DEVELOPMENT OF A CONO-PUDDLER ATTACHMENT FOR A 5HP TILLER

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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2000

DECLARATION

I hereby declare that the thesis entitled "**Development of a cono-puddler attachment for a 5 hp tiller**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Development of a cono-puddler attachment for a 5 hp tiller**" is a record of original work done independently by Sri. Ph. Tejendra Sharma, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to him.

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PH. TEJENDRA SHARMA

DEDICATED TO
MY
BELOVED MOTHER

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SYMBOLS AND ABBREVIATIONS

AAU	Assam Agricultural University
ACIAR	Australian Center for International Agricultural Research
Agric.	Agricultural
AMA	Agricultural Mechanization in Asia, Africa and Latin America
APAU	Andhra Pradesh Agricultural University
ASAE	American Society of Agricultural Engineers
cc.	cubic centimetre (s)
CIAE	Central Institute of Agricultural Engineering
cm	centimetre (s)
Dept.	Department
Engr.	Engineers
Engng	Engineering
et.al.	and others
Fig.	Figure (s)
FPME	Farm Power, Machinery and Energy
g.	gram (s)
G.I.	galvanised iron
ha	hectare (s)
hp	horse power
h	hour (s)
i.e	that is
IRRI	International Rice Research Institute, Philippines
ISI	Indian Standard Institute
J.	Journal
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg.	kilogram (s)
Kmph	kilometre per hour

KPa	Killo pascal (s)
lt.	litre (s)
m.	metre (s)
min.	minute (s)
MJ	Mega Joule (s)
Model-1	Developed cono-puddler, Model-1
Model-2	Developed cono-puddler, Model-2
Model-3	Developed cono-puddler, Model-3
Model-4	Developed cono-puddler, Model-4
Model-5	Developed cono-puddler, Model-5
mm.	millimetre (s)
MS	mild steel
N	North
NPK	Nitrogen, Phosphorous and Potassium
q	quintal (s)
RNAM	Regional Network for Agricultural Machinery
rpm	revolutions per minute
Rs.	Rupee (s)
S	South
Sci.	Science
sec.	Second (s)
t	Tonne (s)
Trans.	Transactions
viz.	namely
yr	year (s)
&	and
@	at the rate of
o	Degree
/	per
%	per cent

INTRODUCTION

INTRODUCTION

Agriculture is the backbone and prime mover in the industrial life of any nation. Indian economy primarily depends on agriculture. The population of our country is rapidly increasing, as a result the requirement of food products is also increasing. The increase in demand of food grains can be met only by increasing the productivity per unit area per unit time, which it is possible only through utilization of proper and efficient mechanical power in this field. The development of agriculture in India has been closely related to the utilization of effective labour saving implements and equipments. The development of machinery and mechanical power to make man's effort more effective and productive is one of the most prominent features of development. Human power and animal power output are limited as well as affected by the stress of the high temperature, humidity, diseases and imbalance diet.

Agriculture uses energy intensive technologies for maximizing the productivity whereas, in India the intensity of mechanization is still quite low compared to other developed countries.

In India the food grain production has increased considerably from a mere 51 million metric tonnes in 1950-51 to 193 million metric tonnes in 1997-98. This increase was possible due to adaption of quality seeds, appropriate usage of fertilizers, plant protection chemicals and assured irrigation. The efficacy of agricultural inputs and natural resources further increased through the adaption of appropriate agricultural implements/equipments.

Paddy (*Oryza sativa*) is one of the most important agricultural out put in the world even though it counts less than 5% of the total agricultural commodity in the world trade. It is grown in 111 countries and is a dietary component for more than a third of world population. Considering the importance of rice it was described as the "Grain of Life" by the United Nations.

Rice forms the largest consumed component among the food items providing 31% of the total calorie requirements. In Asia, the production, consumption and trade of rice, accounts for 90-95% of the world production. Rice is the principal staple food for 65% of the population in India and the foremost food of the developing countries. It occupies about 42 million hectares of land accounting 34% of the total area under food crops and 42% of the area under cereal crops and 46% of the cereal production in India. India is one of the leading exporters of rice in the world and contributes about 15% of the export market of rice.

Rice also occupies a prominent place among the crops cultivated in Kerala where it is consumed mostly in the form of parboiled rice. The production and area of cultivation in Kerala for the last few decades are presented in table 1.1.

Table 1.1 Rice production and area of cultivation in Kerala

	Year (19')							
	85-'86	90-'91	91-'92	92-'93	93-'94	94-'95	95-'96	96-'97
Area ('000ha)	678.281	559.450	541.327	537.608	457.830	503.290	471.15	430.83
Production (''000 t)	1173.05	1086.58	1060.35	1084.88	1003.94	975.07	953.03	871.36

Source: Economic Review 1993, State Planning Board, Kerala, Table 4.10, page 38 and The Hindu, Survey of Indian Agriculture, 1999, page 47.

The area of cultivation of rice in Kerala is decreasing due to the expansion of industrialization and building construction during the last few decades. The area under paddy is also being converted into garden lands for raising other crops like coconut and construction purposes as the paddy cultivation was reported to be un economical loss because of high labour wages. High labour scarcity is also experienced during peak seasons for seedbed preparations, transplanting, harvesting and threshing operations.

This necessitates the introduction of labour saving and economical farm implements and machines for the paddy cultivation areas of Kerala. So far the agricultural mechanization in India is limited to only some selected areas because of the unavailability of economic and appropriate machines.

Rice usually grows well by transplanting paddy seedlings in puddled soil and flooded condition. Many studies have shown that transplanted paddy crop gives higher grain yields compared to other methods of cultivation and is one of the most widely accepted cultivation practice for paddy crop. Rice requires high amount of water of approximately 10^7 liters per hectare of land for its proper growth in which rice is the lowest productive crop per unit of water among the cereals.

Lack of proper water management practices is probably the most widespread constraint to higher rice yields. So it requires good water management practices, which is generally found efficient in a well prepared soft soil bed obtained by puddling.

Puddling of soil is one of the common and important operations in paddy growing areas, which is done after initial ploughing in standing water of 5-10 cm depth on the field. Adequate puddling of soil is important from the point of view of reducing loss of water and nutrients from the soil by deep percolation of water. Approximately 75% of the total water supplied to the rice crop is lost through deep percolation during submergence.

