DEVELOPMENT AND TESTING OF A LARGE DIAMETER PIT DIGGER FOR LATERITE TERRAIN

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Technology in Agricultural Engineering

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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MALAPPURAM

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DECLARATION

I hereby declare that this thesis entitled ***"DEVELOPMENT AND TESTING OF A LARGE DIAMETER PIT DIGGER FOR LATERITE TERRAIN"*** *is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.*

Place : Tavanur

Date :

PREMAN, P.S.

CERTIFICATE

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SYMBOLS AND ABBREVIATIONS

Agrl	:	Agricultural
AMA	:	Agricultural Mechanization in Asia, Africa and Latin America
BSW	:	British Standard Whitworth
cm	:	centimetre(s)
Co	:	Company
DI	:	Direct Injection
Engg	:	Engineering
et al.	:	and others
etc.	:	etcetra
Fig.	:	Figure(s)
Fmg.	:	Farming
h	:	hour(s)
ha	:	hectare(s)
hp	:	horsepower
ICAR	:	Indian Council of Agricultural Research
i.e.	:	that is
kg	:	kilogram
kgf	:	kilogram force
kgf-cm	:	kilogram force centimetre
kgf/cm^2	:	kilogram force per square centimetre
kgf-m	:	kilogram force metre
kWh	:	kilowatt hour
L	:	Litre(s)
Ltd	:	Limited

SYMBOLS AND ABBREVIATIONS

m	:	metre
min.	:	minute(s)
mm	:	millimetre(s)
MS	:	Mild Steel
M/S	:	Messers
m/s	:	metre(s) per second
No.	:	Number(s)
P.C.D.	:	Pitch Circle Diameter
pp	:	pages
PTO	:	Power Take Off
PWD	:	Public Works Department
rpm	:	revolutions per minute
Rs	:	rupees
s	:	second(s)
Sl	:	Serial
sq. km	:	Square Kilometre(s)
viz.	:	namely
&	:	and
@	:	at the rate of
°C	:	degree centigrade
ϕ	:	diameter
"	:	inche(s)
/	:	per
%	:	per cent
π	:	pie

Chapter I

Introduction

INTRODUCTION

Tree crops occupy an important position in the agricultural scenario all over the world. Besides, trees are a vital component in the forest sector. Few of the tree crops grown in India are mango, coconut, rubber, cashew, and orange. Teak, rosewood, mangium, and acacia are some of the trees grown for obtaining timber. In India tree crops are grown in an area of about 4.3 million ha whereas 65.9 million ha is under forest cover. Trees grow in all types of soil stretching from sea coast to the top of mountains. Coconut palms (*Cocos nucifera*) are a common sight in the coastal area. These are also cultivated in the midland regions of Kerala and so also in the mountainous regions of the Western Ghats. Similarly, teak, rosewood, etc. are also grown in these regions.

Some of the trees like coconut palm and rubber thrive even in the laterite region. According to the cultural practices followed in cultivating these crops their seedlings are planted in large pits. These pits are often dug manually using spade, pickaxe and crowbar. As the population density of coconut palm ranges from 150 to 200 per ha and that of rubber 420 to 520 per ha large amount of human work force is required to make pits. It is estimated that a man of average health digs about three pits of size 1 m^3 in ordinary soils like sandy, alluvial, etc. in a day of 8 h. In the laterite region a person takes more than a day of 8 h to dig a pit of size 1 m^3. At the present wage rate of Rs. 120 per day existing in Kerala, the cost per pit ranges from Rs.40 to 140.70. The socio-economic changes in Kerala are driving the human work force away from the farm work. As a result farmers are finding it difficult to complete the pitting operation within a reasonable period of time. Besides, the exorbitant cost of digging is also discouraging the farmers. These problems can be solved to some extent by resorting to mechanization of pitting operation. The post-hole auger diggers available in the market are capable of making pits of diameter normally ranging from 150 to 600 mm and to a depth of 1000 mm. However, in hard laterite these auger diggers are found to be ineffective. Further, the pit size generally recommended for planting coconut seedlings in laterite is 1200 mm in diameter and 1200 mm in depth. By the same standards a cubicle pit must have a side of 1200 mm. A pit tapering to the bottom to a side of length 300 to 450 mm shall also suffice. To make pits of this size post-hole diggers are not recommended particularly in hard laterite.

However, mechanical laterite cutters are in use for cutting laterite stones (*vettukallu*) used in masonry works. Power tiller operated laterite cutters are used extensively in the northern parts of Kerala. Because of the limitations imposed, the power tiller operated laterite cutters cannot be used for making pits for planting coconut.

A twin-blade laterite cutter similar to the one attached to the power tiller, but mounted on a jib crane, attached to a tractor was conceived, as a solution to overcome the above problem. Based on this, the present study was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur with the following objectives:

1. to design and fabricate a large size pit digger suitable for laterite terrain,
2. to evaluate its performance in the field and
3. to evaluate the economics and operation of pit digger.

Chapter II

Review of Literature

REVIEW OF LITERATURE

A brief report based on the available literature on the studies relevant to the present investigation is presented in this chapter.

2.1 Origin and distribution of coconut palms

According to Thampan (1982), coconut palms are known to exist in most regions of the tropics from prehistoric times. Besides having a far wider spread in the humid tropical lowlands than many other useful crops, the coconut palm has a hoary antiquity in some of the countries. But, the original home of coconut is still not precisely known.

Major coconut growing countries of the world are found in Asia, Oceania, West Indies, Central and South America and East and West Africa (Thampan, 1982). In Asia, the major coconut growing countries are Indonesia, India, Philippines, Sri Lanka, Thailand and Malaysia.

2.2 Cultivation

As per the Package of Practices Recommendations of Kerala Agricultural University (1993), coconut requires an equable climate with high humidity. The ideal mean annual temperature is 27°C with 5-7°C diurnal variation. It is grown in different soil types such as laterite, coastal sandy, alluvial and also in reclaimed soils of marshy lowlands. The cultural practices adopted for coconut vary with climate and soil conditions. Generally, the coconut seeds are germinated in nurseries and then transplanted in the pits. The size of pits for coconut depends upon the type of soil and depth of water table. Normal pit sizes are shown in Table 2.1.

Table 2.1 Size of pits

Sl. No.	Description about soil type and presence of water table	Size of pit (mm)
1	Sandy soil	750x750x750
2	Loamy soil with low water table	1000x1000x1000
3	Laterite soil with underlying rock	1200x1200x1200

Source: Package of Practices Recommendations 'Crops' 1993, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala.

2.3 Area and production

Thampan (1995) has reported that India, with an area of 1.63 million ha and annual production of 12,355 million nuts, ranks second in the world among the coconut growing countries after Indonesia. According to Aravindakshan (1995), Kerala accounts for 54 per cent (8.81 lakh ha) of the total area and 45 per cent (5586 million nuts) of the total production in India. The state-wise area and production of coconut are shown respectively in Tables 2.2 and 2.3.

2.4 Occurrence and distribution of laterite

It is in Kerala at a place known as Angadippuram, that a ferruginous, vesicular, soft material occurring within the soil which hardens irreversibly on exposure and used as a building material, was first recognised as laterite by Francis Buchanan (Varghese and Byju, 1993).

Laterites are widely distributed in the semi-humid and humid intertropical regions of the globe (Maignien, 1966). In India, it is well developed on the summits of Decan hills, Karnataka, Kerala, the Eastern Ghats, West Maharashtra and central parts of Orissa and Assam. It occupies an area of 1,30,066 sq. km (Varghese and Byju, 1993).

Table 2.2 Area under coconut cultivation in India

Year	Area, ('000 ha)													Total ('000 ha)
	Andhra Pradesh	Assam	Goa	Karna-taka	Kerala	Mahara-shtra	Orissa	Tamil Nadu	Tripura	West Bengal	Andaman/ Nicobar Islands	Laksha Dheep	Pondi-chery	
1989-'90	59.0	9.8	23.5	226.3	832.2	7.8	32.6	225.9	7.0	19.8	23.8	2.8	1.7	1472.2
1990-'91	61.2	9.8	23.8	232.9	864.1	7.8	32.6	226.4	7.0	19.8	23.9	2.8	1.8	1513.9
1991-'92	63.4	13.6	24.0	238.6	846.3	7.9	36.4	240.3	10.5	19.2	24.1	2.8	1.8	1528.9
1992-'93	71.7	15.6	24.2	246.0	877.0	7.9	38.4	196.4	11.3	20.4	24.1	2.8	1.9	1537.7
1993-'94	79.9	15.6	24.2	252.2	881.6	7.9	38.4	270.3	11.3	21.1	24.4	2.8	1.9	1631.6

Source: Indian Nalikera Journal (1995), 24(10): 2-8.

Table 2.3 Coconut production in India

Year	Number of nuts, (in million)													Total (in million)
	Andhra Pradesh	Assam	Goa	Karna-taka	Kerala	Mahara shtra	Orissa	Tamil Nadu	Tripura	West Bengal	Andaman/ Nicobar Islands	Laksha Dheep	Pondi-chery	
1989-'90	654.8	78.9	107.5	1166.5	4357.6	108.3	182.0	2302.4	4.2	263.3	83.1	25.3	24.9	9758.8
1990-'91	730.6	78.9	110.0	1201.6	4527.3	109.0	182.0	2358.3	4.2	263.3	83.6	25.6	25.8	9700.2
1991-'92	959.2	94.3	110.0	1227.6	4206.1	121.5	214.4	2755.8	4.9	254.3	84.4	21.0	26.1	10079.6
1992-'93	1081.8	103.2	113.0	1269.7	5125.2	131.0	219.5	2771.1	4.9	285.1	84.4	21.0	31.0	11240.9
1993-'94	1103.5	103.2	113.0	1340.8	5586.4	148.5	219.5	3281.9	4.9	310.3	85.3	26.3	31.4	12355.0

Source: Indian Nalikera Journal (1995), 24(10): 2-8.

According to Raychaudhuri *et al.* (1963), the laterite terrain is widely located in the midland region of the state of Kerala (Fig. 2.1). As the state's economy, to some extent, depends upon this laterite terrain which produces a variety of cash crops like coconut, cashew, pepper, banana, etc. it can be considered as the backbone of the state (Jacob, 1979).

2.5 Equipment for preparing pits/holes

Perennial crops, like coconut, are planted in pits. The size of pits vary depending upon the crops being planted.

For planting coconut, the pit is often made manually using spade, crowbar and pickaxe. Manual method is effective in sandy and loamy soil areas, but tedious and time consuming in laterite soils. This problem becomes extremely severe in hard laterites.

Low cost and effective machines for digging pits for coconut are not available till now. But, mechanical devices such as post-hole diggers operated by means of engines, power tillers and tractors are available for making holes upto a diameter of 600 mm and a depth upto 1000 mm. However, these are found to be ineffective in laterites.

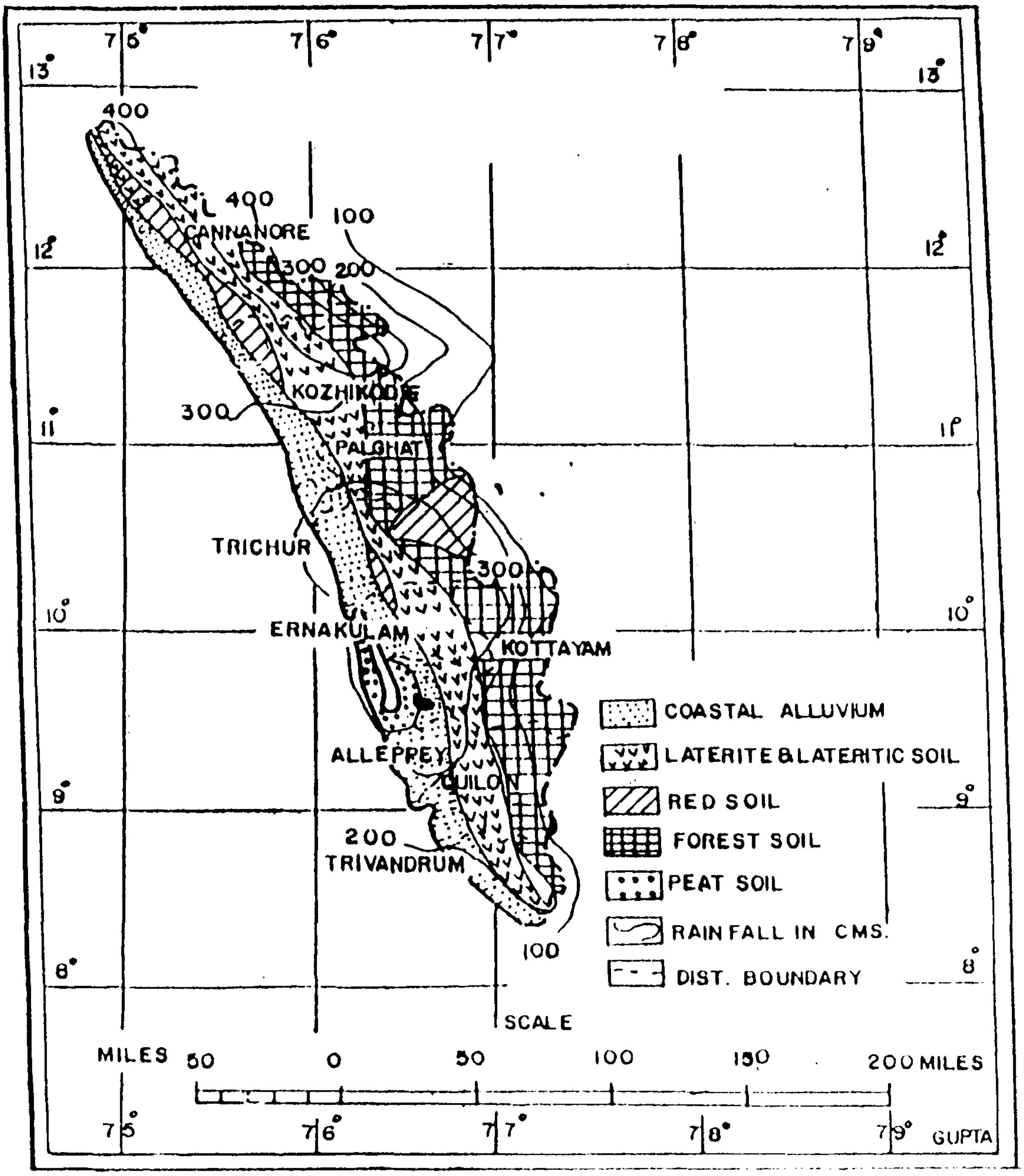


Fig. 2.1 Laterite distribution in Kerala.

