DEVELOPMENT OF POWERTILLER OPERATED PADDY REAPER WINDROWER

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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1997

DECLARATION

I hereby declare that the thesis entitled **"Development of Powertiller Operated Paddy Reaper Windrower"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Development of Powertiller Operated Paddy Reaper Windrower"** is a record of original work done independently by Smt. Shiny Lukose, under my guidance and supervision and that it as not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Shiny Lukose

SHINY LUKOSE

Dedicated to

My loving parents

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SYMBOLS AND ABBREVIATIONS

Agric.	-	Agricultural
APAU	-	Andra Pradesh Agricultural University
AICRP	-	All India Co-ordinated Research Project
AMA	-	Agricultural Mechanisation in Asia
Asst.	-	Assistant
CAAMS	-	Chinese Academy of Agricultural Mechanisation Sciences
cc	-	cubic centimetre(s)
CI	-	Cast Iron
CIAE	-	Central Institute of Agricultural Engineering
cm	-	centimetre(s)
CMERI	-	Central Mechanical Engineering Research Institute
DARE	-	Department of Agricultural Research and Education
Dept.	-	Department
dia	-	diameter
Dr.	-	Doctor
Ed.	-	Edition
Engng.	-	Engineering
et al.	-	and others
FAO	-	Food and Agricultural Organisation
Fig.	-	Figure
FIM	-	Farm Implements and Machinery
FPME	-	Farm Power, Machinery and Energy.
g.	-	gram(s)
G.I.	-	Galvanised Iron
H:	-	Height
ha	-	hectare(s)
HG	-	High Gear
hp	-	horse power
hr.	-	hour(s)
IARI	-	Indian Agricultural Research Institute
ICAR	-	Indian Council of Agricultural Research
ie	-	that is
IRRI	-	International Rice Research Institute

ISI	-	Indian Standard Institution
J.	-	Journal of
KAMCO	-	Kerala Agro-Machinery Corporation
KAU	-	Kerala Agricultural University
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kg	-	Kilogram(s)
kmph	-	Kilometres per hour
kw	-	Kilowatt(s)
L:	-	Length
LG	-	Low Gear
Lit	-	Litre(s)
Ltd.	-	Limited.
LWRCE	-	Land and Water Resource and Conservation Engineering
m	-	metre(s)
m.s.	-	mild steel
M/s	-	Messers
min.	-	minute(s)
mm	-	millimetre(s)
No.	-	Number
PAU	-	Punjab Agricultural University
Proc.	-	Proceedings
PTO	-	Power Take Off
Pvt.	-	Private
Res.	-	Research
RNAM	-	Regional Network for Agricultural Machinery
rpm	-	revolutions per minute
Rs.	-	Rupees
Sci	-	Science
Sec.	-	second(s)
Sq.m	-	Square metre
t	-	tonne(s)
TNAU	-	Tamil Nadu Agricultural University
viz.	-	Namely
W:	-	Width
wb	-	wet basis

@	-	at the rate of
/	-	per
%	-	per cent
°	-	degrees
π	-	pie

INTRODUCTION

INTRODUCTION

Cultivation of high yielding varieties of paddy, use of fertilizers, pesticides and better means of irrigation have resulted in a progressive growth in paddy production in India. But the harvesting techniques employed are still primitive. Indian farmers mostly use hand sickles for this purpose. Manual harvesting requires about 25 per cent of the total labour requirement of paddy cultivation. This high labour requirement has made acute shortage of lobourers, resulting in delayed harvesting and consequential grain loss. The continued growth in paddy production can be sustained only with the introduction of appropriate mechanization. The power availability in our farms has to be increased from the present level of 0.54hp per hectare to atleast 1.00hp per hectare.

Agricultural production in Kerala is lagging behind other states of India. The present yearly production of paddy which is the staple food of the state is only 975 thousand tonnes while the actual requirement is 3275 thousand tonnes. Paddy cultivation in the state is confronting a crisis today. The area under paddy has decreased from 881 thousand hectares to 458 thousand hectares from 1974-75 to 1993-94 (Farm guide, 1977-96) with an average annual reduction of 2.48 per cent. This is because paddy is a labour intensive crop and the wages in Kerala are very exorbitant leading to high cost of production. Shortage of labourers during peak season worsen the situation. So the farmers are forced to convert their farms in to residential plots, cultivate less labour intensive crop or keep fallow. Inorder to arrest any further conversion of paddy fields, immediate introduction of appropriate machinery for labour saving is found necessary. Paddy farmers face acute shortage of labourers during harvesting seasons and thus results in huge loss of crop in the field. This compelled the farmers even to leave their fertile paddy lands fallow. Introduction of labour saving paddy harvesters suitable to local conditions is highly felt by the farming community of the state.

Tractors and powertillers are easily available for the farmers to carry out all the tillage operations. As the majority of farms are small and medium in size, tractors and powertillers are mostly used on hire basis. A harvesting system mounted on tractors or powertillers will easily be accepted by the farmers if they are available on hire basis. As the powertillers are considered to be the most appropriate machine for paddy cultivation in Kerala, the development of a powertiller mounted reaper is considered appropriate. This reaper will be of much use in increasing the utility of the powertiller as well as reducing the cost of harvesting. The system should have a suitable reaper mounted in front of the powertiller for harvesting the crop and laying them as windrows. These windrowed crop will be collected manually for threshing.

Self-propelled walking type harvesters are being introduced in India based on Kubota and IRRI designs. As the paddy harvesting is a seasonal work, the yearly use of these machines will be very much limited. Lower power availability and smaller traction wheel diameter are the limiting factors for their usage in heavy, loose soils of low lying flooded fields.

There is no paddy reaper available as an attachment to any of the commercially manufactured powertiller in India at present. Since KAMCO powertiller is the most popular one among

Indian farmers, this study was undertaken on KAMCO 9hp powertiller with the following objectives:

1. Design, development and fabrication of a combination frame suitable for the powertiller to mount its engine and paddy reaper-windrower
2. Development of a power transmission system to the reaper-windrower from the rotary driving unit.
3. Structural modifications in the vertical conveyor reaper to suit the combination frame and the power transmission system.
4. Field studies on the ergonomical suitability, mechanical stability and economical feasibility of the reaper.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Research works conducted in India and abroad on harvesting machinery, their power requirement, forward travel speed, speed of cutterbar, field capacity and economics of harvesting are reviewed.

Wheat and paddy are the two major food crops in India. About 90 percent of the area under these crops was harvested manually with sickles. About 150-200 man hours were required for harvesting one hectare (Garg *et al.* 1984). Various types of power driven harvesters and combines are in use in developed countries. Japan had made a major contribution in this area by developing small harvesters and combines. These have not been readily accepted in India, because of its high cost and complexity. At present, limited numbers of combines are in use for harvesting wheat along with the indigenous tractor front mounted reapers mostly in Punjab and Haryana. But these machines were seldom used for harvesting paddy. Fragmented fields, difficult topography, smaller farm holdings of the paddy farmers, as well as high cost and complexity of harvesters restricted their use in Indian paddy fields.

Field evaluation and adaptive trials of power driven IRRI model paddy harvesters were intensified in India during 1980's. Vertical conveyor reapers with a width of cut varying from 0.9 to 2.75m for matching different power sources were developed and studied for harvesting wheat and paddy.

2.1 Power required for harvesting

Trivedi and Arya (1966) suggested the following expression for calculating the power requirement of harvesting:

$$HP = \frac{N.E}{75\ t}$$

HP - Horsepower for harvesting one hectare.

N - Number of tiller per hectare.

E - Energy required per tiller which is computed from the shear resistance and the area sheared.

t - Time taken to harvest one hectare in seconds.

Rajput and Bhole (1973) reported that for 10 cm cutting height the force and energy were found to be minimum for the blade having 30 degree bevel angle.

According to Singh and Singh (1978) for a given mower the average cutting force was directly proportional to the feed rate and it was as great as the maximum inertia force of the knife. Both average and maximum cutting forces were found to increase with decrease in straw moisture content and increase with forward velocity and plant density.

Devnani and Howson (1981) investigated the optimum size of harvesters for crops in Indian farms. They concluded that appropriate width of cut are 1.6m and 2.0m for the reapers to be operated by powertillers and tractors respectively. For countries where yields were higher than 2 t./ha, small reapers might be economically viable.

Rangaswamy (1981) found that the (a) power required for cutting and conveying of paddy per hill was 0.128hp, (b) power required for traction of powertiller mounted reaper was 2.22hp, and (c) static shear stress and dynamic cutting stress of paddy varied from 22.79 to 42.06Kg per cm. and 1.04 to 11.25Kg per square cm. respectively.

Sindhu (1987) investigated the power requirement of a tractor front mounted vertical conveyor reaper-windrower. He found that the total power requirement increased with increase in forward speed. Net power, total power as well as net and total specific power requirements were less at higher cutting height than at lower cutting height. All these parameters were increased with an increase in conveyor index.

O'dogherty and Gale (1991) studied cutting of grass stem using single blade with varying parameters like the cutting speed, blade rake angle, blade thickness, nature of cutting edge, and stem inclination. Stem inclination was found to be proportionately increased with critical speed.

2.2. Animal Drawn Reapers.

Animal drawn reaper consisted of cutterbar assembly, side gauge wheel, crop board, and inner and outer shoes, with a pair of transport wheels for adjusting the height of cut of the crop. Drive to the cutting mechanism was given from the wheels through a lever mechanism. For lifting the lodged crop a fixed bat type reel had been provided. Harvested crop was released in the form of bunches.

Bhatnagar (1969) developed an animal drawn reaper with engine driven cutterbar and its field performance was evaluated.

A simple harvester having 1.05 m cutterbar operated by a pair of bullocks was developed in India. The power requirements for different components at no load and loaded conditions were analyzed (Singh and Singh 1977).

Animal drawn paddy reaper was developed in Ludhiana during 1964. Fig.1 shows the animal drawn reaper. The output of the machine was 0.2 to 0.3 ha/hr and the field efficiency was 86 per cent. The major drawback of this model was the high draft requirement. To overcome this problem the PAU animal pulled engine drawn reaper was developed so as to operate it with a pair of bullocks (Fig.2). The machine was found have the field capacity of 0.2 to 0.3 ha/hr and a field efficiency of 82 per cent. But the quality of windrow formed was not found good (Yadhav, 1988).

A light weight, simple and rugged animal drawn reaper with low draft requirement was designed and developed. The crank and lever mechanism helped in deriving cutting force in a magnified way from the low soil thrust developed at traction wheels (Yadav and Yadav, 1991)

An improved animal drawn reaper with engine operated cutting and conveying mechanism was designed and developed by Singh and Singh (1995).

Because of the peculiar field conditions reapers developed for animal power were not recommended to harvest paddy crops. Moreover the use of draught animals in Kerala is getting vanished at a faster rate. In this context a self-propelled, or powertiller mounted or tractor mounted reapers are to be introduced.

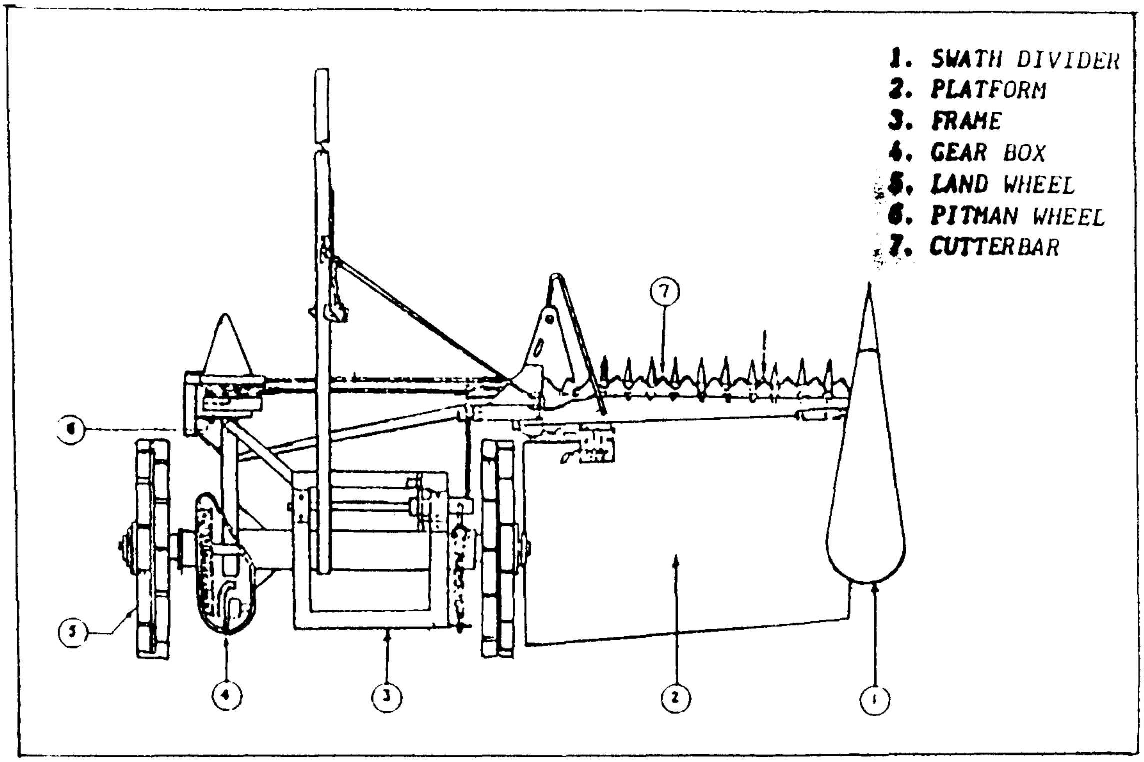


Fig.1 Animal operated reaper.

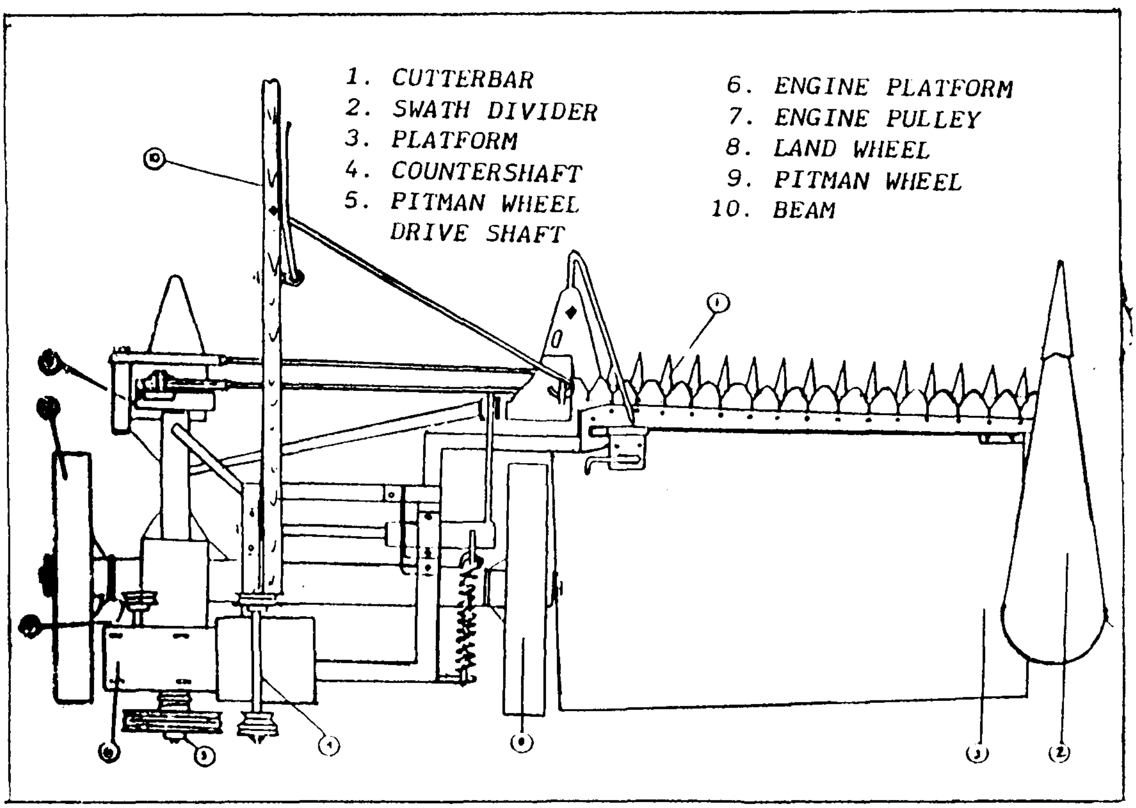


Fig.2 Animal drawn engine operated reaper

2.3. Self-propelled Reaper.

IRRI, Philippines had developed a self-propelled vertical conveyor reaper suitable for paddy and wheat. This engine mounted reaper consisted of cutterbar and conveyor belts. Flat belts with metal clads at regular intervals running on two pulleys on either side were used for conveying the cut crop. Crop dividers with star wheels were fitted in front of the cutterbar for lifting and gathering the crop.

Self-propelled canvas type reaper was developed and evaluated at different countries under Regional Net work of Agricultural Machinery (RNAM) programme during 1978-80 (Devnani 1980).

Devnani and Pandey (1982) developed a harvester for wheat and its performance data such as field capacity, field efficiency, fuel consumption, labour requirements, field losses were evaluated. From the field evaluation of Chinese vertical conveyor type reaper (Model Jin Feng K4 G-1.6), Amjad and Clough (1983) concluded that vertical conveyor reaper was ideal for good harvesting performance, timeliness and overcoming labour shortage.

A harvester operated by 5·4hp Lombardini diesel engine was developed and field tested for sorghum harvesting (Chinnaswamy, 1983).

According to Devanani and Pandey (1985) the ratio of cutterbar speed to forward speed was 1:1.0 to 1.4 and the ratio between conveyor speed to forward speed was 1:1.0 to 1.5. The minimum power requirement for propelling 1.6 m. width reaper with 5hp engine was 2.5hp.

Rahman *et al.* (1985) and Ranganna (1986) attempted on a push type manually operated harvester, obtaining power transmission for the cutterbar knife operation from traction wheel.

A self-propelled paddy reaper windower was developed based on the design available from IRRI. The effective cutterbar width was 1 m. and it was powered by a 5hp engine (Devnani 1988. a). Fig.3 shows the outline of IRRI self-propelled vertical conveyor reaper-windrower.

Singh *et al.*(1988) found out that the field capacity of AMRI and Ittifag reaper was about 0.36 ha per hr.

A self-propelled reaper-windrower similar to Kubota AR 120 reapers of Japan had been developed by M/s KAMCO in Kerala. It is suitable for paddy and wheat (Indian Express, 1994).

The field studies of the IRRI model self-propelled reapers modified for Kerala conditions indicated that by the reaper had a field capacity of 0.15 ha per hr., saving an amount of Rs.735 and reducing 126 man hrs per ha (KAU, 1991; Sivaswami, 1994).

A gasoline powered mechanical paddy harvester had been developed at Philippines. The stripper rotar of the machine fitted with slotted teeth combs detached the grains from the straw. The grain was then moved in an upward direction and fed into a container (The Hindu, 1995). The machine could harvest 0.5 t /hr and it required only six people for operating in shift.

Difficulty in turning the self propelled reaper during harvest due to absence of clutch and differential system was reported by Datta and Datta(1996).

Deshpande *et al.*(1996) conducted field trials with a self-propelled vertical conveyor reaper. The preharvest losses in the field was to the extend of 0.52 per cent. The field capacity of the reaper was found to be 0.19ha/hr and cost of operation was Rs.174.84/ha.

Sinha *et al.*(1996) reported that the effective field capacity of the self-propelled reaper was 0.199 and 0.219ha/hr for wheat and paddy crops respectively. The cost of harvesting were Rs.130/ha and Rs.118/ha respectively.

A riding type 10hp self-propelled vertical conveyor reaper-windrower was developed for harvesting wheat with a field capacity of 0.23 ha per hr. (Prasad and Devanani, 1996; ICAR, 1997). Fig.4 gives the schematic diagram of a commercial riding type self-propelled vertical conveyor reaper-windrower.

