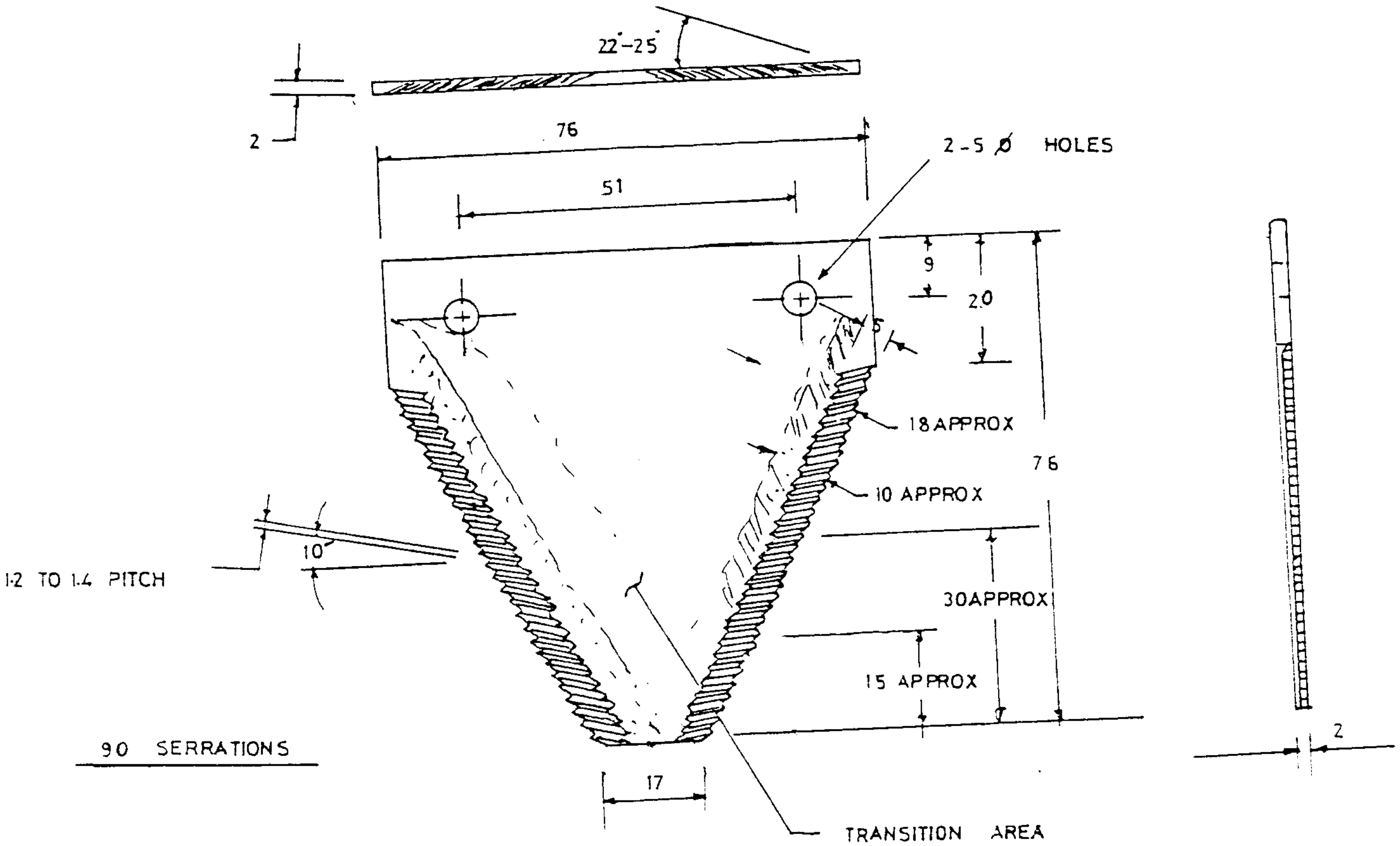
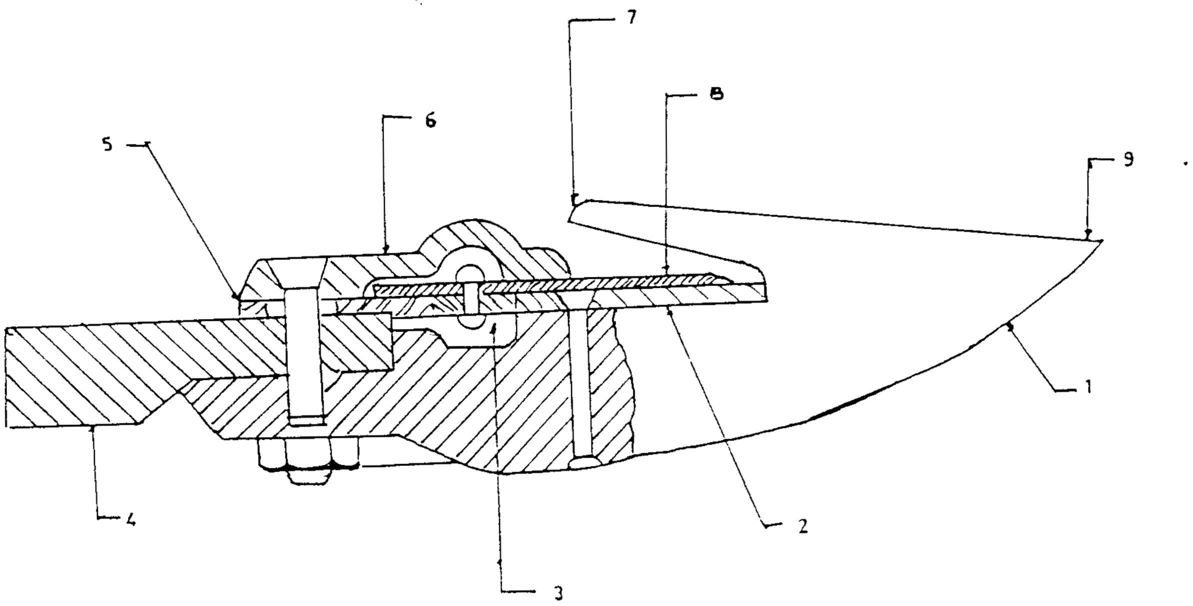


FIG.9 DETAILS OF KNIFE SECTION USED IN THE REAPER

Scale 1:1.2



1. Guard
2. Ledger plate
3. Knife back
4. Main bar
5. Wearing plate
6. Knife clip
7. Guard lip
8. Knife section

FIG.10 KNIFE GUARD WITH BLADE

Scale 1:1

Wearing plate - It is a hardened steel plate rectangular in shape attached to the reaper bar to form a bearing surface for the back of the knife during the reciprocating movement.

Knife clip - It is an irregular piece of metal which holds the knife sections down against the ledger plates. It prevents lifting of knife section during operation.

Pitman - It is the rod connecting the crank of the reaper to the cutter bar.The crank and pitman convert the rotary motions from anxiliary gearbox into reciprocating motion and is transmitted to the knife. The drive to the knives is provided by the slider crank mechanism. The plain of the knife is offset to the centre of the crank. The length of connecting rod must be at least ten times larger than the crank radius.

The knife segment pushes the stalk against the finger liner (ledger plate) and presses it in the gap between them and shears it. Since the cut crop rest against the finger liner and lip of the guard, the danger of bending of the stalk is reduced and thereby the reliability of cutting increases. Serrations prevent the slipping of the stalks from the knife while they are pushed towards the ledger plates and then they are gripped between them during cutting.

If the serrations of the knife have a pitch close to the diameter of the stalks, then the stalk become wedged in the space between serrations. This may choke the cutterbar and result in great power demand for cutting. To avoid this, the pitch of the serrations is made two to three times smaller than the diameter of the stalk. In cereal crops the stalk diameter is about 2 to 4 mm and hence the pitch of serrations of knives of reapers is between 1.0 and 1.2 mm.

The smaller rake angle and greater the sharpness, the greater is the cutting ability of the knife. Wear resistance is a measure of the rate at which the knife blunts. Knives of smaller rake angles and sharp cutting edges become blunted more rapidly.

For high quality cutting, the cutting resistance must be less than the resistance for bending. The resistance for bending increases with the reductions of the clearance between the cutting pair and decreases with the increase of the height at which cutters are mounted. When the clearance is more, then the resistance of stalks for bending may became less than the resistance for cutting. Then the stalk bends and is subjected to a stretching action between the knife and the ledger plate. This problem increases when the cutter bars are mounted at greater height. Clogging of the cutting pair with shreds of the plant not only lowers the quality of cutting but also increases the power requirement for the operation of the knife. The clearance between knife and ledger plate should normally be fixed at 0.3 mm to get best results.

Crop conveying assembly

The harvested crop is conveyed from left side to the right side of the reaper unit in the vertical position by means of the crop conveying assembly.

Crop row dividers

The total width of cutter bar is 1.6 m. There are five crop row dividers at a distance of 30 cm. They are provided to divide the whole crop that can be cut by the reaper unit into four equal portions and guide them to the cutting and conveying unit. The crop row dividers are fitted at the bottom of the main board in front of the cutter bar assembly. They are mounted at an angle of 20 degree to the horizontal. The shape of the crop row divider is triangle in plan and a shoe is attached in the front. To each crop row divider (except the one at the left most end) a star wheel is attached below the shield of crop row divider. Figure 11 shows the arrangement of crop row dividers with star wheels. The shield acts as a cover to the star wheel exposing only the fingers of the star wheel at one side. The crop row dividers with star wheels and pressure springs are designed to perform three functions of lifting, gathering and guiding the crop towards the cutter bar.

1. **Main frame assembly**
2. Flat belt pulley (Tension side)
3. Upper lug
4. Knife box
5. Gearbox
6. Chain drive
7. Upper discharge deplector
8. Crop row divider
9. Star wheel
10. Header shield
11. Divider shoe
12. Pressure spring
13. Knife guard
14. Left header

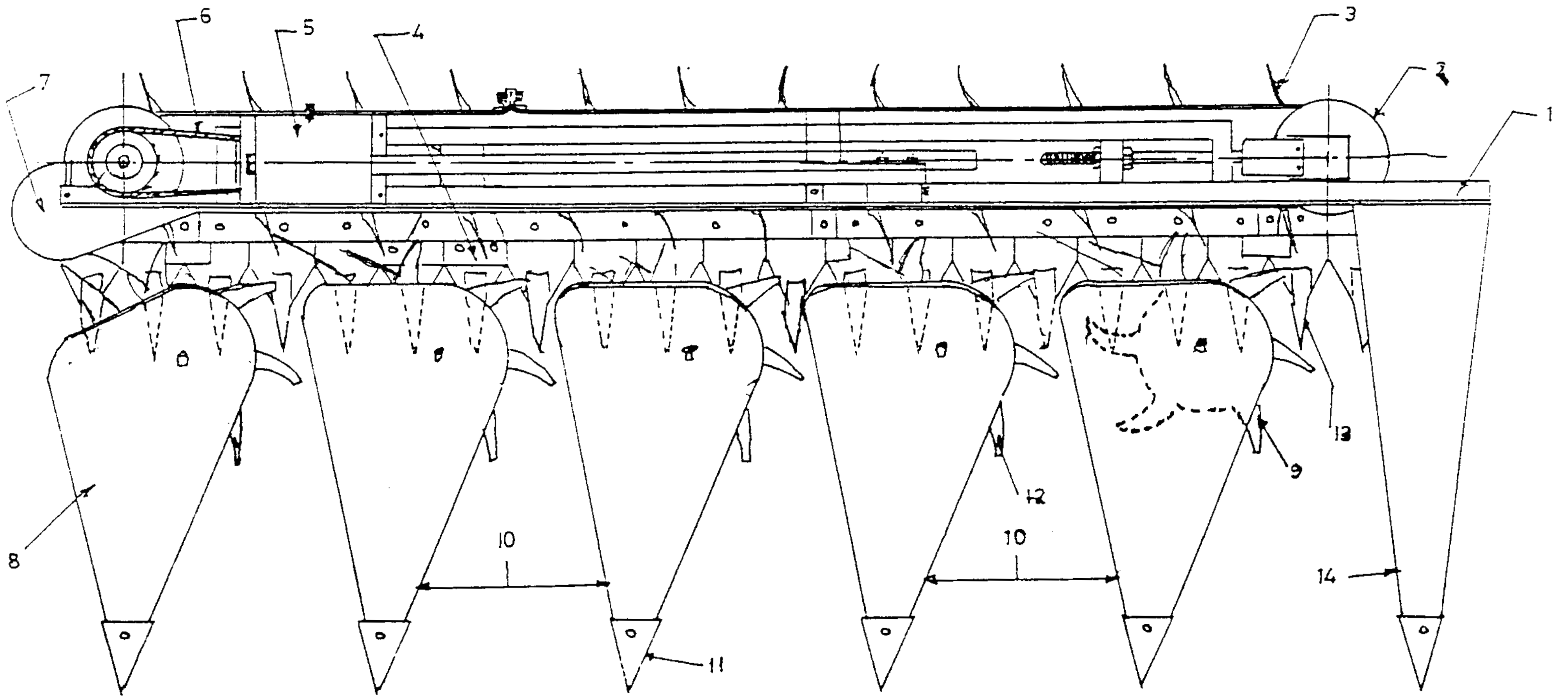


FIG.11 MAIN ASSEMBLY OF THE REAPER UNIT

Scale 1:9

Star wheels

The star wheels are designed to gather the crop and to feed it to the cutting mechanism. Star wheels also perform the functions of holding the crop during cutting and then feeding the cut crop to the conveying unit. They get the drive for its rotary motion from the lugs provided on the top conveyer belt.

The velocity component of the star wheel which is responsible for guiding the crop:

$$V = V_s \text{ Cos}$$

where,

V_s = the peripheral velocity of the star wheel along it plane

= the angle of inclination of the star wheel to the horizontal

which is equal to the angle of inclination of the crop divider to the horizontal

The angle also depends upon the position and length of crop row divider.

The velocity component of star wheel Vs Cos and this should be greater than the forward velocity of the machine in order to have the gathering action on crop towards the cutter bar by the star wheel. The minimum recommended value of speed ratio between Vs Cos and forward speed is 1.026 for proper functioning. Similarly if the ratio between the speed of lugged conveyer belt forward speed of machine is lower than unity it will result in pushingof crop away from the cutter bar without cutting thus resulting in uncut loss. The high velocity of star wheel results in shattering loss (Devanani, 1988b). The design parameter of the starwheel is given in Appendix-XIII.

Pressure springs

Pressure springs and star wheels together hold the cut crop in vertical position during conveying. To each of the crop row dividers except the one at the left most end, two pressure springs are attached. The pressure springs also ensure a smooth flow of crops along the crop board during conveying to the discharge plate by the pair of conveyer belts.

Conveyer belts

The harvested crop from the cutter bar is delivered to the vertical crop board and is held by the springs. There are two conveyer flat belts of 6 cm width with lugs fixed at every 13 cm. The spacing between the belts is 10 cm. The bottom belt is having lugs of triangular shape whereas the top belt is having lugs of rectangular shape. The power required to drive the conveyer flat belts is received from the gear box through a chain drive.

The cut stalks are loaded on the conveyer in vertical position, and are removed in a direction perpendicular to the direction of motion of the powertiller and are delivered in windrows at the right side. The ratio between speed of conveyer belts to the forward speed is about 1.5 to 1.6. Figure 12 shows the relationship between the movement of conveyer belt and the power filler forward travel. The lug height, which is the projected length from the belt, is determined based on the assumption that the entire cut crop is to be moved out of the machine at the outer most end.