(Raychaudhuri et al., 1963)

The post-hole digger developed by Lines (1952) was fitted with a hydraulic equipment and it was claimed that it was the first hydraulically operated post-hole digger that fitted on any tractor or truck (Fig. 2.2). It could be used for boring concrete, not reinforced with iron, and for making holes for planting saplings.

Threadgate (1952) developed a home made post-hole digger for his Ferguson tractor (Fig. 2.3). Two universal joints from an old truck were used as the drive shaft. The raising and lowering of the digger was effected by the tractor's hydraulic system. When travelling, the unit was allowed to tip up and assume a horizontal position by removing the top stay-rod and drive shaft. The top stay-rod was telescopic, so that it was possible to set the machine to dig vertical holes on hill sides. He claimed that the outfit worked satisfactorily.

MacDonald (1952) developed a post-hole digger with hydraulic control (Fig. 2.4). The unit was fitted to Ferguson tractor and made use of an external hydraulic cylinder to raise and lower the auger through toggle system. The 250-mm auger used was driven by V-belts from the tractor's PTO shaft.

Fig. 2.2 Vengar post-hole digger.

(Lines, 1952)

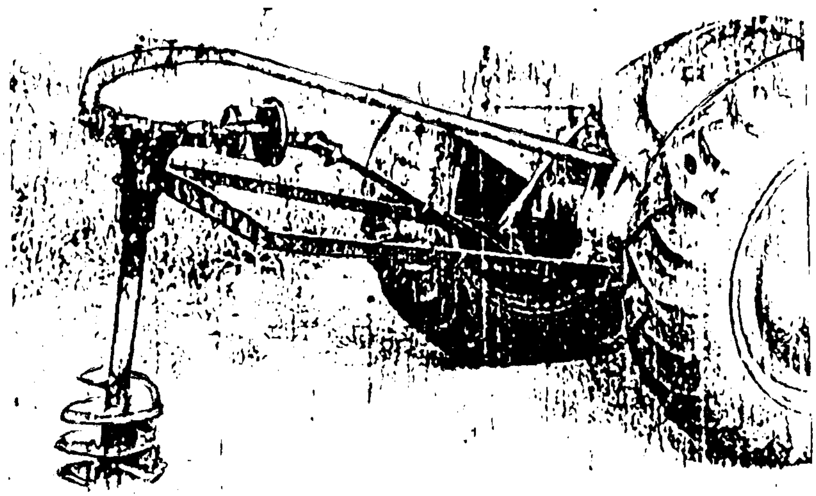


Fig. 2.3 Home made post-hole digger.

(Threadgate, 1952)

Fig. 2.4 Post-hole digger with hydraulic control for Ferguson.
(MacDonald, 1952)

Kathirvel *et al.* (1990) developed an auger digger as an attachment to a power tiller (Fig. 2.5). This auger unit could be mounted in front of a power tiller and was simple to operate. It was developed to dig holes for planting saplings in agro-forestry and social forestry programmes. The auger unit consisted of a spiral auger actuated by rack and pinion arrangement which enabled the auger to move up and down with the help of a simple rotating hand wheel. The drive for the rotation of auger was transmitted from the power tiller engine pulley through belt pulley and bevel gear transmission systems. With the help of bearings and fixtures, the entire unit was mounted on a rectangular frame. During operations, depth control was achieved using the hand wheel which was provided at the side of the unit. This unit digs holes of size 225 mm in diameter and a depth of 450 mm.

As reported by Kumar *et al.* (1990), Sampathrajan developed a trolley-mounted post-hole digger controlled by one man. The height of the auger could be varied using hand screws. This also was suitable only for making holes of small diameter.

As reported by Kumar *et al.* (1990), Miel developed a post-hole digger using a separate engine as prime mover. The digger could be operated by a single person.

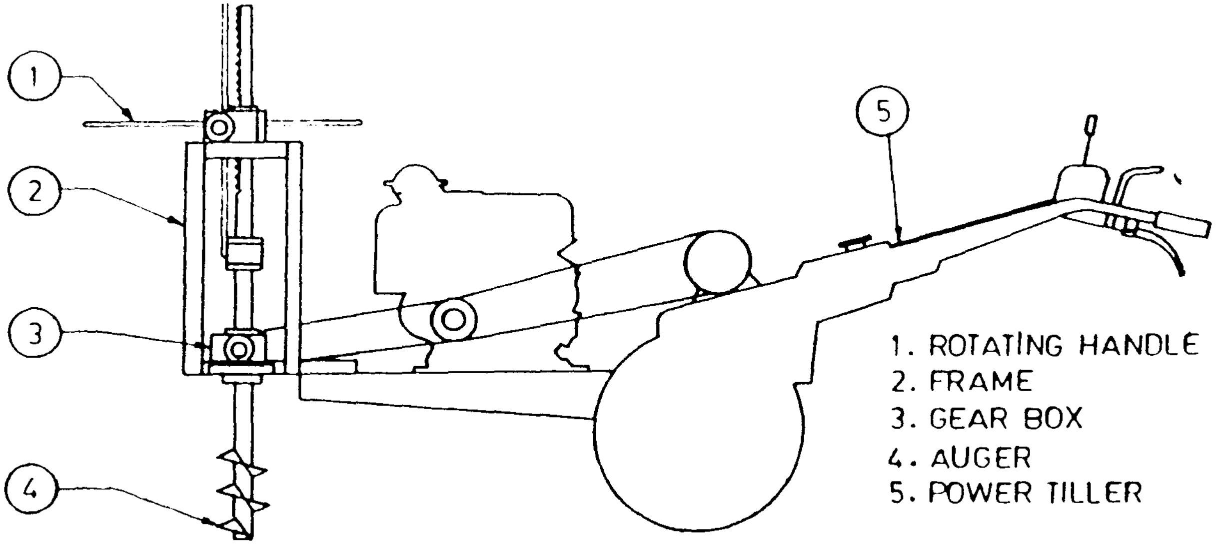


Fig. 2.5 Auger digger as an attachment to power tiller.

(Kathirvel *et al.*, 1990)

It could be used for making holes of only small diameter.

Kumar *et al.*(1990) developed a power operated portable tree hole digger (Fig. 2.6). It consisted of an engine of 1.7 hp with speed reduction unit, bevel gear box assembly, frame, auger tips, etc. The engine and gear box were aligned and mounted on the main frame. Two auger bits of sizes 100 mm and 150 mm in diameter could be fixed to the output shaft of the gear box with the help of shear pins. The power from the engine to the auger for rotary motion was transmitted using a chain and sprocket, and a bevel gear assembly. During operation, two persons were required for holding the whole unit. With this unit, a hole of size 150 mm in diameter and a depth of 250 mm could be made.

Tractor operated post-hole diggers are commercially available in our country (Fig. 2.7). These post-hole diggers are used for digging holes of different diameters and depths for fencing, erecting marking stones, and planting trees and saplings. It is an attachment to the hydraulic power lift of tractor, and it saves a great deal of time, where a large number of holes are to be dug. It consists of an auger, which is driven through bevel gear by the tractor PTO. Auger points and the leading blades are made replaceable. Different

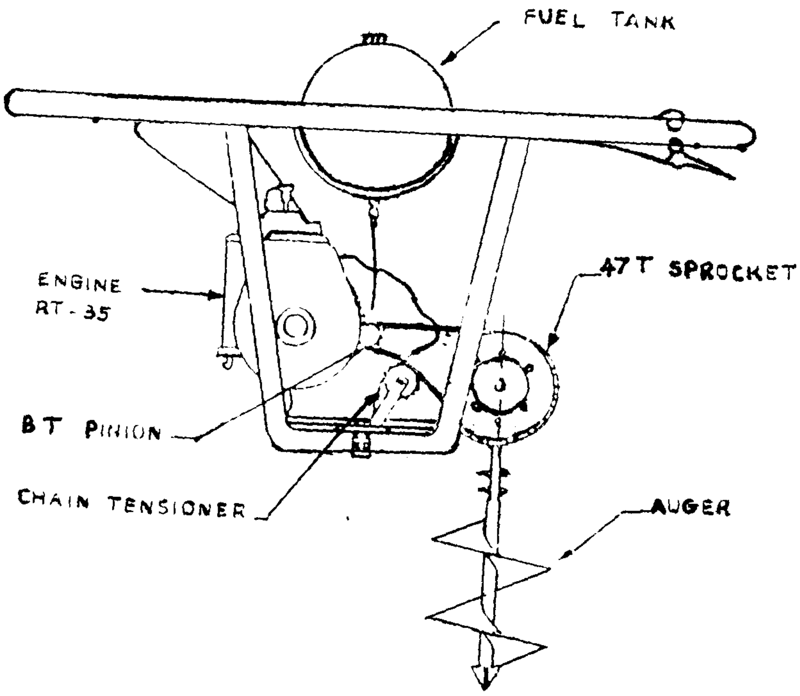


Fig. 2.6 Power operated portable tree hole digger.

(Kumar *et al.*, 1990)

Fig. 2.7. Tractor-mounted PTO driven post-hole digger.

shapes of points are available for dealing with different types of soil. According to Kathirvel *et al.* (1990) an auger of diameter 300 mm has a capacity of 100 pits, of 450 mm depth in 2 h and 48 min.

In parts of Kerala and Karnataka, power tiller operated laterite stone cutters are used to cut laterite stones (Plate I). The cutting unit is locally fabricated and is attached to the power tiller. It consists of a circular blade, a pair of depth adjusting cage wheels and a speed reduction unit. Two persons are needed for operating this machine. In this case also no systematic studies are seen conducted. One disadvantage with this machine is that it cannot be used for making the deep pits required for planting coconut seedlings.

From the literature reviewed, it was seen that no mechanical devices were available for preparing large size pits in hard laterites. In this context, an attempt was made to develop a large size pit digger suitable for laterite terrain.

Plate I Power tiller operated laterite stone cutter

1. Laterite cutter blade
2. Depth adjusting cage wheels
3. Additional gear box

Chapter III

Materials and Methods

MATERIALS AND METHODS

Details of the experimental set-up and the methodology adopted in the conduct of experiments are explained in this chapter.

3.1 General features of the experimental set-up

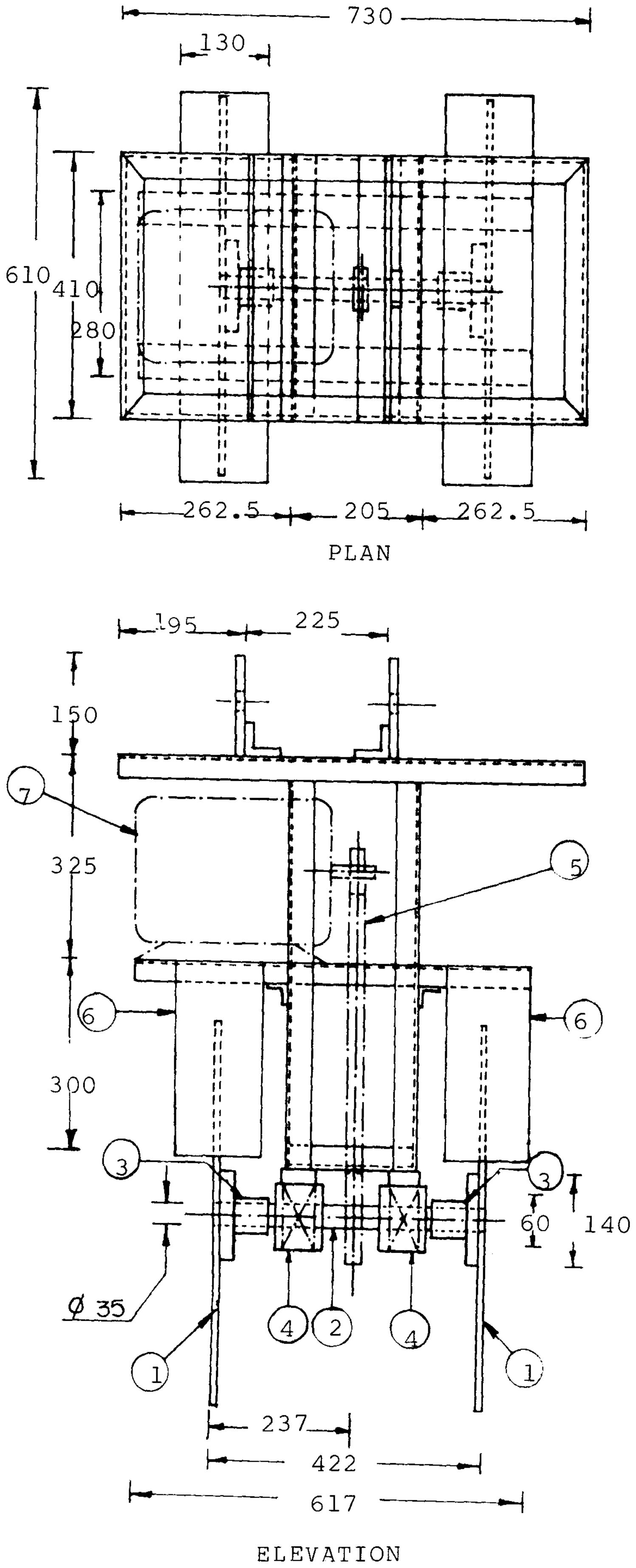
The experimental set-up mainly consisted of a tractor rear-mounted twin-blade laterite cutter (Fig. 3.1 & 3.2, and Plate II). The laterite cutter was lowered and raised with the aid of a jib crane mounted on the three point hitch system of the tractor. This being an experimental unit the cutter was operated by an electric motor instead of taking drive from the tractor.

3.2 Twin-blade laterite cutter

The twin-blade laterite cutter essentially consisted of two circular blades mounted on a shaft and driven by an electric motor. These were fixed on a frame which was capable of being hitched to a tractor-mounted jib crane.