2.4. Tractor Operated Reaper.

Vertical conveyor reapers adopted to tractors of 25-35hp were evaluated in Punjab. The main parts of the reaper-windrower were the cutterbar, crop divider with star wheel as lifting and gathering mechanism and lugged belt conveyor. The cutterbar assembly consisted of cutterbar knife sections, and knife guards. The power to the auxiliary gear box of reaper was transmitted from PTO shaft through a long intermediate shaft running beneath the tractor body to the front. The cutterbar unit was connected to the front of the tractor on a hitch frame. The power in the auxiliary gear box is divided into two - one for the cutterbar and other for the conveyor. The three point linkage of the tractor enabled the cutterbar to move upward and downward through

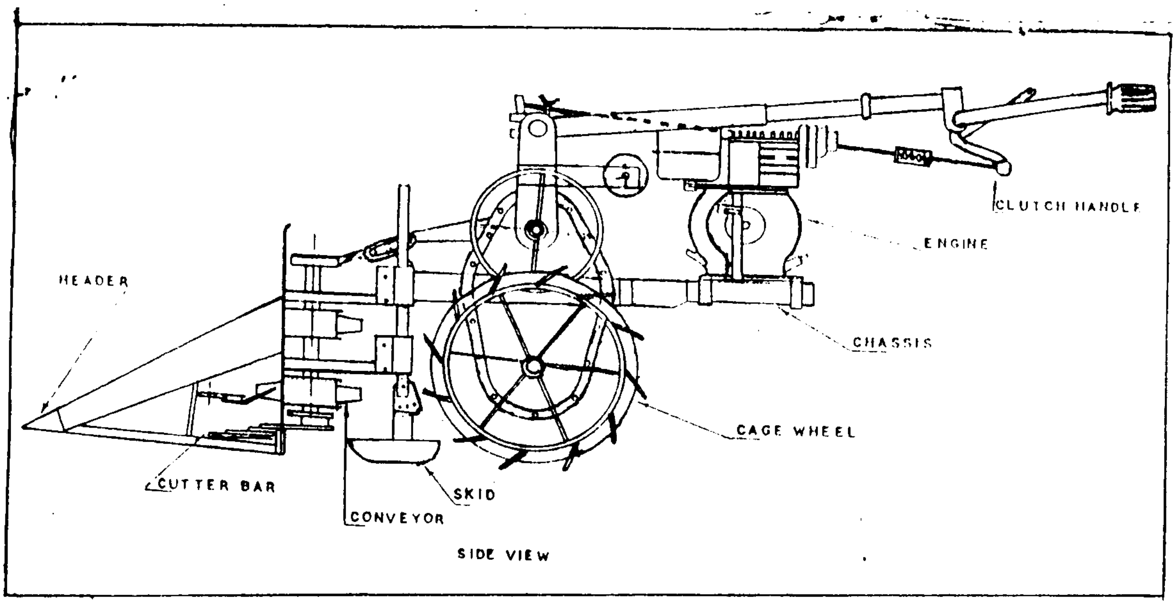


Fig.3 IRRI self-propelled vertical conveyor reaper-windrower

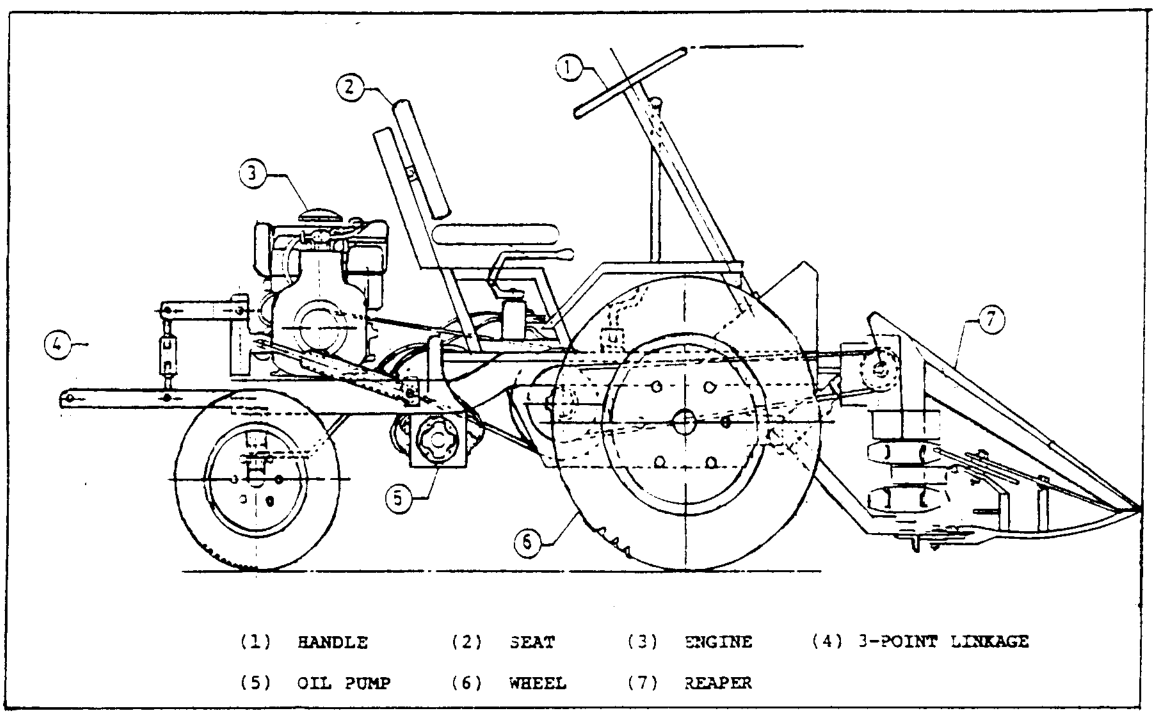


Fig.4 Schematic diagram of a commercial riding type self-propelled vertical conveyor reaper-windrower

wire ropes to adjust the cutting hight. Fig.5. shows the tractor operated vertical conveyor reaper-windrower.

Chauhan and Kalkat (1976) had adopted a cutterbar speed at 130 m. per minute in the tractor rear mounted reaper-binder and the cutterbar length was 1.36m.

Devnani and Pandey (1984) studied the forward speed, cutterbar speed and other parametres of tractor mounted vertical conveyor reaper-windrower.

Tractor front mounted reaper-windrower for harvesting wheat and paddy was developed by Garg and Sharma (1991). This tractor mounted reaper had a field capacity of 3ha/day. Unlike combine harvester, it did not distroy the straw and had labour saving compared to manual operation. Sheruddin *et al.* (1991) compared the performance of the machine with manual harvesting methods for harvesting wheat. The total grain losses by mechanical harvesting averaged 41.1Kg/ha compared to 84.9Kg/ha from manual harvesting. Labour requirements for machine and manual harvesting and bundling were 31.1 and 85.8man.hr/ha respectively.

A tractor mounted 2.2m wide vertical conveyor reaper for paddy was field tested at Tavanur, Kerala. Modifications to achieve efficient power transmission, hitch, lifting and lowering of reaper and prevention of winding of paddy straw were carried out (Sujatha,1993).

According to Sivaswami and Sujatha (1995) the tractor front wheel reaction had an increase of 56.7 per cent while the rear wheel reaction indicated a reduction of 8.9 per cent when fitted with a reaper. Special cage wheels were designed and fabricated for its use in wet paddy fields.

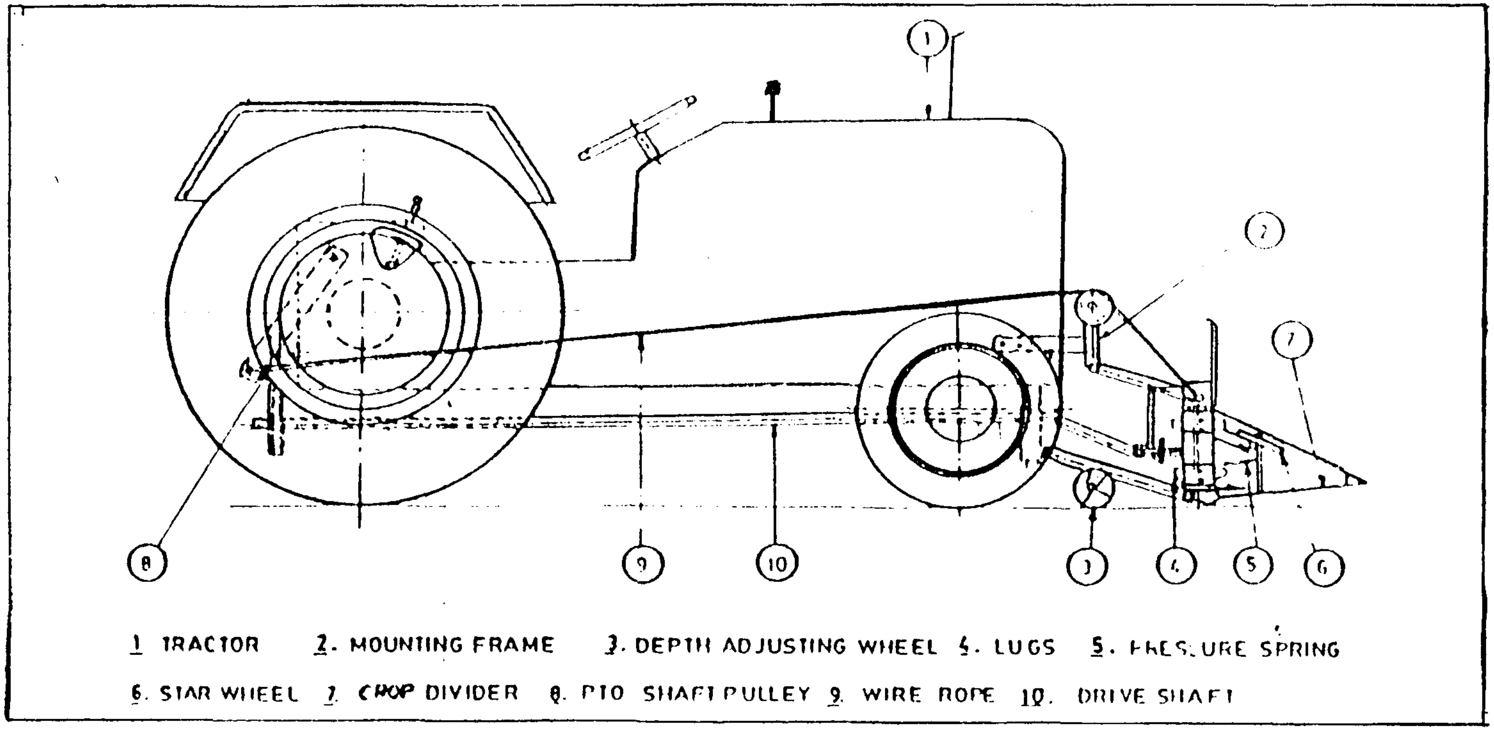


Fig.5 Tractor operated vertical conveyor reaper-windrower.

Two types of tractor drawn front mounted forage harvesters that is (i) reciprocating type (ii) rotary disk type were developed by Garg and Mahal (1996). Trials with reciprocating cutterbar machine gave a field capacity of 0.2ha per hr.

A tractor front mounted 2.2m wide paddy reaper-windrower with a simple collection unit and a special cage wheel attachment to pneumatic wheels for tractor was developed and evaluated at Tavanur, Kerala. Optimum cutterbar index, conveyor index, cutterbar speed and conveyor speed were studied (Sushilendra, 1996).

2.5 Powertiller Operated Reaper

Rangaswamy (1981) has observed that only 1.5 per cent shattering loss occurred in the field while working with windrow type paddy harvester as an attachment to a Mitsubishi powertiller. In this machine a reel was mounted in front of the cutting knife to feed the crop.

Shanmugham and Boopalan (1982) studied the defects of paddy harvester attached to Mitsubishi powertiller. Higher weight at the front, increased length of tiller, hindering the maneuverability, conveyor slippage and cutterbar vibrations were the difficulties in the field.

Valentino and Dietro (1982) tried with 1.0m and 1.6m cutterbar harvesters which are mounted infront of the powertillers. They found that the average field capacity of 2.4ha per day and 3.8ha per day were achieved with 1.0m and 1.6m reapers respectively with a cutting speed of 1.68m/sec.

Amjad and Clough (1983) evaluated the performance of powertiller operated vertical conveyor reaper for paddy and reported that the optimum machine performance was obtained with faster cutterbar speed at high gear. The field capacity was 0.47 ha per hr with 70 per cent field efficiency.

Garg *et al.* (1984) while designing a powertiller driven vertical conveyor reaper observed that 3.6 km per hr was optimum forward speed.

According to Devnani (1988 b) 1.6m was the suitable width of the cutterbar for powertiller to harvest crop in Indian farms.

Aribi and Salleh (1988) have observed that 1.5 to 2.0 hp was required for grass cutting by power reaper.

Field evaluation of paddy harvester of 1.6m cutting width operated by Mitsubishi powertiller was carried out at Tavanur. The average field capacity was 0.2ha per hour. The saving of 186man hours per ha and Rs.1277/ha were achieved by the introduction of powertiller operated harvester. With improvements and modifications it was found suitable for harvesting paddy in wet and dry fields except for fully lodged crops (Selvan, 1995). Even though the development on powertiller mounted reaper-windrower were started during the last quarter of 1980, in India, reaper attachments to the commercially available 8-12hp powertillers were still not available to the farmers.

The reapers available are of the two types:

a) The self-propelled model operated by 5hp diesel engine and KAMCO KR 120 model with 3hp kerosene engine.

b) Tractor front mounted model.

Due to the non-availability of differential, side clutches, reverse gear, and reduction gears, 5hp reapers were not fully accepted by the farmers. Moreover the 5hp reapers and the KR 120 reapers, are exclusively used for harvesting purpose, their working time per year is only 60 to 80 days. This limited working days resulted in high cost of operation. Moreover the power at traction wheel was insufficient in highly clayey and sticky soil in the paddy fields. Fragmented holdings, high initial and maintenance cost restrict the use of tractor mounted reapers in Kerala. Only a small fraction of the power developed by the tractor is required for the operation of 2.2m harvester. So the wastage of power is another limiting factor. Keeping the above factors in view, the powertiller mounted vertical conveyor reapers with 1.6m cutterbar is acceptable because of its simple design, low cost and high efficiency. Since KAMCO powertiller is the most common powertiller in Kerala, it is selected for mounting the reaper in this study.

MATERIALS AND METHODS

MATERIALS AND METHODS

Details of the studies conducted for the selection of cutterbar width, design of combination frame for mounting the engine and reaper, suitable methods of power transmission to the reaper and structural modifications on the reaper and powertiller are being discussed. Details of the laboratory and field studies, methods of evaluation of the performance of the unit, economic analysis and its feasibility in Kerala are also discussed.

3.1 Selection of Powertiller

Indian farmers have accepted powertillers as an ideal powersource for paddy cultivation particularly where the fields are fragmented and size of holdings are smaller. In India only two firms are now manufacturing powertillers commercially with power ranging from 8 to 12hp. The Kubota model powertillers are the most popular in India and are manufactured by M/s Kerala Agro-Machinery Corporation , Athani, Erunakulam. These powertillers are marketed under the brand name KAMCO. KAMCO powertiller production has shown an increase by 14 per cent every year due to its increased demand in the country. The annual production for the last six years is shown in Appendix-I. The technical specifications of the powertiller are given in Table 1.

Table 1 Technical Specification of KAMCO Powertiller

Model	: ER 90 Engine, KMB 200 Tiller
Type	: Single Cylinder, horizontal, diesel powered, water cooled with radiator
hp	: continuous 9 and maximum 12
Starting system	: Hand cranking assisted by decompression lever
Engine weight	: 145kg
Cylinder bore x stroke	: 95x105mm
Stroke Volume	: 744 cc
Compression ratio	: 20:1
Cylinder liner	: Wet type
Type of compression chamber	: Spherical
Governor	: Fly ball type centrifugal
Type of nozzle	: Pintle nozzle
Cooling watercapacity	: 3.8 Lit
Fuel tank Capacity	: 12 Lit
Crank case oil capacity	: 3 Lit
Lubricating oil	: SAE 30
Specific fuelconsumption	: 195 to 205 gm/hr/hp
Engine dimension	: L:820xW:512xH:640mm
Weight of rotary unit	: 160kg
Total weight of tiller	: 485kg
Ground clearance	: 203mm
Overall dimension	: L:2250xW:820xH:1030mm
Tilling width	: 60 cm

Tyre : 6.00x12

Traveling speed

	Gear position	Speed
Low	1	1.5kmph
	2	2.4kmph
	3	3.3kmph
	Reverse	1.3kmph
High	4	5.7kmph
	5	8.9kmph
	6	14.0kmph
	Reverse	4.9kmph

Blade shaft revolution

H-position 310rpm

L-position 215rpm

Cost of powertiller with a pair of cage wheel and without rotavator unit. : Rs.91500

For the present study a KAMCO powertiller bearing engine number K1 94 0334 and chassis number P2 95 0082 was selected as the power source for mounting and evaluating the paddy reaper.

3.2 Selection of Reaper

In countries like China, Philippines and Japan where paddy is the main food crop, the vertical conveyor reaper-windrowers are popular as its design is simple and produce clear windrows after harvesting paddy crop. Studies on 5hp self-propelled vertical conveyor reaper and tractor front mounted vertical conveyor reapers in Kerala also revealed its suitability. Hence the vertical conveyor reaper is adopted for developing a suitable harvester unit for the KAMCO powertiller. The main parts of 1.6m vertical conveyor reaper-windrower is shown in Fig.6.

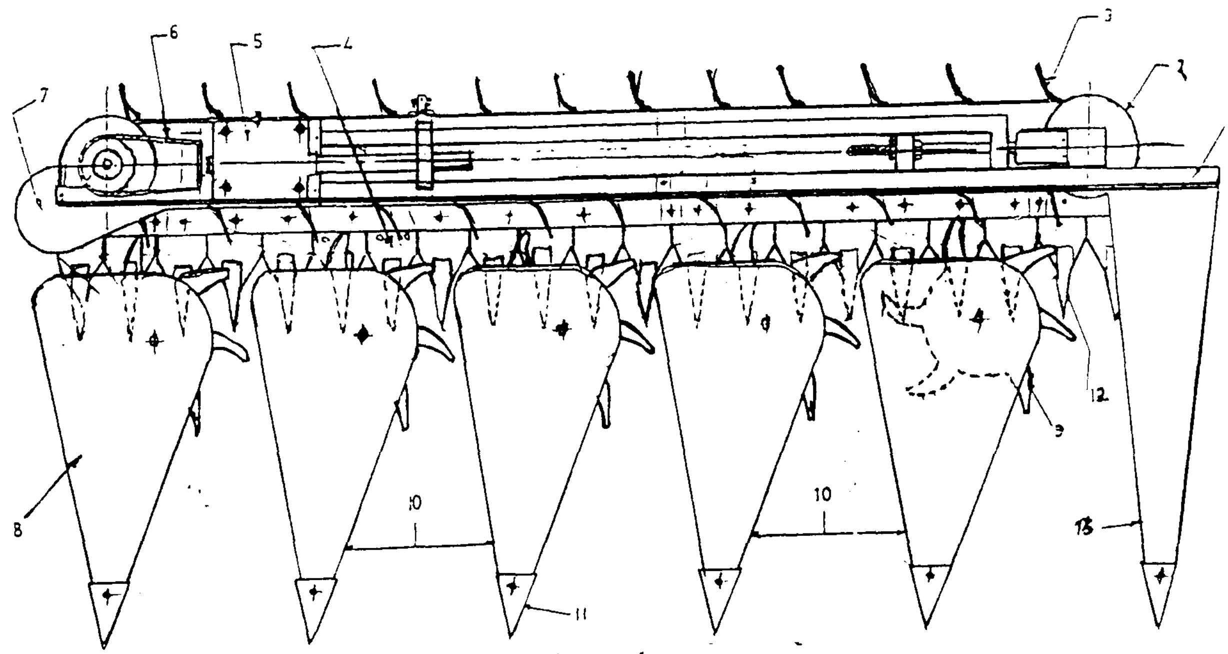
3.2.1 Width of cut of the reaper

The size of the paddy reaper suitable for KAMCO powertiller was based on the following criteria:

1. Minimum width of the cutterbar should be atleast equal to the track width of the powertiller with pneumatic as well as cagewheel.

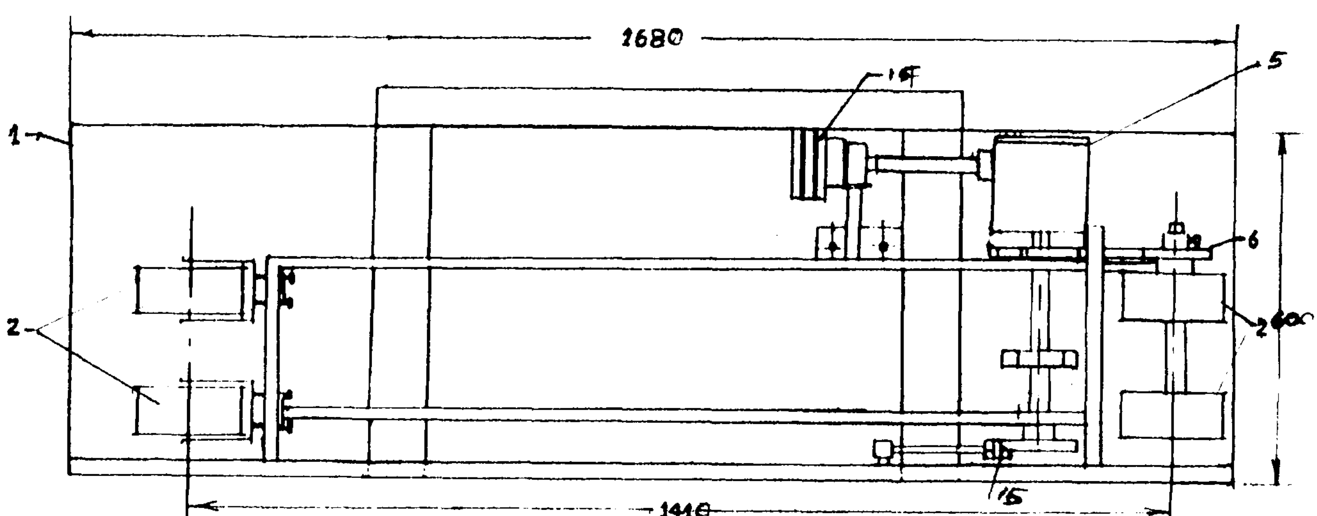
2. Additional width of cutterbar should be allowed on bothsides of the powertiller so that the traction wheels should not disturb the windrowed as well as standing crops.