The main objectives of puddling are to reduce deep percolation of water, to destroy weeds by decomposing them, to facilitate transplanting of paddy seedlings by making the soil softer, levelling of the field and even distribution of fertilizers.

The area of cultivation of paddy crop is more than any other crops as adapted to different methods of cultivation including direct seeding and transplanting. Direct seeded rice has certain disadvantages over transplanted rice viz. uneven germination, initial stunting and lodging of crop due to poor root anchorage and more weed growth. Paddy seedlings establish well and grow better when seedbed is prepared in puddled condition before they are transplanted. In contrast to direct seeding, transplanting uses healthy seedlings and gives a more uniform crop stand with effective weed control and less crop lodging (Khan and Gunkel, 1989).

Puddling operation is usually done using animal drawn indigenous plough (country plough) in most part of the country which is highly inefficient and time consuming. Due to the advancement of agricultural mechanisation, many mechanically operated implements are commercially available for puddling operation. But because of the low land holding and low investing capacity of our farmers, the mechanisation in the field of agriculture could not fully be implemented. In Kerala puddling is commonly done by using tractor operated cage wheels, power tiller operated rotavator and animal drawn indigenous plough. It was felt that, there is good scope to develop small engine operated puddler in the field of agriculture to suit our marginal farmers. Hence, studies were carried out in this regard to develop a cono-puddler attachment for a 5hp tiller. The main objectives of this study are :

1. to fabricate a cono-puddler based on the IRRI design and evaluate its performance in the field,
2. improve the design to suit our soil condition,
3. evaluation of cones of three sizes,
4. measurement of soil properties, machine and operational features,
5. testing the feasibility of increasing the width of operation to increase the field capacity,
6. study the feasibility of providing a seat for the operator to facilitate during the operation,
7. optimisation and development of final prototype model and
8. to asses the economics of operation with indigenous method of puddling.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In this chapter literature available on the soil-implement system with regard to origin, cultivation practices of rice, physical characteristics of soil before and after puddling and performances of available puddlers are reviewed.

2.1 History, origin and properties of rice

Rice is grown primarily for human consumption. It is the staple food for people in nearly all Asian countries and major source of livelihood in the rural economy. Copeland (1924) reported that rice was first cultivated in the South East Asia. Vavilov (1926) suggested that India and Burma should be regarded as the centres of origin of cultivated rice. Rice cultivated today reportedly is originated in Asia (Chapman and Carter, 1982).

Rice is grown under widely varying conditions of altitude and climate. Rice cultivation in the world extends from 39^0 S latitude (Australia) to 45^0 N latitude (Japan). In India it grows from 8^0N to 35^0 N latitude. It also grows from below the sea level as in the Kuttanadu region of Kerala and 1979m above the sea level as in parts of Jammu and Kasmir (ICAR, 1980). Rice crop needs a hot and humid climate where the average temperature required throughout the life period ranges from 21^0C to 37^0C (Singh, 1984).

Among the cereals, rice provides maximum calories per unit area of land. As the fat content is low, its suitability for storage is enhanced in the hot and damp climate. About half of the consumers in India prefers parboiled rice while the rest prefers white rice.

2.2 Cultivation of rice

In Kerala rice is grown either by broadcasting or by transplanting during three seasons as shown below depending on the availability of water and other local conditions.

' Virippu '	-	First (Autumn) crop April-May to September-October
' Mundakan '	-	Second (Winter) crop September-October to December-January
' Punja '	-	Third (Summer) crop December-January to March-April

The system of rice cultivation in various rice growing areas of the country are largely dependent upon the rice growing conditions prevalent in the respective regions. The principal methods of cultivation followed in India are "dry", "semi dry" and "wet land" systems (ICAR,1980).

2.2.1 Dry and semidry system

The dry system of cultivation is basically followed in rain fed areas. The land is prepared by ploughing and harrowing in summer for achieving the required tilth. The seeds are sown directly with the onset of the monsoon shower. It is confined in the rain fed areas and does not have supplementary irrigation water facilities. The rain water is impounded when crop is 45–50 days old and there after it is converted to wetland system of cultivation. This system is generally adapted in April/May to September/October season.

2.2.2 Wet land system

In wet land system, the land is ploughed thoroughly and puddled with a suitable puddler with 5–10 cm of standing water over the surface. Sprouted seeds are either sown in the puddled soil or alternately grown in a nursery bed and then transplanted into the main field. Weeds are buried and better water management is ensured by levelling of land after puddling.

2.3 Puddling of soil

Bodman and Rubin (1948) defined puddling as the reduction of apparent specific volume of a soil by doing a mechanical work and suggested a term puddability to mean the change in specific volume per unit work for such a change.

According to Baver (1956), puddling is the structural change associated with the consistency of soil.

Jaswanth Singh (1961) defined puddling as the art of tilling the soil by a mechanical device which caused shear or compression or both.

Bhole and Yadav (1969) reported that when a puddler was in operation, the action on soil was compressed, sheared, accelerated to the blade speed and shifted.

Thorne and Peterson (1980) defined puddling as a process in which soil lost its granular structure and became defloculated.

Wan *et al.* (1990) reported that the practice of direct sowing of pre germinated seeds in puddled soil was a common practice in Malaysia because of labour shortages and high labour cost.

Paddy seedlings establish well and grow better when paddy seedbed is prepared in puddled condition before they are transplanted. To achieve this goal, farmers plough the land with a wooden plough or an iron plough for a number of times. In heavy black soils, the animals walk knee-deep while puddling in water virtually dragging themselves out of the mud every time they step forward. This naturally consumes more time, energy and money which takes nearly 123-136 hr per hectare land of puddling (Datt, 1992).

Doraiswamy *et.al.* (1999) tested the simultaneous sowing of paddy (pre germinated) and daincha seed (not pre germinated) as green manure crop in alternate rows in puddled soil. It was suggested that the field for this method of cultivation required adequate puddling and proper levelling to ensure uniform germination.

2.3.1 Objectives of puddling

Puddling decreases permeability, increases water retention capacity of the soil, facilitates transplanting and eradicates weeds. Some of the main objectives of puddling according to Datt(1992) are as follows

2.3.1.1. Prevention of water percolation

When the submerged paddy field is puddled, a muddy suspension is created. The larger particles of the soil in the suspension settle first and finer ones later. These particles block the pores in the top soil surface and reduce the percolation of water. During the puddling operation the soil layer just below the puddled soil is compacted by the puddling equipment. This causes crushing and blocking of the pores in the hard pan and results in a reduction of water percolation.