3.2.1 Laterite cutter blades

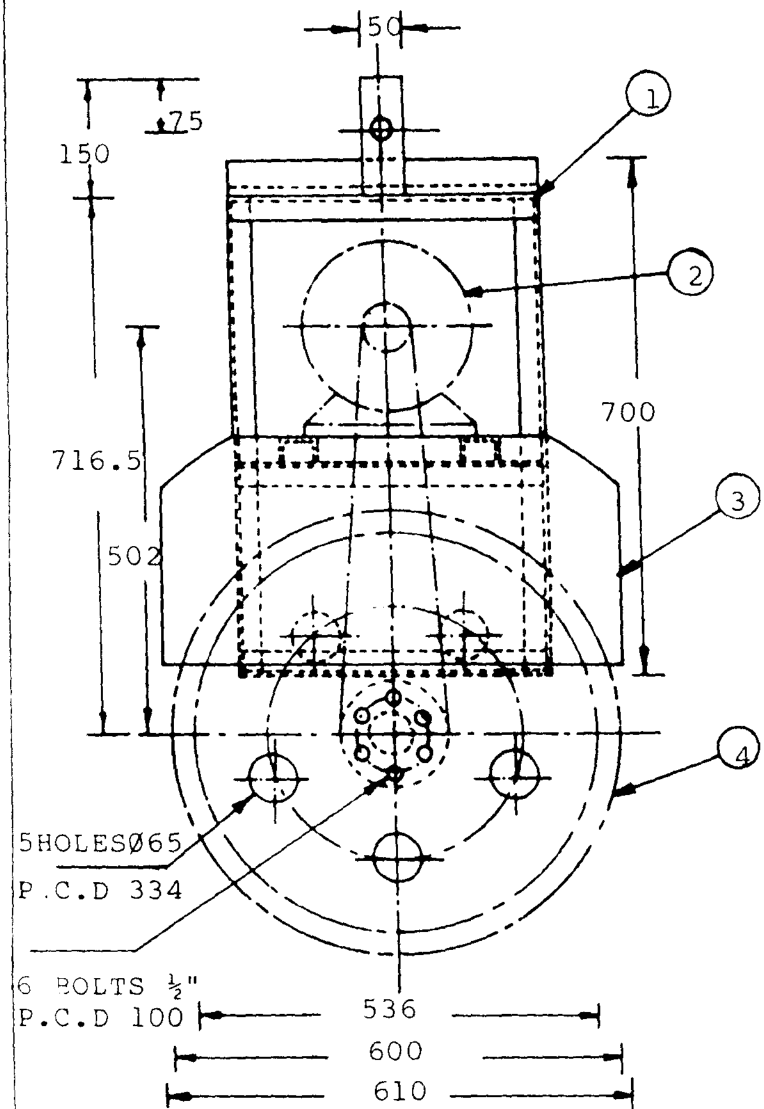
The cutter blades had the resemblance of a circular saw used for cutting wood (Fig. 3.3). Maximum diameter



1. Laterite cutter blades
2. Main shaft
3. Cast iron hubs
4. Bearing and bearing blocks
5. Transmission by chain
6. Protective shields
7. Electric motor

Scale 1:10
All dimensions in mm.

Fig. 3.1 Large diameter pit digger.



1. Main frame
2. Electric motor
3. Protective shield
4. Laterite cutter blade

Scale 1:10
All dimensions in mm.

Fig. 3.2 Side view of large diameter pit digger.

Plate II Experimental set-up

1. Laterite cutter blades
2. Cast iron hub
3. Protective shields
4. Electric motor
5. Main frame

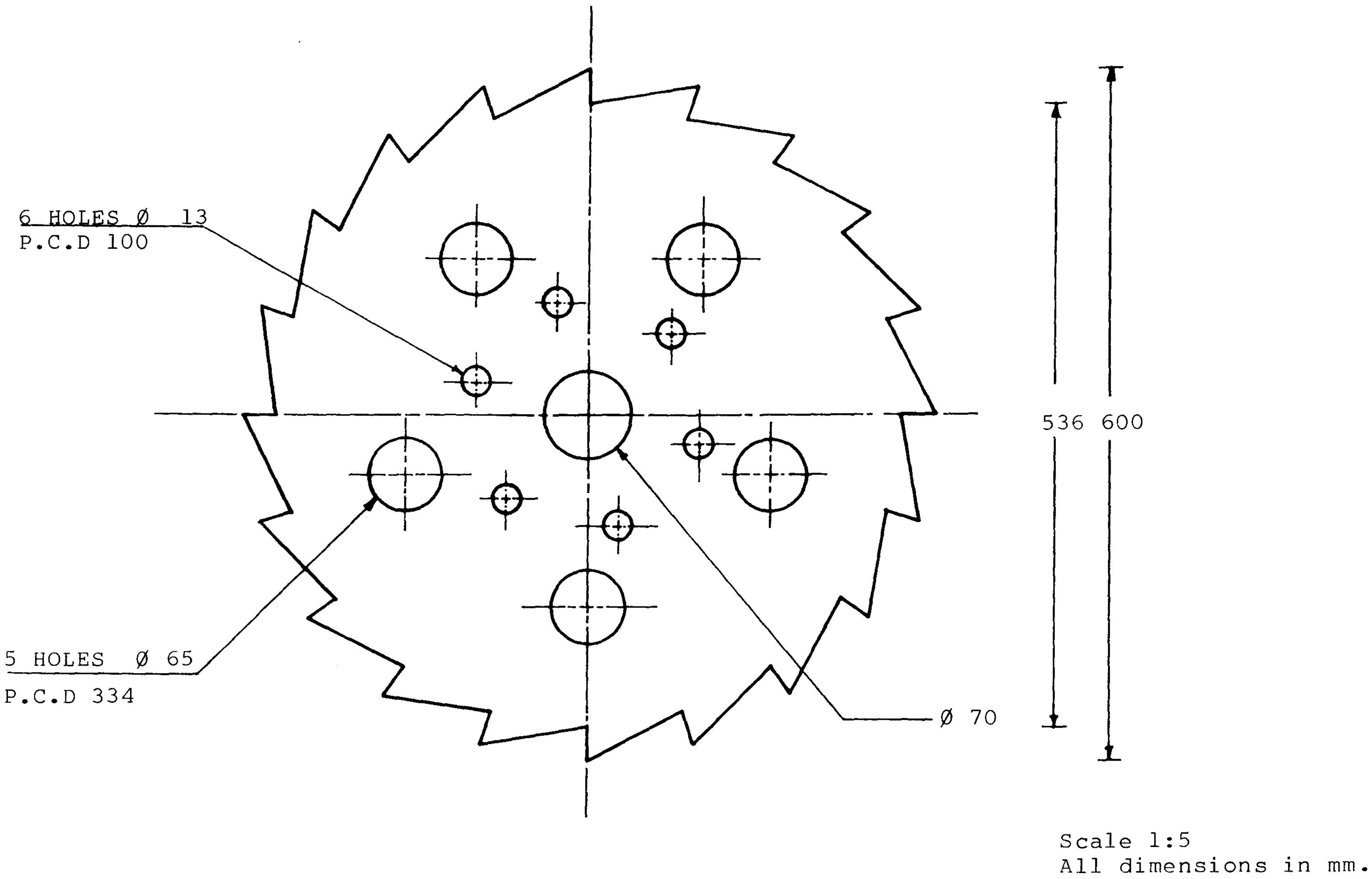
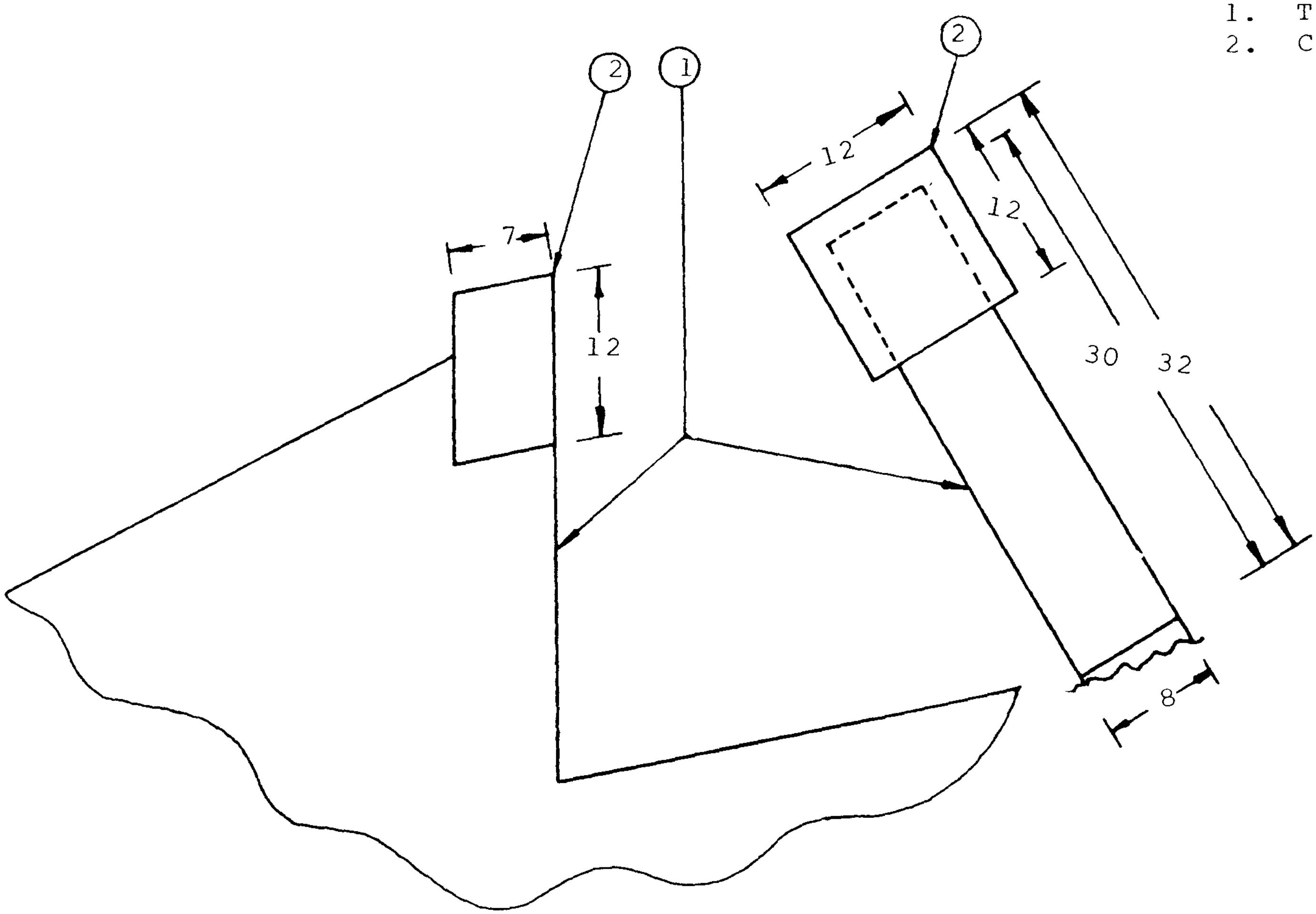


Fig. 3.3 Laterite cutter blade.

of the blade was 600 mm and was measured between the tips of diametrically opposite teeth. Minimum diameter of cutter blade was 576 mm and was measured at the root of the cutting bit. The cutter blades were fabricated from MS plate of 8 mm thickness. There were 20 teeth on its periphery. Height of the teeth measured 30 mm. A rebate of length of 8 mm, width 7 mm and depth 10 mm was made at the tip of each tooth to provide a seating for the cutting bits. Separate cutting bits made from high carbon steel were brazed to the tip of teeth after placing them in the rebates provided at the tip of each tooth (Fig. 3.4). Length of cutting edge was 12 mm. Accordingly, the theoretical kerf width was 12 mm. These dimensions of the blade took care of tear and wear to some extent. Five holes of diameter 65 mm were uniformly placed at a pitch circle diameter of 334 mm. This was done to reduce the weight of blade and thereby the energy consumption. Care was taken to ensure that the total cross-sectional area of hole did not undermine strength of the blade. The two cutter wheels were then fixed to their hubs with the help of six pairs of nuts and bolts. Centre to centre distance between the two cutters was 414 mm.

1. Tooth of blade
2. Cutting bit



Scale 2:1
All dimensions in mm.

Fig. 3.4 Tooth of blade with bit brazed at rebate.

3.2.2 Main shaft

Main shaft was rigidly fixed at the bottom of a rectangular main frame made of MS angle iron by means of two ball bearing assemblies. The two hubs carrying the cutter blades were keyed to the end of the main shaft. A sprocket was keyed to the main shaft at such a point that correct alignment with the driver sprocket was attained. The main shaft along with laterite cutter blades were driven by a chain drive. According to the design, diameter and length of the main shaft were 35 mm and 422 mm respectively. The design of main shaft is shown in Appendix A.

3.2.3 Cast iron hubs

Hubs on which the cutter blades were assembled were made of cast iron. The hubs were firmly mounted on the main shaft using MS rectangular keys. The dimensions and positions of the hubs on the main shaft are shown in Fig. 3.5.

3.2.4 Bearing and bearing blocks

A pair of ball bearings (No.6207) and their bearing blocks were used to hold the main shaft to the bottom of main frame. The bearing blocks were bolted to main frame.

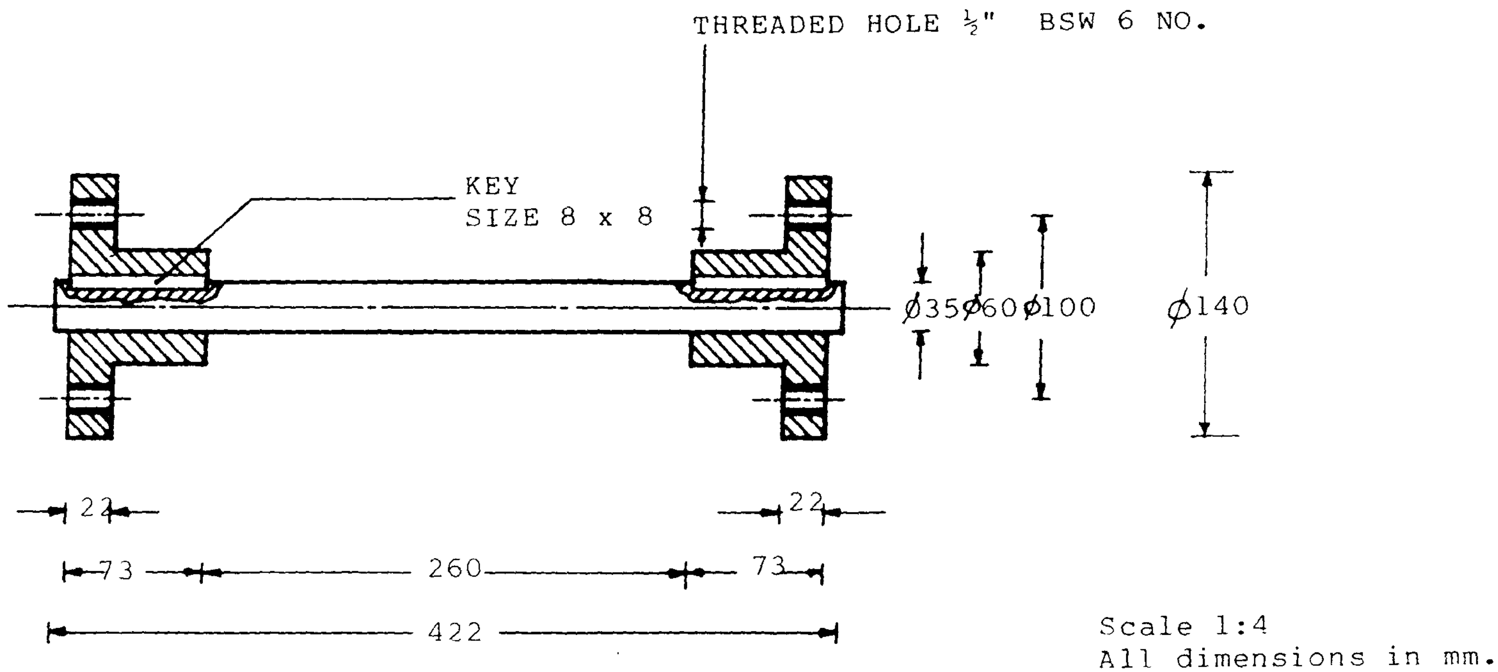


Fig. 3.5 Hubs assembled on main shaft.