3. The maximum width of the cutterbar should be limited for restricting the weight in the front which will otherwise create unbalancing.



Top view.

1. Main frame assembly
2. Flat belt pulley (Tension side)
3. Upper lug
4. Knife box
5. Gearbox
6. Chain drive
7. Upper discharge deflector
8. Crop row divider
9. Star wheel
10. Header shield
11. Divider shoe
12. Knife guard
13. Left header
14. Reaper pulley (double groove 100 mm)
15. Crank and lever.



Rear view of the crop-board. Scale : 1 : 11

Fig.6 Main parts of 1.6m vertical conveyor reaper-windrower.

4. Increase in width of the unit increases the total weight which inturn increase sinkage and slippage of powertiller in different fields.

5. Width of the cutterbar is to be restricted to avoid problems in its maneuverability.

6. The width of cutterbar should be limited to match the power source of the tiller which in addition to harvesting, is also expected to meet the traction in the field.

The KAMCO powertiller has a minimum track width of 820mm with pneumatic wheels, 1320mm with type II cagewheels and 1600mm with type IV cage wheels. We need to use the pneumatic wheels in dry fields and type II cagewheels in wet soil for harvesting. Hence the width of track of tiller fitted with type II cagewheels, which is 1320mm was considered for selecting the width of the reaper.

In addition to the track width of 1320mm, a freeboard of atleast 140mm was given on each side of the wheels. Hence the total width came to 1600mm. The minimum width of the unit was thus determined as 1600mm The gap between a pair of knifeguards was 80mm. In between two crop dividers four knife guards were provided and thus the standard space between the crop dividers was 320mm. By designing six crop dividers we achieve a width of cut of 1600mm, which satisfy its requirement for covering the trackwidth and the freeboard needed on bothsides of the powertiller.

3.3 Check for Size of Primemover

The total power requirement of the powertiller operated paddy reaper-windrower will be the power consumed in cutting and conveying of the crop in the form of windrow, in propelling the total unit in the forward direction and the power loss in transmission.

3.3.1 Power required for forward propulsion

The power required for the propulsion of the machine depends on the total weight of the machine, the speed of operation and type of soil. The speed of operation was taken as 3.6kmph. The power required was determined by the formula given by Devnani and Pandey (1985):

Power = Rolling resistance X speed

Rolling resistance = Total weight of the unit X Rolling resistance coefficient

The total weight of the unit without rotavator (assumed), Kg

= 451

Rolling coefficient for the two wheel tractor was taken as 0.20 for sandy clay soil.

Normal working speed = 1m/sec

$$\text{Power for forward propellsion (hp)} = \frac{\text{Rolling resistance (kg)} \times \text{Speed (m/sec)}}{75}$$

$$= \frac{\text{Total weight (kg)} \times \text{Rolling coefficient} \times \text{Speed (m/sec)}}{75}$$

$$= \frac{451 \times 0.20 \times 1.0}{75}$$

$$= 1.22\text{hp}$$

3.3.2 Power required for cutting the crop

The recommended ratio of forward speed to average cutterbar speed of the reaper was 1:1.10 to 1.40. Taking the higher value, 1.4m/sec was taken as the average cutterbar speed (Vc), for the forward speed of 1.0m/sec.

The power for cutting the crop was determined based on the cutterbar length. In earlier studies, it had been shown that for a cutterbar speed of 1.4 m/sec, the power for cutting the crop was only 0.53hp per metre length of the cutterbar. Hence the power required for cutting the crop with 1.60 m cutterbar was arrived as 0.85hp

3.3.3 Power required for conveying the crop

The power required for conveying the crop was assessed as 50per cent of the cutting power. Therefore power required for conveying was arrived as 0.43hp

3.3.4 Total power requirement of the unit

The power requirement for the total unit was the sum of power required for its forward propulsion, cutting and conveying of crop in addition to transmission losses.

Power required for forward propulsion, cutting and conveying the crop(hp) = 1.22+0.85+0.46 = 2.53

Considering an overall power transmission efficiency of 80 per cent, the power required for the entire unit during its operation(hp),

$$= \frac{2.53 \times 100}{80}$$

$$= 3.2$$

The continuous power output of the proposed KAMCO ER-90 engine is 9hp. The total power requirement of the unit even if it is operated at twice of its calculated load, the engine will be able to take care of the requirement.

3.4. Criteria Considered for Developing the KAMCO Powertiller Operated Reaper

The following criteria were considered for the development of the system:

1. Only minimum modifications should be carried out on the original configuration of the powertiller.

2. Assembling or dismantling the various units of the reaper with the tiller should be made very easy.

3. Separate controls for the operation of the reaper should be available.

4. A fully balanced weight distribution should be achieved for different field conditions.

5. Shifting of any tiller components is to be kept minimum to prevent toppling and to improve its stability.

6. No hindrance should be faced for starting, operating or stopping the powertiller along with the reaper.

7. With the reaper attachment, any field bunds should be easily be crossed by the powertiller.

8. The cost and time in converting the powertiller for mounting the reaper should be kept minimum.

3.5. Modifications on the Tiller

3.5.1 Removal of rotavator assembly

The rotavator assembly is an unnecessary component when the powertiller is used for harvesting. The weight of the rotavator assembly which is about 160Kg will be reduced from the total weight of the unit if it is dismantled. The reaper fitted infront of the powertiller can not be lifted upward for crossing the field bunds, if rotavator assembly is allowed to be at its original position. The rotavator assembly was thus dismantled from the powertiller.

The handle stays, the main handle cover, rotary speed change rod and the blade speed change pipe were dismantled from the powertiller. The oil from the central gear case was drained. The intermediate rod of the central gear case was made free by removing the split pin and collar. The central gear case along with the entire rotavator was thus removed. After replacing the collar and split pin the central collar was fixed.

3.6 Mounting of Reaper with the Tiller

Different positions for the reaper and the engine were studied and its disadvantages were noted . Inorder to make the system compact, well balanced, and easily maneuverable, appropriate positions for the reaper and the engine were determined.

The ground clearance of the tiller was only 200mm. So that reaper cannot be placed beneath the engine chassis. Moreover without modifying the powertiller, if the reaper was fitted in the front end of the existing engine foundation, the overall length of the entire unit was increased from 2.25m to 3.00m. This increased length and the added weight of the reaper at the front of the powertiller create problem in maneuverability besides increased load to the operator at the handles. It will not be feasible with this arrangement to turn at the corners in the paddy fields.

Mounting the reaper either to its left or right of the powertiller is also ruled-out, as it will increase the total width of the unit to 2.50 m which is not feasible for our paddy fields. Moreover the uncut and the windrowed crops will get damaged when the reaper unit is fitted right or left side of the powertiller respectively.

It necessitated that the reaper has to be mounted only at the front of the powertiller. Inorder to achieve stability, maneuverability and balancing of load at the handles, the reaper unit should be close to the wheel axle. Fitting the reaper infront of the powertiller after removing the rotavator assembly needed shifting of the engine backwards *ie* towards the wheel axle. After trial and errors, it was found that the engine has to be mounted just above the wheel axle. The engine was removed from its original front frame assembly. The front frame assembly along with the pair of foundation blocks and front stand were removed from the powertiller for accommodating the newly built combination frame.

3.7 Development of a Combination Frame

The development of a new frame called 'Combination Frame' to mount the engine was necessary for the following reasons:

1. To act as an engine chassis to accommodate the engine to obtain best weight balancing.

2. To accommodate the reaper at the best position both in vertical and horizontal planes, so that during operation the handles are positioned at an ergonomically comfortable height for varying height of cut of crop.

3. To absorb the static and dynamic load of the engine and the reaper and also to transmit the weight safely to the powertiller basic frame.

4. The combination frame which is developed as a single unit will facilitate easy and quick assembling and dismantling of the reaper attachment with the powertiller.

3.7.1. Preliminary considerations for the design of combination frame

The optimum height of the handle of powertiller was decided as 1m from the ground level. The minimum gap between the tip of the cagewheel and the tip of the conveyor belt lugs was decided as 50mm. By keeping the reaper on the ground at the predetermined horizontal gap, the horizontal location of the engine foundation was decided for the combination frame. Similarly the various dimensions for fitting the combination frame with the powertiller basic frame were determined. During the design of the combination frame, it was also kept in mind to achieve all the required alignment, like V-pulley alignment for belt drives.

A temporary frame had been fabricated to fix the reaper at 290mm in front of the powertiller cage wheels. The best location of the engine for achieving balanced weight distribution was found out by moving the engine on the temporary frame. It has been found that static balancing was achieved by mounting the engine on the frame such that the centre of crankshaft is 50mm, infront of the wheel axle. Based on the above information the location of slots on the frame was decided

3.7.2 Materials for combination frame.

Two 740mm length m.s angle bar of size 60x60x6mm were used for making of the engine foundation. Slots of 12mm width and 195mm length were cut on the engine foundation, to enable sliding movement of the engine. The rear end of the foundation were supported on the rotary driving shaft supports with a pair of m.s angle bars of size 35x35x4mm. The left supporting arm was made in to two pieces for easy detachment from the powertiller. The rear supports were of the length 180mm made from m.s angle bar of size 35x35x4mm. The rear supports were welded on a specially cut m.s angle bar of size 40x40x6mm. The specially cut angle bar piece is 130mm length and these were fastened on the powertiller supporting arm with bolts and nuts. The front support of size 40x40x6mm m.s angle bars with 500mm length were fitted on the powertiller main gear box, from where the original engine front frame assembly was dismantled.

Four suitable supports for the combination frame were provided to mount the reaper. The top two were 35x35x4mm size m.s angle bars of 400mm length and the bottom two supports were of size 30x30x3mm size with 410mm length. Suitable modifications on the supports were done for accommodating them at their correct places. The plan, elevation and front view of the combination frame is given in Fig.7. The combination frame was mounted on the powertiller.

3.8. Power Transmission.

The easy way to provide power to the reaper is to transmit power from the engine pulley directly. But this method is not adopted because:

1. lack of separate clutch for the reaper which is essential to control its operations.
2. only limited speed reduction is possible between the engine and the reaper, which is not enough for the different field conditions.
3. In certain field conditions inorder to obtain more power we would have to increase the engine speed by adjusting the throttle. The forward speed can be reduced at this high engine speed by selecting suitable gear systems. But there is no way to control the rotovator driving shaft speed.

Hence a new system for transmitting power to the reaper was developed. The new system of taking power from the engine is through the rear transmission assembly of rotavator. The use of rear rotavator drive assembly provided the following advantages:

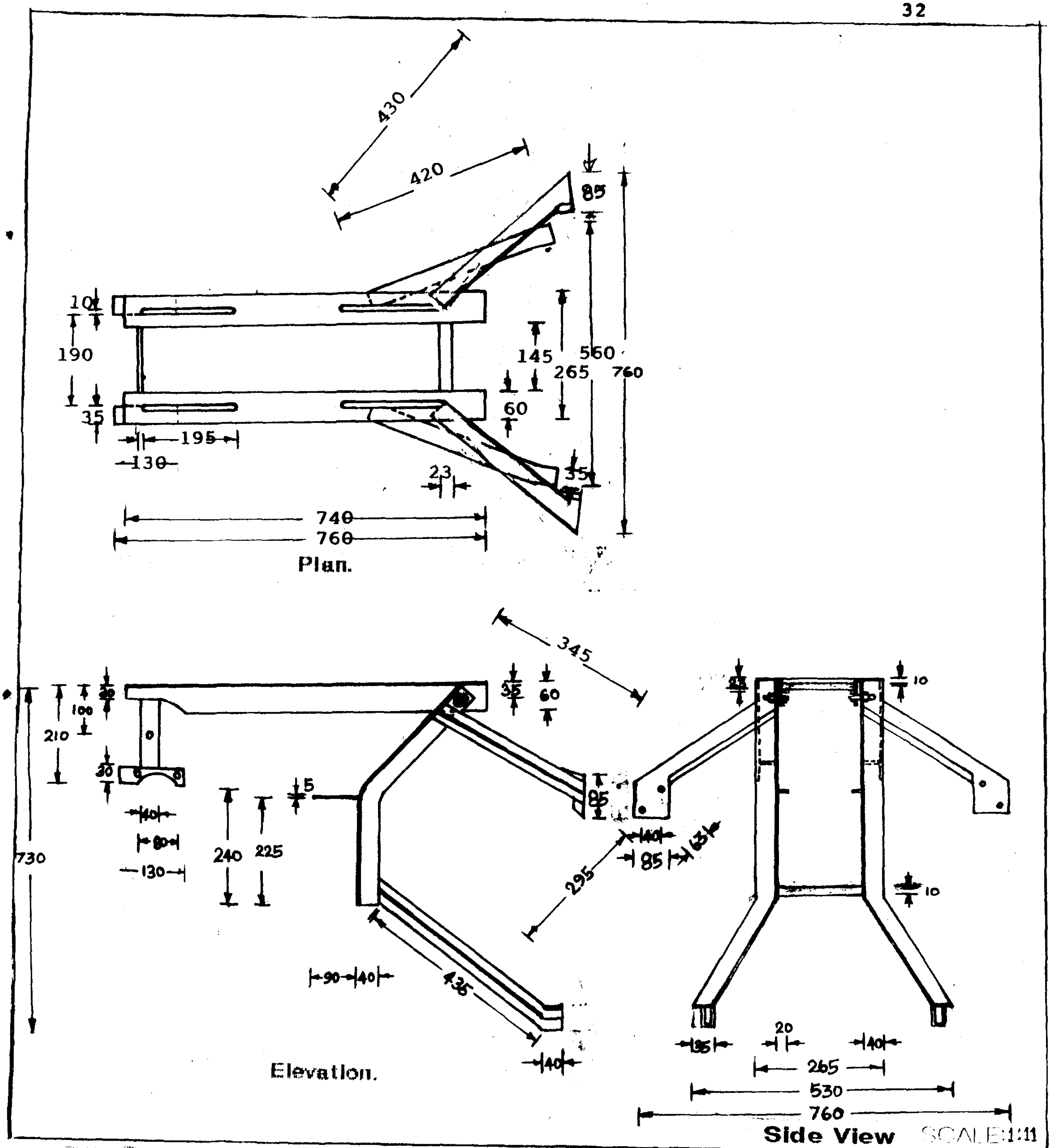


Fig.7 Plan, elevation and frontview of combination frame.

1. the rotavator driving shaft had separate controls with low, high and neutral positions. The neutral positions enables us to stop the reaper while the powertiller was moving from field to field.

2. the rotavator driving shaft had a built-in system which prevented its operation automatically when powertiller was put in reverse gear. This is advantageous for the reaper operation.

3. drive could be taken easily from the rotavator driving shaft from the rear transmission assembly to the reaper. At the optimum engine speed of 1800rpm, two speeds of 315rpm and 210rpm could be taken directly from the rotavator driving shaft of the reaper without any further speed reduction.

4. The rear transmission group at the back of the powertiller also help in balancing by its own weight.

Fig.8 shows the speed reduction mode from main clutch shaft to the wheel axle of the KAMCO powertiller and Fig.9 shows the gear arrangement in the central gear case of the powertiller which is used for transmitting power to reaper. Fig.10 shows the power transmission system of the 1.6m reaper. A new power transmission system to the reaper was developed by making use of the central gear case along with the left and right supporting arms and the shaft. It was fabricated at the central workshop, KCAET, Tavanur as per the drawing given in Fig.11.

Modifications carried out on the shaft and the supporting arms are given in Fig.11. The fabricated unit was assembled in the main gear case at the original location of the central gear case by means of five nuts.

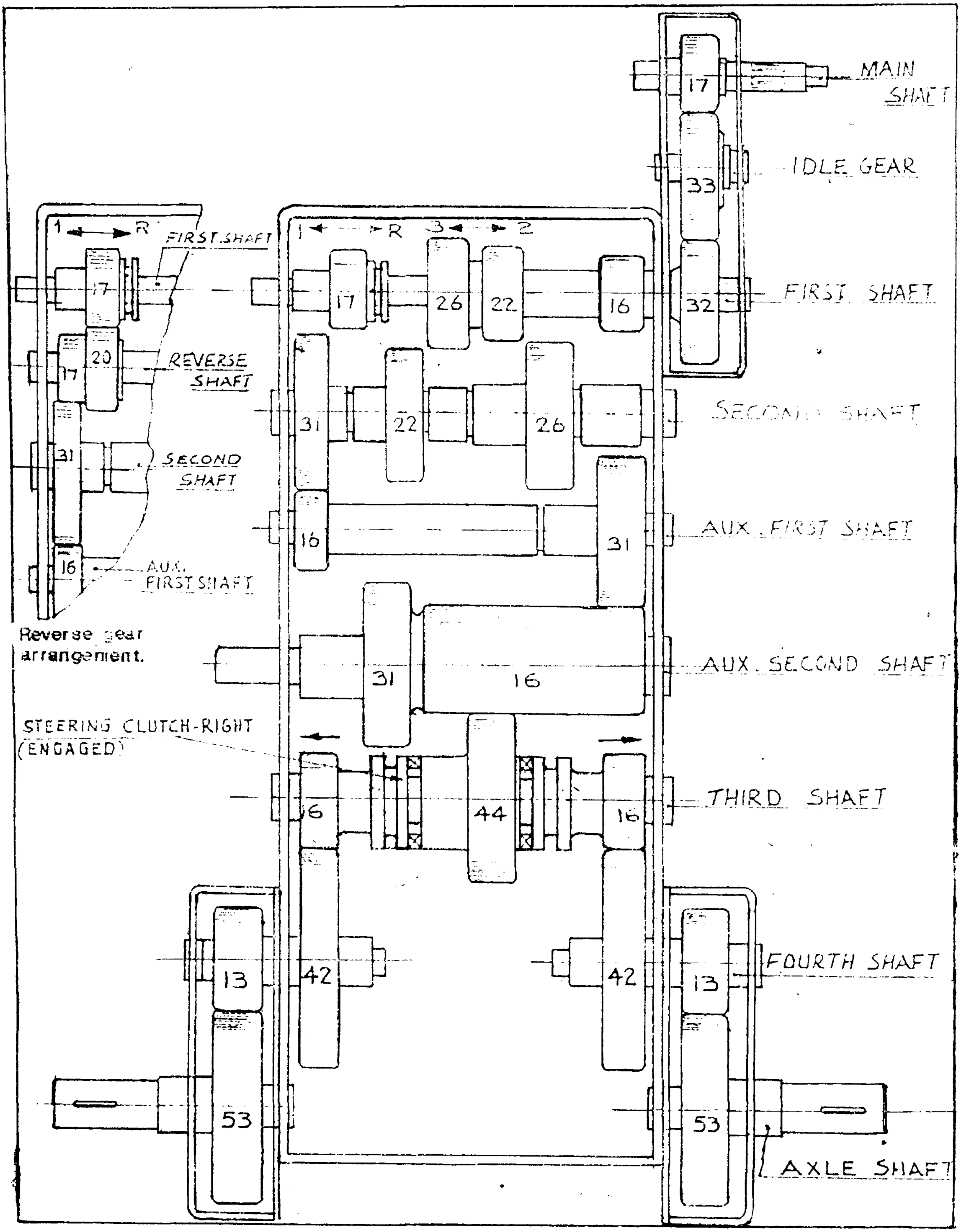


Fig.8 Speed reduction mode from main clutch shaft to wheel axle of KAMCO power tiller.

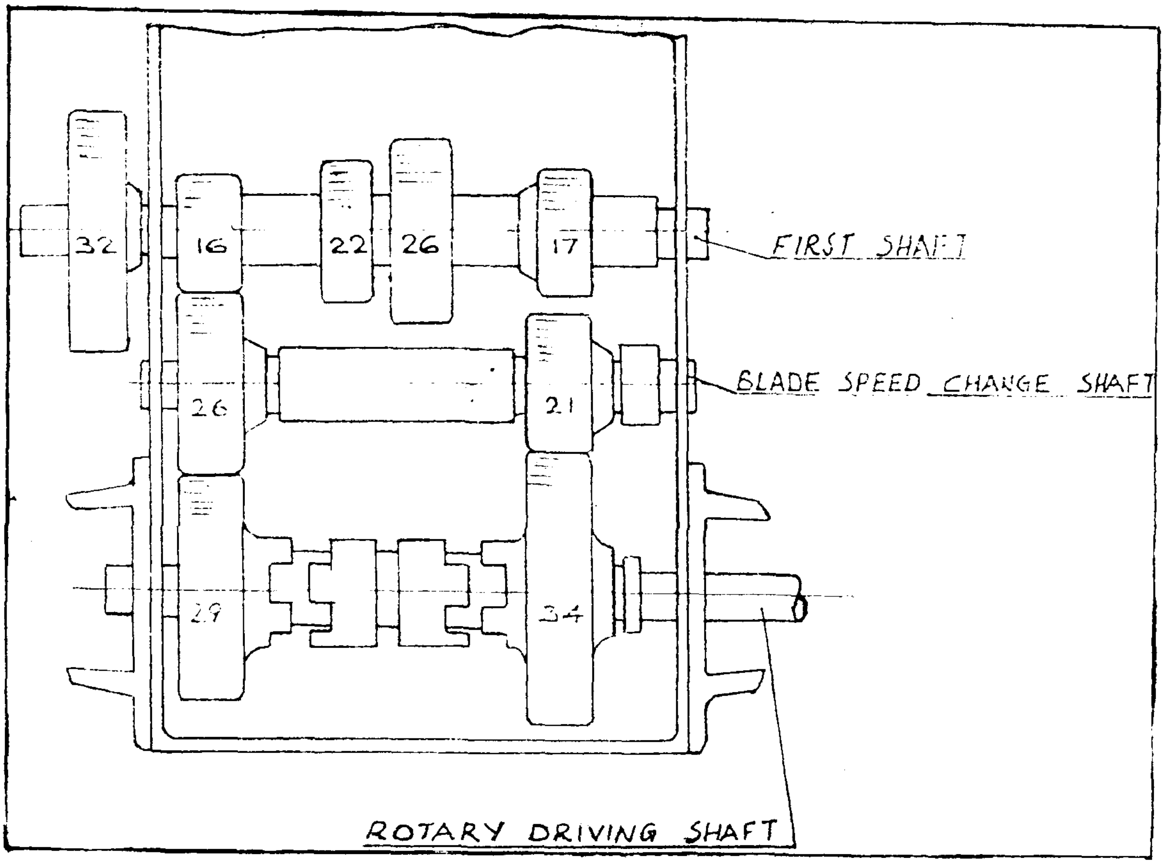


Fig.9 Gear arrangement in the central gear case.