2.3.1.2. Weed control

As the top soil is stirred the weeds are buried under the soil, the reductive gas production in the soil is discharged and the activities of the micro organisms are stimulated, thus accelerating the decomposition of green manure which were ploughed under by the ploughing practice and puddling.

2.3.1.3. Levelling of soil surface

Undulated paddy fields can be levelled as the soil becomes muddy after puddling. Accordingly the water level will become readily adjusted giving uniformity in the rice plant growth.

2.3.1.4. Ease of transplanting

As the soil is stirred and clods are broken up, the soil becomes soft such that seedlings can easily be pushed in to mud to the extent of 4-6 cm deep with little resistance and without any damage to the seedlings.

2.3.1.5. Mixing and distribution of fertilizers

Due to stirring of the topsoil, the fertilizers applied are mixed properly with the soil in which it helps in uniform intake of nutrients by the plant roots.

2.4 Different puddling equipments used in India

The puddlers used in India are of three types according to the source of power used. These are

1. Animal drawn puddler.
2. Power tiller operated puddler and
3. Tractor drawn puddler.

2.4.1 Animal drawn puddler

2.4.1.1. Bullock drawn country (desi) plough

The main parts of this plough are beam, body, yoke, and handle (Appendix–I). The yoke is a long wooden part, which harnessed the power of the bullocks to the plough and transfer at through the beam. The share is the main working part of the implement and is made up of high carbon steel. A wooden handle is provided for the operator to control the implement. It is one of the most commonly used implements among the Indian farmers. It requires around 56 hours to puddle one hectare of land for three times.

2.4.1.2 Bullock drawn puddler

The unit consists of a series of steel blades mounted around a central shaft in a staggered fashion, either on straight or inclined position. These blades rotate during operation and puddle the soil when operated by a pair of bullocks. The width of the implement is 600-700 mm with field capacity of 1ha/day.

2.4.1.3 Bullock drawn helical blade puddler

Five number of helical blades made of mild steel are fixed in a skewed shape and are mounted on a wooden frame having wooden bearing such that the blades rotate freely (Appendix-I). Due to the helical shape of the blade there will be continuous contact between the blades and the soil, which gives a uniform load on the neck of the bullocks. The implement is used to puddle the soil after ploughing and is one of the commonly used puddlers. It is generally operated by a pair of bullocks. The width of the operation is 650 mm and having field capacity up to 0.6 ha/day.

2.4.1.4 Rotary blade puddler

It consists of 50mm diameter GI pipe, 850mm long shaft mounted on side members of a frame (Appendix–I). There are three sets of four MS blades of 200 x 87 x 3mm size fixed around the shaft at 50mm interval. The width of each row is 250 m. An angle of 10 degree is provided between the plane of the blades and shaft. A seat is provided over the puddler for the operator and is served for all types of soil.

2.4.1.5 Float harrow

The float harrow consists of two hallow drums of 35cm in diameter which are closed on both sides. These disc blades are mounted on each drum by nut and bolt. They are of 60cm in diameter with radius of curvature of 60cm. Each gang is mounted on angled iron frame by means of two bearings at the end of each drum. The two frames are hinged together at one end where the angle between the frames can be varied. Tynes are provided in between the two gangs to cultivate the area between the two blades. It is operated by a pair of bullocks with draft varying from 70 to 100kg. The width of cut is 1000mm with field capacity 0.72 ha/day.

2.4.1.6 Puddler for hills

This puddler consists of a wooden rectangular plank to which a MS flat with seven MS pegs is fixed. Four grooves are provided in the plank to vary the depth of operation. Two handles are provided on the top of the plank for operation and lifting the implement while turning. A rectangular MS flat with a circular rope is provided for hitching to the yoke. The implement does the puddling as well as levelling simultaneously. It is operated by a pair of bullocks. The width of cut is 720 mm with field capacity of 0.80 ha/ day.

2.4.2 Power tiller operated puddlers

2.4.2.1 Cage wheels and rotavator

This is one of the most popularly used power tiller operated puddlers in India. It is a self propelled type implement operated normally by 8-12 hp power tillers. The rotavator consists of a series of tynes, which puddle the soil when rotated. It cuts and buries the weeds effectively. The rotavator tynes are fixed on a single shaft and rotates through chain and sprocket mechanisms from the engine. Cage wheels are attached in place of the pneumatic wheels. The cage wheels provide traction and puddling while the rotavator primarily puddle the soil.

2.4.3 Tractor drawn puddlers

2.4.3.1 Wetland puddler cum leveller

The puddler is a peg type unit fitted on a rectangular frame made of a channel section usually of 75 X 40 X 6mm size. Pegs of 15 X 15mm in cross section and

150mm in length are welded on an angled iron frame 200mm apart. While the pegs do the puddling, the frame levels the soil.

2.4.3.1 Paddy puddler

This implement is attached to the three point linkage system of the tractor and is controlled hydraulically. It is a wheel of 2150mm long with lugs spaced uniformly. As the tractor moves forward, the puddler is pulled and it puddles by rotating in the soil. Three or four passes are required to make the field suitable for rice transplanting. Cage wheels are attached to the tractor to avoid ground wheel slippage.

2.4.3.2 Extra width cage wheel puddler

This implement is operated by a four wheeled tractor. It is a special cage wheel designed for puddling operation, which is fitted in place of the pneumatic wheels. It is made up of angle iron, each having a width of around 1200mm. When the tractor moves forward, the soil is cut and mixed with water because of the weight of the tractor. It requires three or four times operations to get the soil suitable for transplanting. Usually a leveller is fitted to the three point linkage of the tractor, which is used for levelling the field after the puddling is over.

2.5 Comparison of different puddlers and puddling with non puddling

2.5.1. Water use and percolation

Adequate pudlling of soil is important from the point of view of reducing loss of water and nutrients from the soil by deep percolation of water. Approximately 75% of the total water supplied to the rice crop is lost through deep percolation during submergence.