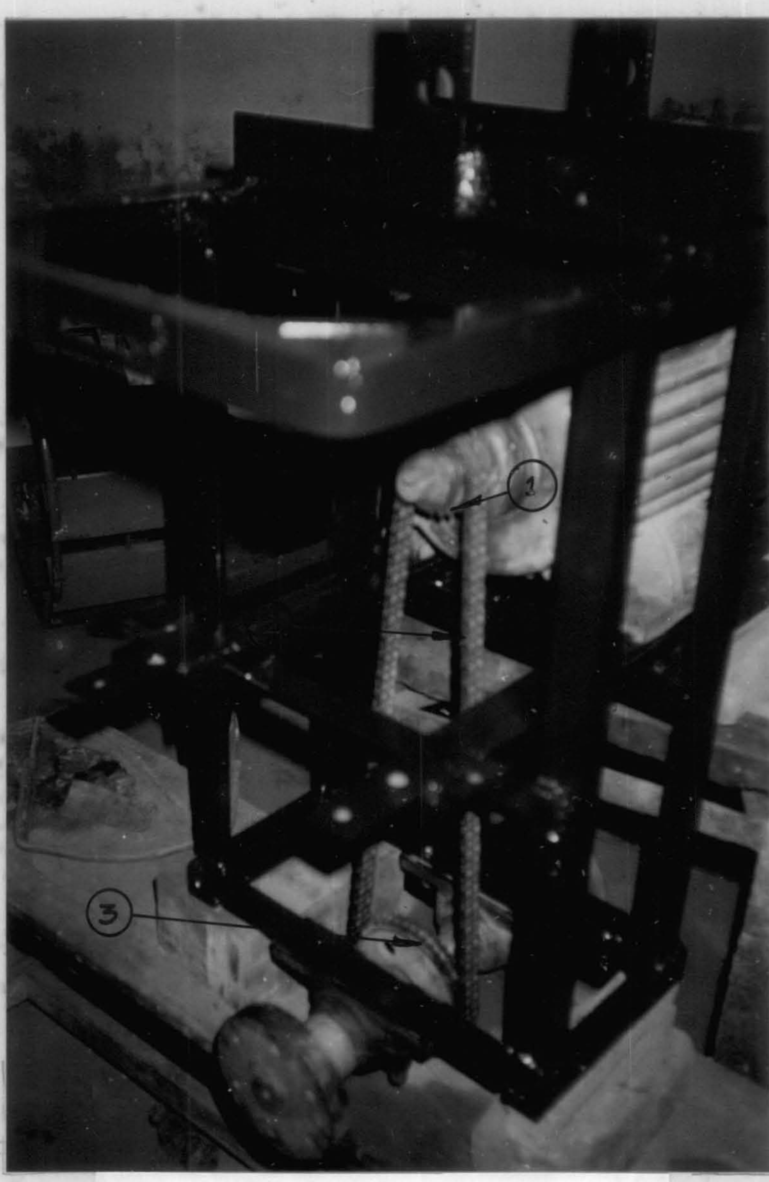
3.2.5 Power transmission elements

Chain and sprocket transmission system was used to transmit power from a 3-phase, 3-hp electric motor to the main shaft at a speed ratio of 2.1:1 (Plate III). This ratio was fixed on the basis of preliminary trials. Chain and sprocket were preferred to other systems of power transmission because it offers positive drive between two shafts quite a distance apart. The distance over which power was to be transferred was 502 mm (Appendix B).

3.2.6 Main frame

The main frame which was nearly rectangular in shape held the cutter blade assembly, power transmission elements, prime mover and protective shields. Main frame was fabricated from MS angles of 50 x 50 x 6 mm, 35 x 35 x 6 mm, 25 x 25 x 3 mm and 12.5 x 12.5 x 2 mm in sizes and joined by welding. The main frame was provided with suitable eyelet for facilitating its hitching to the jib crane. Fig. 3.1 and 3.2 shows various details of the main frame.

Plate III Power transmission by chain and sprocket



1. Driving sprocket
2. Chain
3. Driven sprocket

3.2.7 Protective shields

The laterite cutting blades were rotated with a peripheral speed of 21.46 m/s. This imparted a high velocity to the cut laterite chips. These laterite chips were thrown to considerable distance because of the momentum. So it was found necessary to provide a protective shield to each blade to protect the operator from flying chips and to cause the chips to fall near the equipment in operation.

Protective shields were fabricated from 18 gauge MS sheets and 35 x 6 mm MS flat. The sheets and flats were joined together by welding. The protective shields were bolted to the main frame and it partly covered each blade from the top (Fig. 3.1 and 3.2).

3.2.8 Stopper

It was found that the pit digger had a tendency to tilt towards the tractor during operation. This occurred due to the combined action of downward thrust and the resistance offered by the laterite. In order to prevent this tilting, a wooden block of size 210 x 100 x 160 mm was used as a stopper. It was inserted between jib crane and main frame and held in place with the help of U-frame as shown in Plate V.

3.2.9 Jib crane

A jib crane was used to mount the pit digger on the tractor (Plate IV). This also aided in lowering the equipment into the pit and lifting it out of the pit. Lowering and raising of the equipment was achieved by mounting the jib crane on the tractor 3-point hitch system. This also facilitated in controlling the depth of cut.

3.3 Power source

An electric motor of 3-phase, 3-hp, 1440 rpm was selected as the prime mover. The electric motor was preferred only because of convenience. It was mounted on the main frame. Power was transmitted to the main shaft by chain and sprocket drive.

3.4 Experimental programme

Firstly, the pit digger was attached to the 3-point linkage of the tractor through the jib crane. The motor was connected to a main switch of 3-phase electric supply through an energy meter (Fig 3.6). Then, by switching on, the pit digger was put into operation without any load. For this, the pit digger was lifted from the

Plate IV Jib crane

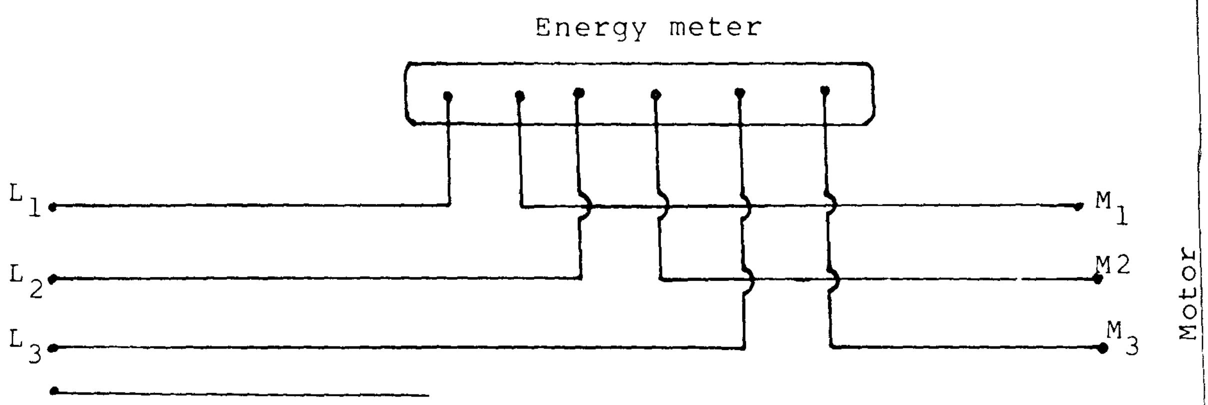


Fig. 3.6 Connection diagram of experimental set - up.

Plate V Pit digger in operation

ground with the help of the hydraulic system of the tractor. Alignment of the power transmission system and the rotation of the laterite cutting blades were observed and any misalignment or incorrect rotation found thereof was corrected.

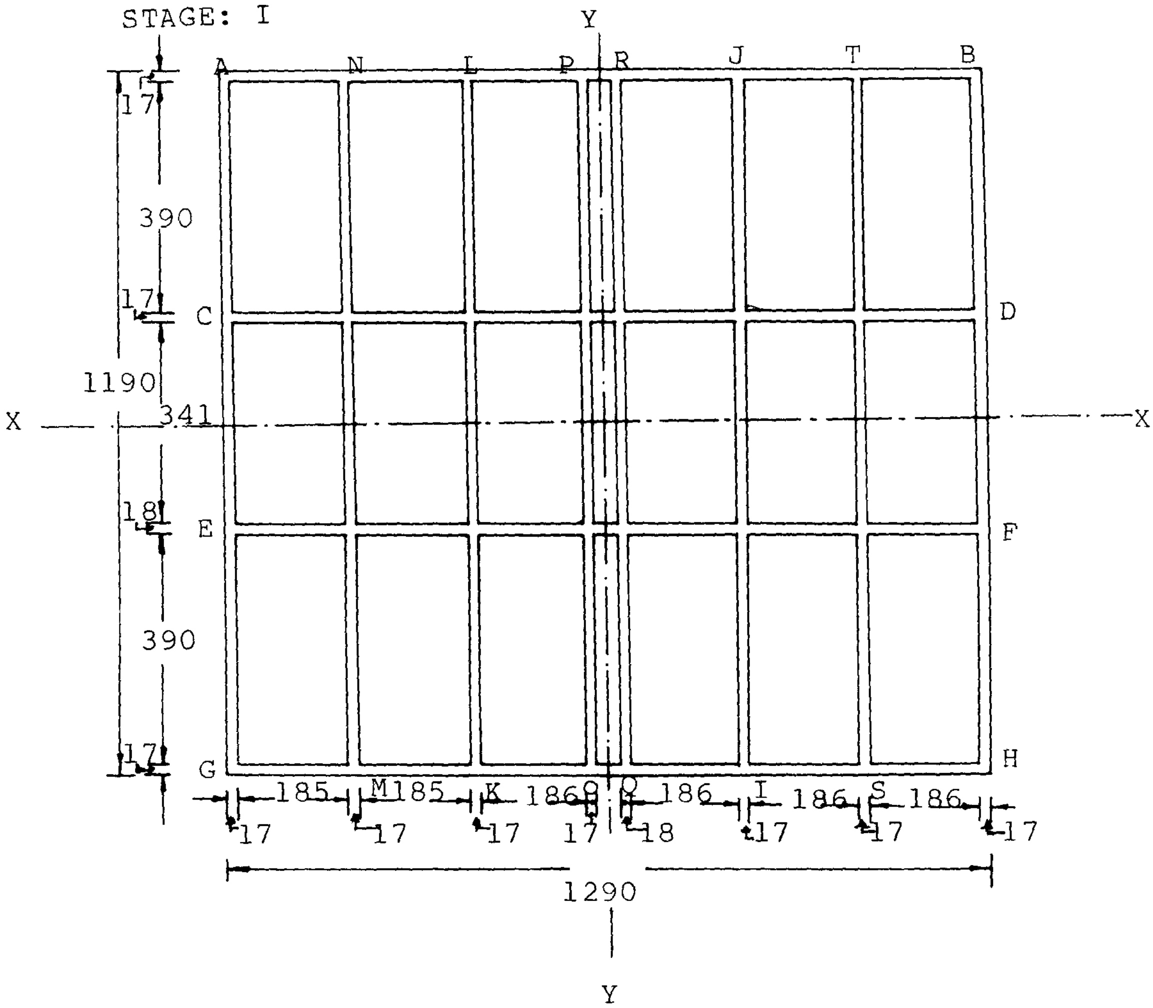
3.5 Field evaluation of the pit digger

Field evaluation tests were conducted in the month of September, 1995 near the Agricultural Engineering Workshop of Kelappaji College of Agricultural Engineering and Technology, Tavanur.

In order to make a pit suitable for planting coconut seedling an area of 1200 x 1200 mm was marked on the field. The pit digger was attached to the tractor and aligned over the marked area. Then by operating the equipment, it was lowered with the help of hydraulic system of tractor so that the rotating blades touched the laterite surface at the boundary line of the area marked and grooving was initiated along the marked line. As the cutting progressed, the whole equipment was slowly lowered till the groove being cut attained a mean depth of 225 mm. By keeping the blades cutting at this depth, grooving was continued lengthwise upto a mean distance of 1240 mm by moving the tractor backwards (Plate V). This

1. Laterite cutter blade
2. Protective shield
3. Main frame
4. Jib crane
5. Stopper

backward movement of tractor was considered as the forward movement of cutter blade. Thus, two grooves AB and CD of uniform depth were made during the first run of the tractor (Fig. 3.7). Then, the pit digger was oriented by the side of these grooves for cutting the next pair of grooves. The distance between the adjacent grooves was maintained at 390 mm. The process was repeated as in the first run of the tractor and two more grooves EF and GH were made during the second run of tractor in the same direction (Fig. 3.7). After this, the tractor with the pit digger attachment was oriented across the grooves over the same area. Four grooves HB, IJ, KL and GA were made in the successive third and fourth run of the tractor (Fig. 3.7). Thus, the entire area was divided into 9 blocks. Four more grooves MN, OP, QR and ST were made in the same direction in the fifth and sixth run of tractor, thus reducing laterite block size to about 390 x 185 mm (Fig. 3.7). Finally 18 laterite blocks of approximate size 390 x 185 x 225 mm were removed manually with the help of crowbar as shown in Plate VII. Since, grooving was initiated exactly from the boundary line and finished exactly at the opposite boundary line of area marked, grooves obtained have some extension towards the outside of the area marked (Plate VI). This enabled a uniform depth for the grooves throughout its length and this length between boundary lines was measured as the length of run (Fig. 3.7).