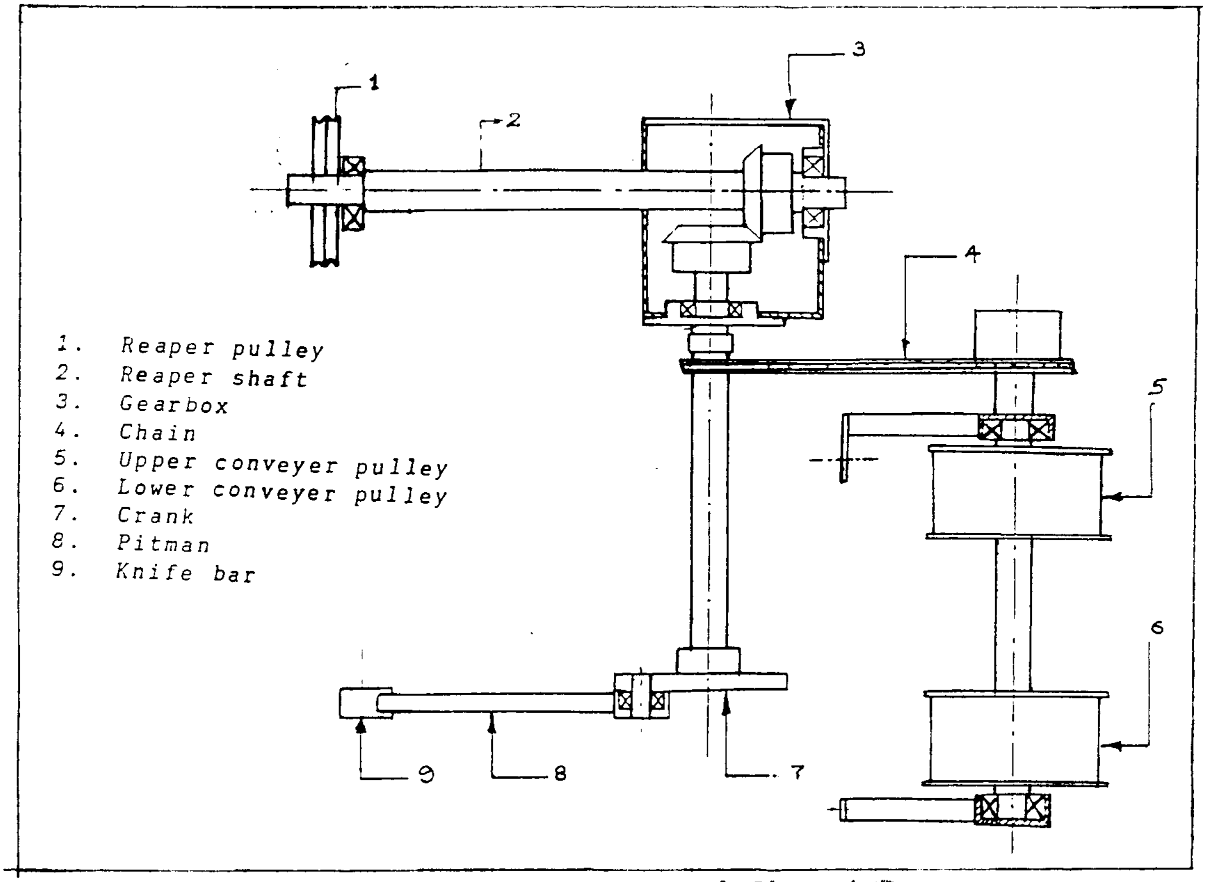
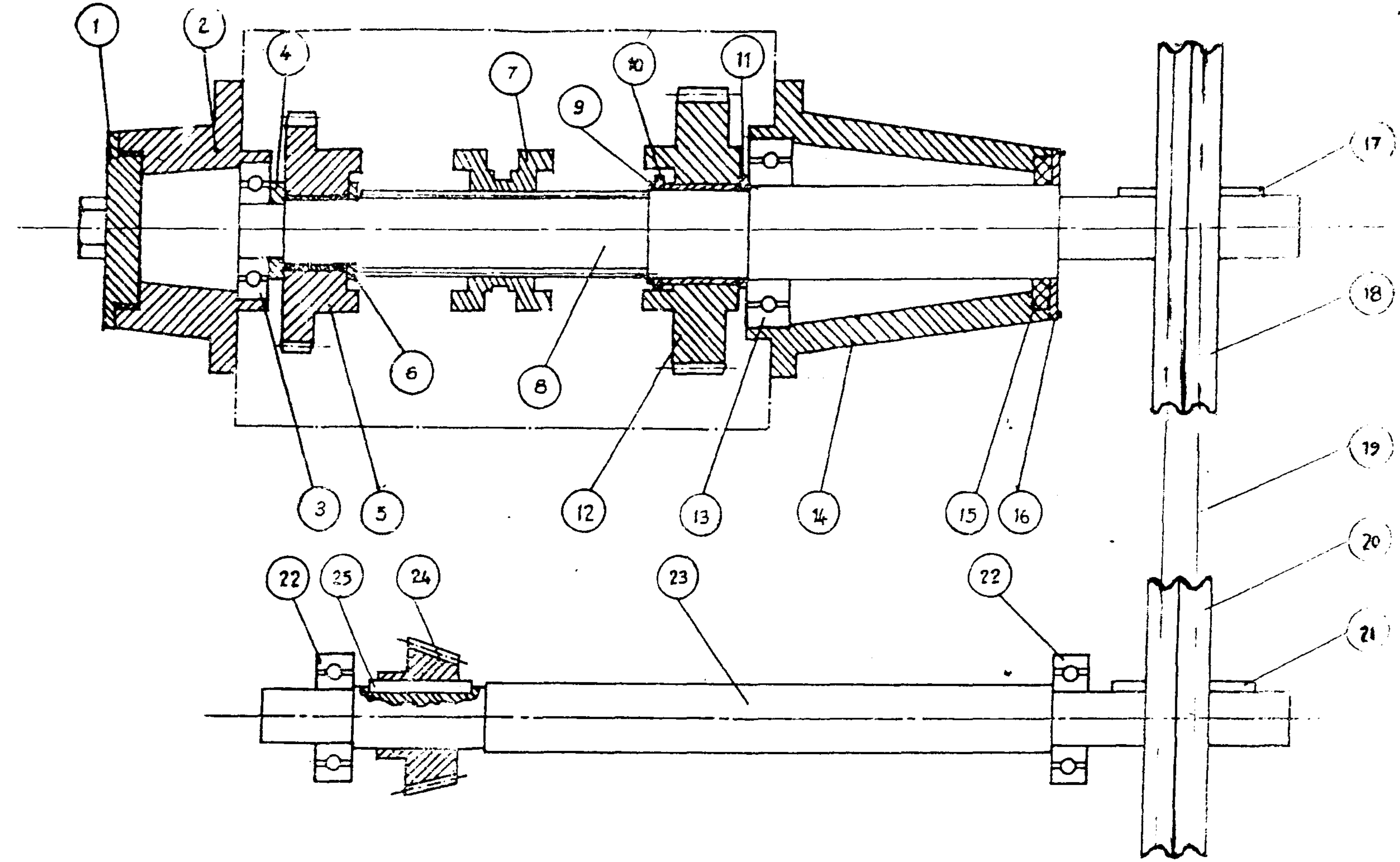


Fig.10 Power transmission system of the 1.6m reaper.



1. Oil Plug
2. Supporting arm left
3. Ball bearing 6304
4. Coller for 29 Teeth gear
5. 29 Teeth gear with pawl
6. Coller 24 dia
7. Dog clutch
8. Rotary driving shaft
9. Stopper ring 32 dia
10.& 11 Collar 32 dia
12. 34 teeth gear with pawl
13. Ball bearing 6307 .
14. Supporting arm right
15. Oilseal Vc 35616
16. Stopper plate
17. Key for rotary driving shaft
18. V-pulley(150mm)
19. V-belt(B section)
20. V-pulley (100mm)
21. Key for reaper shaft
22. Ball bearing 6204 ZR
23. Horizontal reaper shaft
24. Bevel gear 16 teeth
25. Key

Fig.11 Modified rear transmission group with reaper shaft.

3.9. Additional Stays to the Handle.

When the rotavator assembly was removed from its original position and when the reaper unit was mounted in the front of the powertiller, the original handles became weak. This was because of the removal of a pair of supporting links along with the rotavator assembly. The cantilever length of 1.50m handles had undergone bending. The added weight of the reaper at the front of the tiller was also to be taken care of by the handles, hence it needed additional support. A pair of stays made out of pipes, were provided in the same way as the powertiller was supplied for transporting purpose. The drawing of the additional stays for strengthening the handle is given in Fig.12.

3.10. Location for Mounting the Engine

When the 1.60m reaper was fitted in the front end of the combination frame, the weight at the front becomes more. The problem due to the increased weight at the front end could be balanced only by shifting the engine to a new position, towards the rear side. After assembling all the components of the reaper attachment, the best location of the engine on the combination frame was found out by sliding the engine in the slotes on the foundation of the frame. At the new location of the engine, the reaper attachment would be statically balanced. The engine was mounted after taking in to account of the correct alignment for belt transmission from the engine pulley to the powertiller clutch pulley.

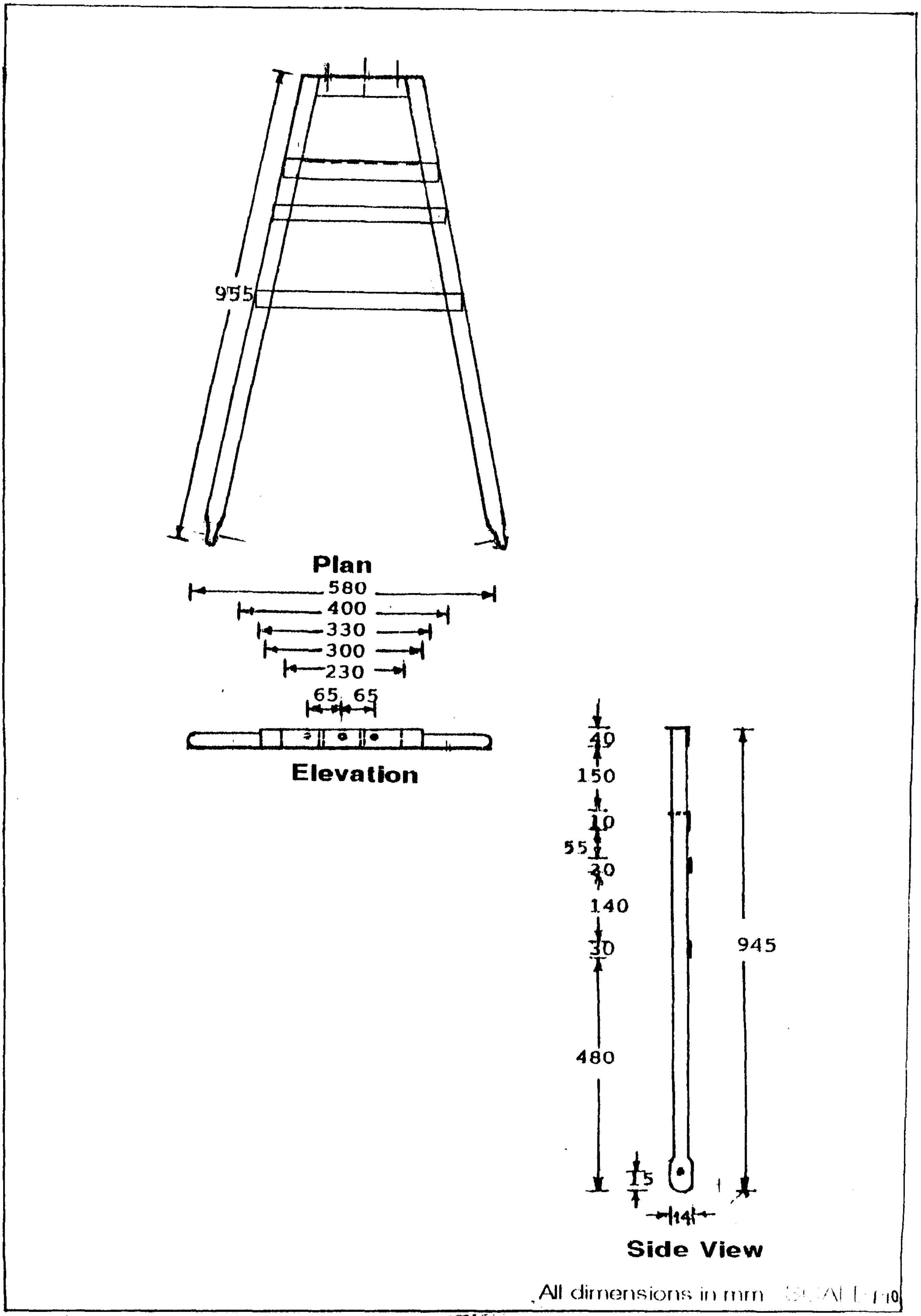


Fig.12 Additional stays to the handle.

3.11. Selection of Belts

3.11.1. Engine Belt

Only centre to centre distance between the engine pulley and the clutch pulley was changed by shifting of the engine to the new location. A set of three B-section V-belts were selected.

3.11.2 Reaper belts.

It was decided to transmit the power from the modified rotavator shaft, rotating at 310rpm at an engine speed of 1800rpm to the horizontal reaper shaft by means of V-belts and pulleys.

The specific power requirement to harvest paddy and the maximum power needed for operating the 1.60m reaper unit was determined. Sufficient reserve power was available to overcome any unexpected load from the crop.

By considering the power required, pitch length and speed of belt, the appropriate section and number of belts needed were determined by using the following method:

The maximum power in Kilowatts which the V-belts of particular section (B-section) could transmit is calculated from the formula

$$kw = \left(0.79\ S^{-0.09} + \frac{50.8}{de} - 1.32 \times 10^{-4}\ S^{2}\right)S$$

kw - Maximum power at 180° arc of contact for a belt of average length.

S - belt speed, m/s

de - equivalent pitch diameter, dp X Fb

dp - Pitch diameter of the smaller pulley, mm

Fb - Small diameter factor to account for variation of arc of contact from standard tables

$$hp = \frac{kw}{0.746}$$

hp- power in horse power

When the horse power transmitted by a single belt is known, the number of belts needed for transmitting the power to match the load is calculated.

By knowing the centre to centre distance of the pulleys and their diameters, the nominal pitch length could be found from the equation

$$L=2C+\pi \times \frac{(D+d)}{2} + \frac{(D-d)^2}{4C}$$

L - nominal pitch length of belt,mm

C - centre to centre distance,mm

D - diameter of smaller pulley,mm

The calculated pitch length of the belts is used to find out the correct size of the belt from the manufacturer's table

3.12 Calculation of Grain loss by Reaper

The influence on the shattering loss of grain during harvesting and windrowing by the reaper was estimated and compared with manual harvesting loss. These values are used for deciding the optimum speed ratios between the powertiller forward speed and the cutterbar speed.

3.12.1. Manual harvesting loss

Manual harvesting was done with sickles. Grain shattered on the ground during manual harvesting from one square metre area was found. Three randomly selected one square metre area were harvested manually and the average weight of grains shattered(Wgm) was determined. The average yield of grain from one square metre was also found (Yg).

Then grain loss by manual harvesting was calculated thus,

Percentage grain loss= (Wgm/Yg) X 100

3.12.2 Grain loss by machine harvesting.

The total grain loss while harvesting with the reaper-windrower was the sum of cutterbar loss and windrowing loss, measured from one square metre area.

The shattered grains from three randomly selected one square metre area in each trial were collected and weighed. Average weight was found as Wg_1 , The uncut crop from three randomly selected area of one square metre after each mechanical harvesting was manually harvested and weighed. Let the average weight of grain be Wg_2. Cutterbar loss (Wgt) was the sum of shattering loss and uncut loss and was calculated by,

$$Wgt = Wg_1 + Wg_2$$

Inorder to find the windrower loss a 12m long gunny bag sheet was placed along side of the crop to be harvested. After reaping with machine, the crop windrowed on the sheet and later removed. The shattered grains on the sheet were collected and weighed. The average weight from an area of one square metre was also computed from it. Average weight from the three randomly selected area was also found (Wgw).

Total grain loss= Wgt+Wgw

Total grain loss in percentage

$$= \frac{(Wgt + Wgw)}{Yg} \times 100$$

The inclination of the windrow with respect to the direction of machine travel and the distance of throw of the harvested crop from the discharge plate end were considered for deciding the quality of windrowing. The windrow distance of 150mm and windrow angle of 80 to 90 degrees were taken as acceptable.

3.13 Laboratory Trials

The unit was assembled and the preliminary trials were done. The performance of individual as well as total units were observed in the laboratory.

The cutterbar assembly, conveyor assembly and the auxiliary gearbox assembly were properly fixed on the reaper frame. The reaper alone was then operated and the following adjustments were checked;

1. Registration and alignment

2. Conveyor belt tension and

3. Star wheel rotation

The weights of individual units as well as overall weight were taken. The following step by step procedure was adopted and time taken for converting the powertiller into a reaper was also noted:

1. removal of engine and its chassis, rotovator unit, main handle cover and pneumatic wheels, from the commercially available powertiller.

2. fixing the cagewheel type II on the powertiller

3. assembling of modified rear transmission group and fixing it on the powertiller.

4. fixing the handle height of 1m using a stand made from 25x25x3mm size m.s angle bar.

5. mounting the combination frame on the powertiller.

6. fixing the handle supports.

7. mounting the reaper and the engine on the combination frame at the appropriate locations.

8. fixing of power transmission components.

After mounting all the components the engine was started and the difficulties in starting the engine with the new location were observed. Then power was transmitted from the engine to the main gear box of the powertiller and its performances were checked for all the three forward gears and one reverse gear. The reaper was then operated by engaging the rotavator clutch. For each engine speeds, two cutterbar speeds and two conveyor speeds were obtained by selecting low and high gears. The cutterbar and conveyor speeds were measured for engine speeds from 1000 to 1800rpm.

The turning radius was also measured in the laboratory. The reaper was operated for full range of speeds of the engine to detect any problem for its operations.

3.14. Field Trials.

The field trials were conducted in the paddy fields of KCAET, Tavanur during November and December, 1996. The details of the field and the crop were collected. Average yield of the crop per square metre area of the field and the harvesting loss were determined by manual harvesting.

An area of 2mx2m was manually cut from each corners of the experimental plot and a strip of 0.20m width was cut manually at the four sides of plot along the field bunds.

The following gear combinations were chosen for experimental purposes:

1. Gear combination I - Low cutterbar speed and low first gear
2. Gear combination II - Low cutterbar speed and high first gear
3. Gear combination III - high cutterbar speed and low first gear
4. Gear combination IV - high cutterbar speed and high first gear

Trials were done for the engine speeds from 1000 to 1800rpm for all possible gears. The powertiller could not be operated with high forward gear position at high engine speeds in the field. Inorder to avoid intervarietal difference only one paddy variety was harvested with the machine. Before taking observations, it was operated continuously for sufficient time to confirm its reliability. The cutting height and throttle setting were kept constant for each experiment.

3.14.1 Field capacity

The field capacity was determined by measuring the distance travelled by the machine and the width of cut of the machine. It was found from formula,

$$\text{Field Capacity (ha/hr)} = \frac{\text{Distance travelled (m/sec) X width of cut of the machine (m) x 3600}}{10000}$$

Without considering the idle time in calculating the distance travelled by the machine we can calculate the theoretical field capacity. Field efficiency is the ratio of actual field capacity to theoretical field capacity expressed in percentage. Field capacities for all gear combinations were found.

3.14.2 Grain loss

Cutterbar loss and windrowing loss were taken from the field for three randomly selected area of one square metre for each gear combinations. The average values of each gear combinations were used for determining the total loss. The average grain yield before harvesting was also taken for one square metre area. The total grain loss was calculated by using the formula discussed in section 3.12.2.

3.14.3 Reaction at the handles.

The downward effort on the handles at the time of releasing the clutch for forward travel was measured using a spring balance for each gear combinations at different engine speeds.