De-Datta *et.al.* (1974) studied the water and nitrogen economy of rain fed rice on clay soil. The water use efficiency of rice in the irrigated controls was found 2.5 times higher in the puddled soil than in the un puddled soil. And also because of the large water losses, nitrogen losses were greater in the un puddled soil than in the puddled soil. It was also found that the plants grown in the un puddled soil had less nitrogen and lower grain yield.

Tyagi *et.al.* (1975) conducted field experiments of puddling with different types of combination of implements viz. local plough, mould board plough, disc harrow, power tiller plus rotavator and tractor plus cage wheels. From the experiment, it was concluded that power-tiller plus rotavator was most efficient in terms of percolation losses and water use efficiency, followed by tractor plus cage wheel and disc harrow.

In trials on a sandy clay loam soil, the minimum percolation loss of 18.0 cm was obtained in plots puddled with a power tiller with rotavator and cage wheels followed by the plot puddled with a tractor having cultivator and cage wheel with percolation loss of 22 cm (Raj, 1977).

Agarwal *et.al.* (1978) conducted field experiments in sandy loam soil to study the performance of various puddling implements and the duration of operation for reducing percolation losses. Tractor with cage wheels and Escort puddler and Yan mar power tiller with cage wheels were almost similar in effect. Tractor with cage wheels and disc harrow was least effective in reducing the percolation losses by a single operation. Percolation losses were markedly reduced by tractor with cage wheels and harrow and Yan mar power tiller when operated twice.

Reddy and Hukkeri (1979) concluded that puddling twice at 15 days interval markedly increased the water use efficiency in the cultivation of rice. Continuous submergence increased the yields marginally over partial submergence but was not economical because of high water requirement.

Reddy and Hukkeri (1983) showed that, the saturated hydraulic conductivity was decreased from 113 mm/day by ordinary ploughing to 48 mm/day with puddling twice and to 29 mm/day with soil compaction. Kar *et al.* (1986) analysed rice growth by compaction with a load of 0.21 kg/cm^2 and puddling. Irrigation requirement was 2295 mm with ordinary ploughing compared to 1350 mm with soil compaction.

Bhadoria (1987) indicated from field study that, initial infiltration of puddled soil was higher by 1.1 mm/hr and the final infiltration rate decreased by 0.6 mm/h when compared to un puddled soil. Ramanand *et,al.* (1988) found the percolation rate reduction from 1.35 cm/day to 0.45 cm/day in the puddled soil compared to the un puddled soil.

Adachi (1990) showed that, puddling reduced macro porosity by breaking soil clods and by closing the remaining macro pores to be partially filled by dispersed fine particles resulting in reducing percolation of water through the soil.

From the experiment conducted by Sharma *et.al.* (1991) on different bullock drawn puddling equipments i.e. rotary blade puddler, disc harrow and harrow cum puddler in comparison with the desi plough to evaluate their performances, the rotary blade puddler was found very satisfactory when operated twice in terms of reducing percolation loss. The percolation loss of water was found varying from 0.5mm/h to 1.6 mm/h from the plots puddled by the implements tested.

Singh *et.al.* (1993) recorded the effects of submergence conditions and depth of soil puddling on the mean infiltration rate of water using a double ring infiltrometer measured at 5, 10, 20 and 30 days after treatment. It was reported that, soil puddling decreased infiltration rates by up to 61.7 per cent and was the most important factor involved in the study.

Tuong *et.al.* (1994) found that inclusion of small un puddled area of 1.5 square meter per 100 square meter of puddled soil within the field with 5 cm ponding water increased field water loss from 2.7 mm/day to 15 mm/day due to deep percolation and suggested that sealing of the bund walls with puddled soil materials will reduce the horizontal conductivity of the bunds and may further reduce under bund percolation.

Ringrose *et.al.* (1996) observed that water percolation beneath rice fields was a major contributor in rising ground water leading to water logging and salinization in Australia. Two experiments were conducted on clay loam soil to study the effects of puddling on rice yieds, percolation and soil physical properties. It was found from the experiments that, in terms of water use, the rotavation and roller treatments performed best. Roller treatment created denser, stronger soil and destroyed macro porosity in the surface soil. The rotavation treatment caused aggregate breakdown, blocking of macro pores and disruption of pore continuity of the soil. Utomo *et.al.* (1996) studied the effects of soil puddling intensity on the growth and yield of rain fed lowland rice and observed that, puddling is necessary to reduce percolation rate especially on the coarse textured soils.

2.5.2. Yield performances

Kaushik and Mani (1977) conducted trials on puddled soil and transplanting conditions on rice growth and found that, the grain yield was increased 2.5 times by transplanting after puddling compared to direct seeding. In trials on a sandy clay loam soil, the maximum paddy yield of 56.89 q/ha was obtained in plots puddled with a power tiller having rotavator and cage wheels followed by the plot puddled with a tractor having cultivator and cage wheels which yielded 56.66 q/ha (Raj, 1977).

Reddy and Hukkeri (1979) observed the superiority of puddling to compaction in terms of yield of rice and concluded that, puddling twice at 15 days interval markedly increased growth and yield of rice. Singh *et.al.* (1984) reported that rice transplanted on puddled soil gave significantly higher yields than that of the un puddled soil.

Razzaq (1987) compared performances of cultivator tillage and rotary cultivation, independently and in combination for puddling fine textured soil and also the effect of puddling and dry preparation was investigated. It was established from the experiment that, puddling by two cultivator passes plus rotary cultivator followed by one planking gave significant increase in paddy yield compared with any one of these implements used alone.

Das and Mandal (1986) studied effects of farm yard manure applications on puddling and no puddling conditions, and found that highest yield was obtained with the application of farm yard manure 28 days before transplanting in combination with puddling and water logged condition.

Kar *et.al.* (1986) analysed rice growth by compaction with a load of 0.21 kg/cm^2 and puddling. They concluded that, grain yields were increased by up to two passes with the roller but decreased with further passes and also the yield increased with increase in depth of puddling. Purushothaman *et.al.* (1987) conducted experiments in the monsoon and winter seasons with rice to observe the effects of different puddling methods on rice cultivation. It was found that puddling twice with an iron plough followed by one puddling with helical blade puddler produced the highest grain yield.