The bunches of the crop can be continuously conveyed without any blockage only when the conveyed output per unit time is greater than or equal to the cut crop.

It is represented

$$Q_{con} \geq Q_{cut}$$

$$\mathcal{f}_2 \times h \times B \geq \mathcal{f}_1 \times B \times V_m \times t$$

$$\mathcal{f}_2 \times h \times B \geq \mathcal{f}_1 \times B^2 \times V_m / V_c$$

then $$h \geq \frac{B . V_m}{q . V_c}$$

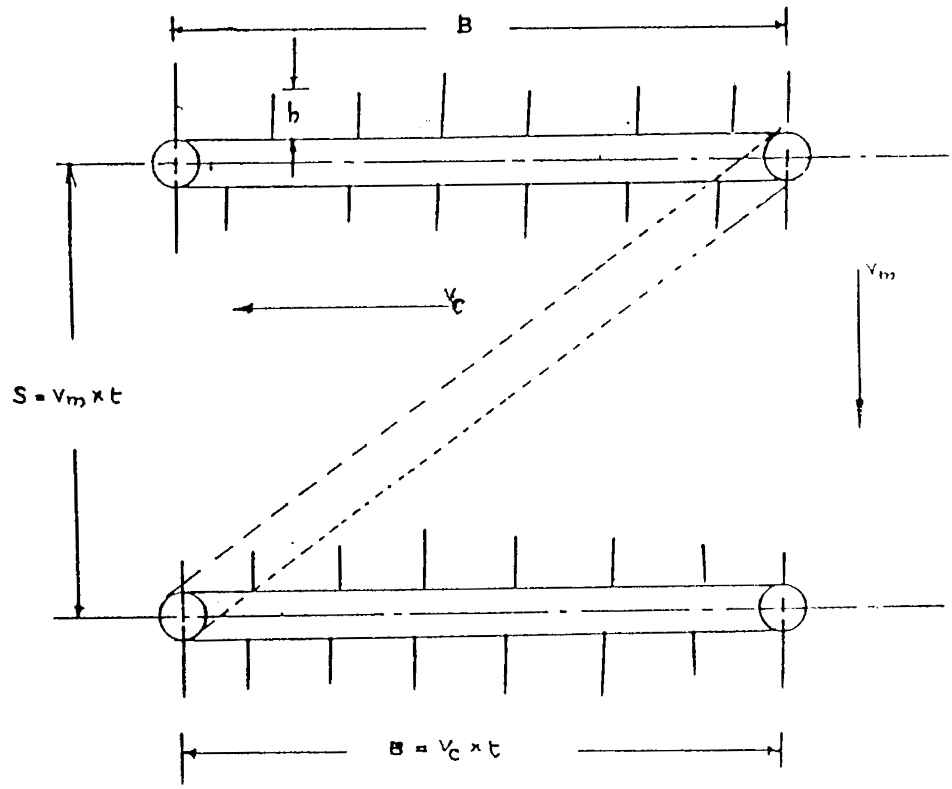


FIG.12 RELATION BETWEEN MOVEMENT OF CONVEYER BELT AND MACHINE FORWARD TRAVEL

where

h = height of lugs

B = cutting width

V_m = travelling speed

t = time

V_c = speed of conveyer belt

ρ_1 = density of plant in the field

ρ_2 = density of cut crop on the vertical platform

q = gathered cut crop parameter

$$1q = \rho_2/\rho_1 = S_1/S_2 = \frac{1}{\pi R^2} = \frac{1}{\pi \times \left(\frac{C}{2\pi}\right)^2}$$

$$= 4\pi/C^2$$

where

S_1 = 1 m^2 of area in the field

S_2 = area of the circle of bunched cut crop from 1 m^2 of area in the field its tightness being similar to the cut crop on the vertical platform and

C = Circumference of the cut crop bunch whose area in S_2

It is designed to discharge the cut crops carried by the conveyer in a neat windrow.

The discharge plate slightly projects from the line of conveyer belt so that the cut crops strike the discharge plate and then are laid as neat windrows on the field.

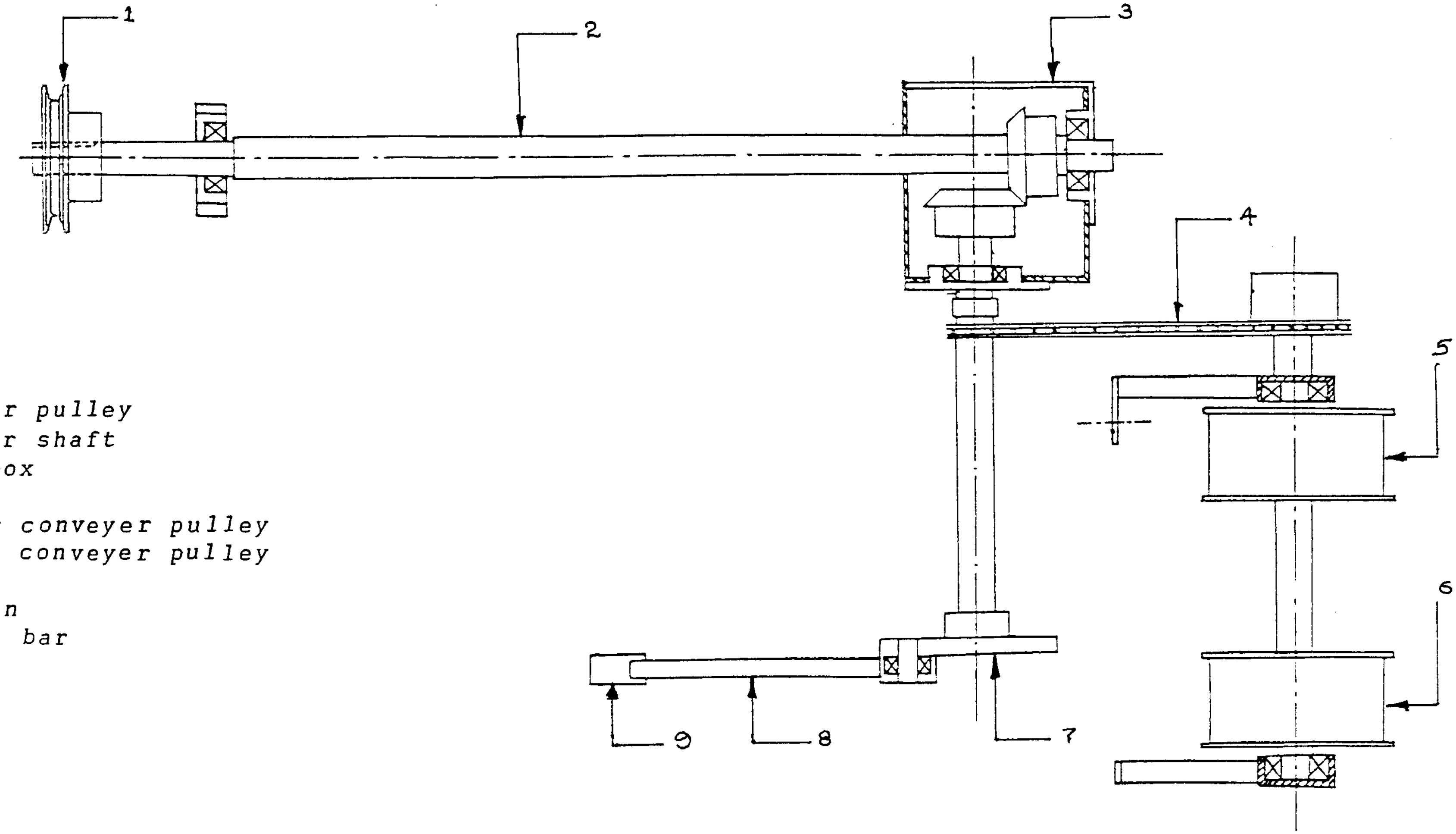
Main frame

It is the basic structure which holds the cutter bar assembly, crop row divider assembly, conveyer belts, four pulleys for the conveyer belts, gear box, crank and pitman. The vertical plate which is called as crop board, helps the harvested crop to keep vertically and to convey them to the right side with the help of conveyer belts. The main frame is hitched to the specially fabricated front chasis ofthe powertiller. The engine is also mounted on this chasis.

3.4 Power transmission assembly

As the reaper-windrower is a powertiller operated unit, the forward movement is achieved by the forward movement of powertiller. The power for operating the cutter bar assembly and conveying assembly is obtained from the engine of the powertiller through V-pulleys. The power for the operation of the reaper is directly transmitted from the prime-mover using V-pulley and V-belt in the first phase. The power transmission system of the reaper is shown in Fig. 13.

When the clutch is released, the powertiller attains forward motion. While the tension lever is engaged, power is transmitted from the engine to the reaper. After evaluating the performance, an alternative method of power transmission from the tiller was devised to improve the control on the power



1. Reaper pulley
2. Reaper shaft
3. Gearbox
4. Chain
5. Upper conveyer pulley
6. Lower conveyer pulley
7. Crank
8. Pitman
9. Knife bar

FIG.13 POWER TRANSMISSION SYSTEM OF THE REAPER

Scale 1:5

transmission system. The rotovator assembly of the tiller was removed and in its place a specially designed auxiliary gear box which was fabricated at KCAET workshop was assembled. It takes power from the rotovator drive gear of the powertiller gear-box and is transmitted to the reaper through V-pulley and belt. Figure 14 shows the details of the newly developed gear box. When the rotovator lever isengaged, the power is transmitted from the powertiller gearbox to the auxiliary gearbox and then to the reaper unit.

With original chasis of the Mitsubishi powertiller, the following incompatibilities were noticed:

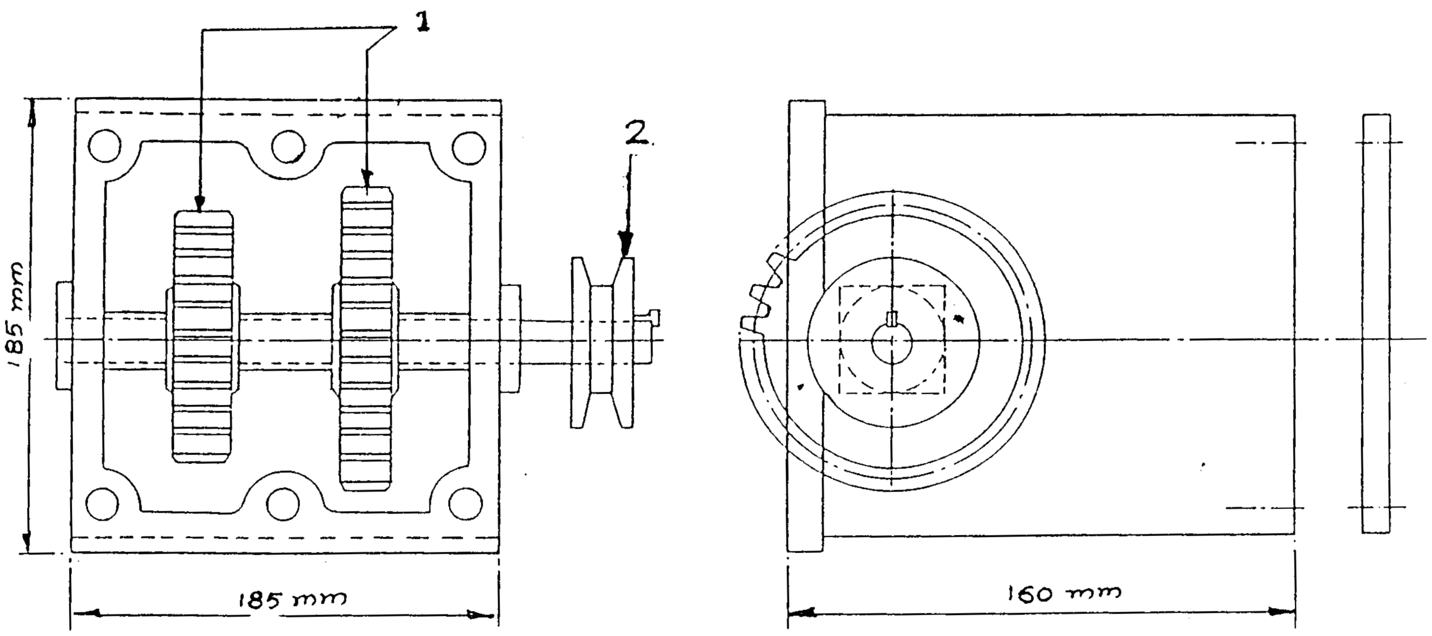
1. The engine and chasis of the tiller are at a lesser height from the ground level to hold the reaper.

2. There is no provision to mount the reaper on the original chasis of the powertiller.

3. The engine is mounted further in front of the powertiller axle creating problem in fixing the reaper.

4. Balancing becomes a problem when mounting the reaper with the powertiller chasis.

Based on the drawings of Tamil Nadu Agricultural University, a new chasis for mounting the engine and reaper was



1. Gears
2. Pulley

FIG.14 NEWLY DEVELOPED AUXILIARY GEARBOX FOR PADDY REAPER

Scale 1:2.5

fabricated at KCAET, Tavanur. The original chasis was dismantled and the engine was mounted on the new chasis. The problems arised while mounting the engine and reaper are:

1. The oil filter of the engine has to be replaced to mount the engine properly.

2. For adjusting tension belt the engine cannot be moved.

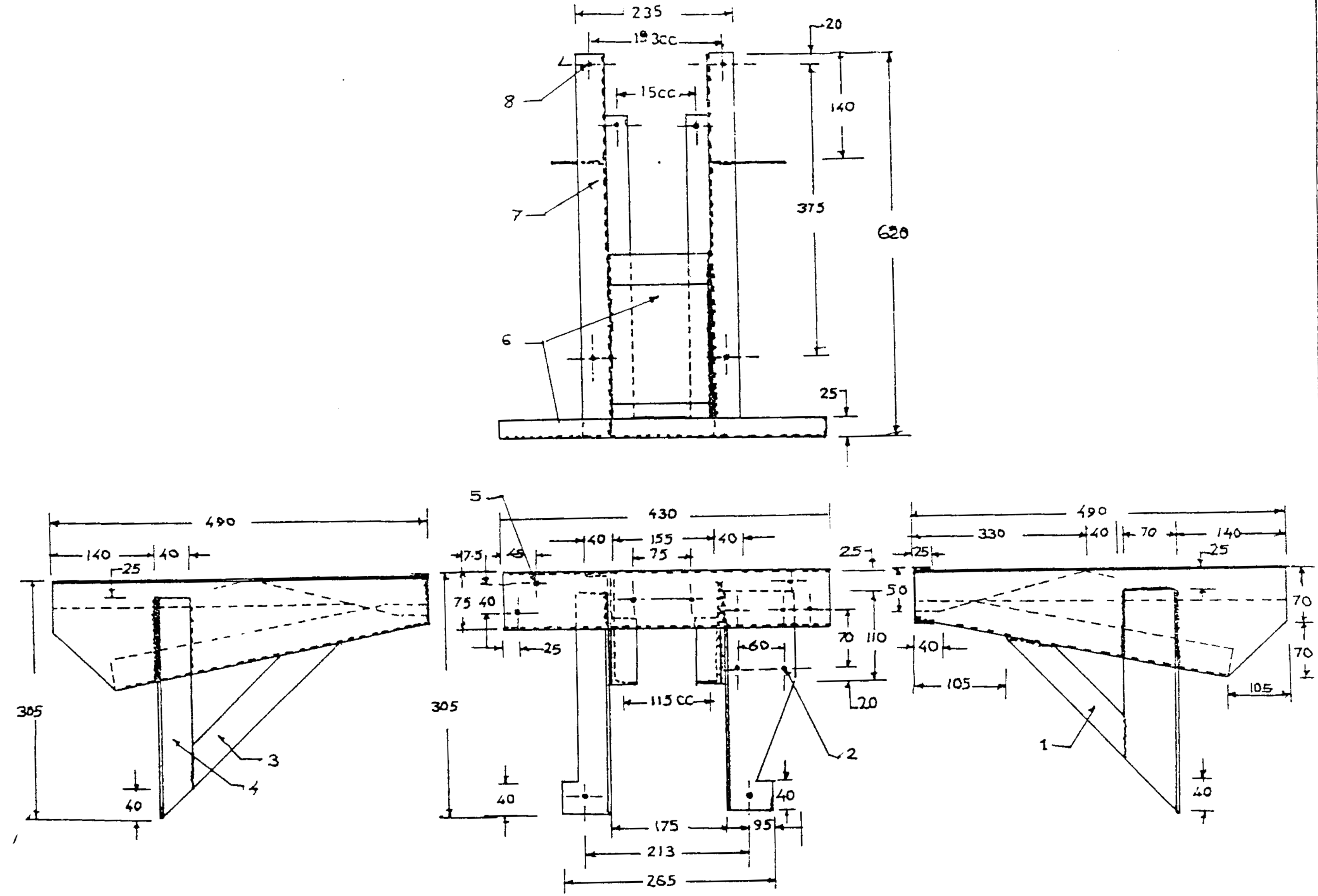
3. Enough anchorage and mounting of reaper unit was not possible.