The cutterbar linear speeds, conveyor belt linear speeds and rotovator shaft speeds for each engine speeds were measured using a tachometer.

Field performance of the reaper was directly compared with the conventional methods.

3.15. Labour Requirement

The average labour required for cutting and bundling of paddy crop manually for one hectare for the last five years were collected from the Instructional Farm, Tavanur. The labour requirement in the case of powertiller reaper including the labour required to carry out the preparatory hand harvesting needed in the field and the labour requirement for its operation were calculated from the actual field capacity of the machines. The labour requirement of the reaper was compared with manual harvesting.

3.16. Economic Analysis.

The labour charge per day was collected from the Instructional Farm. The cost of harvesting with the powertiller reaper was calculated from the test results and making assumptions for machine life, hours of operation, rate of interest, and initial cost of machine as per standard procedure.

The cost of harvesting with the powertiller operated reaper and manual harvesting costs were compared. The break even point and payback period were calculated as per the following formula and was analyzed.

a) Break Even Point (ha/year)

$$= \frac{\text{Fixed cost (Rs./Year)}}{\text{Custom charge(Rs./ha)-Variable cost(Rs./ha)}}$$

b) Pay back period (years)

$$= \frac{\text{Purchase price(Rs.)}}{\text{Average annual net benefit (Rs./year)}}$$

RESULTS AND DISCUSION

RESULTS AND DISCUSSION

The KAMCO 9-hp powertiller was suitably modified for harvesting paddy with 1.6m reaper. Basic laboratory studies on its general construction, stability, maneuverability, load at the handles and operation in forward and reverse gears were carried out. The modified unit was evaluated in actual field conditions during November and December, 1996. Field performance and economic feasibilities were studied.

4.1. Selection of Powertiller

It was discussed in section 3.3, that the total power requirement of the harvester unit was 3.2hp. Normally the engine of the KAMCO powertiller(ER-90 model) was operated around 1400rpm deriving 9hp. It was noted that even if the power required for the field operation was doubled in the most adverse conditions, the engine was in a position to undertake the task. Hence the selection KAMCO powertiler was appropriate for the 1.6m width reaper windrower.

4.2. Positioning of the Reaper

During the field operation of many type of reapers, it was observed that more clearance was needed in the left side to prevent the chances of the wheel running over the standing crop. It was also found that the reaper was not in a position to cut the crop if it is trampled over the field by the wheels. It was expected that the right side of the reaper would just cover the track width as the windrowed crop was thrown atleast 50mm from the discharge plate.

Based on these observations, the reaper of 1.6 m width having a crop board width 1680mm, a left side clearance of 205mm and a right side clearance of 155mm was used. Specifications of 1.6m vertical conveyor reaper-windrower is given in Table 2.

4.3. Combination Frame

Based on the observations, in section 3.7 and as per the figure the combination frame was fabricated. The weight of combination frame was found to be 20kg. The newly made combination frame for KAMCO powertiller to mount the 1.6m reaper is given in plate.I. Mounting details of the frame is shown in plate.II.

4.4 Power Transmission to the Reaper

The criteria for selection of power transmission and the advantage of utilizing the rear transmission group for the reaper operation were given in section 3.4. Accordingly a new power transmission system from the powertiller gear case to the reaper through the rear transmission group was designed.

Plate.I Combination frame for KAMCO powertiller to mount 1.6m reaper

Plate.II Mounting details of combination frame on the KAMCO powertiller.

Table. 2 Specifications of 1.60m vertical conveyor reaper - windrower

Suitability of Crop	:	Paddy
Suitable crop height	:	500-1100mm
Cutting width	:	1600mm
Minimum cutting height	:	80mm
Number of crop dividers	:	6
Distance between crop dividers	:	320mm
Number of star wheels	:	5
Number of Knife sections	:	20
Number of knife guards	:	21
Number of pressure springs	:	8
No. of Crop retaining spring row	:	2
Pitch of knife section	:	75mm
Stroke length	:	75mm
Crank radius	:	37.5mm
Width of conveyor belt	:	60mm
Number of conveyor belt	:	2
Spacing between belts	:	100mm
Lug spacing	:	130mm
Angle of star wheels From horizontal	:	20°
Overall dimensions	:	L:700xW:1740xH:570mm
Weight	:	81kg
Cost of machine	:	Rs 17,000

The rear transmission group consists of standard KAMCO powertiller parts such as

1. Rotary driving shaft
2. 29 Teeth gear with pawl
3. 34 Teeth gear with pawl
4. Collar for 29 Teeth gear
5. 34 Teeth gear bush
6. Dog clutch
7. 29 Teeth gear bush
8. Collar 24mm diameter
9. Collar 32mm diameter
10. Ball bearing 6304
11. Ball bearing 6207
12. Oil Seal Vc 35616
13. Stopper ring 32mm diameter

4.4.1. Modifications on the rear transmission group

1. The left supporting arm was removed for reducing the total weight. In its place a suitable plug was fabricated to arrest any leakage of gear oil.

2. The original length of right supporting arm was 265mm. By cutting the right end of the support to a length of 145mm, the modified length of the arm was reduced to 120mm.

3. The rotavator driving shaft running through the right supporting arm was also modified. A length of 85mm from its splinned end was removed. The actual diameter of the shaft was reduced from 38.0mm to 25.4mm for a length of 125.0mm from reduced end. A key way of 8mm x 50mm size was made on its right end.

4. The inner diameter of the open end of the right support was machined to 50mm so as to accommodate the oilseal Vc 35616

5. A stopper for the oilseal was fabricated and fitted at the right support by using 4mm thick m.s. plate and a set of four cap screws.

The modified rear transmission group with the reaper shaft is shown in Fig.11. After carrying out all the above modifications, the components of the rear transmission group was assembled. The oilseal and cap for oil seal were also assembled at the right support and the plug was provided at the left support.

The modified rear transmission unit was mounted with the powertiller and its operation was inspected for both low and high speed selections, prior to connecting it to the reaper.

4.5. Recommended engine speed

Fig.13 shows the performance curve of KAMCO ER-90 engine. The recommended engine speed was 1000 to 2000rpm and it was found to give a power between 6hp and 12hp as per the manufacturers engine performance curve. The recommended continuous power output of 9hp is obtained, by operating the engine at 1400rpm. The engine could be operated between 1400 and 2000rpm for a very limited time only to produce more than 9hp. For operating the reaper a range of speed between 1200 and 1400rpm was selected to produce power between 7.75hp to 9.00hp which was found enough for operating the reaper. It was also found that between 1200rpm and 1400rpm the engine was found to produce the maximum torque of 4.6kgm to 4.7kgm. Operating the engine beyond 1400rpm actually reduced the torque output of the engine.

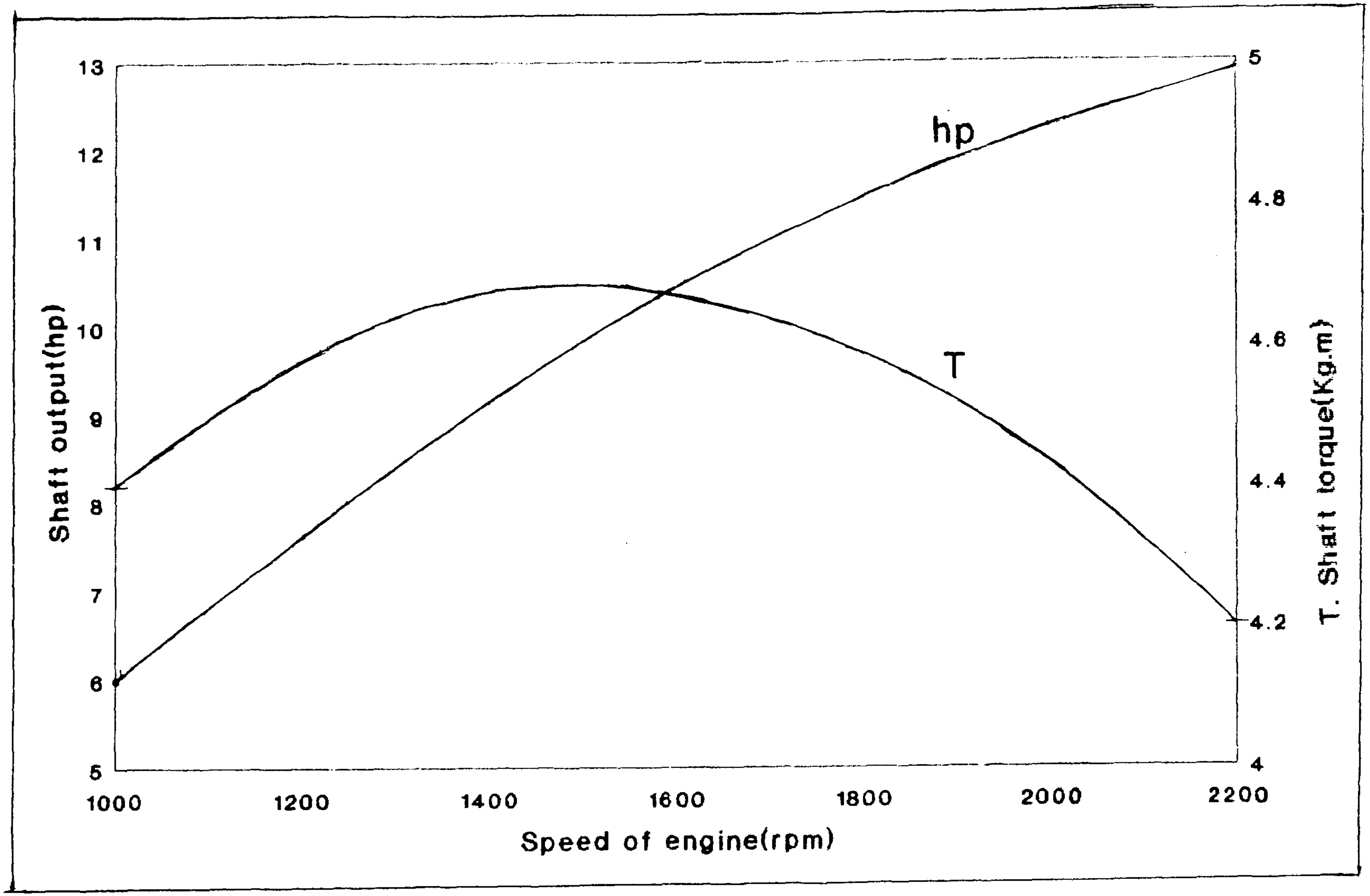


Fig.13 Performance curve of KAMCO ER-90 engine.

4.6. Selection of Belts

4.6.1 Engine belt

The centre to centre distance of engine pulley and clutch pulley was 357mm. The diameter of clutch pulley was 250mm and engine pulley was 167mm. A set of three numbers of B 52/1370 belts were selected and used.

4.6.2. Selection of belts for the reaper

4.6.2.1 Selection of pulley

Paddy crop was expected to be harvested both from the dry fields as well as from wet clay fields, according to the season and location. Hence the power transmission was developed to accommodate the correct forward speed, cutterbar speed, the ratio between forward speed and cutterbar speed as well as engine speed to match the varying field requirements. The speed for reaper shaft was selected by the low and high lever of the rotary drive. The minimum rotavator shaft speeds of 134rpm and 194rpm were obtained for low and high rotary selection with the engine speed of 1000rpm. The corresponding maximum rotar shaft speed of 268rpm and 388rpm were obtained at low and high rotary selection, when the engine speed was increased to 2000rpm.

The KAMCO powertiller was operated in the field to suit the walking speed of the operator by selecting appropriate forward gear corresponding to engine speed. A speed of 0.85 to 1.00m/sec was found to be the suitable walking speed in the field. For matching the various field conditions the engine speed was also to be varied for getting enough power for forward propullsion. When the soil condition was changing from dry sandy to wet clayey, for getting adequate power, the engine speed was increased from 1000 to 1800rpm. The optimum ratio between forward speed and cutterbar speed for harvesting cereal crop was kept in the range of 1:1.0 to 1:1.4.

4.6.2.2. Reaper belt

The power required by the reaper was estimated based on the maximum forward speed by the operator in the paddy fields with respective cutterbar speed. The maximum forward speed of the operator with the reaper was found 3.6kmph, with the corresponding cutterbar speed of 1.4m/sec. It was estimated that the 1.6m paddy reaper requires minimum power of 1.23hp for cutting and conveying operations. The engine was found to produce 7hp to 9hp when it was operated 1.6m paddy reaper requires a minimum power of 1.23hp for cutting and conveying operations. The engine was found to produce 7hp to 9hp when it was operated at a speed of 1100 to 1400rpm, which were the recommended operating speeds of the engine. The minimum torque 4.5kg.m is obtained at the engine speed 1400rpm.

The cutterbar driving shaft had two speeds *viz.* 215rpm and 310rpm for engine speed of 1800rpm. Since the usual operating speed of rotavator shaft is around 213rpm, it was considered for the selection of the reaper belt. The centre to centre distance between the driving rotavatory shaft and horizontal reaper shaft was 890mm. The diameter of the driver and driven pulleys were 150mm and 100mm respectively.

The maximum power for one V-belt was found as 1.58hp since the power required reaper is double for more for different working condition, we need two V-belts. The pitch length

2174mm. So two numbers of B-81/2100 belts were selected to transmit the power in the above condition, and also to take care of any unexpected load developed by the crop in the field.

4.7. Laboratory Studies

The 1.6 m width reaper-windrower was thoroughly examined before assembling it with the powertiller.

The registration of the cutterbar and alignment of various components and quality of fabrication of each unit were inspected and confirmed for its proper performance. Weights of individual components of the powertiller operated 1.6m reaper are given in Table 3. Details of materials used for the modification of the KAMCO powertiller to mount the 1.6m reaper is given in the Table 4. After carrying out all the necessary modifications on the KAMCO powertiller as described in section 3.13, the reaper was assembled with the combination frame. The time taken for dismantling the components from the powertiller and assembling the reaper components was found to be 6 hours. The total weight of the reaper with the powertiller was found as 451kg which is 34kg less than the original weight of the powertiller, with rotavator. The unit was run in the laboratory and the reliability of the individual components were observed.

4.7.1 Change in location of engine

The position of the engine of the powertiller was represented by the horizontal and vertical distances of the centre of starting shaft to the centre of wheel axle. In the original powertiller, prior to any modification, it was found

Table 3 Weight of individual Components of powertiller operated 1.6m reaper.

Sl.No.	Unit	Weight in kg
1	Engine	145.00
2	Reaper	81.00
3	Combination frame	20.00
4	Cage wheel (1 pair.)	46.00
5	Power transmission assembly with central gear case and left and right support	157.50
6	Handle strengthening unit	1.50
	Total weight	451.00

Table 4 Details of material used for the modification of KAMCO powertiller to suit the reaper.

Sl. no	Main parts	Size	Quantity	Cost (Rs.)
Power Transmission Unit				
1	Rotavator driving unit (central gear case assembly)	purchased from KAMCO	1 set	4800.00
2	Double grooved pulley	150mm	1 No.	189.00
3	Double grooved pulley	100mm	1 No.	126.00
4	V - Belt	B-52	3 Nos.	395.00
5	V - Belt	B-81	2 Nos.	375.00
		Machining Cost		1000.00
				6883.00
Combination frame				
1	m.s. Angle	60x60x6mm	1.5m	130.00
		40x40x6mm	1.4m	210.00
		35x35x4mm	1.1m	37.00
		30x30x3mm	0.9m	20.00
2	m.s. Flat	40x4mm	0.3m	7.00
3	m.s. Bar	dia.5mm	0.2m	6.00
		Fabrication cost		400.00
				810.00
Handle strengthening unit				
1	m.s. Pipe	32mm	2.0 m	150.00
2	m.s. Flat	30x2mm	1.0 m	12.00
3.	m.s. Angle	40x40x3mm	0.3m	9.00
		Fabrication cost		20.00
				191.00
		Total Cost		7884.00

that the centre of the starting shaft was 370mm horizontally infront and 410mm vertically above the centre of the wheel axle.

With the combination frame, after mounting the reaper and carrying out the required modifications, the new engine location for the statically balanced position was determined and the engine was mounted. At the new location of the engine, it was found that the horizontal distance between centre of starting shaft and centre of the wheel axle was reduced to 55mm by bringing the engine towards the wheel axle. The vertical distance between the centre of starting shaft and the centre of the wheel axle was increased to 590mm.

4.7.2. Change in location of centre of gravity of the engine

The centre of gravity of the engine was found to lie on the line passing vertically downwards from the point where the eye hook of the engine was fitted. Before modification of the powertiller, the centre of gravity of the engine was 430mm horizontally in front of the centre of the wheel axle. With the combination frame, the centre of gravity of the engine was found to pass vertically through the centre of wheel axle. In the new location the centre of gravity of the engine was raised to lie at a vertical distance of 180mm above its initial position. Fig.14 shows the assembled view of the KAMCO powertiller mounted reaper-windrower.

The following observations were made on the powertiller reaper during its laboratory trials:

1. in the static condition, the balancing at the handle was found to be perfect. The reaper was found to float upto 100mm above the ground but no load was felt at the handle.

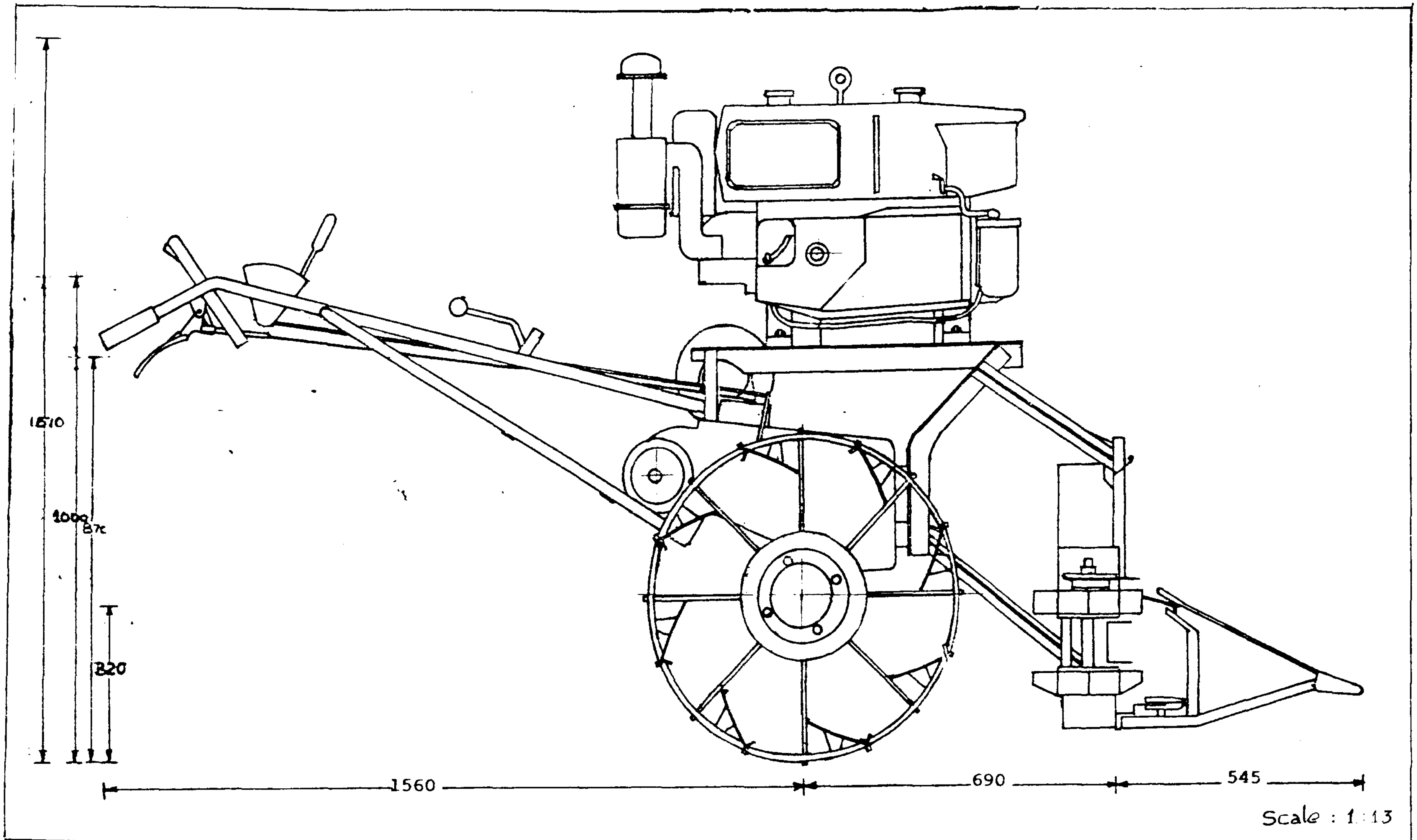


Fig.14 Assembled view of the KAMCO powertiller-mounted 1.6m vertical conveyor paddy reaper-windrower.

The powertiller with the reaper was found to move very easily in neutral gears before starting the engine, and there was no load experienced at the handle.