Experiments were conducted by Singh and Sangliene (1987) on nitrogen management for lowland transplanted rice. Of the various methods of application of urea in different forms to lowland rice under flooded conditions, the placement of urea in the root zone after transplanting or incorporation of granulated compost at puddling gave the highest yields and nitrogen use efficiency. Thorat *et al.* (1987) observed that, the rice grain yields from the plots which had been puddled using a rotary power tiller, an iron puddler, an iron plough, a wooden plough and a wooden puddler were 3.6, 3.5, 3.0, 3.3 and 3.1 t/ha respectively.

Das and Choudhury (1988) reported from the experiment conducted for the effect of puddling intensity that, puddling thrice at 7 day interval gave the highest yield compared to puddling twice and puddling twice after preliminary tillage and showed that primary tillage before puddling gave no extra benefit. Mahanta *et.al.* (1990)

compared no-tillage and dry ploughing with puddling under identical cultivation conditions for their effect on growth and yield of wet season rice and found that the growth of rice seedlings was faster and more vigorous after puddling which was reflected in early flowering and maturity followed by greater grain and straw yield. These results were attributed to the ability of the roots to obtain more nitrogen from the puddled soil.

Sharma (1990) tested some animal drawn puddling implements to evaluate their puddling efficiency and concluded that two ploughings by local or mould board plough followed by planking were sufficient to give the same grain yield as four ploughings and two ploughings by mould board plough followed by planking.

Varshney and Bhagwan (1990) compared tractor drawn Pantnagar blade type rotary paddy puddler with local method of puddling. The tiller intensity and the yield obtained from the plot puddled with the puddler was found higher than that of the local method of puddling. Rachhpal *et.al.* (1995) compared no puddling, two runs of tractor drawn cultivator in standing water, four cultivations and four plankings for rice cultivation. More yield of rice was found from the field puddled 4 times than from the fields puddled 0 and 2 times, all followed by planking.

Dacanay *et.al.* (1996) conducted field experiments to measure the effect of pre rice puddling intensity on post rice rain fed mung beans, soybeans and ground nuts and found that on highly puddled soils the soybean and groundnut yields were increased on heavy textured soils whereas it reduced on light textured soils.

2.5.3. Weed control

Kaushik and Mani (1977) conducted trials on puddled soil and transplanting conditions and found that intensive puddling before transplanting prevented weed competitions during the entire growing season of rice crop. Reddy and Hukkeri (1979) concluded that puddling twice at 15 days interval markedly reduced the weed infestation in the rice field.

Kar *et.al.* (1986) analysed rice growth by compaction with a load of 0.21 kg/cm^2 and puddling. Dry weight of weeds was only 0.6 and 0.7 t/ha with puddling twice and soil compaction respectively and 3.9 t/ha with ordinary ploughing. They concluded that, weed shared 57 per cent of nutrient (NPK) uptake with ordinary ploughing and only 8 per cent and 15 per cent with puddling twice and soil compaction respectively.

Cruz *et.al.* (1992) determined the number of passes required with use of a rotary cultivator for optimum puddling and found that, in areas with few weeds only, one pass was necessary at rotavator speed of 235 rpm whereas with large number of weeds at least two passes are required. Garg *et.al.* (1995) studied the effects of puddling on the field before transplanting rice using four different moisture regimes and observed that population densities of many of the weeds were significantly reduced after puddling.

2.5.4. Time saving and economy

Sinha (1963) had compared the performances of desi plough, melur plough, rice land puddler, modified puddler and voltas puddler. It was observed that, the time required for puddling operation was 52 to 93 h/ha of land with 5.8 to 9.6 cm. depth of puddling for the implements tested.

Guruswamy *et.al.* (1982) studied with puddlers viz. local wooden plough, a rectangular blade puddler, a 'C' type blade puddler, a local plough/rectangular blade puddler combination, a curved (helical shaped) blade puddler and local plough/curved blade puddler combination and concluded that puddlers are superior to the local plough in terms of time saving and in preventing percolation. The curved blade puddler followed by the rectangular blade puddler/local plough combinations were quickest and least expensive.

Sharma (1990) concluded from experiments of animal drawn puddlers that, two ploughings done at 90 degree to each other by local or mould board plough followed by one planking are adequate to puddle light textured sandy loam soil for paddy transplanting where puddling index and grain yield obtained were similar to those obtained from other costlier puddlers. Two ploughing by mould board plough followed by one planking was recommended because of lowest time and cost involved. Varshney and Bhagwan (1990) compared tractor drawn pantnagar blade type rotary paddy puddler with local method of puddling. The field capacity of the tractor drawn pantnagar blade type rotary paddy puddler was found as 0.59 ha/h with 39% field efficiency.

Manaligod (1991) modified the puddling type floating power tiller to obtain desired combinations of traction, puddling and lift of soil. A 1m wide hydro tiller had a field capacity of 1.5-2.0 ha/day, which was considerably faster and more economical in waterlogged areas and even in normal field conditions.

From the experiment conducted on rotary blade puddler, disc harrow, harrow cum puddler and desi plough by Sharma *et al.* (1991), the observed field capacity of the implements varied from 0.035 ha/h to 0.145 ha/hr. The time requirement for the rotary blade puddler, disc harrow and desi plough were 18 h/ha, 23.5 h/ha and 55.6 h/ha respectively for puddling three operations. The energy required and cost of puddling operation of the disc harrow and desi plough were 1.35 and 4.64 times that of the rotary blade puddler. (Sharma *et.al.*,1991). Subramanyam (1993) tested and evaluated a hydro tiller operated by a 5hp tiller in a sandy clay soil. The field capacity for the working width of 108 cm. was 0.18 ha/h with 10-12 cm depth of puddling.

An animal drawn and a power tiller operated cono-puddler were developed by IRRI (1993). The animal drawn cono-puddlers were of single gang and double gang type each gang consisting of six rotors, and the power tiller operated was of only one gang consisting of six rotors. The rotors were clamped individually to the tool bar for easy removal and spacing adjustments. The animal drawn cono-puddler had a field capacity of 1ha/day and for the power tiller operated cono-puddler, it was 1.5ha/day.

Rautaray (1998) compared the performances of 10 different animal drawn puddlers available in the country and showed that the time consumed by the lugged wheel puddler, patela puddler, float harrow, disc harrow cum puddler and cono-puddler were 6.5 h, 8 h, 9.5 h, 9.5 h and 10 h respectively which were lower than other types of puddlers tested.