Based on the above requirements and to rectify the difficulties arised with the fabricated chasis, a new chasis was designed and fabricated at KCAET, Tavanur. The details of the drawings is given in Fig.15.

3.5 Method of mounting

The method adopted for mounting the reaper-windrower on the Mitsubishi powertiller (8-10 hp) is discussed below.

Initially the engine is dismantled and the original engine chasis is removed. The newly fabricated chasis is mounted and the engine is replaced on the chasis. The 1.6 m reaper-windrower is attached to the chasis. The power required



Right side view Front view Left side view

FIG.15 DETAILS OF NEWLY FABRICATED ENGINE CHASIS

Scale 1:8

for the reaper is taken from the engine pulley directly using V-pulley and belt in the first phase.

For taking power from the rotovator drive gear of the powertiller gearbox the new auxiliary gearbox was mounted in the second phase. Using the V-pulley from the gearbox the power is transmitted to the reaper shaft.

Mountings and various drive system for various reapers are given in Appendix-XIV.

3.6 Preliminary trials

Phase I

During the preliminary field operation, the power from the engine pulley was directly taken to the cutterbar through a single V-belt while the rotovator was allowed at the rear side. In this condition the balancing was found to be perfect. The ground clearance at the rear rotovator side is found to be very less. Because it was not possible to lower the handle for lifting the front portion for crossing field bunds. It necessitated to remove the rear rotovator assembly.

Phase II

The rotovator assembly was dismantled and the fabricated auxiliary gearbox was attached at its place. By engaging the

Plate 1. Powertiller operated paddy reaper with rotovator assembly

Plate 2. Powertiller operated paddy reaper in operation

rotovator lever, the power is transmitted through this newly developed auxiliary gear box to the reaper shaft. The harvesting is possible only when the powertiller moves in forward direction and the rotovator lever is engaged to operate the reaper.

The powertiller operated paddy reaper windrower is having many components, consisting of not only the fabricated but also purchased and assembled units. In the preliminary trials, performance of individual components were determined. The vibration, noise, operator's safety, balance, steering controls and visibility were checked.

Step 1

The powertiller operated reaper was checked for balancing in the laboratory. The tiller was started and operated in forward gears and reverse gear and at the same time balancing was also noted.

After mounting the reaper assembly to the powertiller, it was operated for five hours to identify any defects in mounting the engine and the reaper on the chasis. The components were rechecked for their rigidness, clearances and proper functioning.

Step 2

By engaging the tension pulley while the engine was already started, only the cutter bar was operated. Observations were made on its performance.

Step 3

In the starting position of the powertiller, by engaging the tension lever the functioning of the conveyer belt, crop divider with star wheels were noted. The required modifications and adaptations were carried out.

Step 4

At the final stage of preliminary trials the cutter bar assembly, the crop conveying assembly, the mounting of engine, attachment of reaper as well as the power transmission assembly were properly connected after carrying out all the needed modifications. While the engine of the powertiller was running and by engaging the tension lever, the cutter bar assembly was operated. Observations were taken on the combined effect of individual components. After carrying out the necessary modifications, adjustments and replacement of the unit were operated at different engine speeds in the starting position of the tiller to check any failure.

Step 5

After ensuring satisfactory results, the tiller operated reaper was moved in low forward gears when all assemblies were put in use. Observation were also made on operator's comfort and manoeuvrability.

3.7 Field trials

The preliminary trials conducted for the powertiller operated reaper with auxiliary gear box was found satisfactory (Fig.16). A number of field trials were conducted to observe the defects of different assemblies and problems arising under different field and crop conditions.

The trials were carried out in three stages.

Stage I

The optimum conditions for a powertiller operated reaper was the field of square or rectangular shape with dry or wet soil without considerable weeds, matured dry paddy crop of height around 60 cm to 100 cm without lodging. The field trials were carried out in the fields having the above conditions. The problems faced by the reaper unit was noted and rectified.

1. Ground wheel
2. Lower link bracket
3. Lower lug
4. Upper lug
5. Flat belt pulley
6. Cutterbar frame
7. Hold down clip
8. Knife guard
9. Lower pressure spring
10. Upper pressure spring
11. Star wheel
12. Sprocket wheel
13. Front cover
14. Header point
15. Main drive driven pulley
16. Power tiller
17. Engine chasis
18. Auxiliary gearbox

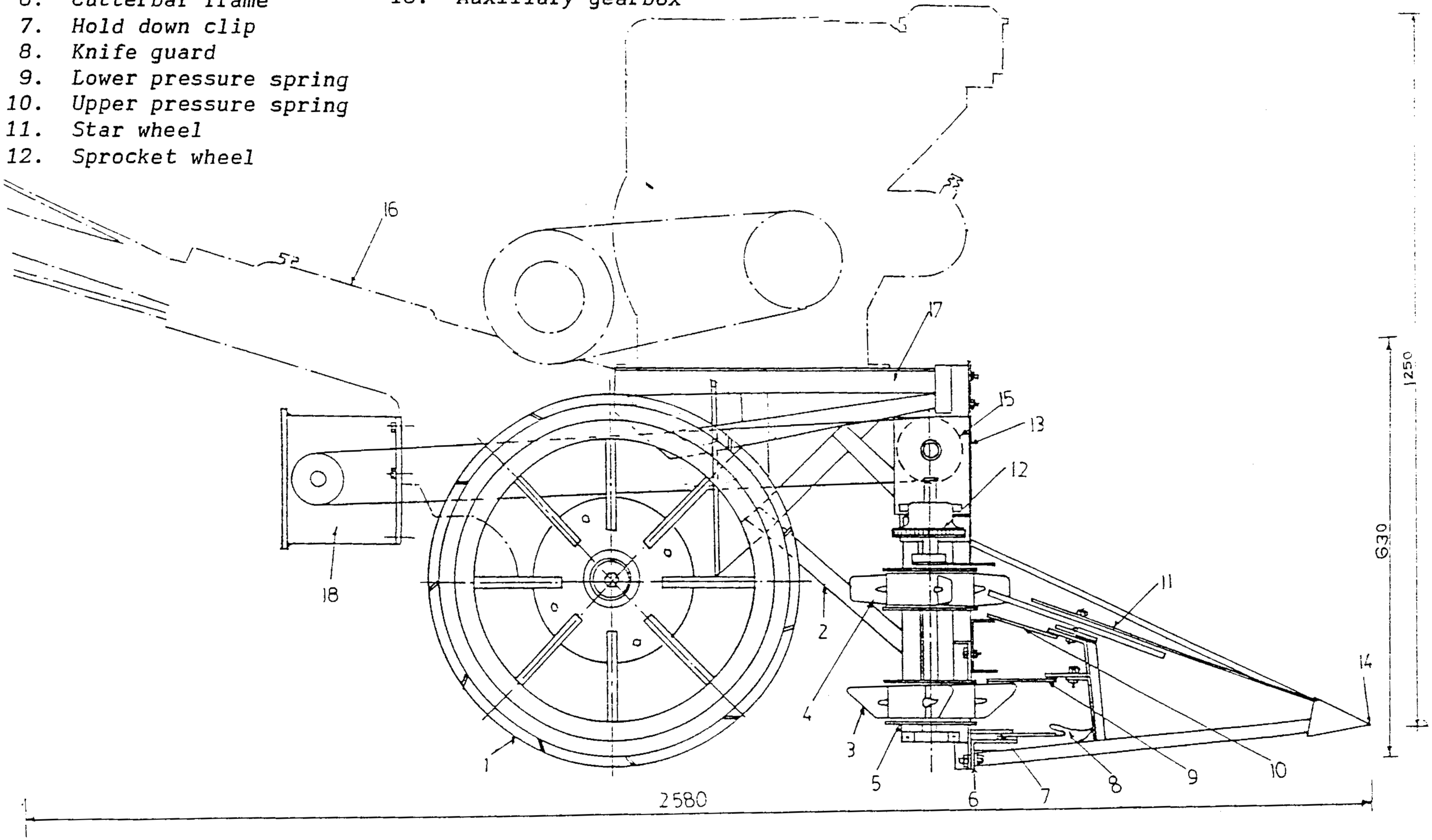
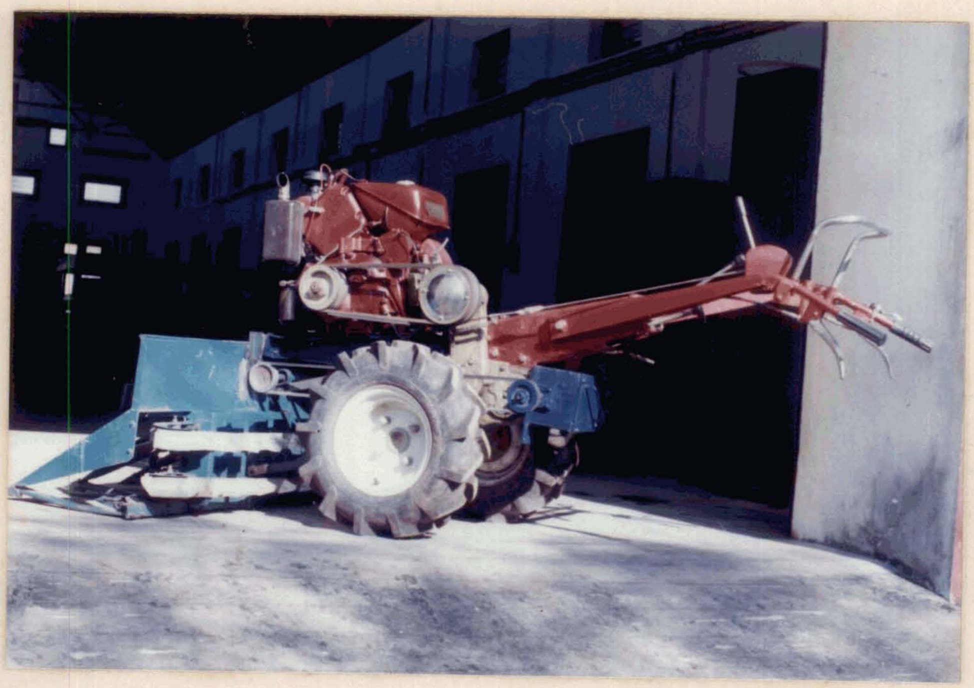


FIG.16 PADDY REAPER MOUNTED WITH MITSUBISHI POWERTILLER

Scale 1:14

Plate 3. Side view of the powertiller operated paddy reaper

Plate 4. Gearbox for the reaper fitted with powertiller



Stage II

Under all the above field conditions as in Stage I, the unit was operated in a green and wet paddy crop instead of matured dry crop. The required adjustments were carried out to achieve satisfactory performance.

Stage III

The powertiller operated paddy reaper-windrower was tested in a field having stagnant water upto 10 cm. The trials were carried out and problems arised were noted.

A number of field trials were conducted to detect the defects in varying crop and field conditions. After the rectifications were carried out, the field trials were conducted to study the performance.

3.8 Evaluation of paddy reaper windrower in field

The field trials were conducted in fields of Instructional Farm, KCAET, Tavanur as per ISI (1985) and RNAM test code. The slope, area, topography and type of the fields were noted. The moisture content of the soil was measured using the oven drying method. Frequency and size of bunds were noted. Variety, appearance and maturing of crop and type and extent of weeds were also observed. Number of grain per earhead was also noted.

Preharvest loss (W_{go}) was noted from five 1 m^2 sample area in each plot. Then the five 1 m^2 area in each plot were harvested by traditional method using sickles. The total weight of harvested crop was noted from each sample area. It was the total biomass per m^2. It was manually threshed. The straw and grain were separately weighed. The weight of grain is the average yield (Y_g). From the weight of straw and grain, straw grain ratio was calculated. Tripple beam balance was used for the weight measurement of straw, grain and soil. The moisture content of the grain was measured using crop moisture meter. The number of tiller per 1 m^2 was noted from the field. The grains left were collected from the fields which were harvested using sickle. The average weight (W_1) was noted. Then sickle loss was calculated as below:

$$\text{Percentage sickle loss} = \frac{W_1 - W_{go}}{Y_g} \times 100$$

Plants in the area at the starting point of the plot, which is equal to the area occupied by the tiller is manually harvested. This is for providing space for easy turning of the tiller with reaper.

The operating speed, cutting width and cutting height from ground level were noted. After completing harvesting, the shattered grains left on five randomly selected 1 m^2 area in each plot were collected. Let the average weight be W_{g1}, and the shattering loss was calculated as below:

$$\text{Percentage shattering loss} = \frac{W_{g1} - W_{go}}{Y_g} \times 100$$

The uncut loss was calculated. For that the uncut crop left in the five randomly selected 1 m^2 area in each plot, was manually harvested. Threshing was done manually. Let the average weight of grains be W_g2.

$$\text{Percentage uncut loss} = \frac{W_{g2} - W_{go}}{Y_g} \times 100$$

The cutterbar loss which is the sum of the uncut loss and shattering loss was calculated.

$$\text{Percentage cutterbar loss} = \frac{W_{gt} - W_{go}}{Y_g} \times 100$$

where,

$$W_{gt} = W_{g1} + W_{g2}$$

3.9 Economic studies

The main aim of introduction of farm machinery is to solve the economical problems. In paddy cultivation the cost of harvesting is accounted to a major share. The powertiller operated paddy reaper will anyhow reduce the cost of harvesting compared to the manual methods. Hence the harvesting cost of paddy by powertiller operated harvester was compared with the manual method and tractor operated reaper windrower method. Economic studies were conducted as per ISI (1979).

The required data for harvesting 1 ha and the labour charges were collected from the Instructional farm, KCAET. With the data, cost of manual harvesting for one ha was calculated.

The cost of harvesting by powertiller operated harvester was analysed. the costs were compared with each other.