2. initial height of the starting shaft from the ground level was 710mm and in this position the operator feels free to bend forward for starting. After modification, when the engine was shifted to the new location on the combination frame, the height of the starting shaft from the ground level was increased to 890mm (an increase of 180mm). Because of the increased height, the operator had to start the engine in the standing position without having any forward bending. This decrease the effort transferred by the operator to the starting handle. The operator preferred starting the engine by standing on a 250mm platform and by getting support from the wheel through one of his legs.
3. the powertiller reaper was operated to move forward in low first and low second gears. It was observed that while releasing the clutch a part of the weight of the engine was transferred to the handles pushing the handle downwards. This is due to the inertia of the engine and the consequent moment created due to the increase in vertical height of the centre of gravity of the engine.
4. the reaction was of opposite nature when it was operated in the reverse gears. It was found that the handle was lifted upwards as a part of weight of the engine was transferred to the front due to inertia.
5. during forward motion a downward load of 5 to 7kgf on the handle was felt by the operator. This needed further balancing by changing the engine position in the forward direction.

6. the engine was shifted forward through a horizontal distance of 50mm from its position so that the horizontal distance of centre of gravity of the engine was shifted through 50mm forward from the centre of the wheel axle. The shifting counter acted the dynamic moment acting downward on handle.

The overall dimension of the powertiller reaper was found to be L: 2795 x W: 1550 x H: 1510mm. The powertiller was operated on the farm road for five hours and the fuel consumption was found to be 1.5 litres per hour. During the preliminary trials, the powertiller reaper was inspected for oil leak, wear and tear, vibrations, clearances on the moving parts and seating of individual components, performance of power transmission components and other controls. Adjustments and improvements needed were carried out. After the satisfactory performance of all the individual components, the powertiller reaper was evaluated in the actual field conditions.

The powertiller could be turned left or right completely by keeping the inner wheel stationary with the use of corresponding side clutch. This made the powertiller to have the minimum space for its turning. An area having a radius of 1.75m is found enough for the unit to take a complete turn.

4.7.3. Speed of cutterbar and conveyor belts

The cutterbar speed in terms of strokes per minute was calculated from the speed of horizontal reaper shaft. The stroke length of cutterbar was found to be 75mm. Since the speed of rotary driving shaft depend on the engine speed, the cutterbar speed increased with an increase in the engine speed. The method of calculating cutterbar and conveyor belt speeds are given in Appendix II. The values of linear speed of cutterbar and conveyor belts for both low and high speeds of rotavator lever selection for the engine speed from 1000rpm to 2000rpm observed in the laboratory trials is given in Table 5.

The minimum value of cutterbar speeds of 0.45m/sec and 0.67m/sec were obtained when the engine was operated at 1000rpm, for low and high rotavator speed selections respectively. When the engine was operated at 2000rpm the values were increased to 0.98m/sec and 1.40m/sec respectively.

The conveyor belt speed also found increased with the increase in engine speed. The linear speed of conveyor belt passing over 120mm diameter pulley was found to be 0.52m/sec and 0.80m/sec for engine speeds of 1000rpm for low and high rotavator speeds respectively. It was also found to increase to 1.17m/sec and 1.60m/sec respectively for engine speed of 2000rpm.

4.8. Field Experiments

Field trials of powertiller reaper was carried out at the Instructional Farm, Tavanur. The powertiller reaper was tested in the second crop season during the months of November and

Table 5 Linear speed Cutterbar and conveyor belt observed in the laboratory trial

		Throttle Setting, rpm					
		1000	1200	1400	1600	1800	2000
A.	Low Shift						
1	Rotary driving shaft, rpm.	120	155	175	268	213	261
2	Cutterbar speed, cm/sec.	45	58	66	75	80	98
3	Conveyor belt speed, cm/sec.	52	68	76	86	91	117
B.	High Shift						
1	Rotary driving shaft speed, rpm.	175	226	254	302	310	378
2	Cutterbar speed, cm/sec.	67	86	95	115	120	140
3	Conveyor belt speed cm/sec.	80	98	110	130	139	160

December, 1996 in the actual field conditions. When the field was found to be saturated with water not fully submerged.

Powertiller-reaper was operated in the field for 8hrs and the required minor adjustments such as knife clearances registration and alignment were incorporated. An area of 0.8ha was harvested continuously before the powertiller-reaper was subjected to field evaluations. Pneumatic wheels were fitted on the powertiller reaper for harvesting in partially wet fields, and cage wheel type II(Appendix-III) was used in wet fields. The following general observations were made during the long duration preliminary trials.

1. The powertiller mounted reaper was found to move forward without any difficulty, in the dry and wet paddy fields. No problem was experienced while negotiating the corners.

2. The cutting of the crop and the conveying of cut crop by the vertical conveyor reaper was found satisfactory.

3. After starting the engine at the time of releasing the clutch for forward movement and at the time of increasing the forward speed an increased load acted downward at the handles due to the moment of inertia of engine.

4.8.1 Field and crop conditions.

Field evaluation of the powertiller reaper was carried-out as per ISI (1985) and RNAM test codes. The actual cutting time, actual cutting distance, idle time, speed of different components, cutterbar and windrowing losses were noted during the field trials. The paddy fields of the Instructionals Farm were harvested by the reaper second crop season. Three paddy fields having size of 40x28m each, was selected. Red Triveni, which is a high yielding and short duration variety was the crop in all the three fields. The plant height varied in the range of 700mm to 1100mm with an average of 900mm in the fields. The crop was manually transplanted in a scattered fashion with an approximate plant spacing of 100mm x 150mm. The crop conditions in to plot are given in Table 6

4.8.2. Powertiller parametres

4.8.2.1. Forward Speed

Field observations of the powertiller mounted reaper for different engine speeds at all gear combinations are shown in Table 7. The forward speeds were calculated(Appendix IV) and are given in Table 8. The following were observed during the field test.

1. The powertiller reaper was found to operate satisfactorily and the operator felt comfortable to walk behind at low first gear with engine speeds of 1000 to 1800rpm.

2. At the engine speed of around 1000rpm, the reaper could be operated in the field for all the six forward speeds in low and high gear combinations.

3. The reaper could be operated in the low first as well as low second gears for engine speeds between 1000rpm and 1400rpm.

4. When engine speed was 1400rpm or more in which the forward speed was too high to walk behind.

Table 6 Details of crop conditions

Variety	:	Red Triveni
Susceptibility of shattering	:	Medium
Date of sowing	:	6-09-96
Date harvest	:	30-11-96 to 10-12-96
Average plant height	:	90mm
Tiller population Average No/sq.m	:	49
Moisture content of grain, (per cent wet basis)	:	18%
Moisture content of straw (per cent wet basis)	:	20
Average grain yield	:	3000kg/ha
Appearance	:	Straight

Table 7 **Field observations of powertiller operated vertical conveyor reaper windrower**

Sl No	Engine speed (rpm)	Forward Gear Selection	Actual distance travelled (m)	Actual time taken (Sec.)	Idling time (Sec.)
1	1000	LG I	26.3	61	20
		LG II	30.0	43	18
		LG III	23.1	26	17
		HG I	28.7	36	16
		H G II	20.7	22	16
		HG III	25.3	27	15
2	1200	LG I	24.5	46	15
		LG II	16.7	21	15
		LG III	22.3	19	14
		HG I	13.5	14	14
3	1400	LG I	19.1	32	14
		LG II	15.9	17	13
4	1600	LG I	7.1	10	13
5	1800	LG I	11.1	13	11

Table 8 **Forward speed of powertiller reaper in the field for different engine speeds and gear combinations.(m/sec.)**

Sl No.	Engine speed (rpm)	Gear combinations					
		LG I	LG II	LG III	HG I	HG II	HG III
1	1000	0.43	0.70	0.90	0.80	0.95	0.99
2	1200	0.53	0.79	1.20	0.96	-	-
3	1400	0.60	0.94	-	-	-	-
4	1600	0.72	-	-	-	-	-
5	1800	0.84	-	-	-	-	-

5. Engine speeds between 1200rpm and 1400rpm were found most suitable for harvesting in the field while the powertiller reaper was operated only with low first, low second and high first gears.

4.8.2.2. Rotavator speed selection

The rotavator driving shaft speed, cutterbar linear speed and conveyor belt speed for different engine speeds were observed in the field. The values of linear speeds of cutterbar and conveyor belt are given in Table 9. The performance of cutting and conveying was also observed.

The powertiller was operated for different engine speeds ranging from 1000 to 1800rpm at different forward gears for low and high rotavator speed selections, for experimental purposes. In the field, it was observed that the low cutterbar speed was not suitable to harvest satisfactorily even in low and high engine speeds, since the uncut loss was more than 10 percent. Moreover the power transmission system was developed to match the optimum continuous speed of the engine with the feasible forward speed and technically correct ratio between forward and cutting speeds as discussed in 4.6.2.1. The engine was operated below 1800rpm with a forward speed below 1m/sec. The minimum required linear speed of the cutterbar was achieved by operating it only in high rotavator speed selection.

4.8.3 Field observations

An average width of cut was observed as 1.5 m and height of cut was ranging from 70mm to 200mm. An average sinkage of 160mm in wet paddy fields was also observed. Plate III shows the side view of the KAMCO powertiller mounted reaper. The

Table 9 Linear speeds Cutterbar and conveyor belt observed in the field.

Sl.No.	Engine speed (rpm)	Rotovator speed (rpm)	Cutterbar speed (cm/sec.)	Conveyor belt speed (cm/sec.)
1.	1000	85	32	38
		125	47	56
2.	1200	112	42	50
		165	62	75
3.	1400	136	51	61
		192	72	86
4.	1600	160	60	72
		224	84	100
5.	1800	189	274	85
		272	102	122

field evaluation of the KAMCO powertiller mounted reaper is shown in plate.IV. Windrowing pattern of KAMCO powertiller mounted reaper can be seen in plate V. Plate.VI gives the long duration field evaluation of KAMCO powertiller mounted reaper.

4.8.3.1 Field capacity

Fields performance of powertiller reaper for different forward speeds is given in Table 10. The method of its calculation is given in Appendix V. The theoretical field capacity obtained was increasing with increase in forward speed. But at high forward speeds, the actual field capacity had not shown proportionate increase because of the increase in idle time for taking turnings and to clear the knife sections during field operation. This can also be observed from the fact that the increase in forward speed from 0.43 m per sec. to 1.20 m per sec. had decreased the field efficiency from 77 per cent to 51 per cent.

The high theoretical capacity of 0.691ha/hr was obtained for the high forward speed of 1.2m/sec and engine speed of 1200rpm at low III gear position. The maximum efficiency of 85 per cent was obtained for theoretical field capacity of 0.305ha/hr and actual field capacity of 0.259ha/hr at the engine speed of 1200rpm at low first gear (Table 10). The reaper was found to give satisfactory performance upto forward speed of 0.95m/sec. corresponding to 0.543ha/hr field capacity. For the recommended engine speeds of 1200 to 1400rpm, forward speed of 0.53m/sec to 0.95m/sec were obtained for low first and low second gear.

Plate.III Side view of KAMCO Powertiller mounted reaper.

Plate IV Field evaluation of KAMCO powertiller mounted reaper.

Plate V Windrowing pattern of KAMCO powertiller mounted reaper.

Plates VI Long duration field evaluation of KAMCO powertiller mounted reaper.

Table 10. Field performance of KAMCO powertiller-reaper in the field for different forward speeds.

Sl.No.	Distance travelled (m)	Total time (sec.)	Forward speed (m/sec.)	Actual field capacity (ha/hr)	Theoretical field capacity (ha/hr)	Field effi-ciency (%)
1	26.3	71	0.43	0.230	0.250	77
2	24.5	61	0.53	0.259	0.305	85
3	19.1	46	0.60	0.224	0.344	65
4	30.0	60	0.70	0.270	0.403	65
5	7.1	73	0.72	0.167	0.415	40
6	16.7	36	0.79	0.251	0.455	55
7	28.7	51	0.80	0.298	0.461	64
8	11.1	24	0.84	0.249	0.484	52
9	23.1	41	0.90	0.297	0.518	57
10	15.9	30	0.94	0.286	0.540	53
11	20.7	37	0.95	0.302	0.543	59
12	13.5	28	0.96	0.360	0.547	48
13	26.3	42	0.99	0.338	0.570	59
14	22.3	34	1.20	0.354	0.691	51

Fig.15 Shows the variation in theoretical field capacity, actual field capacity and field efficiency of powertiller operated reaper with various forward speeds.

4.8.3.2 Grain losses

The crop left in the field after machine harvesting was manually harvested for three randomly selected one square metre for each gear combination for different engine speeds. The crop was then threshed and weighed. The windrowing loss was also taken for three randomly selected one square metre area for each gear combination for different engine speeds were foundout in the field. A sample calculation for total grain loss is shown in Appendix-VI. The values are given in Table 11. The total losses were observed high for the low cutterbar speeds(rotavator speeds), due to the low ratio of cutterbar linear speed to the forward speed. The low ratio of cutterbar speed to forward speed is found responsible for the high uncut loss due to insufficient impact force. It was also found that even with increased cutterbar speed, it was not possible to operate the reaper in high forward speeds *ie.*, for high first gear onwards due to the reduction in the ratio of cutterbar speed hence low impact force for the high density feed to the reaper. This contributed the total grain loss in the field.

Fig.16 shows the effect of forward speed on average total grain loss by keeping the cutterbar speed constant. It was observed that the losses were decreasing for high engine speeds with high rotovator gear selection, as the uncut losses were reduced. By way of increasing engine speed and high rotovator speed selections the ratio of cutterbar to forward speed is increased. This reduced the total grain loss.

Table 11 Total grain losses obtained in the field for different forward speeds.

Sl. No.	Forward speed (m/sec.)	Reaction of the handle (kg)	Rotavator speed (rpm)	Cutterbar loss (gm/m^2)	windrowing loss (gm/m^2)	Total loss (%)
1	0.43	8.0	85	120.75	1.00	40.00
			125	2.52	1.00	1.20
2	0.53	9.0	112	6.00	1.80	2.60
			165	2.20	1.90	1.40
3	0.60	12.0	136	7.50	2.10	3.10
			192	2.10	1.00	1.00
4	0.70	10.0	125	9.10	2.70	3.00
5	0.72	15.0	160	4.12	1.88	2.00
			224	2.13	1.00	1.10
6	0.79	12.0	165	5.60	1.20	2.20
7	0.80	12.0	125	6.00	3.80	3.30
8	0.84	14.0	189	7.20	1.20	2.80
			272	1.80	1.80	1.20
9	0.90	13.0	125	10.80	2.00	4.20
10	0.94	14.0	192	4.50	1.00	1.80
11	0.95	13.5	125	12.80	2.80	5.10
13	0.96	15.5	165	4.50	3.10	2.80
14	0.99	16.0	125	14.00	10.10	8.00
15	1.20	17.0	165	19.00	9.80	9.60

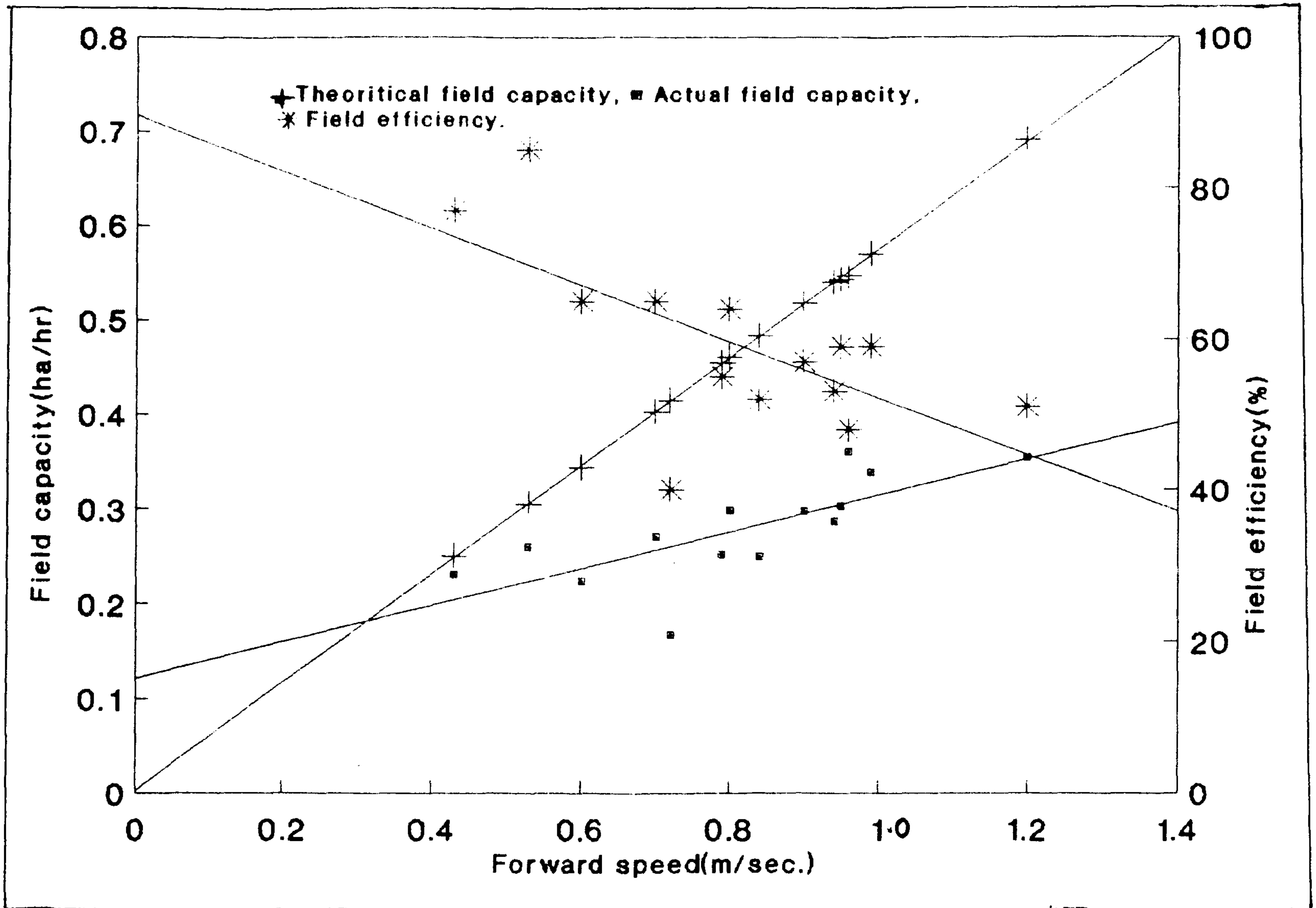


Fig.15 Variation in theoritical field capacity, actual field capacity and Field efficiency with forward speed.

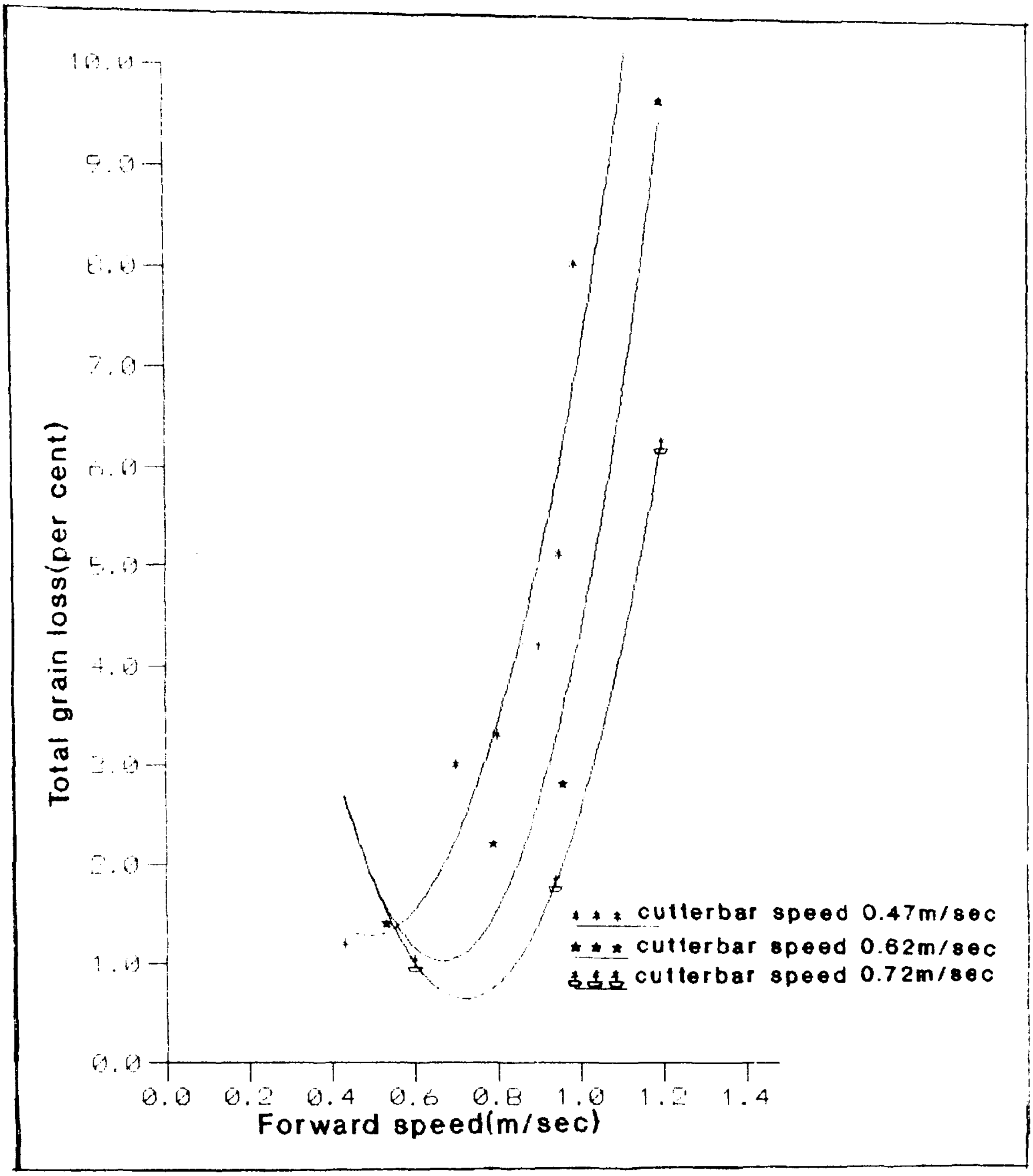


Fig.16 Variation in total grain loss with forward speed at constant cutterbar speeds.