2.5.5. Energy requirement

Sinha (1963) had compared the performances of desi plough, melur plough, rice land puddler, modified puddler and voltas puddler. The draft requirements varied from 100 to 155 kg in his experiment with 5.8 to 9.6 cm. depth of puddling. Patil *et.al.* (1974) conducted comparative studies of the performance of power tillers and bullock power for seedbed preparation in red and black soils. The power tiller had no advantage over bullock for dry land cultivation but offered clear advantage over bullock in reducing time and cost of puddling operation.

Narayana Rao and Sirohi (1975) had compared the performances of country plough, APAU puddler and disc harrow and found that draft requirements varied from 45 to 64 kg. with 15.5 to 17.0cm. depth of puddling where APAU puddler was better.

Kuether (1977) reported that the higher power requirement and fuel consumption in wetland preparation is due to the excessive depth to which paddy land is generally tilled by farmers and also excessive sinkage in soft clayey fields which is a chronic problem resulting in poor fuel efficiency.

Rautaray and Singh (1982) concluded that a zero degree lug angle cage wheel gave a slip variation from 30.20 per cent at no draw bar load to 37.20 per cent at 400 kg draw bar load whereas a 42 degree lug angle gave higher slip variation from 38 per cent at no draw bar load to 52.30 per cent at 400 kg draw bar load.

The puddling operation in West Bengal was generally done using animal drawn desi/bose plough and a leveller. Traditionally one or two ploughing (cross wise) was done and then land is flooded with water. After two days the land is puddled by bose plough three to four times till the land is well puddled and finally levelled with a planker. Totally four to six cross wise operations were required to get the soil puddled and thus the cost of puddling was very high (Ingle, 1986).

Khan *et.at.* (1988) compared and concluded that the conical rotor is a rather versatile concept for use in a wide range of simple implements by the farmers especially in terms of reducing energy input for the traditional operations of land preparation and the weeding.

A animal drawn and a power tiller operated cono-puddler were developed by IRRI (1993). The draft of the animal drawn cono-puddler was 30-70 kg and required one draft animal to operate.

Surendra *et.at.* (1997) analysed the energy requirement for production of major crops in India. Studies were conducted on different crops for various cultivation practices in some selected states of India. They recorded various operation wise and source-wise energy requirement and found that tillage operation for rice before transplanting required minimum of 846 MJ/ha in rabi season in Orissa and maximum of 3237 MJ/ha in Tamil Nadu among the places selected.

2.5.6. Agronomic factors

Mahanta *et.al.* (1990) compared no-tillage and dry ploughing with puddling under identical cultivation conditions for the growth and yield of wet season rice. The seedling growth was faster and more vigorous after puddling which was reflected in early flowering and maturity followed by greater grain and straw yield. The results were attributed to the ability of the roots to obtain more nitrogen from the puddled soil and suggested that continuous no-tillage is not recommended for a soil with lower clay content.

Garg *et.al.* (1996) indicated that although soil bulk densities under compaction and puddling were not significantly different throughout the crop growth, during the initial crop growth stage, saturated conductivity and percolation rate under the compaction treatment were significantly lower than under the puddled treatment. The root growth, plant height and rice yield under puddled conditions were significantly higher than that under compaction.

2.5.7. Properties of puddled soil

The desired physical properties of puddled soil are low value of soil resistance up to 20cm depth, low bulk density, low percolation loss of water from the soil, burying and killing of surface weeds. Bulk density influences infiltration rate, permeability, percolation rate, aeration of soil and root growth. Bulk density is inversely proportional to soil porosity. A proper value of bulk density is required with minimum compaction to create adequate soil water, soil air and soil water root contact for healthy growth of plants. To define and compare different puddled soil conditions and different implements, various indices have been used by different scientists. Bulk density, puddling index, cone index, percolation loss of water, viscosity of puddled soil, shear strength and aggregate size distribution are few of them. However no single index can satisfactorily describe a puddled soil bed because of various limiting soil characteristics.

Chaudary and Ghildayal (1969) studied the aggregate stability of puddled soil during rice growth under different manure addition practices. The loss of structure and aggregation was studied by wet sieve analysis method and concluded that aggregate size reduced from 1.70 mm to 0.36 mm due to puddling. Palta *et al.* (1969) discussed various methods of measurement of bulk density like cone method, sand cone method and displacement method. They also suggested correction factors of some of the methods.

Rane and Varade (1972) used hydraulic conductivity as an index for evaluating the performance of different puddlers. Minimum hydraulic conductivity was obtained in case of angular blade puddler and maximum in case of no puddling treatment. From the research in Andhra Pradesh state. Mathankumar *et.al.* (1979) concluded that, variations in soil water parameters due to change in texture are compensated by bulk density.

Reddy and Hukkeri (1983) showed that dry soil bulk density increased from 1.42 g/cc with ordinary ploughing to 1.69 g/cc with puddling twice and to 1.80 g/cc with soil compaction. In the laboratory test conducted at laboratory by Khan and Gunkel (1989) on the puddled soil properties, the cone index at different puddled soil aging applied at different penetration speeds were recorded. The cone index at different puddled soil aging of 2, 3, 4 and 5 days for different cone penetration speeds of 2.0, 4.16 and 8.33 mm/sec at 5 cm depth was found to be minimum of 2.248 KPa on the second day for 4.16 mm/sec speed and maximum of 3.168 Kpa on fourth day for 2.08 mm/sec penetration speed.

The average cone index values over the range of 0 - 21 cm. before first ploughing, before puddling, before levelling and before transplanting during the growing season and at harvest were 420, 245, 311, 240 and 385 Kpa. respectively. The average hard pan was at 21 cm. and soil strength in the top layer of 0-14 cm dropped considerably after ploughing while at the bottom layer, between 21-31.5 cm, it decreased slightly (Eam-O-Pas and Gee Clough, 1987).

Manian and Jivaraj (1989) compared 13 different treatments of puddling implements for preparation of black clay soil under wet conditions for rice. Combinations of 4-bullock drawn implements viz. country wooden plough, victory metal plough, helical blade puddler and sheep foot roller were used in the study.

Measurements of soil resistance, bulk density, surface tension, percolation loss, weed and plant growth, grain and straw yield were recorded. The optimum treatment was found to be ploughing once with victory plough, followed by 24 h of watering and then puddling with helical blade puddler and sheep foot roller.