Break even analysis for manual harvesting and harvesting by reaper was also carried out.

Results and Discussion

RESULTS AND DISCUSSION

The results of work carriedout on the powertiller operated paddy reaper-windrower towards making a unit suitable for field conditions in Kerala is discussed. It included the fabrication of accessories, modifications of components, laboratory and field trials, evaluation of the reaper, extensive testing of the reaper and other relevant studies.

4.1 General study of components

For matching the 8-10 hp Mitsubishi powertiller, the dimensions of the various components of vertical conveyer reaper were selected. The basic unit was fabricated by M/s Swathi Industries, Coimbatore as per the drawings.

The following are the main components of the vertical conveyer reaper-windrower.

(i) Cutter bar - to cut the crop by reciprocating blades.

(ii) Knife guard - to protect the knife and act as stationary edge for moving section

(iii) Wearing plate- to form a bearing surface to the blades

(iv) Knife clip - to prevent lifting of knife section during operation

(v) Pitman- to transmit the reciprocating movement from the crank to cutting knife and also acts as a link.

(vi) Knife bar bracket - to connect the cutterbar assembly and pitman and oppose the vertical play of the cutterbar assembly.

(vii) Crop-row dividers - to divide the standing crop in the field and to supply it in correct quantity.

(viii) Star wheels - to hold the crop during cutting and to feed it to the conveyer

(ix) Pressure springs - to hold the cut crop in vertical position against the crop board during conveying.

(x) Conveyer belt - to convey the crop towards the right hand side

(xi) Discharge plate - to lay the cut crop in windrows on the ground.

(xii) Main board - to hold all components of the vertical conveyer reaper-windrower.

The unit was thoroughly examined before hitching with powertiller for its materials used and the method of fabrication. On verification, the following defects were found.

1. The cutterbar was not perfectly aligned and not straight, hence not moving freely.

2. Some of the welding points were found to have insufficient strength.

3. The knife bar bracket was found touching the cutterbar assembly.

4. The edge of the conveyer belt was running over the cutterbar bolts.

5. Sufficient space was not available between the transmission pulley and crop board for fixing the belt.

6. The pulleys were not properly fixed and alignments of several components were not accurate.

4.1.1 Improvements of individual systems

The complete unit was dismantled. The cutterbar was made perfectly aligned and straight so as to move freely. Enough weldings were done wherever necessary for improving the stability. The knife bar bracket was modified to avoid the touching of bolts with the cutterbar. Touching of the conveyer belt with the cutterbar was avoided by replacing bolts of correct specification. The taper head counter bolt were used for this purpose. The crop board was modified to have a provision to fix the belt to the transmission pulley easily. The alignments of pulleys were carried out. Accurate alignments between different components were ensured.

(i) Chasis

The chasis for engine and for attaching the reaper was designed and fabricated as per Fig.15. Two foundation bolts and additional four other bolts were used to fit the chasis with the powertiller. The engine was mounted on the chasis. The weight of the chasis is found to be 21.5 kg. The reaper was attached to the chasis by means of four bolts and nuts so as to facilitate dismantling and assembling easily. Additional four supporting members from the reaper to the chasis were also fitted by means of bolts and nuts. It was examined and was found that these fixtures are enough to avoid any deflection.

(ii) Power transmission to the cutterbar

In the powertiller the power from engine to the clutch assembly is given by means of three V-belts. To operate the reaper, power from the engine to the cutterbar is directly obtained by means of a single V-belt from the engine pulley.

The remaining two belts were allowed to transmit power from the engine pulley to the clutch assembly for operating the powertiller. It was also found that the single B-section V-belt is capable of transmitting enough power to operate the cutterbar. The machine was operated for more than five hours in the laboratory.

The knife bar bracket was found sheared horizontal to the movement of the cutterbar during the pilot trials in the field. Continuous overloading by frictional forces among all the moving members was found to be the reason. Reduction of friction among the moving parts was achieved for smooth operation. A new bracket with higher strength was used instead of sheared one. Moreover by using accurate instruments, the cutterbar was again aligned and made straight for achieving smooth operation.

(iii) Fixing of knife guard

Use of ordinary bolts for connecting the knife guard with reaper bar created several problems. This is because ordinary bolt has no counter-sunk to sit in the square slot provided in the knife guard. Also the ordinary bolts could not exert enough tightness. Hence a set of 21 pairs of counter-sunk bolts of size 40L, 9D were used with spring washers and lock nuts instead of ordinary bolts. This also eliminated the possibility of any tilting of knife guard about the bolts. As the counter-sunk bolt sits perfectly in the groove, there is no projection of the bolt head when compared to the knife guard.

(iv) Adjustment of the cutterbar

The cutterbar adjustment includes the following operations.

a. Adjusting the knife register

A sharp knife properly adjusted is the key for efficient reaping. The knife must run smoothly in the cutterbar. Each section was ensured for its sharpness and tightness to the knife back. The knife register is an important adjustment for smooth cutting and minimum draft. As it is essential to avoid uneven job of cutting and any clogging at the cutter bar, the centre of the knife section should stop in the centre of the guard on each stroke. In other words it should have proper registration. The length of the stroke is found to be 70 mm.

b. Adjusting the knife head guides

During the operation of cutterbar, the knife head will slap or hammer if it is not in proper adjustment. The slapping problem is caused by excessive vertical play due to wear of the knifebar bracket guides. The guides were polished for smooth operation and adjusted properly.

c. **Adjusting the wear plates**

The wear plates act as guides for knife back. They support knife back to maintain a shearing action between the ledger plates and knife sections. Any play between the knife back and wear plates started producing vibration and faster wear on other part of cutterbar, hence the wear plates were adjusted properly with respect to knife back.

d. **Adjusting the knife hold down clips**

The hold down clips are provided to ensure the close catchment between the cutting edge of knife and edge of the ledger plate. If the hold down clip holds the knife too closely then ragged cutting and chocking will result and if it is to tight the knife will bend. By properly hammering the hold down clips. A clearance of 0.8 mm was maintained to obtain proper operation.

e. **Adjusting the guards**

The individual guards were inspected for wear, nicks, breakage, rust and bending which may cause improper operation. Either filing the rust, nicks and to sharpen guard points or replacing the damaged guards improved the operation. All plates were tightened to maintain the opposing shearing force to the cutting edge of knife section. It is also noted that regard to the position of the guard points, the guard ledger plates must be in line. The knife guards should also be checked for proper lip clearance and if not either should be reduced or increased by tapping lightly on the tip with a hammer or by using chisel as a wedge.

f. Adjusting the ledger plates

The clearance between the ledger plate and knife section is an important parameter for achieving efficient cutting. But achieving the accurate value of clearance with respect to every knife is found difficult as the construction of knife guard was by means of drop forging. It also provided no uniformity among knife guards. Hence the individual ledger plates and knife guards were manually checked and polished to achieve the accurate clearance with only minimum tolerance.

The crop board and the main frame of the reaper unit were retained as such, but straight shoes of the crop divider were replaced with curved shoes. This was necessitated to avoid penetration of crop dividers in the soil.

Loose conveyer belts will not convey all the cut crops in time, thus clogging will be created. This will overload the conveying system. The conveyer should efficiently transmit all the cut crops in time and discharge as neat windrows. Provision is available for tightening the pair of conveyer belts by means of spring loaded pulleys.

The lugs on the conveyer belts is provided at uniform spacing accurately so that the starwheels are operated at uniform speed. This will take care of transmitting all the cut crops to the conveyer belt. In addition, the pressure springs also take care of the cut crop to keep in the vertical position against the crop board so that positive transmission of the crop is achieved.

After carrying out the necessary improvements and adjustments on the individual components, the unit was operated in the laboratory and satisfactory performance as per the requirements was observed.

With commercially available powertillers the modern equipments like the paddy reaper cannot be attached as such at the front. The chasis has to be modified accordingly. A special chasis which will provide a seat for the engine as well as provisions to attach the reaper has been developed and fabricated. Care was taken to bring the engine maximum towards the axle of the powertiller for improving the balancing in weight.

4.2 Preliminary field trials

Performance of the powertiller operated paddy reaper was studied to understand the defects and to incorporate further modifications and improvements. The unit was tested at KCAET Instructional Farm, Tavanur.

With the conventional rotovator at the rear end of powertiller and the new paddy reaper at the front, it was found that the operator has no problem in balancing the machine. The unit was operated in the field for more than 25 hours and no difficulty was found in harvesting as well as in windrowing of the crop. But climbing over the bunds to reach another field is not possible as the reciprocating cutterbar is found to penetrate the soil bunds. This happens as there was no space at the rear of the powertiller to bring down the handle towards the ground level to lift the front mounted cutterbar. Penetration of the crop divider and knife guards in the soil bunds are the defects. There was no separate clutch system for the cutterbar. This worsened the situation as the reciprocating blade is found to operate continuously even after penetration in the soil bund. Removal of rotovator assembly is the only solution to bring the handle down closerto the ground level. This will lift the cutterbar assembly which is fitted in the front of the powertiller to a height for easy crossing of the field bunds.

The removal of the rotovator assembly from the powertiller created another problem of balancing the front weight. Without addition of counter weights, difficulty was experienced by the operator for easy manoeuvrability. To bring balancing of weight distribution, counter weights of 35 kgs were hinged in between the handles. By this arrangement, the problems of weight balancing was overcome. Long term field trials were taken with the counter weights.

The relative position of the shoe of the crop dividers with respect to the ground level and cutterbar level is important. The straight shoe crop dividers were found to plough the field while dividing the standing crops. This was rectified by bending the bottom pipe almost horizontal to the ground level and refixing the shoes. This decreased the height of stubbles moreover improved the efficiency of dividing the crop without much disturbance.

4.2.1 Development of auxiliary gear box

Field trials were taken on the powertiller operated paddy reaper without rotovator assembly. Engine power was directly transmitted to the cutterbar unit from the engine pulley. This system was found to have the following defects.

(i) Difficulty in starting the engine

If the prime mover is directly loaded by the cutterbar operation without any clutch or tension pulley arrangement, then the starting of the engine noted to be difficult. Hence a suitable tension pulley arrangement was provided.

(ii) Continuous running of the cutterbar

The cutterbar is found to operate always whenever the prime mover is running. When the powertiller along with reaper unit is transported, the cutterbar is also found to operate continuously. This is not preferred as it will increase the wear and tear.

The above two problems necessitated the development of an alternate method for transmitting the engine power to the harvester so as to have an easy clutching system.

After thorough analysis of various methods in providing an alternate power transmission system, it was decided to utilize the existing clutch and gear system of the powertiller, for operating the rotovator assembly as a built-in attachment. The powertiller is having a proper power train to the rear end of the tiller to transmit rotory motion to rotovator. It also operates with main clutch of the powertiller and has two rotory speeds. The rotovator attachment was also dismantled for achieving front clearance. If the engine power is transmitted by the gearbox through a suitable auxiliary gear box to the harvester, both the above two problems will be solved. Hence, a simple auxiliary gearbox was developed and fabricated.

4.2.2 Details of auxiliary gear box

The auxiliary gear box consists of a set of spurgear having 32 and 26 teeth, bearings, bearing cap, oil seals, shaft, bushes and a single groove pulley. The box was fabricated with 25 mm MS sheet and a clock-wise rotation is achieved for the output shaft. Oil seals are provided at the ends of the shaft to prevent any oil leakage. The oil required for the lubrication is obtained from the rotovator gear box assembly directly. There is also provision to fill the oil in the gear box assembly. In order to avoid any oil leakage, the auxiliary gear box assembly is additionally provided with two rubber packings. A single B groove 100 mm dia V-pulley is provided at the shaft to transmit power to the reaper. The details of the auxiliary gear box is given in Fig.14.

4.2.3 Attaching the auxiliary gear box

The rotovator assembly has to be removed from the rear side of the powertiller. The auxiliary gear box was correctly assembled at the rotovator section by using two rubber packings to avoid oil leakage and to mesh the gears in alignment. This gear box can be operated in two positions, viz., high and in low gear positions. The spur gear of auxiliary gear box having 32 and 26 tooth will mesh with the powertiller gearbox giving 350 rpm and 280 rpm respectively to the output pulley. With this double speed arrangements the vertical conveyer reaper can be controlled very effectively in the field conditions. Moreover the transmission of power to the harvester is also controlled by the main clutch as well as rotovator clutch of powertiller.

The details of various components of the powertiller operated paddy reaper windrower is given in Table 2.

4.3 Evaluation of paddy reaper windrower

Critical evaluation of the powertiller operated paddy reaper windrower was carried out at KCAET Instructional Farm, Tavanur as per ISI (1985) and RNAM test code.

The safety of the powertiller with front mounted paddy reaper-windrower was analysed. The attachment at the front side did not affect the operator's visibility. For balancing the reaper an additional weight of 35 kg was provided at the handle. It was found that the operator did not feel any difficulty due to this counter weight. Ergonomically, also the paddy reaper is found suitable for operation. For achieving perfect weight distribution and balancing, without the additional counter

Table 2. Details of components of paddy reaper windrower

Sl. No.	Main parts	Specification or size (mm)	Material of construction	Quantity (nos)
I	Cutter bar assembly			
1.	Cutter bar	9x30x1600	MS	1
2.	Knife section		High grade steel	20
3.	Knife guard		Forged steel	
4.	Wearing plate	2x34x110	High grade steel	
5.	Knife clip		MS	3
6.	Reaper bar	38x47x1700	MS	1
7.	Pitman	20x32x154	MS	1
8.	Counter sunk bolts	40 L, 9 D	MS	21
9.	Hexagonal nuts	40 L, 8 D	MS	21
10.	Spring washers	8 D	High grade steel	21
II	Crop conveying assembly			
1.	Shield		MS	1
2.	Star wheel	280 D	Aluminium	5
3.	Bolts (connecting shield, starwheel & pipe frame)	22 L, 8 D	MS	5
4.	Hexagonal nuts	8 D	MS	5
5.	Shoe		MS	6

Contd.

Table 2 (Contd.)

6.	Bolts (connecting shoe, shield & pipe frame)	14 L, 6 D	MS	6
7.	Hexagonal nuts	6 D	MS	6
8.	Pipe frame	25 D	MS	6
9.	Pressure springs	270 L, 4 D	Special along	10
10.	Conveyer	5x60x3160	Canvas reinforced rubber	2
11.	Lugs	2.5x50x60	Aluminium	50
12.	Bearing	6204 Z		
13.	V pulley (single groove)	B 100 D	CI	2
14.	Conveyer belt pulley	70 W, 130 D	CI	4
15.	Main board	2x570x1000	MS	1
16.	Frame		MS	1
III	Attaching assembly			
1.	Supports	55L, 32B, 6T	MS	2
		30L, 32B, 6T	MS	2
2.	Bolts	28 L, 8 D	MS	8
		30 L, 8 D	MS	4
3.	Nuts	8 D	MS	12

Contd.

Table 2 (Contd.)

IV	Power transmission assembly			
1.	Engine pulley		CI	1
2.	Reaper pulley, single grove	B, 100 D	CI	1
3.	Auxiliary gear box pulley, single grove	B 100 D	CI	1
4.	V Belts	B 52		2
		B 40		1
		B 89		1

weight, the powertiller prime-mover can be shifted towards the rear side.

The paddy field of size 33 m x 29 m was selected. Pneumatic tyres were used when the land was dry and for the wet land, cage wheels were used. The paddy varieties harvested are Jyothi, Red Thriveni and Hwarswa which are high yielding, short duration and dwarf varieties. The crop was erect and not lodged. The details of the field and crop are given in Appendix-XVIII.