Fig.17 shows the variation of total grain loss for all the operated forward speeds. The lowest average grain loss of 1.6 per cent was recorded when the powertiller reaper was operated in low first and low second gears and high cutterbar speeds (0.51 and 0.60m/sec) at the engine speed of 1200 to 1400 rpm.

4.8.3.3 Handle reaction

Handle reaction at the time of releasing the clutch was found increasing from 8 kg with increased forward speed due to inertia of the engine as discussed in section 4.7.3. For steady forward speed the reaction at the handle which was at the operating height was found to be negligible. But at sudden acceleration, the load on the handle found increased. The operator can afford to take care of the sudden downward effort when the forward speed is within the range of 0.53 to 0.70m/sec. This was well achieved with the engine speed of 1200 to 1400 rpm in the field in low forward gears.

Fig.18 shows reaction at the handle of the powertiller reaper for different forward speeds. The handle reaction was found to be varying from 9 to 14 kgf for forward speed of 0.53 to 0.95m/sec in the field. The handle reaction increased with the increased forward speed.

The lifting of the handle due to sudden retardation was not felt at the handle as the front mounted reaper was found resting on the ground.

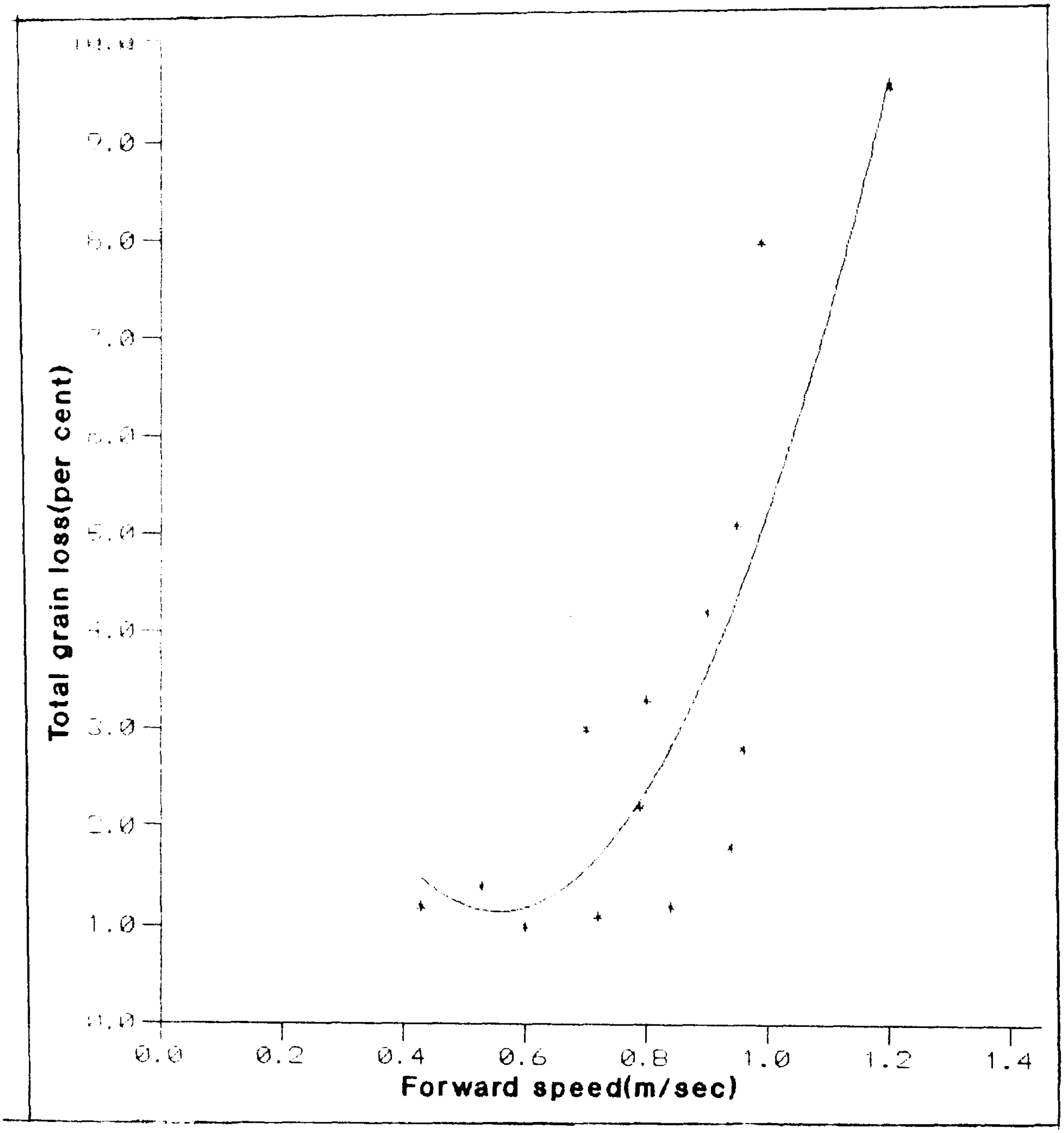


Fig.17 Variation in total grain loss with forward speed.

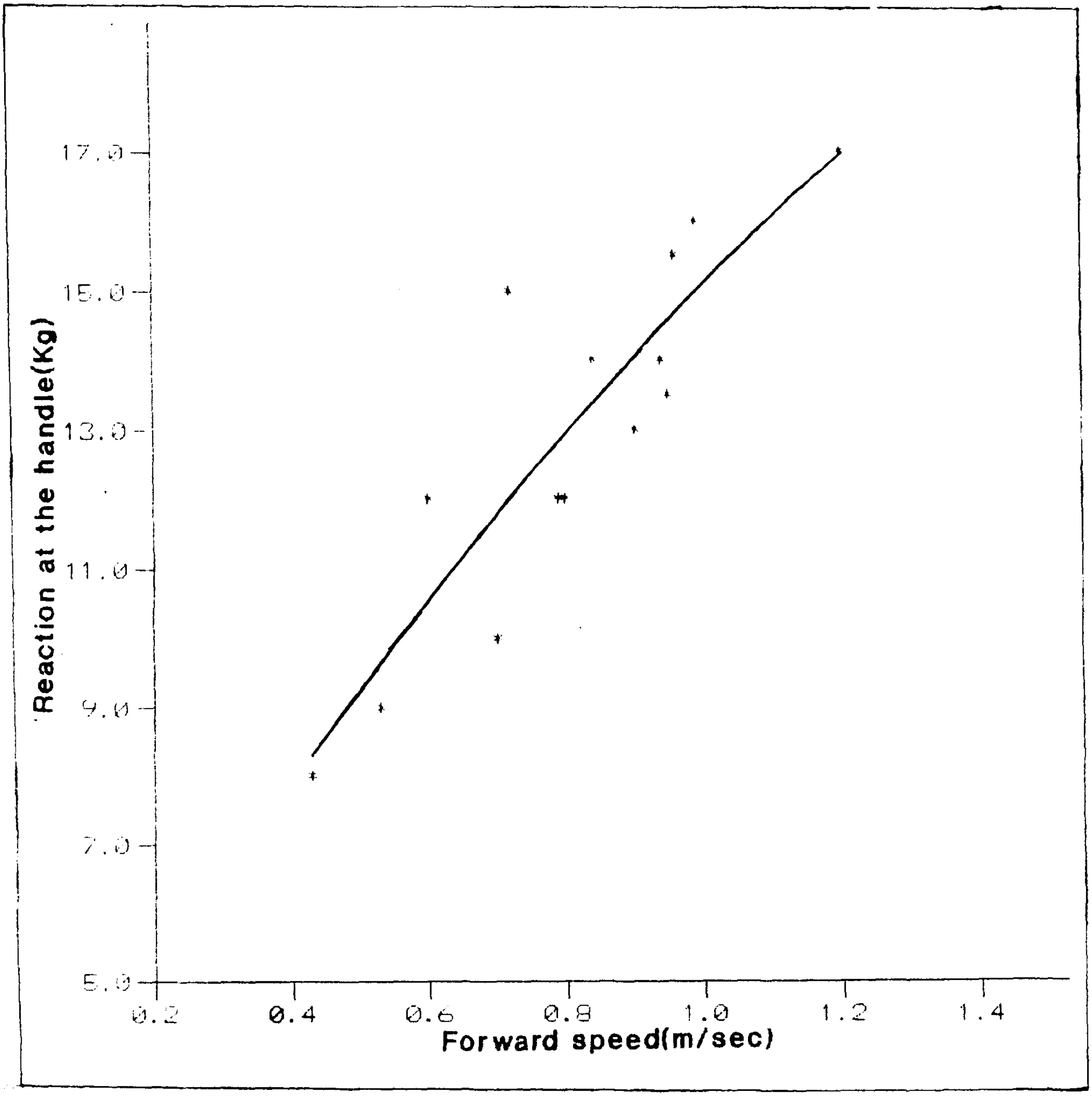


Fig.18 Reaction at the handle of powertiller reaper for different forward speeds.

Thus for the recommended engine speeds of 1200 to 1400rpm, low forward gears were recommended. For forward speeds of 0.53 to 0.90 m/sec the effort on the handle was found increasing from 9 to 14Kgf downward.

4.9 Labour Requirements

The lowest field capacity of 0.24 ha per hr. for the recommended forward speeds were selected for calculating the labour requirements for harvesting with powertiller reaper as shown in Appendix VII. This lowest field capacity was obtained by operating the reaper in the low first gear with the lowest recommended engine speed of 1200rpm.

For cutting and laying the crop, a labour requirement of 14 man hrs per ha was needed for machine harvesting compared to 175 man hrs per ha for manual harvesting. It was noted that for reaping alone about 92 per cent labour saving was achieved. A labour requirement of 20 man hrs per hectare is needed for bundling, gathering and transporting to one corner. Hence the total labour requirement for powertiller reaper harvesting is calculated as 34 man hrs per hectare, when compared to 195 man hrs per hectare for manual harvesting (Table.12).

4.10 Economic Analysis.

The cost of harvesting paddy manually was calculated as Rs.1830 per hectare as shown in Appendix VIII. The cost of harvesting by powertiller reaper was Rs.620/ha and is shown in Appendix VIII. Fig.19 shows the percentage distribution of cost of skilled labour, unskilled labour, fixed cost and other variable cost for harvesting with powertiller reaper by the owner. The

Table 12 **Labour requirement for paddy harvesting by powertiller reaper and manual methods.**

	Machine harvesting, man hrs/ha	Manual harvesting man hrs/ha
a) Reaping	14	175
b) Gathering bundling and transporting to one corner of the field	20	20
Total	34	195

owner of the powertiller reaper could harvest paddy for Rs.620/ha. In case of hiring the powertiller reaper at a rate of Rs.150 per hour, the farmer could harvest paddy at the cost of Rs.950/ha. Thus the farmer would get a monetary benefit of Rs.880/ha compared to manual harvesting. The owner of the powertiller reaper will get a profit of Rs.74/hr or Rs.333/ha by way of giving it on custom hiring.

Fig 20 gives labour requirements and cost of opeartion of powertiller reaper compaired with manual harvesting mathod. It indicates that the total labour which is the non-productive input in agriculture was reduced from 195 man-hrs/ha to 34 man-hrs/ha by the powertiller reaper. The farmer could reduce the cost of harvesting from Rs. 1830/ha to Rs. 950/ha by the introduction of the reaper.

4.10.1 Break even analysis

The powertiller modified for the reaper was only used for harvesting. The harvesting season in Kerala itself is not very short as the crop was raised based on the onset of monsoon starting from south to north.

By moving from one region to another the reaper can easily be engaged for harvesting paddy during the three harvesting seasons, amounting more than 1000 hours of operation per year.

Break even analysis carried out for the reaper is shown in Appendix IX. The cost of maintaining the reaper would be paid back if the machine is operated for atleast 48 hectare or for a period of 218 hours. Hence it is recommended that the owner is expected to operate the reaper for more than 27 days per year to start getting profit out of it.

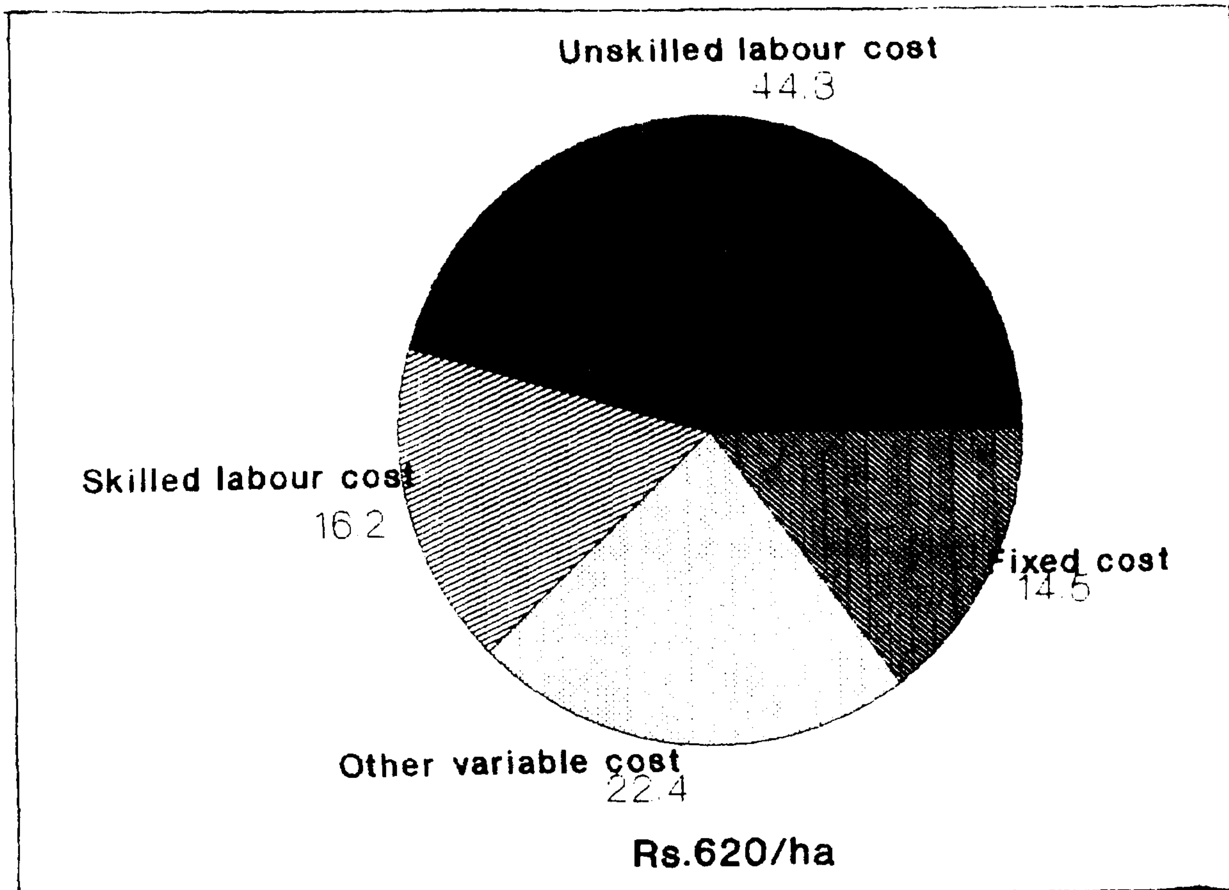


Fig.19 Percentage distribution of operating cost of powertiller reaper by the owner.

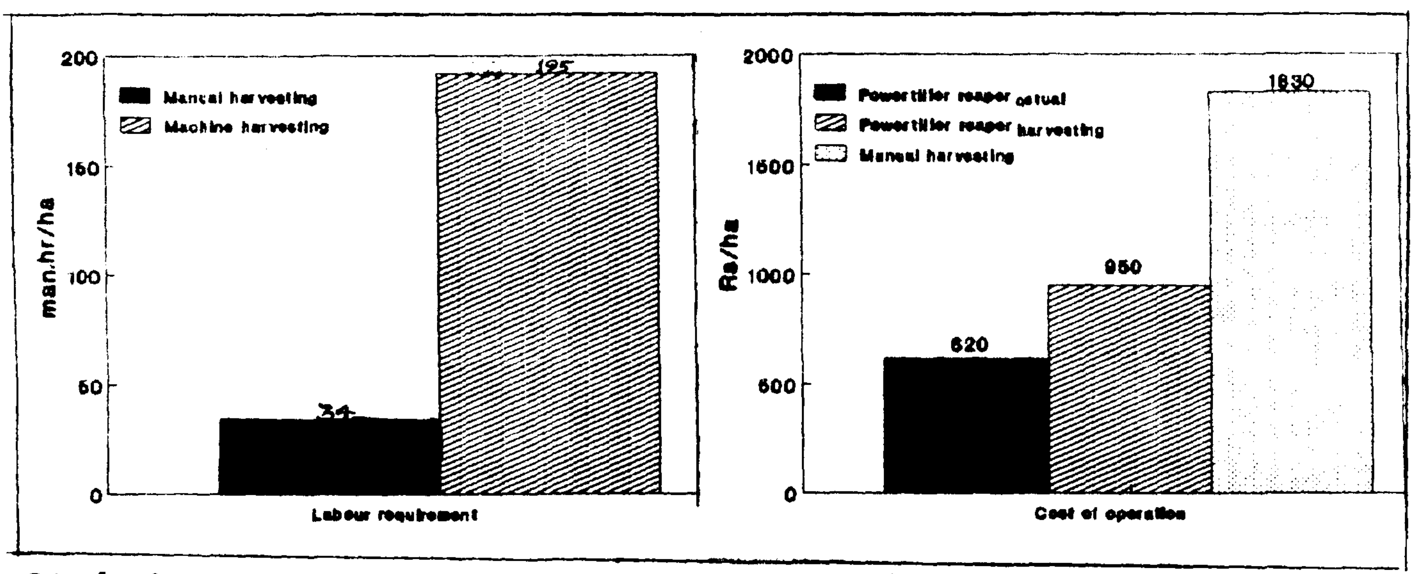


Fig.20 Labour requirement and cost of operation ofpowertiller reaper compared with manual harvesting method.

4.10.2 Pay back period

The pay back period analysis (Appendix-IX) shown that the total investment (Rs.1,16,500) of powertiller reaper was reimbursed to the investor within two years of introduction of the reaper by operating it for atleast 1000 hours per year.

The powertiller operated vertical conveyor reaper is found to perform satisfactorily in wet as well as in dry paddy fields. The machine could profitably be used in Kerala by the farmers either by owning or self use or by custom hiring. The machine has great potential for its introduction in the state on custom hiring basis.

SUMMARY

SUMMARY

Paddy is the major cereal crop in Kerala. The area under paddy has decreased at the rate of 2.48 per cent per year during the last two decades. The acute shortage of labourers forced the paddy farmers either to cultivate alternative crops or to leave it fallow. The introduction of labour and time saving machinery for paddy cultivation has thus become necessary. As harvesting is one of the labour intensive farm operations, introduction of an appropriate paddy harvester suitable for local condition is highly felt.

As the majority of farms in Kerala are small or medium in size, the powertillers are the appropriate machine for paddy cultivation. The development of a powertiller mounted reaper was taken up as it will increase the annual usage of the powertiller.

The KAMCO 9hp powertiller is most popular in Kerala. After considering the maneuverability, weight distribution, field capacity and power transmission, the 1.6m width reaper was selected for front mounting with the powertiller. It required 3.2hp for normal operation in the field.

The reaper unit had a reciprocating cutterbar with 21 knife sections, a pair of conveyor belt and 6 crop dividers. Modifications on the powertiller for fixing the reaper in front included the substitution of engine chasis and foundation blocks with a newly designed combination frame, so as to bring the centre of gravity of the engine very close to the wheel axle. The combination frame also facilitated to mount the

reaper in front of the wheels very closely. The complete rotavator unit is dismantled and a newly designed power transmission unit was fitted.

The combination frame is developed to accommodate the engine and the reaper at the most appropriate location, to achieve the static and dynamic balancing during field operation. The ideal location of the engine of the combination frame was decided. The centre of gravity of the engine which was originally at a distance of 430mm in front of the wheel axle is brought to 50mm in front of the wheel axle. The engine is also lifted vertically to a height of 180mm from its original plane.

Instead of taking power directly from the engine to the reaper, a new power transmission system is developed by modifying the rear transmission assembly for achieving a reduced speed and to have separate controls to operate the reaper. The left supporting arm was removed and instead a plug is provided. The right supporting arm and the rotary driving shaft are modified to transmit the power by a 150mm diameter double groove B-section pulley to the reaper. The power transmission unit was developed to achieve the recommended ratio of 1:1.0 to 1.4 between the forward speed and cutterbar speed.