Mahanta *et.al.* (1990) compared no-tillage and dry ploughing with puddling under identical cultivation conditions for the growth and yield of wet season rice. The seedling growth was faster and more vigorous after puddling. Soil strength measured at the end of the rice growing season was significantly greater after continuous no tillage. The decreasing trend in grain and straw yield was associated with increasing soil strength.

Sharma (1990) concluded from the experiments using few animal drawn implements for evaluating their puddling efficiencies that, two ploughings by local or mould board plough followed by planking were sufficient to give the same puddling index and grain yield as four ploughings and two ploughings followed by planking.

From the experiment conducted on bullock drawn puddling implements by Sharma *et.al.* (1991), it was concluded that rotary blade puddler gave a satisfactory performance when operated twice before transplanting with puddling index of 49.10 per cent to 57.02 per cent in clay loam soil with an average puddling depth of 10 to 15 cm.

Awadhawal and Singh (1992) indicated that, shear strength, secant modulus, shear velocity and cone index decreased with increasing level of puddling but increased with time. Degree of puddle, derived from shear yield strength ratio was suggested as a suitable index for quantification of puddling and thixotropic effects on mechanical characteristics of the soil.

Salokhe *et al.* (1993) revealed that soil moisture content, percentage reduction in bulk density, falling cone penetration, puddling index, viscosity and aggregate size distribution increased as puddling increased, shear strength and cone index decreased when the number of passes increased and when forward speed decreased. Garg *et al.* (1995) studied the effects of puddling on the field before transplanting rice and observed that puddling reduced aeration and gave high moisture levels for prolonged periods.

Ringrose *et al.* (1996) observed that, roller treatment created denser, stronger soil and destroyed macro porosity in the surface soil whereas, rotavation treatment caused aggregate breakdown, blocking macro pores and disrupting pore continuty at the base of the puddled layer.

Rautaray *et.al.* (1997) conducted experiment to provide basic data about the changing physical, mechanical, and structural conditions in a rice soil. Soil moisture content, hydraulic potential, evaporation, soil strength properties, cracking, and hydraulic conductivity were measured. It was then concluded that, water content of puddled layers decreased with an increase in depth of puddling and settling time. Dry bulk density and shear strength increased with an increase in depth, turbidity, electrical conductivity and reduction in aggregate size per unit dry weight of the puddled sample increased with increased amount of puddling.

2.6 Development of matching equipment of power-tiller

Power-tiller is a multi purpose hand tractor designed particularly for rotary tilling and other operations on small farms (Pandey *et al.,* 1983). It is also known as a garden tractor, hand tractor, walking tractor or a two-wheel tractor. For small and medium size farmers who can not afford for four wheel tractors, the power-tiller offer a major option to achieve the designed level of mechanization. Pandey *et al.* (1983) found that, non availability of matching implements for different farm operations limit the versatility of the power-tillers. The development of matching implements was listed by them as a gap in the power-tiller research and development. The Western Ghats of

Karnataka Plateau which includes Kerala has been identified by them as a conductive region for introduction of power-tillers.

2.7 Economy of power-tiller farming

A study conducted at CIAE (1989), revealed that there was a saving of 48.15 , 45.82 , 45.1 and 78.13 per cent time in seed bed preparation with power-tiller system over bullock system in soybean, wheat, sorghum and bengal gram crops respectively. The cost benefit analysis showed advantage under power-tiller system over the bullock system. In case of sorghum-bengal gram crop rotation, the cost of cultivation was more by Rs. 86 per hectare in power-tiller system but the increase in profit in power-tiller system was Rs.1901 per hectare of land. CIAE (1989) had recommended that though the energy input is more in power-tiller system than the bullock system, the yield and net profit favoured the use of power-tiller in the cultivation practices.

Ullah *et al.* (1989) conducted a comparative study on the performance of four wheel tractor and two wheel tractor in small plots ranging from 0.25 ha to 4.00 ha of different shapes. The objective was to determine the superiority of one tractor over another for small plots. The two wheel tractor consumed 41 % more fuel than the four wheel tractor for an average plot size of one hectare. On the other hand, for a plot size of 0.25 ha the four wheel tractor consumed 5 % more energy than the two wheel tractor, which is expected to be higher for small holdings. From the view point of quality of tillage, both tractors gave equally good rotary tilling. However the cost analysis showed that it was not economical to work a plot smaller than 0.6 ha with a four wheel tractor in Bangladesh.

2.8 Mounting of implement

Uniform depth of tillage with constant width of ploughing is one of the basic parameters determining the quality of work of soil manipulating machines and implements. The stability of operation of the working tools of soil working machines depends on the forces acting on them. The magnitude, the time of action and the nature of change of these forces depend on the forces acting on the implement, their method of mounting, the type of machine, its mode of assembly, working conditions and so on. (Klemin *et. al.,* 1978). Crossley and Kilgour (1983) have suggested that the design of a soil engaging implement for two wheel tractors should be to make the implement run at the required depth without any need for the operator to supply a hand force continuously. The center of gravity should be as close to the wheel as possible so that the wheel force is nearly vertical in position to give better traction characteristics.

MATERIALS AND METHODS

MATERIALS AND METHODS

In this chapter, the methodology adopted for the development of o cono-puddler attachment for a 5hp tiller to suit sandy loam soil has been described. The methods followed to study the performance characteristics of the puddler in the field have been explained. The method of comparing the performance with the conventional methods of puddling in relation to the cost economics has also been analysed. These are arranged in the following sub headings :

1. objectives and concept
2. development of the cono-puddler
3. field evaluation
4. observations and measurements

3.1 Objectives and concept

A critical review of the existing implements and practices available for paddy cultivation has brought out the following facts.

1. low land-holding capacity of farmers,
2. low investing capacity of farmers,
3. low field capacity of animal drawn puddlers,
4. more human energy required for animal drawn puddlers,
5. non availability of wide variety of power tiller operated puddlers and
6. non economic use of tractor operated puddlers in small plots.

It was then decided to develop a cono-puddler attachment to a power tiller for wetland preparation to overcome the above drawbacks of the existing practices.