Scale 1:10
All dimensions in mm.

TRACTOR RUN NO:	1	2	3	4	5	6
GROOVE'S NAME	AB & CD	EF & GH	HB & IJ	KL & GA	MN & OP	QR & ST

Fig. 3.7 Layout of grooves made in first stage.

In the second stage, the pit digger was lowered into the pit of size 1290 x 1190 x 225 mm made in the first stage. The entire procedure was repeated with the exception that the grooves near the walls were cut at an average distance of 75 mm away from the pit wall (Fig. 3.8 and Plate VI)). This was done to provide easy movement for the pit digger and the protective shield which covered the blade. After removing the cut blocks with the help of a crowbar, the bottom dimension of the pit was measured.

The same procedure was repeated for the third and fourth stages and the grooves made are shown respectively in Fig.3.9 and 3.10. The dimensions of the pit after each stage were noted down.

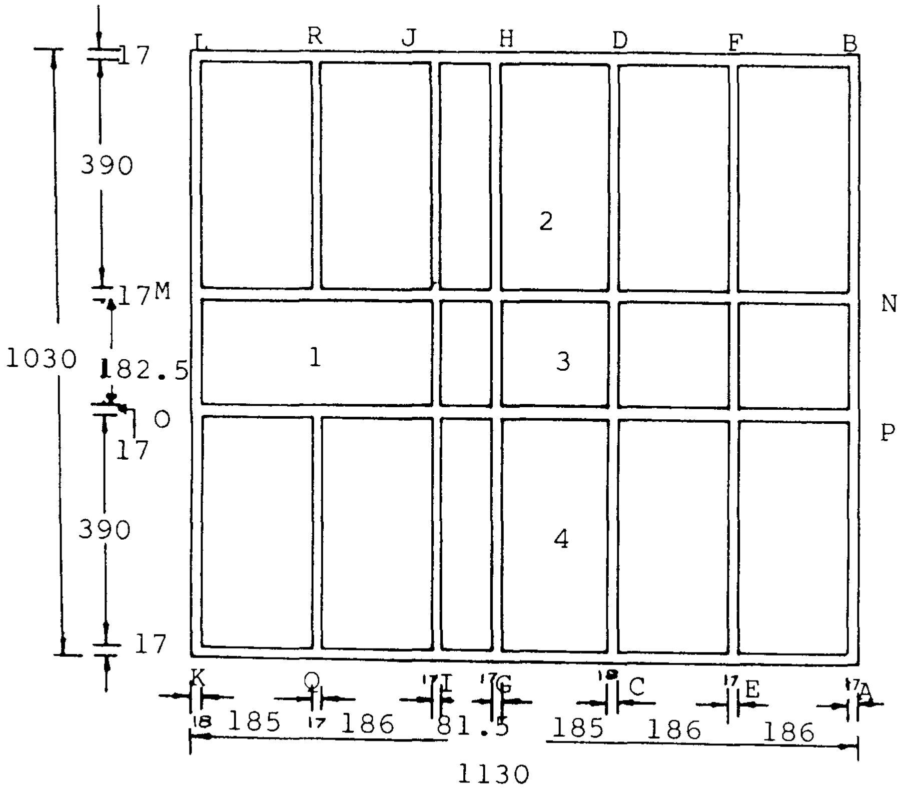
3.5.1 Kerf width

The length of cutting edge of the laterite cutter blade was 12 mm. The kerf width in each run of cutting was noted and the mean of the same was determined.

3.5.2 Downward cutting speed

Initially a cut to a pre-determined depth was made through the laterite in each run and the corresponding

STAGE:II



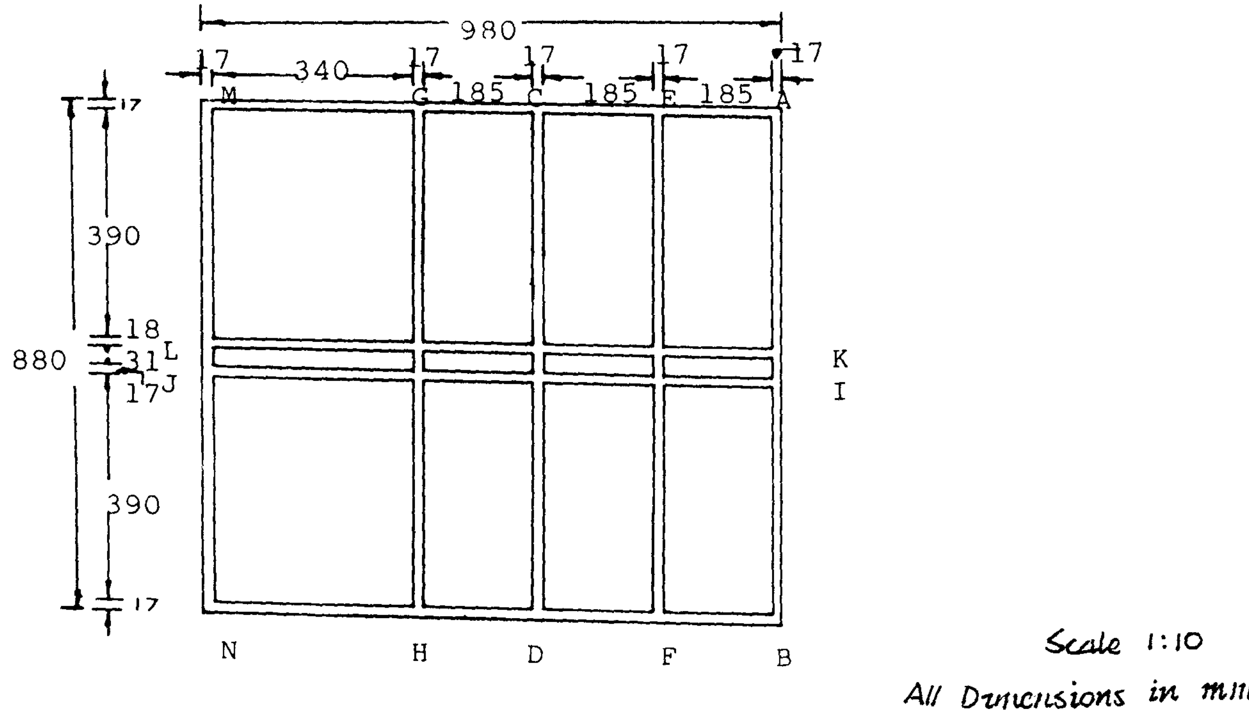
Scale 1:10
All dimensions in mm.

TRACTOR RUN NO:	1	2	3	4	5	6
GROOVE'S NAME	AB & CD	EF & GH	IJ & KL	LB & MN	OP & KA	QR
REMARKS	6th run was made only after removing blocks 1,2,3 and 4. Hence during this run only one groove QR was made and other blade rotated freely in the empty space.					

Fig.3.8 Layout of grooves made in second stage.

Plate VI Grooves made during field evaluation

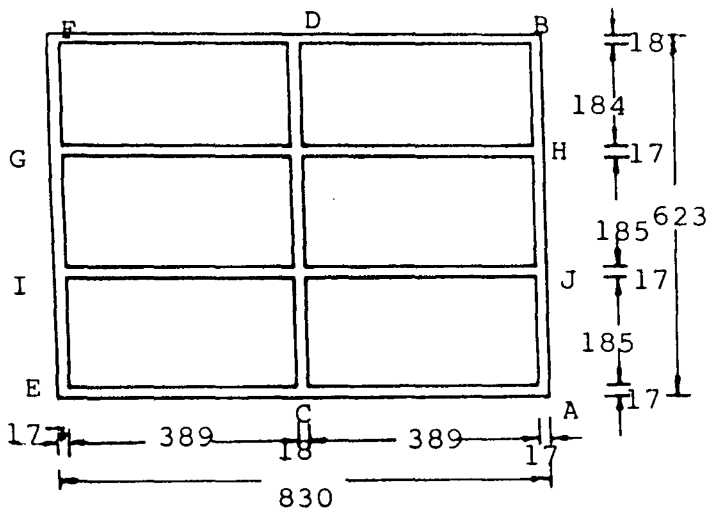
STAGE: III



TRACTOR RUN NO:	1	2	3	4	5
GROOVE'S NAME	AB & CD	EF & GH	BN & IJ	KL & AM	MN
REMARKS	After removing all the blocks from the area ABGH, the Vth run was made. Hence only one groove MN was made and other blade was rotated freely in the empty space.				

Fig. 3.9 Layout of grooves made in third stage.

STAGE: IV

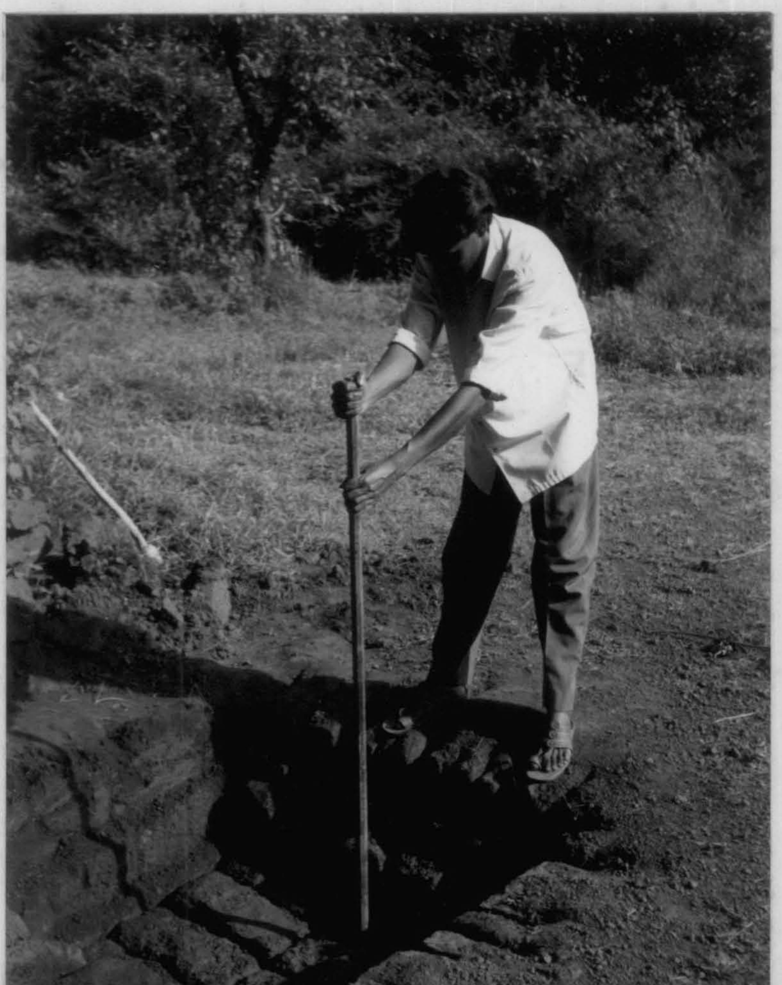


Scale 1:10
All diamensions in mm.

TRACTOR RUN NO:	1	2	3	4
GROOVE'S NAME	AB & CD	EF	EA & GH	IJ & FB
REMARKS	In the second run one blade was passed through the groove CD, while the other made a groove EF.			

Fig. 3.10 Layout of grooves made in fourth stage.

Plate VII Removal of laterite block using crowbar



time was noted. From that, the downward cutting speed was calculated using the expression:

$$\text{Downward cutting speed (m/s)} = \frac{\text{Depth of cut in each run (m)}}{\text{time (s)}} \qquad \ldots(3.1)$$

3.5.3 Forward cutting speed

After the blades had moved to the required depth of cut, grooving was continued lengthwise for the required distance by moving the tractor backwards in each run. This backward movement of tractor was considered as the forward movement of the cutter blade. The length of groove made and the time taken for the forward cutting in each run were noted and the forward speed of cutting was calculated as:

$$\text{Forward cutting speed (m/s)} = \frac{\text{Length of groove in each run (m)}}{\text{time taken (s)}} \qquad \ldots(3.2)$$

3.5.4 Shape and size of pit

The shape and size of the pit made were noted by measuring the principal dimensions of the pit.

3.5.5 Capacity

The time for setting-up the machine at the correct position, the time for cutting grooves through hard laterite in each run and the time for removing the laterite stones at each stage were noted. From that the total time for making the required pit and the capacity of machine were determined.

3.5.6 Energy requirement

Energy requirements of the electric motor and the tractor was separately determined. For measuring the electrical energy requirement, a 3-phase energy meter was used and connected in series with the motor. The electrical energy consumed for grooving in each run of each stage was noted separately and the total electrical energy consumed for all the groovings taken together was found out. Specifications of the energy meter used are given in Appendix H.

The tractor was operated for setting-up the machine over the marked line and also for moving the blade assembly forward while grooving. The total quantity of diesel consumed was then measured.

3.5.7 Economic analysis

The operating cost of the machine was calculated and presented in Appendix J. The cost of manual pit digging in hard laterite was found and presented in Appendix K. Based on these data, a cost analysis was done.

Chapter IV

Results and Discussion

RESULTS AND DISCUSSION

This chapter deals with results of the experiments conducted in the field to evaluate the performance of the newly developed pit digger. Discussions on these results are also presented in this chapter.

4.1 Field evaluation of the pit digger

The newly developed pit digger was evaluated in terms of peripheral velocity of cutter blade, kerf width, downward and forward cutting speeds, shape and size of pit, capacity, energy requirement, labour requirement and economics The results are presented in the subsequent sections.

4.1.1 Peripheral velocity of cutter blade

Theoretical cutter blade speed was 687 rpm for a transmission ratio of 2.1:1 and motor rated speed of 1440 rpm. Corresponding peripheral velocity at the tip of cutting bit was 21.58 m/s for the maximum cutter blade diameter of 600 mm. Minimum diameter of cutter blade was measured at the root of the cutting bit. The momentum created by a velocity of this magnitude was necessary to rip the laterite. Speeds lower than this was found to interrupt the cutting operation by way of instantaneous ceasing of rotation. The average speed of rotation was 683 rpm for which the peripheral velocity was 21.46 m/s.