The powertiller was operated in low first gear. The actual cutting time, actual cutting distance, cutting width, idle time and the total time taken for covering the plot were noted. Speeds of different components of the harvested were also noted.

The powertiller operated harvester was tested in the first crop season during August and September 1993 with the pair of drum type cage wheels as the field was submerged with water. In the second crop season during January and February, 1994 when most of the field was found to be moist but not submerged with water. The use of pneumatic wheels with powertiller was found suitable. Both pneumatic wheels and drum type cage wheels can be used with 1.6 m cutterbar without any problem of traction.

During the evaluation of paddy harvester, optimum values of the different parameters were found out for efficient and smooth functioning of the paddy harvester.

4.3.1 Relation between operating parameters of reaper

The changes of important parameters of the reaper viz. the speed of auxiliary gear, cutterbar speed and conveyer belt speed with change of the speed of the prime-mover were observed in the field (Table 3). It was observed in the field that the reaper can efficiently be operated at the engine speed between 1700 rpm and 2200 rpm, depending upon the operator's choice, field and crop conditions.

4.3.2 Field coverage

For a plot of 957 sq. m, the total cutting length is observed to be 618.3 m for the reaper having an effective width of 1.55 m compared to the theoretical width of 1.60 m. Theoretical field capacity was calculated to be 0.3053ha/hr and the actual field capacity was found to be 0.2036ha/hr which amounted to a field efficiency of 66.69 per cent. The results of the field operation of the reaper with pneumatic wheels in circuitous pattern is given in Table 4 and 5. For a field of 2040 sq.m area, the total cutting length was 2549 m. The average speed of cutting was 0.53 m/sec. The actual width of

Table 3. Reaper parameters of varying engine speed

Sl. No.	Engine speed rpm	Auxiliary gear speed rpm	Cutterbar speed m/s	Conveyer belt speed m/s
I	825	135	0.34	0.46
II	1000	160	0.40	0.56
III	1280	205	0.51	0.68
IV	1700	270	0.68	0.93
V	2000	318	0.80	1.06
VI	2200	350	0.88	1.17

Table 4. Performance of the power tiller operated paddy reaper in dry paddy fields (circuitous pattern)

	Distance (m)	Cutting Time (s)	Cutting Speed (m/s)	Idling Time (s)
1	30.0	57	0.53	18
2	27.9	52	0.54	18
3	31.9	60	0.53	18
4	26.3	49	0.54	18
5	30.0	57	0.53	18
6	24.7	46	0.54	17
7	28.7	54	0.53	17
8	23.1	43	0.54	17
9	27.1	51	0.53	17
10	21.5	40	0.54	17
11	25.5	48	0.53	17
12	19.9	37	0.54	17
13	23.9	45	0.53	16
14	18.3	34	0.54	16
15	22.3	42	0.53	16
16	16.7	31	0.54	16
17	20.7	40	0.52	15
18	15.1	28	0.54	15
19	19.1	36	0.53	15

Contd.

Table 4 (Contd.)

20	13.5	26	0.52	15
21	17.5	34	0.51	15
22	11.9	22	0.54	15
23	15.9	30	0.53	15
24	10.3	19	0.54	15
25	14.3	28	0.51	15
26	8.7	17	0.5	15
27	12.7	24	0.53	14
28	7.1	13	0.55	14
29	11.1	20	0.56	14
30	5.5	11	0.5	14
31	9.5	18	0.53	13
32	3.9	7	0.56	13
33	7.9	15	0.53	13
34	7.9	15	0.53	13
35	7.9	15	0.53	
	618.3	1164		

Time taken for actual cutting = 1164 S = 19 min 24 S

Idle time = 528 S = 8 min 48 sec

Total distance of cutting run = 618.3 m

Average speed of cutting = $\frac{618.3}{1164}$ = 0.53 m/s

Total time taken forharvesting = Cuttingtime + idle time

$$= 1164 + 528 = 1692 \text{ sec}$$

Percentage of time taken for actual cutting w.r.t total time $= \frac{1164}{1692} \times 100 = 68.79\%$

Area of plot (A) $= 957 \text{ m}^2$

Actual width of cutting $= \frac{957}{618.3} = 1.55 \text{ m}$

Theoretical width of cutting $= 1.6 \text{ m}$

Theoretical field capacity $= \frac{0.53 \times 1.6 \times 3600}{10000} = 0.3053 \text{ ha/hr}$

Actual field capacity $= \frac{957 \times 3600}{1692 \times 10000} = 0.2036 \text{ ha/hr}$

Field efficiency $= \frac{0.2036}{0.3053} = 66.69\%$

Table 5. Performance of the power tiller operated paddy reaper in dry paddy fields (circuitous pattern)

	Distance (m)	Cutting		Idling
		Time (s)	Speed (m/s)	Time (s)
	1	2	3	4
1	57.0	110	0.52	19
2	32.5	62	0.52	18
3	55.5	106	0.52	18
4	32.5	63	0.52	18
5	54.0	103	0.52	18
6	31.0	59	0.53	18
7	52.5	100	0.53	18
8	29.5	54	0.52	17
9	51.0	98	0.52	18
10	28.0	51	0.52	17
11	49.5	95	0.52	18
12	26.5	48	0.52	19
13	48.0	92	0.52	18
14	25.0	45	0.52	18
15	46.5	89	0.52	17
16	23.5	43	0.51	17
17	45.0	86	0.52	18
18	22.0	39	0.53	17

Contd.

Table 5 (Contd.)

	1	2	3	4
19	43.5	83	0.52	16
20	20.5	36	0.53	16
21	42.0	80	0.53	17
22	19.0	33	0.53	16
23	40.5	77	0.53	17
24	17.5	30	0.53	17
25	39.0	74	0.53	17
26	16.0	28	0.52	16
27	37.5	71	0.53	17
28	14.5	25	0.52	16
29	36.0	69	0.52	17
30	13.0	22	0.52	17
31	34.5	66	0.52	18
32	11.5	19	0.53	17
33	33.0	63	0.52	17
34	10.0	17	0.50	17
35	31.5	60	0.53	16
36	8.5	14	0.50	16
37	30.0	57	0.53	15
38	7.0	11	0.50	16
39	28.5	54	0.53	15

Contd.

Table 5 (Contd.)

	1	2	3	4
40	5.5	8	0.50	15
41	26.0	50	0.52	15
42	4.0	8	0.52	15
43	26.0	50	0.52	15
44	26.0	51	0.51	15
45	26.0	50	0.50	-
	1356.5	2549		742

Time taken for actual cutting = 2549 S = 42 min 29 S

Idle time = 742 S = 12 min 22 sec

Total distance of cutting run = 1356.6 m

Average speed of cutting = $\frac{1356.5}{2549}$ = 0.532 m/s

Total time taken for harvesting = Cutting time + idle time

= 2549 + 742 = 3291 S

= 54 min 51 sec

Percentage of time taken for actual cutting w.r.t total time = $\frac{2549 \times 100}{3291}$

= 77.45

Area of plot (A) = 60x34 = 2040 m^2

Actual width of cutting = $\frac{2040}{1356.5}$ = 1.5 m

Theoretical width of cutting = 1.6 m

Theoretical field capacity = $\frac{0.530 x 1.6 x 3600}{10000}$ = 0.3053 ha/hr

Actual field capacity = $\frac{2040 x 3600}{3291 x 1000}$ = 0.2232 ha/hr

Field efficiency = $\frac{0.2232}{0.3053}$ = 73.11%

cut is 1.5 m. The actual field capacity was 0.2232 ha/hr. The field efficiency was found to be 73.11 per cent.

The results of the reaper operated with drumtype cagewheels is given in Table 6. With the effective cutting width of 1.5 m at an average cutting speed of 0.433 m/s, the actual field capacity was found to be 0.1634 ha/hr. The field efficiency recorded to be 59.98 per cent, which is found to be below compared to the method of harvesting paddy in dry fields.

4.3.3 Harvest losses

The results of the experiments conducted to find out the grain losses during harvesting by the powertiller operated reaper-windrower are given in Appendix-XIX. The percentage of preharvest loss, sickle loss, uncut loss, shattering loss and cutterbar loss from the randomly selected five plots having 1 sq m area were calculated. The average values are given in Table 7.

The difference between sickle loss and total cutter bar loss is 0.77 per cent. For the yield of 3 tonnes/ha, the difference between the sickle loss and cutterbar loss is 23.10 kg. At a cost of Rs.5 per kg of paddy, the loss is Rs.115.50 per ha. This loss is multiplied by the reduction in cost of harvesting.

Table 6. Performance of the power tiller operated paddy reaper in wet paddy field (circuitous pattern)

	Distance (m)	Cutting Time (s)	Cutting Speed (m/s)	Idling Time (s)
1	13.5	29	0.466	23
2	27.5	59	0.466	23
3	15.0	32	0.469	23
4	25.5	54	0.470	23
5	13.5	29	0.466	23
6	24.5	51	0.480	23
7	12.0	26	0.460	22
8	23.0	49	0.469	23
9	10.5	22	0.477	22
10	21.5	46	0.467	22
11	9.0	19	0.474	22
12	20.0	43	0.465	22
13	20.0	44	0.455	26
14	20.0	44	0.455	26
15	20.0	45	0.444	28
16	20.0	43	0.465	28
17	20.0	44	0.455	
	319.0	675		379

Time taken for actual cutting = 675 S = 11 min 15 sec

Idle time = 379 S = 6 min 19 sec

Total distance of cutting run = 319 m

Average speed of cutting = $\frac{319}{675}$ = 0.47 m/s

Total time taken forharvesting = Cutting time + idle time

= 675 + 379 = 1054 S

= 17 min 34 sec

Percentage of time taken for actual cutting w.r.t total time = $\frac{675 \times 100}{1054}$

= 64.04

Area of plot (A) = 16.5 x 29 = 478.5 m^2

Actual width of cutting = $\frac{478.5}{319}$ = 1.5 m

Theoretical width of cutting = 1.6 m

Theoretical field capacity = $\frac{0.47 \times 1.6 \times 3600}{10000}$

= 0.2707 ha/hr

Actual field capacity = $\frac{478.5 \times 3600}{1054 \times 10000}$ = 0.1634 ha/hr

Field efficiency = $\frac{0.1634}{0.2707}$ = 60.36%

Table 7. Average paddy yield and various losses for five plots

		I	II	III	IV	V	Average
Total yield	Y_g (g)	310	300	300	296	299.2	301
Pre harvest loss	W_{go} (g)	0.04	0.00	0.02	0.06	0.00	0.02
	$\frac{W_{go}}{Y_g}$ x 100 (%)	0.01	0.00	0.01	0.02	0.00	0.01
Sickles loss	W_1 (g)	2.56	2.16	2.48	2.42	2.52	2.43
	$\frac{W_1 - W_{go}}{Y_g}$ x 100 (%)	0.82	0.72	0.82	0.80	0.84	0.80
Uncut loss	W_{g1} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g1}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.00
Shattering loss	W_{g2} (g)	0.16	0.04	0.06	0.20	0.00	0.09
	$\frac{W_{g2} - W_{go}}{Y_g}$ x 100 (%)	0.04	0.01	0.02	0.06	0.00	0.03
Cutter bar loss (Total loss)	$W_{gt} = W_{g1} + W_{g2}$ (g)	0.16	0.04	0.06	0.20	0.00	0.09
	$\frac{W_{gt} - W_{go}}{Y_g}$ x 100 (%)	0.04	0.01	0.02	0.06	0.00	0.03

4.4 Comparison of different harvesting methods

The cost of paddy harvesting by the following three methods are compared.

4.4.1 Savings in costs

(i) Manual harvesting

Labour required for harvesting/ha	=	25 man-days
The cost of harvesting one ha @ Rs.65 per man-day	=	25 x 65/ha
	=	Rs.1625/ha

(ii) Harvesting by tractor mounted reaper (on hire basis)

Labour requirement for harvesting manually at the boundaries and for collecting the cut crop is 11 man-hours per ha.

The cost manual labour	=	$11 \times \frac{65}{8}$ per ha
	=	Rs.89.38/ha
Rounded to		Rs.90/ha
Average time for harvesting one ha by tractor	=	2 hr 45 min.
At the hire charge of Rs.250/hr, Cost of harvesting by tractor mounted reaper	=	Rs.687.50/ha
Rounded to		Rs.690/ha

Total cost of harvesting = Rs.690 + 90

= Rs.780/ha

Savings in cost compared to manual harvesting = Rs.1625-780

= Rs.845/ha

(iii) Harvesting by powertiller operated reaper (on hire basis)

Labour requirement for manual harvesting at the starting area and for collecting the cut crop is 9 man-hrs per ha

Cost of manual labour = $9 \times \frac{65}{8}$ per ha

= Rs.73.13/ha

Rounded to Rs.75/ha

At the hire charge of Rs.150/hr, Cost of harvesting by powertiller operated paddy reaper = Rs.675/ha

Total cost of harvesting = Rs.675 + 75

= Rs.750/ha

Savings in cost compared to manual harvesting = Rs.1625-750

= Rs.875/ha

(iv) Self propelled 5 hp reaper (on hire basis)

Labour requirement for manual harvesting at the starting area and for collecting the cut crop is 6 man-hrs per ha

Cost of manual labour = $6 \times \frac{65}{8}$ per ha

= Rs.48.75/ha

Rounded to Rs.50/ha

At the hire charge of Rs.100/hr, Cost of harvesting by self propelled 5 hp reaper	=	Rs.600/ha
Total cost of harvesting	=	Rs.600 + 50
	=	Rs.650/ha
Savings in cost compared to manual harvesting	=	Rs.1625-650
	=	Rs.975/ha

If the powertiller operated paddy reaper-windrower is used on hire basis, the farmers are willing to take it at a hire charge of Rs.150 per hr. The reaper harvests one ha in 4 hr 30 min. Therefore the cost of hiring for harvesting per ha is Rs.675 and the total cost of harvesting per ha is calculated to be Rs.750 (Fig.17). The cost of manual harvesting is Rs.1625 per ha. By the introduction of the powertiller operated reaper, the cost of harvesting can be reduced to 46 per cent. It is established that the farmers can save an amount of Rs.875 per ha which is 54 per cent of manual harvesting.

The saving in cost by the tractor operated reaper is Rs.845 per ha, which is only 52 per cent. It is also established that the introduction of powertiller operated paddy reaper has more saving around 2 per cent of the cost even compared to the tractor operated reaper.