The power developed by the KAMCO ER-90 was enough for the operation of the reaper in the field when the engine was operated from 1100rpm onwards. The forward speed between 1200rpm and 1400rpm at low first and low second gear is found feasible for the operator to work as well as to achieve the ratio between forward speed and cutterbar speed by selecting high rotary lever during its laboratory trials. A downward handle reaction of 4 to 7kgf is observed during laboratory trials.

Field evaluation of the reaper is successfully carried out for harvesting Red Thriveni variety of paddy during November and December, 1996 at KCAET farm, Tavanur. Pneumatic as well as cage wheel type II are used depending on the field conditions. For the recommended speeds of 1200 to 1400rpm at low first and low second gears a forward speed of 0.53 to 0.90m/s is obtained in the field. The actual cutting width is found as 1.5m. The maximum field efficiency of 85 percent is obtained for low first gear when the engine rpm is 1200. Actual field capacity for this speed is 0.224 ha/hr.

The maximum actual field capacity for recommended speed of 1400rpm with low second gear selection is found as 0.286 ha/hr. It is seen that for the recommended engine speed between 1200 to 1400rpm a normal forward speed between 0.53 to 0.94m/sec is obtained with an average actual field capacity of 0.25ha/hr.

For the recommended engine speed the average total grain loss of 1.9 percent was obtained in the field. Downward handle reaction for the recommended forward speed between 0.53m/sec and 0.94m/sec varies in the field between 9 to 14kgf.

Using this reaper 82.5 percent of labour can be saved. The owner of the power reaper would get a profit of Rs.1210/hr, while a farmer would get a saving of Rs.830/hr on hiring compared to manual harvesting. The initial investment of the owner would be paid back within 2 years. The owner of the reaper will also get a net profit of Rs.333/ha by hiring out to others, when the reaper is operated atleast 1000hrs per year.

The cost of maintaining the powertiller will be met if the powertiller is used to harvest atleast 48ha of paddy per year.

The overall dimensions of the powertiller reaper are L:2795 x W:1650 x H:1510mm and it weigh 451kg. The total cost is Rs.1,16,500.

The powertiller reaper is found technically and economically suitable for harvesting paddy which needs further studies on the combination frame to reduce the handle reaction.

REFERENCES

REFERENCES

Amjad,N. and Clough, D.G. (1993). Field Performance Evaluation of Rice Reaper. ***AMA***. **14**(4): 35-40.

Aribi, K. and Salleh, Y.(1988). Cost of Using Power Reapers-Malaysian Experience. ***AMA*** . **19**(3):53-54.

Bhatnagar, A.P. (1969). Development of Animal drawn Reaper with Engine Driven Knife bar. ***Indian Journal of Agricultural Science*** . **39**(1):105-112.

Chauhan, A.M. and Kalkat, H.S.(1976). Development and Evaluation of Tractor Rear Mounted Reaper Binder. ***J. Agric. Engng.***, **13**(2):64-67.

Chinnaswami, R.(1983). Design and Development of Reciprocating Type Forage Harvester. An unpublished B.E.(Ag.) Project. TNAU, Coimbatore.

Datta, R.K. and Datta, A.C.(1996). Feasibility trials of Vertical Conveyor Reaper Harvester. Proceedings of Co-ordination Committee meeting of AICRP on FIM. June 14-16, IIT Kharagpur Centre

Deshpande, J.S., R.T Jadhav and M.B. Shingate (1996). Performance Evaluation of VCR for Harvesting Paddy and Wheat. Proceedings of Co-ordination Committee Meeting of AICRP on FIM. June 14-16, K.V. Pune Centre.

Devnani, R.S. (1980). ***Harvesting Equipment Development in India***. CIAE. Bhopal.

Devnani, R.S. and Howson.D.F.(1981). A width of cut Analysis of a Vertical Conveyor Cereal Reaper for Indian Farms ***AMA*** . **11**(1):19-25.

Devnani, R.S and Pandey. M.M(1982). Design Development and Performance Evaluation of a Reaper with Vertical Conveying System. Annual Report, 1982-83,CIAE,Bhopal:34-53

Devnani,R.S. and Pandey, M.M.(1984). Development and Field Evaluation of Vertical Conveyor Reaper Windrower.***J. Agric. Engng.*****21**(4): 8-17

Devnani.R.S. and Pandey, M.M.(1985). Design Development and Field Evaluation of Vertical Conveyor Reaper Windrower. ***AMA*** . **16**(2):41-52

Devnani,R.S.(1988.a). Harvesting systems and Historical Development of Mechanical Harvesters in India. Proceedings of National training course on Farm Machinery Product Development for manufacturing. Phase II,CIAE, Bhopal.

Devnani,R.S.(1988.b). A width of cut Analysis of Vertical Conveyor Cereal Reaper for Indian Farm. ***AMA*** . Autumn:19-23.

Farm Guide(1977).***Farm Information Bureau*** . Govt. Of Kerala.

Farm Guide(1980). ***Farm Information Bureau*** . Govt. Of Kerala

Farm Guide(1985).***Farm Information Bureau*** . Govt. of Kerala

Farm Guide(1986). ***Farm Information Bureau*** . Govt. of Kerala

Farm Guide(1990).***Farm information Bureau*** . Govt. Of Kerala

Farm Guide(1992).***Farm information Bureau*** . Govt. of Kerala.

Farm Guide(1994).***Farm information Bureau*** . Govt. of Kerala.

Farm Guide(1995).***Farm information Bureau*** . Govt. of Kerala.

Farm Guide(1996).***Farm Information Bureau*** . Govt. of Kerala

Garg,I.K., Sharma,V.K. and Santhosh Singh(1984). A Powertiller mounted Vertical Conveyor Reaper Windrower. ***AMA*** . **15**(3):40-44.

Garg,I.K.and Sharma,V.K. (1991). Tractor Operated Vertical Conveyor Reaper Windrower. ***Indian Farming*** . **40**(11):32-36.

Garg,I.K. and Mahal, J.S. (1996). Development and Field Evaluation of Forage Harvesting Equipment for Small and Medium Farmers. Proceedings of Co-ordination Committee meeting of AICRP on FIM. June 14-16, Ludhiyana.

ICAR (1997). Annual Report of DARE, New Delhi. 116

Indian Express (1994). KAMCO Launching new Reaper. News Report (15.12.1994). Kochi, 5-6.

ISI (1979) Indian standard guide for Estimating Cost of Farm Machinery Operation. Indian Standard Institute, New Delhi.

ISI (1985) Indian Standard test code for cereal Harvesting machines. Indian Standard Institution , New Delhi.

KAU (1991). Research Report. Trichur, 1990-91.

O'dogherty, M.J. and Gale, G.E. (1991). Laboratory studies of the Effect of Blade parametres and Stem Configuration on the Dynamics of cutting Grass. ***J. Agric. Engng Res.***, **49**:99-111.

Prasad, J. And R.S. Devnani (1996). Development and evaluation of riding type self propelled reaper-windrower. Proc. Of AICRP on FIM, Jan. 10-13:22-24.

Rahman, Z.U. (1985) Small scale Farm Equipment for Developing Countries. Proceeding of International conference on small Farm Equipment for Developing Countries. 2-6 sept. 1985. the International Rice Research Institute, Manila Philippines

Rajput, D.S. and Bhole, N.G. (1973) Static and Dynamic Shear properties of paddy stem, ***The Harvestor***. **15** : 17-21

Ranganna, B. (1986). Design and Development of Push type Vertical Conveyor Reaper. M.E. (Ag.) Thesis. TNAU, Coimbatore

Rangaswamy, K. (1981). Design and Development of windrow type paddy Harvester as an attachment to low cost Wheel Tractor. Unpublished M.E. (Ag.). Thesis, TNAU, Coimbatore.

RNAM (1983). ***Test codes and Procedure for Farm Machinery.*** Technical series No. 12 : 207-225

Selvan, P. (1995). Evaluation and Modification of Powertiller operated Paddy Reaper. Unpublished M.Tech. (Ag.). Thesis, KAU, Tavanur.

Shanmugham, A. and Boopalan, R. (1982). Development of Vertical Conveyor Reaper for Paddy. Annual Report, College of Agric. Engng. TNAU, Coimbatore.

Sindhu, S.A. (1987). Effect of selected parametres on the performance of Vertical Conveyor Reaper Windrower. Unpublished M. Tech. Thesis; PAU, Ludhiyana.

Singh, G., Amjad, P. Chaudhery and David Clough (1988). Performance Evaluation of Mechanical Reapers in Pakistan. ***AMA*** **19**(3):47-52

Singh, L.J. and Singh C.P. (1978). Studies on cutting force requirements and shattering losses incurred in Harvesting of Wheat. ***J. Agric.Engng.*** **15**(1):11-18.

Singh T. P. and B.Singh (1995). Design and Development of an Animal-drawn Engine Operated Reaper. ***AMA*** . **26**(2) : 29-34.

Sinha, A.K., Dabral, P.P. and Pramod Kumar. (1996). Feasibility testing of self-propelled reaper for Harvesting Crops. Proceedings of Co-ordination Committee meeting of AICRP on FIM. June 14-16, BAU, Ranchi.

Sivaswami, M. (1994). Evaluation of Vertical Conveyor Reaper for Paddy. Annual Report 1993-94 of AICRP-FIM Scheme, KAU Tavanur.

Sivaswami, M. and Sujatha E. (1995). Optimum operating parametres of Tractor mounted Paddy Reaper in wet lands. Annual Convention. Indian Society of Agricultural Engineers, December 28-30, Trichur : FPM : 95-104.

Sujatha, E. (1993) Studies on Tractor Mounted Paddy reaper. Unpublished M.Tech. Thesis, KAU, Tavanur.

Sushilendra (1996). Dynamics of power transmission in Tractor Mounted Paddy Reaper. Unpublished M. Tech. Thesis, KAU, Tavanur.

Tajuddin, A. (!996). Development of attachments for self-propelled paddy reaper. Proceedings of Co-ordination Committee meeting of AICRP on FIM. June 14-16. TNAU, Centre.

The Hindu (1995) A small mechanical Rice Harvester. News report (24.05.1995) : 26.

Trivedi, O. N. and Arya, S. V. (1966). Harvesting and Threshing - an analysis. The Agricultural Engineer, Vol.II, Annual Publication of the Agric. Engng. Society, Allahabad Agric. Institute: 42-45.

Volentino, T. and I.L. Dietro (1982). Design and Development of CAAMS - IRRI Reaper Handout Sheet. IRRI Philippines.

Yadav, R.N.S. (1988) Design and Development of Bullock Drawn Reaper. Proc. Of National Training Course on Farm Machinery Product Development for Manufacturing phase II, CIAE, Bhopal.

Yadav, R.N.S. and Yadav, B.G. (1991). Design and Development of CIAE Bullock drawn reaper. ***Indian J. of Agric. Engng.*** **1**(2) : 75-80.

APPENDICES

APPENDIX - I

Annual production of KAMCO powertiller

Sl.No.	Year	No. Of powertiller
1	1991	3000
2	1992	3420
3	1993	3860
4	1994	4260
5	1995	4700
6	1996	5100

APPENDIX - II

Calculation of linear speeds of cutterbar and conveyor belt

Cutterbar linear speed (m/sec). $= \frac{\text{speed of horizontal reaper shaft (rpm) X stroke length(cm) X 2}}{60 \times 100}$

$= \frac{180 \times 7.5 \times 2}{60 \times 100}$

$= 0.45$

Conveyor belt linear speed(m/sec.) $= \frac{\text{Speed of vertical reaper shaft (rpm) X } \pi \text{ X diametre of conveyor pulley (cm)}}{60 \times 100}$

$= \frac{82 \times \pi \times 12}{60 \times 100}$

$= 0.52$

APPENDIX - III

Specifications of cage wheel Type II

Outer diametre	:	720mm
Inner diametre	:	250mm
Total width	:	320mm
Weight	:	24Kg
Availability	:	Kerala AgroIndustries Corporation Kerala

APPENDIX-IV

Calculation of forward speed

Forward speed(m/sec.) $= \frac{\text{Distance travelled (m)}}{\text{Actual time taken (sec.)}}$

$= \frac{26.3}{61}$

$= 0.43$

APPENDIX - V

Calculation of theoretical field capacity, actual field capacity and field efficiency

Theoretical field capacity (ha/hr)

$$= \frac{\text{Forward speed (m/sec.) X theoretical field cutting width(m) X 60 X 60}}{10000}$$

$$= \frac{0.43 \text{ X} 1.6 \text{ X} 3600}{10000}$$

$$= 0.25$$

Actual field capacity (ha/hr)

$$= \frac{\text{Distance travelled (m) X actual average width (m) X 60 X60}}{\text{Total time taken (sec) X 10000}}$$

$$= \frac{26.3 \text{ X } 1.5 \text{ X } 3600}{81 \text{ X } 10000}$$

$$= 0.23$$

Field efficiency(%)

$$= \frac{\text{Actual field capacity (ha/hr) X 100}}{\text{Theoretical field capacity (ha/hr.)}}$$

$$= \frac{0.23 \text{ X} 100}{0.25}$$

$$= 77$$

APPENDIX - VI

Calculation of total grain loss

Percentage total

$$= \frac{[\text{Cutterbar loss } (g/m^2) + \text{windrowing grain loss loss } (g/m^2)] \text{ X } 100}{\text{Average grain yield} (g/m^2)}$$

$$= \frac{(2.52 + 1.00)}{300} 100$$

$$= 1.2$$

Appendix - VII

Labour requirement for harvesting by manual and by KAMCO powertiller reaper

[i] Manual Harvesting

An average of 25 labour-days are required for cutting operation for an area of one hectare.

Considering 7 hrs. of continuos cutting in a day, the total man hours = 25 X 7

= 175 man hrs/ha.

[ii] Powertiller Reaper Harvesting

The lowest actual field capacity of powertiller reaper

= 0.224 ha/hr .

Time required to harvest one hectare $= \frac{1}{0.224}$

= 4hrs 30 mints.

Labour required for harvesting one hectare = 4.5man hrs/ha.

Labour required for harvesting the boundaries and clearing the field before harvesting for the powertiller reaper = 9 man hours/ha.

Total man hrs for powertiller reaper for one hectare

= 4.5+9.0

= 13.5 man hrs/ha.

≅ 14 man hrs/ha.

APPENDIX - VIII

Economic analysis of paddy harvesting

[i] Manual harvesting

Prevailing wage rate	=	Rs.75/labour day
Manual harvesting cost	=	Rs. $\frac{75 \times 195}{8}$
	=	Rs.1830/ha.

[ii] Harvesting with powertiller reaper

(a) Cost of powertiller with a pair of cage wheel and with out rotary unit	=	Rs.91500
(b) Cost of reaper	=	Rs.17000
(c) Cost of rotary driving unit	=	Rs.6883
(d) Cost of combination frame	=	Rs.860
(e) Handle Strengthening unit	=	Rs.191
(f) Assembling charge	=	Rs.120
Total cost [c]	=	Rs.1,16,504
	~	Rs.1,16 500
Life [L]	=	10 Years
Operating hours per year	=	1000 hrs.
Salvage value[s]	=	10% of initial cost.
	=	Rs.11,650

1. Fixed cost

Annual depreciation $= \frac{c-s}{L}$

$= \frac{116500-11650}{10}$

= Rs.10,485

Annual interest on investment

@ 10% of initial cost per annum = $\frac{1,16,500+11,650 \times 10}{2x100}$

= Rs.6407.50

Insurance @1% per annum = $\frac{1,16,500 \times 1}{100}$

= Rs.1,165

taxes = Nil

Housing cost @ 2%of initial cost = $\frac{1,16500 \times 2}{100}$

= Rs.2330

Total fixed cost/year = 20,387.50

Total fixed cost/hr = $\frac{20,387.50}{1000}$

= RS.20.39

2. Variable cost

Repair and maintenance cost
@ 5% of initial cost per annum = $\frac{1,16,500 \times 5}{100}$

= Rs.5,825

Fuel cost per annum
@12.9 per litres = 1.5 X 1000 X 12.9

= Rs.18,750

Oil cost per annum
(1/3 of fuel cost) = Rs.6250

labour cost per annum
@Rs 25 per hour = 25X1000

= Rs.25,000

Total variable cost per annum = Rs.55,825

Total variable cost per hour = $\frac{55,825}{1000}$

= Rs.55.83

Total operating cost of powertiller mounted reaper per hour

= Rs.20.39+55.83

= Rs.76.22

Time required to harvest one

hectare = 4.5hrs.

Cost of harvesting one hectare = 76.22 X 4.5

= Rs.342.99

~ Rs.340

Nine man hours are required for clearing the field and harvesting at the corners as well as near the boundaries. Cost of labour for clearing the field corners.

$= \frac{75 \times 9}{8}$

= Rs.84,38

= Rs.85/ha

20 man-hours are required for gathering, bundling and transporting the cut crop to the corners.

Labour cost of gathering, bundling and transporting

$= \frac{75X20}{8}$

= Rs.189.5/ha

~ Rs.190/ha

Actual cost of harvesting paddy with the powertiller reaper per hectare = 340+85+190

Total cost = Rs.620/ha

Harvesting by hiring

Hiring charge of tiller mounted reaper (assumed) = Rs.150/hr

Cost of harvesting one hectare = 150 X 4.5

= Rs.675

Cost of harvesting with the powertiller reaper by hiring per hectare = 675+85+190

= Rs.950

APPENDIX - XI

Specification of Spring Balance

make	:	Salter Spring balance
Range	:	100Kg
Accuracy	:	500g.

APPENDIX-XII

Specification of Hot air oven

make	:	Sri Rudran Instrument Co.
Temperature	:	250° C
Rating	:	18,0000w
Voltage	:	230 V
Sl.No	:	2360.10.91

APPENDIX-XIII

Specification of moisture metre

Name	:	Osaw Agro moisture
make	:	The Oriental Science Apparatus Workshop
accuracy	:	0.2 percent.
Range	:	8 to 40 percent.

APPENDIX - IX

Calculation of Break even point and Payback period

Break even point, (ha/year) = $\frac{\text{fixed cost Rs./year}}{\text{custom charge (Rs./ha) - variable cost (Rs./ha)}}$

$$= \frac{20,388}{675-(55.83X4.5)}$$

= 48 hectares/year.

Pay back period = $\frac{\text{purchase price (Rs.)}}{\text{Annual average net benefit (Rs/Year)}}$

$$= \frac{1,16,500}{(150X1000-76,22X1000)}$$

= 1.58 Years

= 1 year and 7 months.

APPENDIX - X

Specification of tachometre

make : Prestige counting Instruments P.Ltd. Bombay

Rpm range : 30-50,000rpm

APPENDIX - XI

Specification of Spring Balance

make	:	Salter Spring balance
Range	:	100Kg
Accuracy	:	500g.

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DEVELOPMENT OF POWERTILLER OPERATED PADDY REAPER WINDROWER

By

SHINY LUKOSE

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Technology in Agricultural Engineering

Faculty of Agricultural Engineering and Technology

KERALA AGRICULTURAL UNIVERSITY

Department of Farm Power, Machinery and Energy

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

1997

ABSTRACT

A vertical conveyor reaper-windrower suitable for mounting on KAMCO 9hp powertiller was developed Kerala for the first time. After considering the maneuvrability, weight distribution, field capacity and power transmission, the 1.6m width vertical reaper was selected for the KAMCO powertiller and was locally fabricated.

The complete rotavator unit was dismantled and a newly designed power transmission unit was fitted on the KAMCO powertiller. The handle was kept at an ergonomically suitable height of 1m. A combination frame was developed inorder to accommodate both the engine and the reaper at the most appropriate location to achieve the static and dynamic balancing during field operation after the removal of rotavator. The centre of gravity of the engine at the new location was 50mm in front of the wheel axle and at a height of 180mm from its original position.

Field evaluation of the reaper was carried out during November and December, 1996 at Tavanur. The front mounted reaper-windrower was evaluated to find out the optimum engine speed and forward speed to achieve better harvesting and windrowing pattern, maximum field capacity and field efficiency with less harvesting losses were found out. For the recommended engine speed of 1200 to 1400rpm at low first and low second gears a forward speed of 0.53 to 0.94m per sec. was obtained in the field. The actual cutting width was 1.5m. The maximum field efficiency of 85 per cent was obtained for first gear when the engine rpm was 1200. Actual field capacity for this speed was 0.224ha per hr.

It was seen that for the recommended engine speed between 1200 to 1400rpm a normal forward speed of 0.53 to 0.94m/sec was

obtained with an average actual field capacity of 0.25 ha/hr and an average total grain loss of 1.9 per cent in the field. Downward handle reaction for this recommended speeds varied between 9 to 14 kgf at the time releasing the clutch or using the accelarator.

By the use of powertiller reaper a labour saving of 82.5 per cent was obtained. The owner would get a monitory benefit of Rs.1210/ha while the farmer hiring the reaper would get a saving of Rs.830/ha compared to manual harvesting. The initial invest of the owner would be paid back within 2 years if he could hire it out for 1000hrs per year.

The total weight of the unit is 451kg which is 34kg less than the original weight the powertiller with rotavator unit. Its overall dimensions are L:2795 x W:1650 x h:1510mm and the total cost is Rs.1,16,500.

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