4.1.2 Kerf width

The blades were lowered through the laterite to a mean depth of 225 mm by cutting grooves of mean width 17.17 mm (Table 4.1). The width of kerf was observed to be more than the blade length because as the cutting bit shears the laterite under compressive force the interparticulate cohesion of laterite forces the adjacent particles also to be separated from the parent stone thus making the width of kerf larger than the length of cutting edge of blade. The maximum width of kerf was 18 mm whereas the minimum was 17 mm. This variation in width may be due to the difference in the cohesive forces at various points of laterite.

4.1.3 Downward cutting speed

In making the initial groove to a mean depth of 225 mm, the average time taken was 118.6 s (Appendix C). Since lowering of the cutter was achieved by operating the hydraulic system of tractor, uniform speed could not

Table 4.1 Kerf width in laterite for a cutting edge length of 12.0 mm

Stage No.	Width of kerf in laterite*, (mm)												Mean width (mm)
	Kerf number												
	1	2	3	4	5	6	7	8	9	10	11	12	
I	17.0	17.0	18.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	18.0	17.0	17.17
II	17.0	17.0	17.	17.0	17.0	18.0	17.0	17.	17.0	17.0	17.0	17.0	17.09
III	17.0	17.0	17.0	17.0	17.0	17.0	18.0	17.0	17.0	-	-	-	17.11
IV	17.0	18.0	17.0	17.0	17.0	17.0	18.0	-	-	-	-	-	17.29
	Grand mean												17.17

* Mean of 3 replications and rounded off to the nearest whole number

be attained. By incorporating better hydraulic control systems or a mechanical feed screw system it is possible to have better control of the speed of downward cutting. It was seen that, the maximum and minimum speed of downward cutting were 0.0019 m/s and 0.0018 m/s respectively (Table 4.2).

4.1.4 Forward cutting speed

After lowering the cutter to a mean depth of 225 mm into laterite, tractor was driven backward for an average distance of 1240 mm for each of the runs of the first stage. This backward movement of tractor was considered as the forward movement of the cutter blade. The time taken to complete the grooving was recorded (Appendix D). From this, time of forward cutting was measured. Mean of the time taken for forward cutting was 185.3 s (Appendix D). Accordingly average speed of forward cutting was 0.0066 m/s (Table 4.3). As tractor speed was controlled through the accelerator, complete control of speed could not be attained. Very often it was driven at a speed slower than that attainable. This resulted in slower cutter speed.

In the second stage, cutting was done for an average distance of 1065 mm in all the runs. The time taken for each run was recorded and are presented in Appendix D.

Table 4.2 Speed of downward cutting

Stage No.	Speed of downward cutting, (m/s)						Mean speed (m/s)
	Run number						
	1	2	3	4	5	6	
I	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019
II	0.0018	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019
III	0.0019	0.0019	0.0019	0.0019	0.0019	-	0.0019
IV	0.0019	0.0019	0.0019	0.0019	-	-	0.0019
	Grand mean						0.0019

The average time based on these observations was 176.2 s (Appendix D). Accordingly the average forward cutting speed was 0.0061 m/s (Table 4.3).

In the third, and fourth stages average cutting speeds were 0.0064 and 0.0069 m/s respectively (Table 4.3). The variation in speeds of cutting with respect to the stages is not uniform. This may be due to the lack of complete control over the tractor speed as explained earlier.

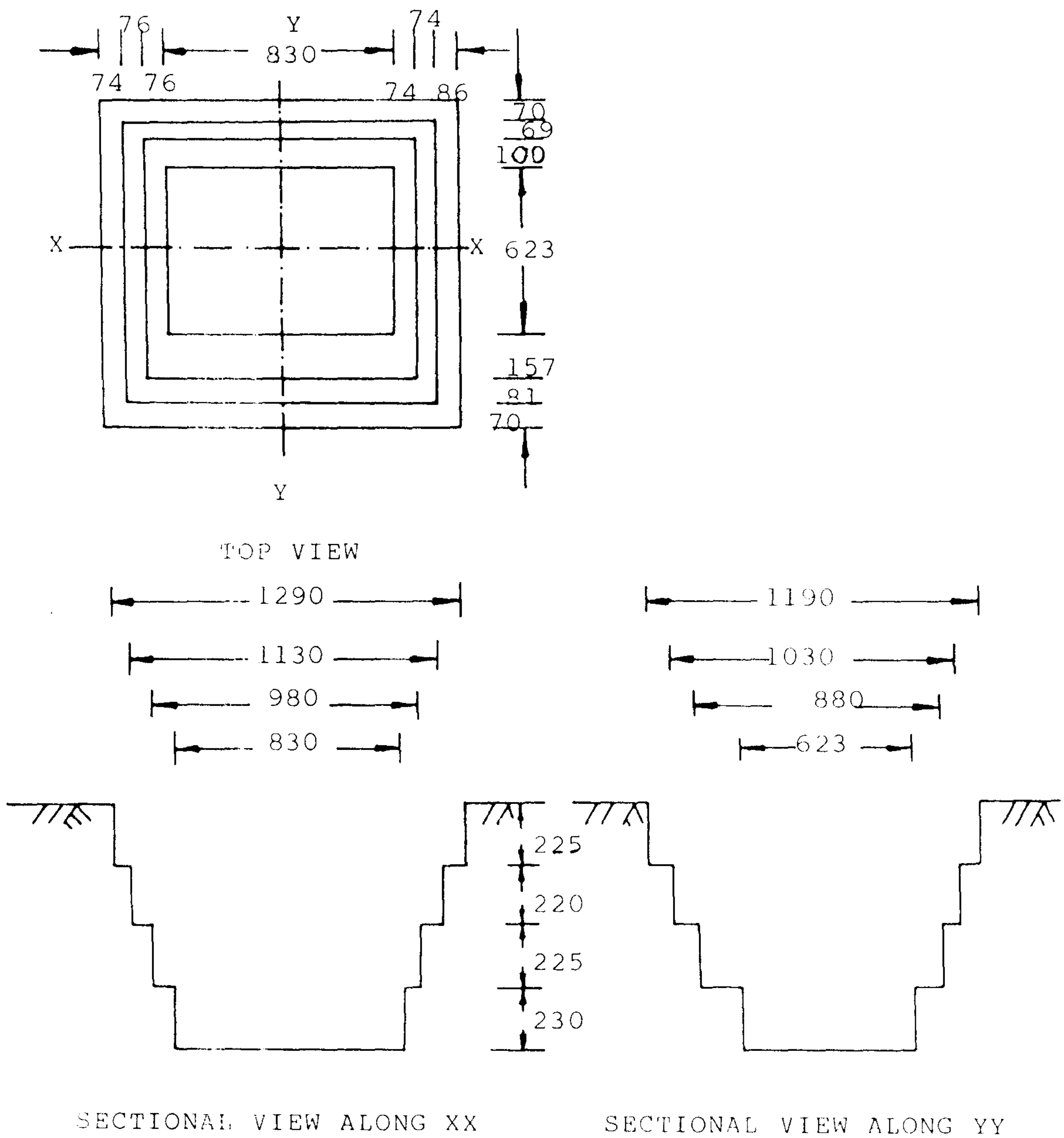
4.1.5 Shape and size of pit

The horizontal cross-section of the pit made in the field had approximately a square shape. The pit was stepped or rebated downwards as shown in Plate VIII and Fig. 4.1. Length of the four sides and depth of the pit for each of the four stages are recorded in Table 4.4. Length of sides of the pit after taking care of the clearances required for the movement of the protective shields were 1200, 1050, 900 and 750 mm for the stages I, II, III, and IV respectively. Slight variations from these dimensions observed were due to lack of absolute control in aligning the cutter blades over the starting and finishing points of the runs. Similarly the design depths for each of the stage was 225 mm. The variations

Table 4.3 Speed of forward cutting

Stage No.	Speed of forward cutting, (m/s)						Mean speed (m/s)
	Run number						
	1	2	3	4	5	6	
I	0.0068	0.0068	0.0066	0.0067	0.0064	0.0065	0.0066
II	0.0059	0.0059	0.0060	0.0064	0.0064	0.0057	0.0061
III	0.0063	0.0061	0.0067	0.0065	0.0062	-	0.0064
IV	0.0063	0.0063	0.0076	0.0074	-	-	0.0069
	Grand mean						0.0065

Plate VIII Pit made during field evaluation



Scale - 1:25

All dimensions in mm

Fig. 4.1 Pit made during field evaluation.

observed in depth were again due to the lack of accurate control over the hydraulic system of tractor. However, in any pitting operation, maintenance of accurate dimension is not very essential. A variation of about five per cent was within the limit tolerated. Total volume of pit as per the design was 0.881 m^3 whereas the actual size of pit dug with the pit digger was 0.914 m^3 (Table 4.4). The variation of 3.77 per cent was within the tolerable limit of five per cent. This variation was also due to the lack of control in aligning the cutter blades over the marked lines.

4.1.6 Capacity

The total time taken for making the pit was the time taken for the three operations, viz. the time for setting-up the machine, the time for cutting the hard laterite, and the time for removing the blocks. The time taken for each of these operations are presented in Appendix E. The maximum time was spent in aligning and setting-up the machine at the right place. Of the three operations the least time was taken for removing the cut blocks from the parent stone. Capacity of the machine was observed to be 2.24 pits of 0.914 m^3 in a day of 8 h. At this rate the time needed to make a pit of 1 m^3 was 3 h and 54 min. The dimensions of the pit are as shown in Table 4.4.

Table 4.4 Dimensions of pit at various stages

Stage No.	Side length of the pit, (m)				Depth of cut at each stage (m)	Cumulative depth (m)	Volume (m^3)	Cumulative volume (m^3)
	Side number							
	1	2	3	4				
I	1.29	1.19	1.29	1.19	0.225	0.225	0.345	0.345
II	1.13	1.03	1.13	1.03	0.220	0.445	0.256	0.601
III	0.98	0.88	0.98	0.88	0.225	0.670	0.194	0.795
IV	0.83	0.623	0.83	0.623	0.230	0.900	0.119	0.914

4.1.7 Energy requirement

The energy requirement was separately determined for the electric motor and the tractor. The electrical energy required for rotating the cutter blades in hard laterite were measured and are presented in Appendix F. The total electrical energy consumed for making the pit was 4.111 kWh. It can be seen that there was small reduction in the energy consumed as the depth of pit increased. This was due to the reduction in length of the groove cut from the second stage onwards. The electrical energy consumption for cutting with the twin-blade cutter was 0.193 kWh per metre length of cut for a depth of 225 mm.

The tractor was operated for a period of 3 h and 15 min. for setting-up the machine over the marked line and for the forward movement of the blade assembly while grooving. The corresponding fuel consumption was 18.5 L of diesel (Table 4.5). This was for making a pit of 0.914 m^3.

4.1.8 Labour requirement

In addition to the tractor driver one more labourer was required for giving guidance to the tractor driver and for removing the laterite slabs after grooving.

Table 4.5 Diesel fuel consumption of tractor (Mahindra B275 DI Tractor) for making a pit

Stage No.	Time for setting up tractor in each stage (h)	Diesel consumption for setting up the tractor (L)	Time for grooving in each stage (h)	Diesel consumption of tractor for grooving (L)	Total diesel consumption = (3) + (5) (L)
(1)	(2)	(3)	(4)	(5)	(6)
I	0.427	2.391	0.506	2.732	5.123
II	0.463	2.662	0.489	2.689	5.351
III	0.406	2.395	0.366	2.086	4.481
IV	0.328	2.001	0.251	1.506	3.507
	Total				18.462

4.2 Economic analysis

The cost of pit digger excluding the motor, jib crane and tractor was Rs. 3800 (Appendix I). Considering the variable and fixed cost, the cost of operation was Rs. 140.61 per hour (Appendix J). Accordingly the cost of making a pit was Rs. 453.23 (Appendix J). This appears to be on the higher side. However, by using this machine, 41 laterite blocks of the size specified for masonry work were recovered from a pit of the size specified. At the cost of Rs.6 per block the cost recovered was Rs. 246. Therefore, the net cost of making a pit was only Rs. 207.23 and the cost per m^3 was Rs. 249.77.

But, when the pit is dug manually the laterite is broken into small pieces which do not have any economic value. The number of pits dug by a man in a day of 8 hours; as per the PWD Data Book (1962); is only one of the size 0.833 m^3. Accordingly, at the wage rate of Rs. 120 per day the cost of making pit manually comes to Rs. 140.70 per m^3 (Appendix K). This shows that cost of making pit manually is cheaper.

From an analysis of the cost of operation of this pit digger it was observed that cost of using the tractor accounted for an amount of Rs. 388.32 out of the total cost of Rs.453.23. At the same time it was also observed that the total time for which the tractor was operated in making a pit was 3 h 15 min. By reducing this time to nearly three-fourth it is possible to make the use of this digger cheaper than that of manual pitting. This can be achieved by making use of proper guide plates for aligning the cutter blades over the marked lines. Similarly guide rails can be used for guiding the tractor to the appropriate spot for ensuring the aligning of the cutter blade over the marked area. These are being suggested for future work. Further, it is also suggested to modify the pit digger as a self-propelled unit incorporating an engine of smaller horsepower to reduce the cost.

Based on the present investigation it is concluded that the jib crane mounted pit digger developed in this study can be used for making in laterite large size pits which are suitable for planting saplings of trees including that of coconut palms. However, modifications, as suggested in this study, may be required to make this equipment more effective and cheaper in operation.

Chapter V

Summary

SUMMARY

Coconut is an important cash crop which is grown extensively in South India. It plays an important role in the socio-economic and cultural activities of this region.

Coconut is usually planted in pits, the size of which varies depending on the type of soil and depth of water table. The conventional method of pitting using spade, pickaxe and crowbar in hard laterites are tedious and time consuming. Mechanical means for pit digging in hard laterite are not commercially available.

In an attempt to overcome these problems associated with pitting in hard laterites, a large size pit digger was developed and tested in this study.

The newly developed pit digger mainly consisted of a tractor rear-mounted twin-blade laterite cutter. The twin-blade laterite cutter essentially consisted of two circular blades mounted on a shaft and driven by an electric motor. These were fixed on a frame capable of being hitched to a tractor-mounted jib crane allowing the raising and lowering of the pit digger.

Chain and sprocket transmission system was used to transmit power from a 3-phase 3-hp electric motor to the main shaft at a speed ratio of 2.1:1.

A protective shield to each blade was provided to protect the operator from flying chips and to cause the chips to fall near the equipment in operation.