Even with the normal hiring cost of Rs.100 per hr, the powertiller operated used to earn profit to the owner. By

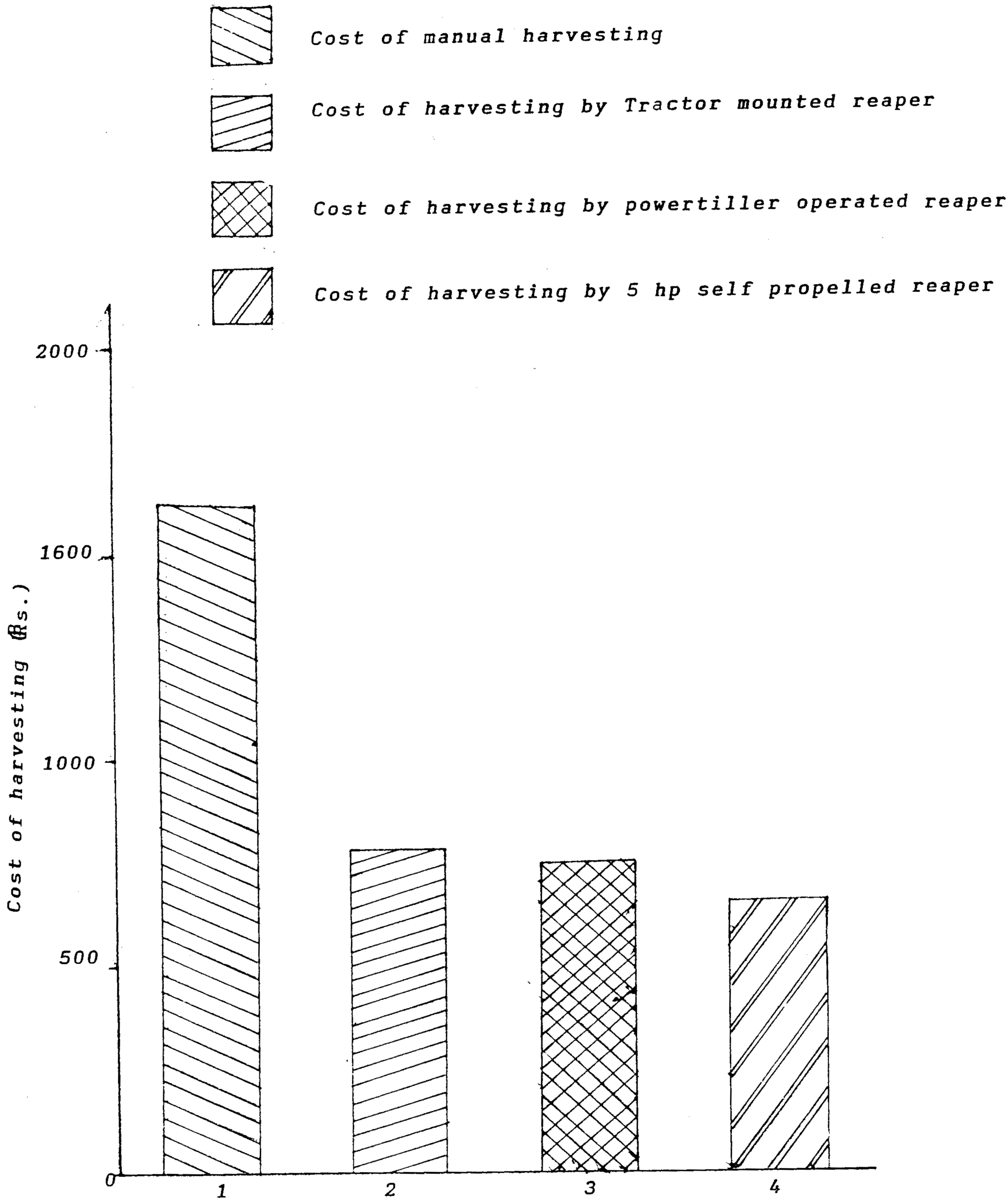


FIG.17 COMPARISON OF PADDY HARVESTING BY MANUAL, TRACTOR MOUNTED REAPER, SELF PROPELLED REAPER AND POWERTILLER OPERATED REAPER

attaching the reaper which costs only Rs.15,000, an additional profit of Rs.50 per hr can be earned by the powertiller owner. It is thus established that both the farmers who use the reaper for harvesting and the owner who hire out for harvesting the paddy crop are getting monetary benefits. The farmer will also be benefited by timeliness of harvesting.

4.4.2 Savings in labour

In addition to the operator of the powertiller operated paddy reaper, two more male or female labours are needed for cutting the crop near the high bunds and for collecting the harvested crop. Thus per ha of land, in addition to the operator, 9 man-hours are additionally needed. Therefore the total labour requirement is 13.5 i.e. 14 man-hrs/ha. The conventional method requires 200 man-hrs/ha. Thus a saving of 186 man hours in harvesting per ha is obtained, which is a saving of 93 per cent in the labour for harvesting alone. Hence, by the introduction of the machine, the present labour shortage for harvesting paddy can be solved.

4.4.3 Break even analysis

Figure 18, a typical 'break-even' chart showing break-even point for owning and operating the three types of paddy harvesters compared to that of traditional method. The

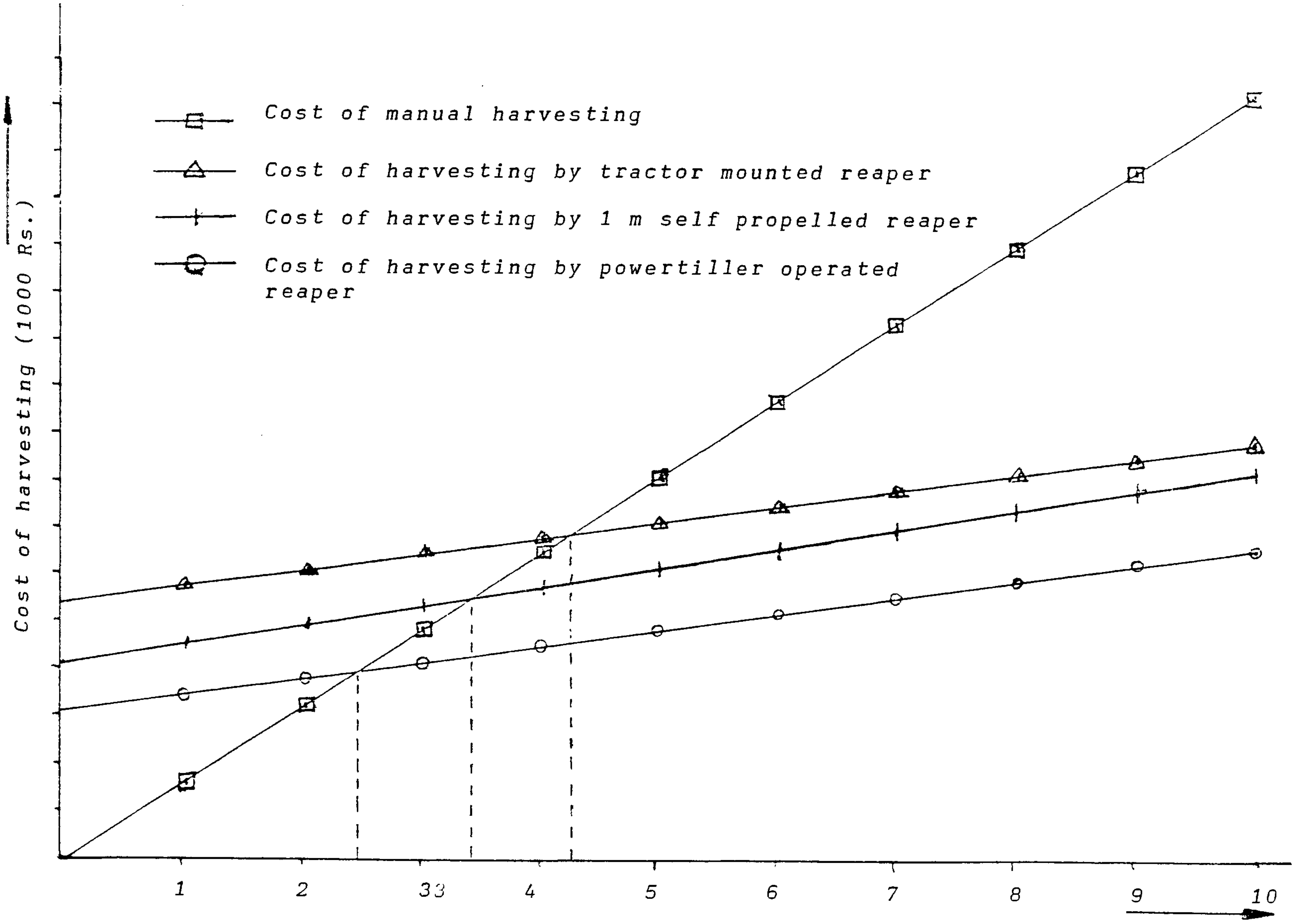


FIG.18 BREAK EVEN ANALYSIS OF COST OF HARVESTING

Table 8. Break even analysis of cost of harvesting

Area (ha)	Cost of manual harvest-ing (Rs.)	Cost of harvesting bytractor mounted reaper (Rs.)	Cost of harvesting by power tiller operated reaper (power tiller is used for other purchase also) (Rs.)	Cost of harvesting by 1m self propelled reaper (Rs.)
0	0	4150	3113	5455
1	1625	4554	3461	5790
2	3250	4958	3809	6125
3	4875	5362	4157	6460
4	6500	5766	4505	6795
5	8125	6170	4853	7130
6	9750	6574	5201	7465
7	11375	6978	5549	7800
8	13000	7382	5897	8135
9	14625	7786	6245	8470
10	16250	8190	6593	8805

calculations pertaining to break-even analysis are given inAppendix-XX.‹Table 8.

As the figure illustrates, if a farmer harvests more than 2.40 ha of paddy field per year, it will be more profitable for the farmer to own and operate his own powertiller operated paddy reaper. But if the farmer harvest an area of less than 2.40 ha, it would be better for him to hire a custom operator. The break-even points for tractor mounted reaper and self propelled reaper are 3.34 ha and 4.16 ha respectively.

Most of the farmers own paddy field less than 0.36 ha in Kerala. Hence it is economical to employ reapers for harvesting on hire basis.

4.5 Appropriate paddy mechanization technology

It has been observed that, in Kerala, the area and production of paddy cultivation is decreasing steadily for the last few decades. The main reason for this situation is that the paddy cultivation has become uneconomical owing to the high production cost. Labour wages are comparatively higher and shortage of labourer is often noticed especially during the peak seasons of agricultural operations like transplanting, harvesting and threshing. Delayed harvesting and threshing usually result in losses upto 5 per cent of the crop, therefore the better cultivation technique alone is not sufficient to solve the food problem and this necessitates the introduction of proper harvesting and threshing equipments. The introduction of labour saving and appropriate farm machinery like powertiller operated paddy transplanters, self propelled, powertiller operated or tractor mounted paddy reaper and rasp-bar paddy thresher will definitely reduce the cost of cultivation and manpower requirements to a certain level. The appropriate mechanization will reduce the peak labour requirement and drudgery of the labourers and thereby increasing the work output of the labourers.

The comparative analysis of the cost of cultivation and man-power saved per ha for the three major operations viz. transplanting, harvesting and threshing are discussed below:

I. Transplanting of paddy seedlings which are pulled and root washed by

   a. Manual method and
   b. Powertiller operated improved paddy transplanter

II. Harvesting of crop and leaving on the field itself as windrow by

   a. Manual method by sickle and
   b. Powertiller operated paddy reaper

III. Threshing and winnowing the harvested crop at the threshing yard by

a. Manual method of crushing under foot or beating against the ground

b. Using 8 hp flow through rasp-bar paddy thresher winnower.

The data pertaining to the cost and man-hr savings per hectare by introduction of appropriate machinery for paddy cultivation are given in Table 9. It is well understood from table that introduction of a powertiller operated transplanter, powertiller operated paddy reaper and 8 hp rasp-bar paddy thresher for the three major operations could reduce the total labour required to an extent upto 93.5 per cent by bringing man power requirement from 890 man-hr to only 58 man-hr per ha. The cost for the above operations are reduced from Rs.4925/- to Rs.1948/- per ha by the introduction of these simple farm machinery. A saving of Rs.2977/- which is 68 per cent when compared to conventional method. This analysis was taken by keeping all other operations like ploughing. Puddling and transporting of seedlings, irrigation, application of chemicals, bundling and transportation of harvested crop as well as other management operations which are similar to both the farms following conventional method as well as farmers adopted the appropriate technology.

From the present study it is well established that the powertiller operated paddy reaper is technically and economically suitable for harvesting paddy crop in Kerala. The powertiller operated paddy reaper reduced the labour requirement for harvesting from 200 man-hrs to 14 man hrs per ha with the saving of 186 man-hr per ha and an amount of Rs.1277/- per ha in harvesting operation alone compared to the manual harvesting.

The introduction of paddy reaper will solve the farm labour shortage and in addition, the establishment of manufacturing, servicing, repair and maintenance facilities for the powertiller operated paddy reaper will actually improve the employment opportunities and income among skilled hands.

Table 9. Cost of cultivation and savings in cost and man-hrs per ha by the introduction of appropriate machinery for paddy cultivation

Sl. No.	Operations	Conventional		Appropriate technology		Savings	
		Man-hr	Cost	Man-hr	Cost	Man-hr	Cost
1.	Transplanting	320	1600	24	800	296 (92.5%)	800 (50.0%)
2.	Harvesting	200	1625	14	348	186 (93.0%)	1277 (78.6%)
3.	Threshing	370	1700	20	800	350 (94.6%)	900 (52.9%)
Total		890	4925	58	1948	832 (9356%)	2977 (60.4%)

Summary

SUMMARY

Paddy is a major crop in India as the rice is the stable food for Indian people. Increase in the production cost as well as decrease in the paddy area is experienced in Kerala. Paddy cultivation is to be appropriately mechanized in Kerala to make paddy cultivation a profitable one.

Appropriate mechanization is necessary for higher labour intensive operations like transplanting, harvesting and threshing as the labour cost is high in Kerala. Nowadays, power tiller is commonly used by farmers mostly in paddy cultivation area. But no paddy harvester is available for any of the commonly available power tillers.

A study was made on paddy harvester suitable to commercially available air cooled Mitsubishi 8-10 hp powertiller. After careful analysis a 1.6 m vertical conveyer reaper-windrower type paddy harvester had been fabricated. Detailed studies on its main components like cutterbar assembly, gathering and conveying assembly and mounting attachments were conducted. Necessary adjustments were carried out on all the individual components like cutterbar, knife, knife head guides, wear plates, knife hold down clip, guards and ledger plates to attain smooth operation.

Substitution of several machine elements and fabrication of additional components were also completed to improve the stability and performance of the reaper. A chasis for mounting the power tiller engine was newly fabricated so that the reaper could also be attached to it. The knife bar bracket which connects the cutterbar with pitman was replaced with an improve one.

During the preliminary field operation, the rotovator was at the rear side. It was found that crossing the bunds to reach another field is not possible with rear rotovator and front reaper. If the power for the cutterbar was taken directly from the engine pulley and hence it was found difficult to start the engine. During transportation the reaper is always in working position. Hence a suitable tension pulley was provided. The straight shoe crop dividers were found to plough the field during operation.

With the removal of rotovator assembly, the problem of crossing the bunds was rectified as the handle of the power tiller could be brought close to the ground level. But it created the balancing problem. Counter weight of 35 kg was provided in between the handles. An auxiliary gear box with 36 and 26 teeth gears was designed and fabricated so that power could be taken from the rotovator gear assembly.

The tip of bottom pipe of the crop dividers were bent to horizontal level and the shoes were refixed. This decreased the height of stubbles and improved the efficiency of dividing the crop without much disturbance.

When the power tiller is moving forward the rotovator lever is engaged to operate the various components of the reaper. The cutting is carried out by the scissor-like cutting action between reciprocating knife sections and stationary ledger plates. The starwheels together with the pressure springs feed and hold the crop to the conveyer belts having links and convey the cut crop to right side through the discharge plate. The cut crop is discharged at the right end of the reaper in the field as a neat windrow.

After carrying out necessary modifications and improvements, field trials were conducted at KCAET Instructional Farm, Tavanur to evaluate the performance of the reaper windrower and also to study the further modifications required. The harvesting was done in counter clockwise pattern. During evaluation, total time taken to cover each plot, duration of harvesting run and duration of idle run were noted. The field efficiency was found to be 66.69 per cent, the actual field capacity is 0.2036 ha per hr.