A stopper was inserted between jib crane and mainframe and held in place with the help of U-frame to prevent the tilting of the pit digger towards the tractor.

Initially an area of 1200 x 1200 mm was marked on the test area. The tractor with the pit digger was aligned over the marked area. By operating the equipment, grooving was initiated upto a mean depth of 225 mm and grooving was continued lengthwise to a mean distance of 1240 mm by moving the tractor backwards. Thus, two grooves were simultaneously made in the first run of tractor. Then the pit digger was oriented by the side of these grooves and the next pair of grooves were made. The distance between the adjacent grooves was maintained at 390 mm. After this, the tractor with the pit digger attachment was oriented across the grooves. Eight grooves were made with an average spacing of 185 mm between adjacent grooves. Thus, the entire area was divided into 18 blocks of approximate size 390 x 185 mm. For all these grooves the mean depth of cutting was maintained at 225 mm. Finally, the blocks were removed manually with the help of crowbar.

The entire procedure was repeated for the second, third, and fourth stages with the exception that the grooves near the walls were cut at an average distance of 75 mm away from the pit wall. This was necessary to allow the free movement of the cutter blade shield while lowering and raising of the blade assembly.

Studies were conducted on the various parameters associated with the use of the equipment.

The test results are summarised below:

1. The peripheral velocity of cutter blade was 21.46 m/s.
2. The mean kerf width was 17.17 mm.
3. The maximum and minimum speed of downward cutting was 0.0019 m/s and 0.0018 m/s respectively.
4. The average forward cutting speed was 0.0065 m/s.
5. Size of the pit obtained was 1290 x 1190 mm at top and 830 x 623 mm at bottom. The pit made has approximately a square horizontal cross-section and is stepped or rebated downwards in four steps.

6. The total depth of pit was 900 mm.
7. The volume of pit was 0.914 m^3.
8. The capacity obtained was 2.24 pits of 0.914 m^3 in a day of 8 h.
9. The total electrical energy consumption was 4.111 kWh per pit of 0.914 m^3.
10. The total quantity of diesel consumed was 18.5 L.
11. A labourer in addition to the tractor driver was required to give guidance to the driver during operation and removing the cut blocks.
12. Total cost of the pit digger excluding the motor, jib crane and tractor was Rs. 3,800.
13. The operating cost of the digger was Rs. 140.61 per hour and the cost of making one pit was Rs. 453.23
14. The net cost of making a pit was Rs. 207.13 after taking into account of the cost recovered due to the 41 laterite blocks obtained while making the pit.

It is suggested that the time and the cost required for making the pits can be further reduced by incorporating certain modifications. Hence, work along the following lines are suggested for further investigation.

1. The laterite cutting blades may be operated with the tractor PTO.

2. A mechanism may be incorporated to remove easily the cut blocks from the bulk material.
3. Design and development of guide plates for quick aligning of the cutter blades over the marked lines.
4. Design and development of guide rails for quick positioning of the tractor at the appropriate spot.
5. Modification of the pit digger as a self-propelled unit incorporating an engine of smaller horsepower to reduce the cost.

References

REFERENCES

Anon (1962). *Standard Data Book of Kerala PWD.* Department of Public Works, Government of Kerala, Trivandrum, pp.8.

Anon (1968). *Design Data.* M/s. DPV Printers, Avanashi Road, Coimbatore, pp.7.75.

Anon (1993). *Package of Practices Recommendations 'Crops'.* Directorate of Extension, Kerala Agricultural University, Vellanikkara, Thrissur, pp.87-90.

Aravindakshan, M. (1995). Keravevasayam Oru Aamugham. *Indian Nalikera Journal.* **24**(10): 2-8.

*Jacob, V.C. (1979). Laterites and Laterites of Kerala, India. In International Seminar on Laterisation Processes. Oxford and IBH Publishing Co., New Delhi.

Kathirvel, K., Job, T.V., Karunanithi, R. and Swaminathan, K.R. (1990). Development of auger digger as attachment to power tiller. *AMA.* **21**(4): 8-9.

Kumar, P., Kunjuramani, R., Mahadevan, R., Mahalingam, K. and Manoharan, P. (1992). Design and development of a portable tree hole digger. B.E. project report, Tamil Nadu Agricultural University, Coimbatore.

Lines, R.A. (1952). New vengar equipped post-hole digger bores through concrete. *Power Fmg. in Australia and Newzealand.* **61**(6): 29.

MacDonald, A.G. (1952). Post-hole digger with hydraulic control for Ferguson. *Power Fmg. in Australia and Newzealand.* 61(8): 76.

*Maignien, R. (1966). Review of research on laterite. UNESCO, National Resources Research Ser. IV., Paris.

Raychaudhuri, S.P., Agarwal, R.R., Biswas Datta, N.R., Gupta, S.P. and Thomas, P.K. (1963). *Soils of India.* ICAR, New Delhi, pp.112-113.

Thampan, P.K. (1982). *Handbook on Coconut Palm.* Oxford and IBH Publishing Co., New Delhi, pp.1-2.

Thampan, P.K. (1995). Prospects for eco-friendly farming. The Hindu Survey of Indian Agriculture. M/s. Kasturi and Sons Ltd., National Press, Kasturi Buildings, Madras-600 002, pp 111-112.

Threadgate, R. (1952). Home made post-hole digger. *Power Fmg.* in Australia and Newzealand. 61 (5): 51

Varghese, T. and Byju, G. (1993). *Laterite Soils.* State Committee on Science, Technology and Environment, Government of Kerala, Thiruvananthapuram, pp.1-16.

* Originals not seen

Appendices

APPENDIX A

Design of shaft

Inorder to rip the laterite, a 3-phase, 3-hp electric motor of rated speed 1440 rpm was selected as the prime mover. In power tiller operated laterite cutters, a blade speed of 500-700 rpm is used and found to give satisfactory performance.

A sprocket of 21 teeth with pitch circle diameter 63.9 mm was fixed on the prime mover and 44 teeth sprocket with a pitch circle diameter of 133.5 mm was selected to be fixed on the main shaft. Accordingly, the speed of the main shaft is given as:

$$\text{Speed of main shaft} = N_1 = \frac{Z_1}{Z_2} \times N \qquad \ldots(1)$$

where, Z_1 = Number of teeth on driving sprocket

Z_2 = Number of teeth on driven sprocket

N = Speed of motor, rpm

i.e. $\frac{21}{44} \times 1440 = 687$ rpm

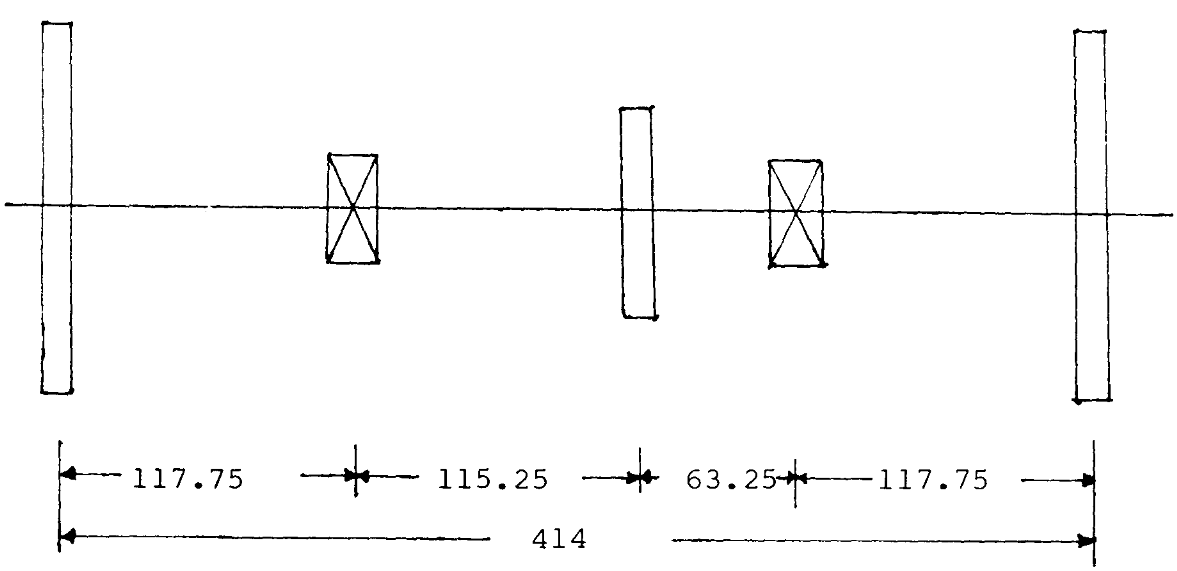


Fig.A1 Space diagram

Now, power to be transmitted by the shaft = P = 3hp

and torque to be transmitted by the shaft =

$$T = \frac{P \times 4500}{2\pi N_1} \qquad \ldots(2)$$

where, N_1 = the speed of the shaft

By substituting the values of P and N_1 in equation (2), $T = \frac{3 \times 4500}{2\pi \times 687} = 3.127$

= 3.127 kg-m

= 312.7 kg-cm

From a measurement of weight of blades, weight of each blade = 15 kg

Power taken by each blade $= \frac{P}{2} = \frac{3}{2} = 1.5$ hp

Therefore, torque required by each blade $= \frac{1.5 \times 4500}{2\pi \times 687} = 1.564$ kg-m

Accordingly, tangential force acting on blade $= \frac{\text{Torque}}{\text{Radius of blade}} \qquad \ldots(3)$

For a radius of 0.3 m of the blade,

Tangential force $= \frac{1.564}{0.3} = 5.213$ kgf

So, total vertical load on the shaft due to the blade = 15 + 5.213

= 20.213 kgf

Now, pitch circle diameter of sprocket $= D = \frac{p}{\sin \frac{180}{Z}}$ ...(4)

where, p = Pitch, mm

Z = Number of teeth on sprocket

For a sprocket of pitch 9.525 mm and 44 teeth, $D = \frac{9.525}{\sin \frac{180}{44}}$

$= 133.517$ mm

Now, load on the shaft due to chain drive $= Q_0 = K_f \times P_f$ ...(5)

where, K_f = Load factor = 1.05

P_f = Tangential force due to power transmission

But, $P_f = \frac{75\ p}{V}$ ...(6)

where, V = Velocity of chain = $\frac{\pi\ DN}{60 \times 1000}$

and D = Pitch circle diameter, m

Therefore, $V = \frac{\pi \times 133.517 \times 687}{60 \times 1000}$

$= 4.807$ m/s

$P_f = \frac{75 \times 3}{4.807}$

$= 46.807$ kgf

$Q_0 = 1.05 \times 46.807$

$= 49.147$ kgf

Considering Fig. A.2 and taking moment about A,

$$49.147 \times 115.25 + R_b(63.25+115.25) - 20.213(117.75 + 63.25 + 115.25) + 20.213 \times 117.75 = 0$$

Therefore, $R_b = -11.519$ kgf

Taking moment about B,

$$20.213(117.25 + 115.25 + 63.25) - R_a(115.25 + 63.25) -$$

$$49.147 \times 63.25 - 20.213 \times 117.75 = 0$$

Therefore, $R_a = 2.742$ kgf

Based on these, the shear force diagram and bending moment diagram are drawn (Fig.A.3 and A.4).

Bending moment at C and E = 0

Bending moment at B = 20.213×11.775

= 238.008 kgf-cm

Bending moment at D = $20.213(11.775+6.325)+(11.519 \times 6.325)$

= 438.713 kgf-cm

Bending moment at A = 20.213×11.775

= 238.008 kgf-cm

Therefore, maximum bending moment = 438.713 kgf-cm

Maximum torque = 312.7 kg-cm

Equivalent twisting moment = $T_e = \sqrt{(K_m.M)^2 + (K_f.T)^2}$ ...(7)

For suddenly applied load with major shock = $K_m = K_f = 3$

$$T_e = \sqrt{(3 \times 438.713)^2 + (3 \times 312.7)^2} = 1616.247 \text{ kg-cm}$$

Equivalent bending moment = $M_e = ½[K_m.M + \sqrt{(K_m.M)^2+)K_f.T)^2}]$ ...(8)

$= ½[K_m.M + T_e] = ½[3 \times 438.713 + 1616.247]$

= 1466.193 kgf-cm

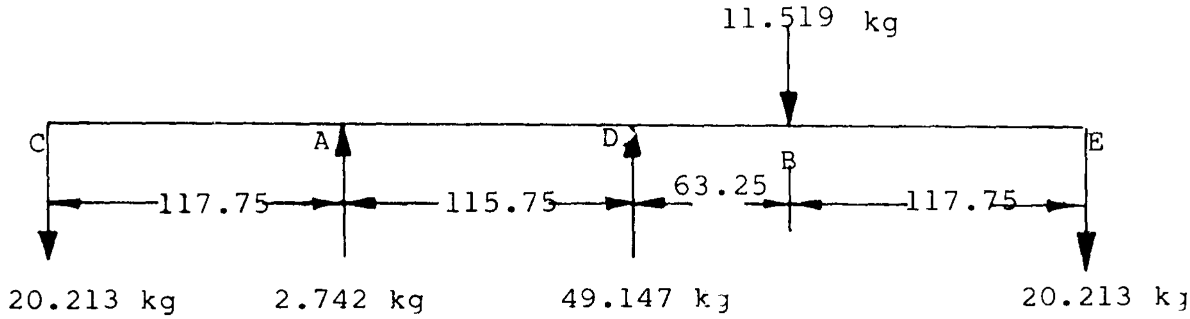


Fig. A.2 Load and reactions on shaft.