Total yield, preharvest loss, sickle loss, shattering loss and total cutterbar loss per sq m area were calculated from five randomly selected areas in each plot. The average values were 301.2 g, 0.005 per cent, 0.008 per cent, 0.026 per cent, 0.026 per cent respectively. the losses occurred by the use of the reaper are lower compared to manual harvesting.

Harvesting of paddy by manual method requires Rs.1625/ha while the power tiller operated reaper requires only Rs.348/ha. An amount of Rs.1277/ha is saved as well as 186 man hours per ha by the introduction of power tiller operated paddy reaper alone. This will reduce the cost of cultivation to a significant level.

The harvesting with powertiller is cheaper and earns more savings in labours, when compared with the tractor mounted reaper. The tractor mounted reaper needs Rs.404/ha with a saving of Rs.1221/ha for harvesting paddy. The labour saving by this harvester is found to be 186 man-hrs/ha.

The studies on the reaper-windrower, which costs Rs.15,000 is mounted on the power tiller showed that it is technically and economically suitable for both the tiller owners as well as the farmers in Kerala. If the power tiller operated reaper windrower is hired out at a cost of Rs.150/hr, the owner of the power tiller will get an additional profit of Rs.50/hr and the farmer who is hiring the reaper will get a savings of Rs.875/ha in addition to the timeliness in harvesting. the saving of 186 man-hrs per ha is an important contribution of the harvester. The cutting and windrowing of the machine was perfect for all types of paddy except for the crop which is completely lodged.

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Appendices

Appendix-I

Specifications of Naveen sickle (C.I.A.E. improved sickle)

1	Name of sickle	:	Naveen
2	Blade		
2.1	Length of blade (mm)	:	260
2.2	Length of cutting edge (mm) along with the edge	:	240
2.3	Maximum width & thickness (mm)	:	33 & 1.12
2.4	Radius of curvature & concavity (mm)	:	260 & 28
2.5	Cross section of blade	:	Rectangular
2.6	Type of cutting edge	:	Serrated
2.7	Number of teeth per cm	:	4.5
2.8	Height of teeth (mm)	:	1.7
2.9	Length of chord of cutting edge (mm)	:	225
2.10	Angle between handle and chord (degrees)	:	150
2.11	Material	:	Carbon steel
3	Handle		
3.1	Material & cross section	:	Wood & elliptical
3.2	Maximum diameter/thickness (mm)	:	40
3.3	Length (mm)	:	175
4	Weight of sickle blade & handle (g)	:	257, 167 & 90
5	Joint of blade and handle	:	Blade riveted

Appendix II

Specifications of PAU Animal drawn reaper

Nominal width of cut	: 1000 mm
Length of cutterbar	: 1060 mm
Ground wheel diameter	: 665 mm
Wheel track	: 1200 mm
Speed ratio between land wheel and pitman wheel	: 1:30
Number of strokes of cutterbar perrevolution of drive wheel	: 60
Approximate weight	: 330 kg
Maximum cutting velocity of cutterbar at 1.6 km ph	: 93.56 m/min
at 2.4 km ph	: 90 mm
Height of cut	: 90 mm
Cost of machine	: Rs.1200 (during 1967)

Field performance data

Output of machine	: 0.2 to 0.3 ha/hr
Field efficiency	: 86 per cent
Average working pull on plain ground	: 110 kg
Average working pull while crossing the field bunds	: 160 kg
Average losses	: 5 per cent (Approx.)
Labour requirement	: 50 man-hrs/ha
Cost of harvesting	: Rs.60 per ha (during 1968)

Appendix-III

Specifications of PAU Animal drawn engine operated reaper

Nominal width of cut	:	1250 mm
Length of cutterbar	:	1370 mm
Wheel diameter	:	625 mm
Wheel track	:	1200 mm
Speed of pitman shaft	:	408 rpm
Maximum cutting velocity of cutterbar	:	816 stroken/min
Engine speed	:	3200 rpm
Height of cut	:	90-95 mm
Cost of machine	:	Rs.3500 with
Field performance data		
Output of machine	:	0.2 to 0.3 ha/hr
Field efficiency	:	82 per cent
Average working pull on level ground	:	129 kg
Average pull while crossing irrigation bunds	:	180 kg
Average grain loss	:	3.5%
Labour requirement	:	50 man-hrs/ha
Number of workers required	:	8

Appendix IV

Comparitive specifications and test result of different designs of animal drawn reaper

Description	PAU, Ludhiyana design	IARI, Pusa design	CIAE, Bhopal design
Type	Animal drawn	Animal drawn engine operated 2-3 hp	Animal drawn
Provision of auxiliary engine	Yes	Yes	No engine is required
Overall length	2725 mm	--	1850 mm
Overall width	3725 mm	1800 mm	2100 mm
Overall height	1225 mm	--	1500 mm
Overall weight	30 kg	--	215 kg
Width of cut	1065 mm	1125 mm	900 mm
Type of cutterbar	Standard cutterbar 76.2 mm pitch	Standard cutterbar 76.2 mm pitch	Standard cutterbar 76.2mm pitch
Output	0.15 ha/hr	0.25 ha/hr	0.13 ha/hr
Draft of the machine	130 kg on plain land 180 kg on irrigation bunds	--	85-100 kg
Number of persons to work with the machine	6	--	3

Appendix-V

Specifications of self propelled paddy harvester

Width of cut	:	750 mm
Speed of operation	:	3 kmph
Power	:	4-5 hp
Field capacity	:	1.0 ha/day

Developed at C.M.F.R.I., Durgapur

Appendix-VI

Specifications of tractor rear mounted self raking type reaper

Length of cutterbar	:	1500 mm
Length of machine	:	3200 mm
Width	:	3170 mm
Height	:	2600 mm
Weight	:	550 kg
Diameter of wheel (for adjusting height of cut)	:	240 mm
Speed reduction from main drive shaft to pitman drive	:	1.33:1
Main drive shaft to spider shaft reduction	:	50.46:1
Number of roller guides	:	4
Cutterbar speed	:	90.054m/min
Spacing between knife guards	:	75 mm
Angle of knife section	:	60
pto speed	:	540 rpm
Field performance data		
Field capacity	:	0.37 ha/hr
Field losses	:	upto 2.0% (with moisture content between 7 to 12% dry basis)
Speed of operation	:	3 km ph
Tractor size required	:	30 hp with PTO shaft and 3 point linkage arrangement
Number of workers required	:	6

Developed at PAU Ludhiyana

Appendix-VII

Specifications of Reaper Binder

Length of cutterbar	: 1300 mm
Overall length of machine	: 1200 mm
Overall width of machine	: 2200 mm
Size of bundle	: 150 mm
Power requirements	: 10 hp through PTO
Type	: Fully mounted

Field performance

Capacity	: 1.2-7.6 ha/day

Developed at C.M.F.R.I., Durgapur

Appendix-VIII

Specifications of PUSA Reaper (Tractor operated)

Width of cutterbar	: 1.5 m or 2.0 m
Number of persons required to operate	: 2
Cutterbar speed	: 800 stroken per min

Performance data

Field capacity	: 2 to 2.5 ha/day (8 working hours)

Appendix-IX

Specifications of tractor front mounted reaper windrower

Size of cutterbar	:	1500 mm
Length of conveyer apron	:	1950 mm
Width of conveyer	:	1000 mm
Slope of conveyer	:	18
Length of machine	:	2600 mm
Width	:	2400 mm
Height	:	1900 mm
Maximum cutting velocity of cutterbar	:	100 m/min
Speed of conveyer	:	51.0 m/min
Conveyer roller diameter	:	65 mm
Diameter of reel	:	1000 mm
Number of bats	:	5
Size of bats	:	40 x 15 mm
Range of height or reel adjustments	:	120 mm
Field performance data		
Output or capacity of the machine	:	0.29 ha/hr
Speed of operation	:	2 to 2.5 km ph
Field losses	:	2 to 6% (crop moisture content 5.6% db and yield 3.78 tonnes/ha)

Developed at PAU Ludhiyana

Appendix-X

Specification of tractor mounted reaper

Suitability of crop	Paddy and wheat
Suitable crop height	500-1000 mm
Cutting width	2200 mm
Minimum cutting height	100 mm
Machine weight without mountings	185 kg
Weight of rear frame	19 kg
Weight of front frame	52 kg
Weight of intermediate shaft + universal joints	34 kg
Number of crop row dividers	8
Number of star wheels	7
Number of knife sections	28
Number of knife guards	29
Stroke length	75 mm
Number of pressure springs	13
Pitch of knife section	75 mm
Crank radius	37.5 mm
Width of conveyer belts	60 mm
Lug spacing	130 mm
Spacing between belts	950 mm
Angle of star wheel for horizontal	20
Recommended forward speed	1 m/s
Speed of PTO	700 rpm
Engine rpm	2000
Belt pulley rpm	400
Centre pulley rpm	625
Time to harvest/ha	2-3 hr
Field capacity	3 ha/day

Appendix-XI

Specifications of self propelled sorghum harvester

Width of cut	:	900 mm
Speed of cutterbar	:	430 rpm
Number of strokes	:	860 per min
Reel speed	:	30 rpm
Conveyer speed	:	240 rpm
Power unit	:	5 hp Diesel Engine

Field performance data

Speed of operation	:	1.3 kmph
Field efficiency	:	50 per cent
Stubble height	:	95 mm

Developed at University of Udaipur, Udaipur

Appendix-XII

Specifications of prototype powertiller operated reaper

Length of machine	:	2480 mm
Width	:	1300 mm
Height	:	1370 mm
Weight	:	588 kg
Length of cutterbar	:	1000 mm
Speed of cutterbar	:	130 m/min
Width of canvas conveyer	:	920 mm
Slope of conveyer	:	30
Speed of conveyer	:	47 m/min
Length of conveyer roller	:	1000 mm
Reel speed	:	50 m/min
Number of bats	:	5
Speed of operation	:	2.5 kmph

Performance data

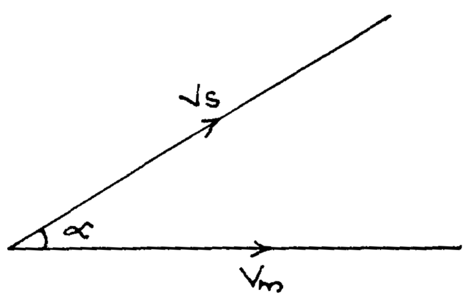
Field capacity	:	0.1 ha/hr
Forward speed	:	2.4 kmph
Grain loss	:	3.5%
Labour requirement	:	50 man h/ha

Developed at P.A.U. Ludhiyana

Appendix-XIII

Design parameter of starwheels

The optimum inclination of star wheels empirically arrived from experiments is 20 with borizontal. The minimum required speed is calculated as the following geometry.



Where

V_s = average starwheel velocity

V_m = machine forward velocity

$\propto$ = angle of onclination of starwheel

Thus

$$\frac{V_m}{V_s} = \text{Cos} \propto$$

$$V_s = V_m \ // \ \text{Cos} \propto$$

$$V_m \ // \ \text{Cos } 20$$

$$V_2 = 1.06 \ V_m$$

Appendix-XIV

Mountings and drive system for various reapers

Sl. No.	Harvesting system	Type of mounting	Power source and drive	Example
1.	Animal drawn reapers	Trailed	Bullock	Not used now
2.	Trailed combine	Trailed	Tractor PTO	Several companies made this types of machines, makes like Mincopalis were imported in India in fifties
3.	Side mounted reapers	Semi-mounted	Tractor PTO	This design is one of the earliest and still used in soyabean reapers developed by CIAE
4.	Front mounted reapers	Mounted	Tractor PTO	Tractor from mounted vertical conveyer reaper of CIAE
5.	Side mounted combine harvesters	Semi-mounted	Tractor PTO	Vicon combine harvester
6.	Self propelled combine harvesters	Self-propelled	Engine	Most of the modern combines used in India like ESPI John Deere Swaraj
7.	Self propelled reapers	Self-propelled	Engine	Italian & Japanese designs are used even today. CIAE self propelled reaper

Appendix-XV

Specification of hot air oven

Make	:	Sri Rudran Instruments Co.
Temperature	:	250C
Rating	:	1800 W
Voltage	:	230
Sl.No.	:	2360 10.91

Appendix-XVI

Specification of Tachometer

Make	:	Prestige Counting Instruments (P) Ltd., Bombay
RPM range	:	30 - 50000 rpm

Appendix-XVII

Specification of moisture meter

Name	:	Osaw Agro moisture meter
Make	:	The Oriental Science Apparatus workshop
Accuracy	:	± 0.2 per cent
Range	:	8 to 40 per cent

Appendix - XVIII

Conditions of experimental field and crops

1. Field condition

a.	Shape of the test field	: Rectangular
b.	Area of the test field	: 33 x 29 m^2
c.	Topography of the field	: Level
d.	Type of field	: Moist field and waterlodged field
e.	Moisture content of the soil	: 20 per cent
f.	Frequency and size of bund	: Nil

2. Crop condition

a.	Variety of paddy	: Jyothi, Thriveni, Hraswa
b.	Appearance	: Straight
c.	Moisture content	: 18 per cent Dry basis
d.	Straw grain ratio	: 1.5:1
e.	Maturity of crop	: 100 days
f.	Number of tillers per m^2	: 38
g.	Total mass of crop and weed	: 750 g/m^2
h.	Number of grains per earhead	: 92
i.	Extent of weeds	: Nil
j.	Type of weeds present	: Not applicable

Appendix-XIX

Paddy yield and various losses for plot No.1. Area: 1 m^2

		I	II	III	IV	V	Average
Total yield	Y_g (g)	310	310	310	310	310	310
Pre harvest loss	W_{go} (g)	0.00	0.00	0.10	0.00	0.10	0.04
	$\frac{W_{go}}{Y_g}$ x 100 (%)	0.00	0.00	0.03	0:00	0.03	0.01
Sickles loss	W_1 (g)	2.70	2.50	1.90	2.80	2.90	2.56
	$\frac{W_1 - W_{go}}{Y_g}$ x 100 (%)	0.87	0.81	0.61	0.90	0.93	0.82
Uncut loss	W_{g1} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g1}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.00
Shattering loss	W_{g2} (g)	0.00	0.00	0.50	0.00	0.30	0.16
	$\frac{W_{g2}-W_{go}}{Y_g}$ x 100 (%)	0.00	0.00	0.13	0.00	0.06	0.04
Cutter bar	$W_{gt} = W_{g1}+W_{g2}$ (g)	0.00	0.00	0.50	0.00	0.30	0.16
loss (Total loss)	$\frac{W_{gt}-W_{go}}{Y_g}$ x 100 (%)	0.00	0.00	0.13	0.00	0.04	0.04

Appendix-XIX

Paddy yield and various losses for plot No.2. Area: 1 m^2

		I	II	III	IV	V	Average
Total yield	Y_g (g)	300	310	290	300	300	300
Pre harvest loss	W_{go} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{go}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.00
Sickles loss	W_1 (g)	2.10	2.30	2.20	2.40	1.80	2.16
	$\frac{W_1 - W_{go}}{Y_g}$ x 100 (%)	0.70	0.74	0.76	0.80	0.60	0.72
Uncut loss	W_{g1} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g1}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.00
Shattering loss	W_{g2} (g)	0.00	0.10	0.00	0.01	0.00	0.04
	$\frac{W_{g2}-W_{go}}{Y_g}$ x 100 (%)	0.00	0.03	0.00	0.03	0.00	0.01
Cutter bar loss Total loss)	$W_{gt} = W_{g1}+W_{g2}$ (g)	0.00	0.10	0.00	0.10	0.00	0.04
	$\frac{W_{gt}-W_{go}}{Y_g}$ x 100 (%)	0.00	0.03	0.00	0.03	0.00	0.01

Appendix-XIX

Paddy yield and various losses for plot No.3. Area: 1 m^2

		I	II	III	IV	V	Average
Total yield	Y_g (g)	300	310	290	300	300	300
Pre harvest loss	W_{go} (g)	0.00	0.00	0.00	0.00	0.00	0.02
	$\frac{W_{go}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.01
Sickles loss	W_1 (g)	2.40	3.00	1.90	2.60	2.50	2.48
	$\frac{W_1 - W_{go}}{Y_g}$ x 100 (%)	0.79	0.97	0.66	0.86	0.83	0.82
Uncut loss	W_{g1} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g1}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.00
Shattering loss	W_{g2} (g)	0.10	0.00	0.00	0.10	0.10	0.04
	$\frac{W_{g2}-W_{go}}{Y_g}$ x 100 (%)	0.03	0.00	0.00	0.03	0.03	0.02
Cutter bar loss (Total loss)	$W_{gt} = W_{g1}+W_{g2}$ (g)	0.10	0.00	0.00	0.10	0.10	0.06
	$\frac{W_{gt}-W_{go}}{Y_g}$ x 100 (%)	0.02	0.00	0.00	0.03	0.03	0.02

Appendix-XIX

Paddy yield and various losses for plot No.4. Area: 1 m^2

		I	II	III	IV	V	Average
Total yield	Y_g (g)	310	300	290	280	300	296
Pre harvest loss	W_{go} (g)	0.20	0.00	0.10	0.00	0.00	0.06
	$\frac{W_{go}}{Y_g}$ x 100 (%)	0.07	0.00	0.03	0.00	0.00	0.02
Sickles loss	W_1 (g)	3.00	2.60	2.40	1.80	2.30	2.42
	$\frac{W_1 - W_{go}}{Y_g}$ x 100 (%)	0.96	0.84	0.82	0.62	0.77	0.80
Uncut loss	W_{g1} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g1}}{Y_g}$ x 100 (%)	0.00	0.00	0.00	0.00	0.00	0.00
Shattering loss	W_{g2} (g)	0.40	0.00	0.30	0.10	0.20	0.20
	$\frac{W_{g2}-W_{go}}{Y_g}$ x 100 (%)	0.12	0.00	0.09	0.03	0.06	0.06
Cutter bar loss (Total loss)	$W_{gt} = W_{g1}+W_{g2}$ (g)	0.40	0.00	0.30	0.10	0.20	0.20
	$\frac{W_{gt}-W_{go}}{Y_g}$ x 100 (%)	0.12	0.00	0.09	0.03	0.06	0.06

Appendix-XIX

Paddy yield and various losses for plot No.5. Area: 1 m²

		I	II	III	IV	V	Average
Total yield	Y_g (g)	300	305	296	290	305	299.2
Pre harvest loss	W_{go} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{go}}{Y_g} \times 100$ (%)	0.00	0.00	0.00	0.00	0.00	0.00
Sickles loss	W_1 (g)	2.80	2.70	2.50	2.60	2.00	2.52
	$\frac{W_1 - W_{go}}{Y_g} \times 100$ (%)	0.93	0.88	0.84	0.90	0.66	0.84
Uncut loss	W_{g1} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g1}}{Y_g} \times 100$ (%)	0.00	0.00	0.00	0.00	0.00	0.00
Shattering loss	W_{g2} (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{g2} - W_{go}}{Y_g} \times 100$ (%)	0.00	0.00	0.00	0.00	0.00	0.00
Cutter bar loss (Total loss)	$W_{gt} = W_{g1} + W_{g2}$ (g)	0.00	0.00	0.00	0.00	0.00	0.00
	$\frac{W_{gt} - W_{go}}{Y_g} \times 100$ (%)	0.00	0.00	0.00	0.00	0.00	0.00

Appendix-XX

Economic studies

(i) Manual harvesting

An average of 25 woman days are required for only crop cutting operation in an area of one ha.

The existing wage rate = Rs.65/woman-day

The cost of harvesting per ha = Rs.25 x 65

= Rs.1625

(The value is also found to be correct when compared with the practice of giving paddy in kind as the wage for harvesting in the region. The share is nearly 1/7th of the total product)

(ii) Harvesting by tractor mounted reaper windrower

(A) Tractor

Initial cost of tractor (c) = Rs.1,70,000

Fuel consumption = 4 lit/hr

Fuel cost = Rs.8/lit

Oil cost = 1/3 of fuel cost

Life of tractor (L) = 10 years

Operating hours per annum (H) = 1000

Salvage value (S) = 10% of initial cost

= Rs.17,000

Fixed cost

Annual depreciation $= \frac{C-S}{L} = \frac{170000-17000}{10}$

= Rs.15300

========

Annual interest on investment @ 10% of initial cost per annum $= \frac{C+S}{2} \times \frac{10}{100}$

$= \frac{170000 + 17000}{2} \times \frac{10}{100}$

= Rs.9350

Insurance = Rs.120

Taxes = Nil

Housing cost @ 1% of initial cost $= 170000 \times \frac{1}{100}$

= Rs.1700

Fixed cost per annum = 15300 + 9350 + 120 + 1700

= Rs.26470
========

Variable cost

Repair and maintenance cost @ 5% of initial cost per annum $= 170000 \times \frac{5}{100}$

= Rs.8500

Fuel cost per annum = 1000 x 4 x 8

= Rs.32000

Oil cost per annum $= \frac{1}{3} \times 32000$

= 10667
=====

Labour cost per annum = Rs.1000 x 30

= Rs.30000

Variable cost per annum = 8500+32000+10667+30000

= Rs.81167

Total cost = Fixed cost + Variable cost

= 26470 + 81167

= Rs.107637

Cost of operations of tractor per hr = $\frac{107637}{10000}$

= Rs.107.64

(B) Reaper

Initial cost of reaper (C) = Rs.20000

Life (L) = 10 years

Operating hours (H) = 480

Salvage value (S) = Rs.1000

Annual depreciation = $\frac{C-S}{L} = \frac{20000 - 1000}{10}$

= Rs.1900

Annual interest on investment @ 10% per annum = $\frac{C + S}{2} \times \frac{10}{100}$

= $\frac{20000 + 1000}{2} \times \frac{10}{1000}$

= Rs.1050

Insurance = Nil

Housing @ 1% of initial cost = $20000 \times \frac{1}{100}$

= Rs.200

Annual repair and maintenance @ 5% of interest cost = $20000 \times \frac{5}{100}$

= Rs.1000

Annual cost of reaper = 1900 + 1050 + 200 + 1000

= Rs.4150

Cost of operation of reaper per hr	=	$\frac{4150}{480}$
	=	Rs.8.65
Cost of operation of tractor mounted reaper per hr	=	107.64 + 8.65
	=	Rs.116.29
Field capacity of tractor mounted reaper	=	0.37 ha/hr
Time required for harvesting one ha	=	2.70 hrs
Cost of operation by tractor mounted reaper per ha	=	2.70 x 116.29
	=	Rs.313.98
Rounded to		Rs.314

Labour requirement for harvesting at the boundaries and clearing the field is 11 man-hrs per ha

Cost of labour for cutting and clearing per ha	=	$\frac{65}{8}$ x 11
	=	Rs.89.40
Total cost for harvesting one ha by tractor mounted reaper including labour	=	314.00 + 89.40
	=	Rs.403.40
Rounded to		Rs.404/-

(iii) Harvesting by power tiller operated reaper windrower

(A) Power tiller

Initial cost of power tiller (C)	=	Rs.70,000
Fuel consumption	=	1.00 lit/hr
Oil cost	=	1/3 of fuel cost
Life of powertiller (L)	=	10 years
Operating hours per annum	=	800
Salvage value (S)	=	10% of cost
Fixed cost	=	Rs.7000

Annual depreciation $= \frac{C - S}{L}$

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

= Rs.6300/-

Annual interest as investment @ 10% of initial cost per annum $= \frac{C + S}{2} \times \frac{10}{100}$

$= \frac{70000 + 7000}{2} \times \frac{10}{100}$

= Rs.3850/-

Insurance = Rs.50

Taxes = Nil

Housing cost @ 2% of initial cost $= 70000 \times \frac{2}{100}$

= Rs.1400

Total fixed cost per annum = 6300 + 3850 + 50 + 1400

= Rs.11600

Total fixed cost per hr = Rs.14.50

Variable cost

Repair and maintenance cost @ 5% of initial cost per annum	=	$70000 \times \frac{5}{100}$
	=	Rs.3500
Fuel cost per annum	=	800 x 1.00 x 8
	=	Rs.6400
Oil cost per annum	=	$\frac{1}{3} \times 6400$
	=	Rs.2133.33
Labour cost per annum	=	Rs.25 x 800
	=	Rs.20000
Total variable cost per annum	=	3500 + 6400 + 2134 + 20000
	=	32034
Total variable cost per hr	=	Rs.40
Cost of operation of powertiller per hr	=	14.50 + 40.00
	=	Rs.54.50

(B) Reaper

Initial cost of reaper (C)	=	Rs.15,000
Life (L)	=	10 years
Operating hours (H)	=	480
Salvage value (S)	=	Rs.750
Annual depreciation	=	$\frac{C-S}{L} = \frac{15000-750}{10}$
	=	1425

Annual interest on investment = $\frac{C+S}{2} \times \frac{10}{100}$

$= \frac{15000+750}{2} \times \frac{10}{100}$

= Rs.787.50

Insurance = Nil

Taxes = Nil

Housing @ 1% of initial cost = $15000 \times \frac{1}{100}$

= Rs.150

Annual repair and maintenance @ 5% of initial cost = $15000 \times \frac{5}{100}$

= Rs.750

Annual cost of operation of reaper per hr = 1425 + 787.5 + 150 + 750

= Rs.3112.50

Cost of operation of reaper per hr = Rs.6.50

Cost of operation of power-tiller operated paddy reaper per hr = 54.50 + 6.50

= Rs.61

Field capacity of the powertiller operated reaper = 0.22 ha/hr

Time required for harvesting one ha = 4.5 hrs

Cost of operation by powertiller operated paddy reaper per ha = Rs. 4.50 x 61.00

= Rs.274.50

Labour requirement for harvesting at the boundaries and clearning the field is 9 man-hrs per ha.

Cost of labour for cutting and clearing per ha = $\frac{65}{8} \times 9$

= Rs.73.10

Total cost for harvesting one ha by powertiller operated reaper including labour = 274.50 + 73.10

= Rs.347.60

Rounded to Rs.348/-

(iv) Harvesting by self propelled 5 Hp reaper windrower

Initial cost of self propelled reaper windrower (C) = Rs.35,000

Fuel consumption = 0.9 lit/hr

Fuel cost = Rs.8/lit

Oil cost = 1/3 of fuel cost

Life of the unit (L) = 10 years

Operating hours per annum (H) = 400

Salvage value (S) = 10% of initial cost

Fixed cost = 3500

Annual depreciation = $\frac{C - S}{L} = \frac{35000-3500}{10}$

= Rs.3150

Annual interest on investment = $\frac{C + S}{2} \times \frac{10}{100}$

= $\frac{35000 + 3500}{2} \times \frac{10}{100}$

= Rs.1925

Insurance = Rs.30

Taxes = Nil

Housing cost @ 1% of initial cost	=	Rs.350
Total fixed cost per annum	=	Rs.3150 + 1925 + 30 + 350
Variable cost	=	Rs.5455
Total fixed cost per hr	=	Rs.13.60

Variable cost

Annual repair and maintenance cost @ 5% of initial cost per annum	=	Rs.1750
Fuel cost per annum	=	0.9 x 8 x 400
	=	Rs.2880
Oil cost per annum	=	$\frac{1}{3}$ x 2880
	=	Rs.960
Labour cost per annum	=	Rs.20 x 400
	=	Rs.8000
Total variable cost per annum	=	1750 + 2880 + 960 + 8000
	=	Rs.13590
Total variable cost per hr	=	Rs.34
Cost of operation of self propelled 5 hp reaper per hr	=	13.60 + 34.00
	=	Rs.47.60
Field capacity of self propelled 5 hp reaper	=	0.16 ha/hr
Time required for harvesting one ha	=	6 hrs
Cost of operation of self propelled 5 hp reaper per ha	=	6 x 47.60
	=	Rs.285.60

Labour requirement for harvesting at the boundaries and clearing the field is 6 man-hrs/ha

Cost of labour for cutting and clearing	=	$\frac{65}{8} \times 6$
	=	Rs.48.80
Total cost of harvesting one ha by self propelled 5 hp reaper including labour	=	285.60 + 48.80
	=	Rs.334.40
Rounded to		Rs.335

EVALUATION AND MODIFICATION OF POWERTILLER OPERATED PADDY REAPER

By

SELVAN P.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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in

Agricultural Engineering

Faculty of Agricultural Engineering & Technology
KERALA AGRICULTURAL UNIVERSITY

Department of Farm Power Machinery and Energy
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING & TECHNOLOGY
Tavanur - 679 573
MALAPPURAM

1995

ABSTRACT

The study on power tiller operated paddy reaper-windrower was taken-up to solve the problems of labour scarcity and uneconomic cost of cultivation of paddy. The 1.6 m vertical conveyer reaper-windrower was fabricated and was mounted with commercially available 8-10 hp air cooled Mitsubishi power tiller. Improvements and modifications were carried out to make the unit suitable for harvesting of paddy in Kerala. The original engine chasis of the power tiller was replaced with a newly fabricated chasis on which both the engine and paddy harvester were mounted.

Difficulties were experienced in starting and in operating the harvester when the drive was taken directly from the engine pulley to the cutterbar. Initially the unit was operated with rotovator at the rear side. It was found difficulty in crossing the bunds, hence rotovator was removed. After detailed studies, an auxiliary gear box was designed and fabricated for transmitting power to reaper from the rotovator gear assembly. The rear rotovator was dismantled and the auxiliary gear box was assembled. For balancing, a counter weight of 35 kg was added in between the handles.

The crop is cut by the reciprocating knife while passing through crop dividers, star wheels, pressure springs and is

conveyed by a pair of lugged conveyer belts and is discharged as a neat windrow. Improvements and modifications were carriedout on most of the reaper components.

Field evaluation of paddy harvester was carried out at KCAET Tavanur for two seasons. It was found that harvester has an effective cutting width of 1.55 m and an average field capacity of 0.2036 ha/hr. The pre-harvest loss, sickle loss, shattering loss and total cutterbar loss were found to be 0.005 per cent, 2.43 per cent, 0.026 per cent and 0.026 per cent respectively.

The power tiller operated reaper-windrower was found suitable for harvesting paddy both in wet as well as dry fields except the fully lodged crops. It is an appropriate machinery for harvesting paddy and is found economically and technically suitable for Kerala conditions.

It was calculated that manual harvesting needs Rs.1625/ha whereas power tiller operated reaper needs only Rs.348/ha and thus achieved a saving of amount of Rs.1277/ha. The savings of 186 man-hrs/ha achieved by the introduction of power tiller operated paddy reaper is a promising solution for the crisis of labour scarcity and the high cost of labour input in the paddy cultivation.