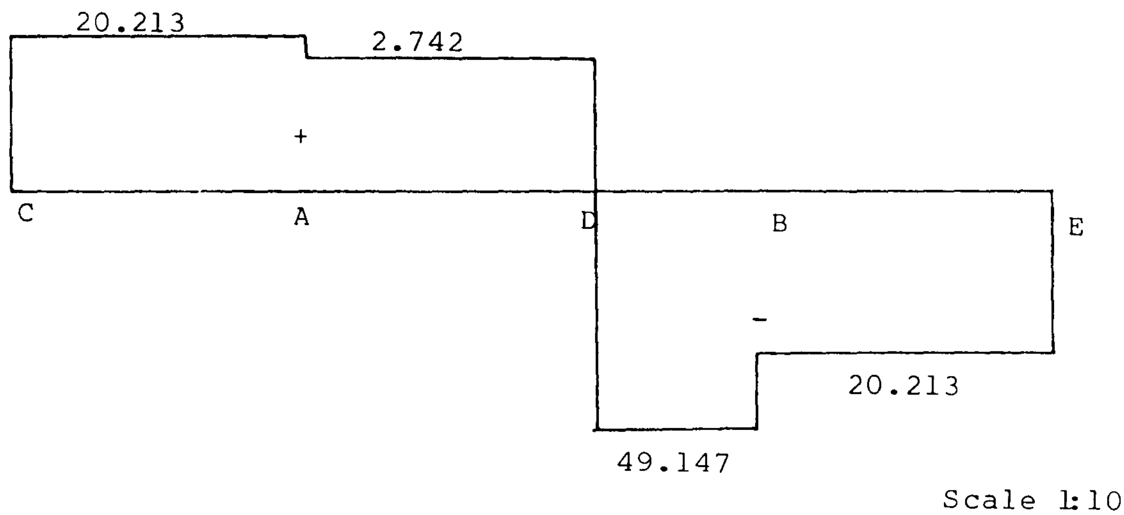
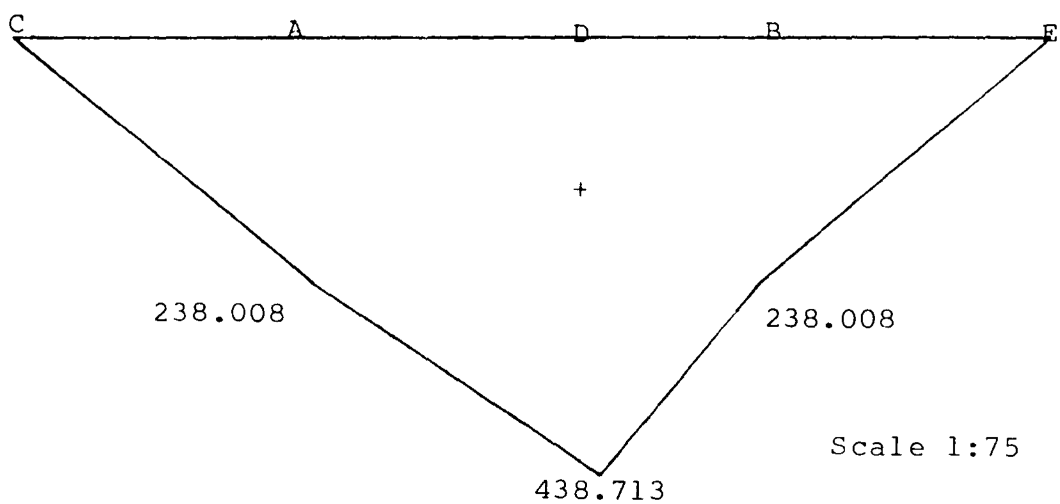


Fig. A.3 Shear force diagram (kgf).



Horizontal Scale 1:3 and dimensions in mm.

Fig. A.4 Bending moment diagram (kgf-cm).

The allowable stresses of MS shaft is 250 kgf/cm^2 in shear (Γ_p) and 450 kgf/cm^2 (σ_p) in tension.

$$T_e = \frac{\pi}{16} \Gamma_p d^3 \qquad \ldots(9)$$

$$\text{Therefore, } d^3 = \frac{16 \times 1616.247}{\pi \times 250}$$

$$d = 3.205 \text{ cm}$$

$$M_e = \frac{\pi}{32} \sigma_p d^3 \qquad \ldots(10)$$

$$\text{Therefore, } d^3 = \frac{32 \times 1466.193}{\pi \times 450}$$

$$d = 3.214 \text{ cm}$$

Hence a shaft of 3.5 cm in diameter and 42.2 cm in length was selected.

APPENDIX B

Design of centre to centre distance between motor shaft and main shaft

Chain and sprockets were used to transmit power from prime mover to main shaft.

According to Design Data (1968),

chain length in pitches,

$$l_p = \frac{2\,a_o}{p} + \frac{Z_2 + Z_1}{2} + \left(\frac{Z_2 - Z_1}{2\pi}\right)^2 x \frac{p}{a_o} \qquad \ldots(11)$$

where, a_o = initially assumed centre to centre distance = 500 mm

p = pitch = 9.525 mm

Z_1 = number of teeth on driving sprocket = 21

Z_2 = number of teeth on driven sprocket = 44

$$\text{Therefore, } l_p = \frac{2x500}{9.525} + \frac{44+21}{2} + \left(\frac{44 - 21}{2\pi}\right)^2 x \frac{9.525}{500}$$

= 137.74 (to be corrected to an even number)

i.e. l_p = 138

Hence the pitch selected = 138

Therefore, corrected centre to centre distance =

$$a = \frac{p}{4}\left[(l_p - \left(\frac{Z_2+Z_1}{2}\right) + \sqrt{\frac{(l_p-Z_2+Z_1)^2}{2} - 2\left(\frac{Z_2-Z_1}{\pi}\right)^2} \right]$$

$$= \frac{9.525}{4}\left[\left(138 - \frac{44+21}{2}\right) + \sqrt{\left(138 - \frac{44+21}{2}\right)^2 - 2\left(\frac{44-21}{\pi}\right)^2}\right]$$

$$= 501.23$$

i.e. $a = 502$ mm

Hence the centre to centre distance selected = 502 mm.

APPENDIX C

Time taken for downward cutting at various stages

Stage No.	Depth of groove (m)	Time taken for downward cutting, (s)						Mean time (s)
		Run No.						
		1	2	3	4	5	6	
I	0.225	120	120	118	118	117	117	118.50
II	0.220	119	116	118	118	117	116	117.33
III	0.225	120	118	119	118	117	-	118.40
IV	0.230	120	119	120	122	-	-	120.25
		Grand mean						118.62

APPENDIX D

Time taken for forward cutting at various stages

Stage No.	Run No.	Length of groove (m)	Time taken for forward cutting (s)	Mean time (s)
	1	1.291	190	
	2	1.290	189	
I	3	1.200	182	185.33
	4	1.200	180	
	5	1.190	187	
	6	1.190	184	
	1	1.030	176	
	2	1.030	174	
II	3	1.030	172	176.17
	4	1.140	177	
	5	1.130	176	
	6	1.030	182	
	1	0.880	140	
	2	0.890	145	
III	3	0.980	146	145.20
	4	0.980	152	
	5	0.880	143	
	1	0.623	100	
IV	2	0.623	99	105.50
	3	0.830	110	
	4	0.830	113	
		Grand Mean		153.05

APPENDIX E

Time taken for making the pit

Stage No.	Run No.	Length of run (mm)	Time for setting-up (s)	Time for cutting (s)	Time for removing blocks (s)	Total time (s)
I	1	1291	225	310	378	3739
	2	1290	240	309		
	3	1200	330	300		
	4	1200	225	298		
	5	1190	240	304		
	6	1190	248	302		
II	1	1030	235	295	322	3748
	2	1030	245	290		
	3	1030	250	290		
	4	1040	345	295		
	5	1030	255	293		
	6	1030	335	298		
III	1	880	235	260	240	3018
	2	890	250	263		
	3	980	370	265		
	4	980	240	270		
	5	880	365	260		
IV	1	623	260	220	252	2338
	2	623	270	218		
	3	830	380	230		
	4	830	273	235		
Grand Total			5846	5805	1192	12843

APPENDIX F

Electrical energy requirement for grooving

Stage No.	Total length of run (m)	Electrical energy consumed for grooving, (kWh) Run No. 1	2	3	4	5	6	Electrical energy consumed (kWh)
I	7.361	0.227	0.225	0.221	0.222	0.222	0.222	1.339
II	6.390	0.200	0.200	0.202	0.203	0.206	0.203	1.214
III	4.610	0.180	0.181	0.184	0.185	0.183	-	0.913
IV	2.906	0.160	0.160	0.163	0.162	-	-	0.645
		Total electrical energy consumed						4.111

APPENDIX G

Specification of electric motor

Horsepower	:	3
Phase	:	3
rpm	:	1440
Cycle	:	50
Volts	:	400/440
Amperes	:	4.5
Type	:	A4Z/T1
Manufacturer	:	Elmot Engineering Co. Pvt. Ltd., Goregaon, Bombay

APPENDIX H

Specification of energy meter

Ampere	:	3 x 10
Volts	:	3 x 400
Cycles	:	50
1 kWh	:	112.5 revolution of disc. Made by General Electric Co. of India (Pvt. Ltd), Calcutta

APPENDIX I

Cost of pit digger

		(Rs)
a)	Total cost of main frame including fabrication charges @ Rs. 21.71/kg	792.42
b)	Total cost of elements of transmission system and bearing assemblies	605.00
	Cost of two cutter blades	2400.00
	Total cost	3797.42

APPENDIX J

Cost of operation

I Pit digger

Cost of pit digger (P) = Rs.3,800

Average life of pit digger (L) = 10 years

Working hours per year (H) = 720

Salvage value (S) (@ 10% of initial cost) = Rs.380

a Fixed cost per hour

1. Depreciation

$$= \frac{P-S}{LxH}$$

$$= \frac{3800 - 380}{10 \times 720}$$

$$= Rs.0.48/h$$

2. Interest on investment (@ 15% per year)

$$= \frac{P+S}{2xH} \times \frac{15}{100}$$

$$= \frac{3800+380}{2x720} \times \frac{15}{100}$$

$$= Rs.0.44/h$$

Total fixed cost per hour = 0.48+0.44

= Rs.0.92/h

b Variable cost per hour

1. Repair and maintenance charge (@ 10% of initial cost per annum)

$$= \frac{3800 \times 10}{720 \times 100}$$

= Rs.0.53

Total variable cost = Rs.0.53/h

Total cost for pit digger = Total fixed cost + Total variable cost

= 0.92 + 0.53

= Rs.1.45/h

II Electric motor

Cost of electric motor (P) = Rs.6,000/-

Average life of electric motor (L) = 15 years

Working hours per year (H) = 720

Salvage value (S) (@ 10% of the initial cost) = Rs.600/-

a Fixed cost per hour

1. Depreciation = $\frac{P-S}{LxH}$

$= \frac{6000 - 600}{15 \times 720}$

= Rs.0.5/h

2. Interest on investment (@ 15% per year) = $\frac{P+S}{2xH} \times \frac{15}{100}$

$= \frac{6000+600}{2x720} \times \frac{15}{100}$

= Rs.0.69/h

Total fixed cost per hour = 0.5+0.69

= Rs.1.19/h

b Variable cost per hour

1. Electricity charge = Rs.1 per kwh

Duration of motor operation = 1.6125 h

Total energy consumed = 4.111 kwh

Electric charge per hour = $\frac{4.111}{1.6125} \times 1$

= Rs.2.55/h

2. Repair and maintenance charge (@ 5% of initial cost per annum) = $\frac{6000 \times 5}{720 \times 100}$

= Rs.0.42/h

Total variable cost = 2.55 + 0.42

Rs.2.97/h

Total cost for electric motor = Total fixed cost + Total variable cost

= 1.19 + 2.97

= Rs.4.16/h

III Tractor

Duration of tractor operation = 3.236 h

Tractor hire charge (@ Rs.120 per hour) (wages for the tractor operator is included in the tractor hire charge) = Rs.120/h

IV Labour charge

Wages for additional labour (@ Rs.120 per day of 8 hours) = Rs.15/h

Total cost of operation = I+II+III+IV

= 1.45+4.16+120+15

= 140.61/h

Cost of making a pit

A. Cost of using the pit digger for making a pit:

Time for which the digger is used = 3.236 h

Cost of pit digger = 1.45/h

Cost of using the pit digger for making pit = 3.236 x 1.45
Rs.4.69

B. Cost of using the motor for making a pit:

Time for which the motor is used = 1.6125 h

Cost of electric motor = Rs.4.16/h

Cost of using the motor for making pit = 4.16 x 1.6125
= Rs.6.71

C. Cost of using tractor for making a pit:

Time for which the tractor is used	=	3.236 h
Tractor hire charge	=	Rs.120/h
Cost of using the tractor	=	120 x 3.236
for making a pit	=	Rs.388.32

D. Wages for additional labourer for making a pit:

Time for which a labourer is used in making a pit	=	3.567 h
Wages for additional labourer	=	Rs. 15/h
Wages for additional labourer	=	15 x 3.567
for making a pit	=	Rs.53.51

Total cost of making a pit	=	A+B+C+D
	=	4.69+6.71+388.32+53.51
	=	Rs.453.23
		=========

APPENDIX K

Cost of manual pitting in hard laterite

According to Standard Data Book (1962) of Kerala PWD, 10 men and 2.3 boys are required to dig a pit of 10 m^3 size to a depth of 1.2 using pickaxe and spade in ordinary rock like hard laterite.

Now according to the existing wage rates,

Wage rate of a man/day = Rs. 120

Wage rate of a boy/day = Rs. 90

Therefore, the cost of making a pit of the above size = 10 x 120 + 2.3 x 90

= Rs.1407.00

Therefore, cost of making a pit of 1 m^3 = $\frac{1407}{10}$

= Rs.140.7

DEVELOPMENT AND TESTING OF A LARGE DIAMETER PIT DIGGER FOR LATERITE TERRAIN

By

PREMAN P. S.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

A large diameter pit digger was developed as an attachment to tractor for making large size pits in laterite suitable for planting saplings of trees especially for coconut palms. It was tested and evaluated at the Kelappaji College of Agricultural Engineering and Technology, Tavanur.

The pit digger mainly consisted of a tractor rear-mounted twin-blade laterite cutter. The twin-blade laterite cutter essentially consisted of two circular blades, a main shaft, two cast iron hubs, two bearings and bearing blocks, power transmission elements, a main frame, two protective shields and one stopper. A 3-phase, 3-hp electric motor of 1440 rpm at a speed ratio of 2.1:1 was used for rotating the blades. By using a jib crane twin-blade laterite cutter was hitched to the three point hitch system of a tractor. Pit having approximately a square-horizontal cross-section and stepped or rebated downwards in four steps was made in laterite. Size of pit obtained was 1290 x 1190 mm at the top and 830 x 623 mm at the bottom with a total depth of 900 mm. The volume of pit was 0.914 m^3. The capacity of machine was 2.24 pits of 0.914 m^3 in a day of 8 h. For

making a pit of 0.914 m^3, the total electrical energy consumption was 4.111 kWh and the diesel fuel consumed by tractor was 18.5 L.

The cost of digger excluding cost of motor, jib crane and tractor was Rs. 3800. The operating cost of the digger was Rs. 140.61 per hour and the cost of making one pit was Rs. 453.23. After taking into account of the cost recovered due to the 41 laterite blocks obtained while making the pit, the net cost of making a pit was Rs. 207.12.