The main objectives of this study were to develop a cono-puddler, evaluate its performance in the field, improve the design and work out the cost economics. The detailed objectives are

1. to fabricate a cono-puddler based on the IRRI design,
2. evaluate its performance in the field,
3. improve the design to suit the soil conditions of coastal Kerala,
4. evaluation of rotors of three sizes,
5. measurements of soil, machine and operational parameters,
6. feasibility testing for increasing the width of operation to increase the field capacity and
7. feasibility testing to provide a seating arrangement to operate in sitting position.

3.2 Development of cono-puddler

Based on the agronomic aspects and cultural practices, the following fundamental points were set for the development of cono-puddler.

a) it should give a minimum puddled soil depth of 10-15 cm.
b) it should be able to operate in different types of soil
c) maximum burial of weeds should be achieved with minimum number of operations
d) a well levelled soil surface is to be achieved after puddling
e) the implement can be attached or detached very easily
f) the power source of the cono-puddler is 5hp engine which also can be used for other purposes and
g) it will give minimum drudgery to the operator by providing a seating arrangement.

3.2.1 Development of cono-puddler based on IRRI design (Model –1)

Based on the IRRI design, a cono-puddler was fabricated with six conical rotors. Its main assembly consisted of the following parts

a) Tool bar assembly
b) Conical rotor assembly
c) Shaft assembly for the conical rotor
d) Power tiller hitch assembly
e) Power tiller hitch bracket
f) Puddler hitch pin and
g) Power tiller hitch pin

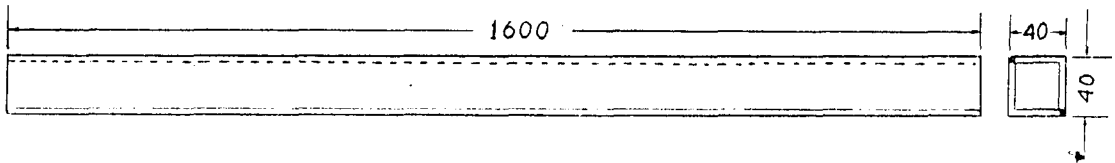
3.2.1.1 Tool bar assembly

A tool bar was fabricated to facilitate fixing of various parts of the implement on it. This was made out of 30 X 30 x 6 mm MS angled bar. Two pieces of 2000 mm long, MS angle bars were cut and welded face to face to form a hollow square. The shaft assembly of the conical rotor and power tiller hitch assembly of the cono-puddler were attached on it using U-bars (Fig. 3.1(a)).

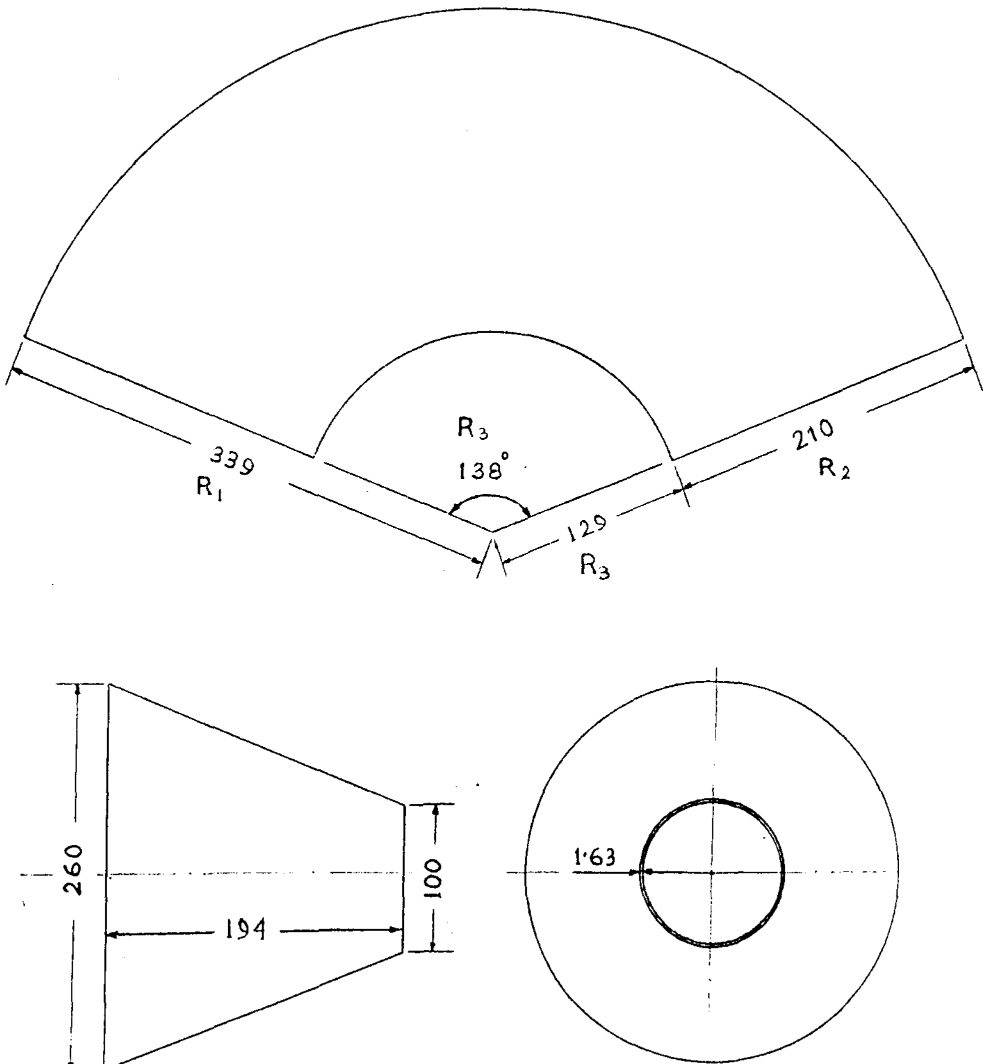
3.2.1.2 Conical rotor assembly

Conical rotors are the actual soil working parts of the cono-puddler. Six rotors were fabricated and were fixed on the tool bar through their individual conical rotor shaft as in fig. 3.4(a). The main parts of the conical rotors are

I. cone pattern
II. blade pattern
III. end covers and
IV. wear sleeve



(a)



(b)

All dimensions are in mm

Fig. 3.1(a) Tool bar assembly

(b) Cone pattern

3.2.1.2.1 Cone pattern

The various parts of the conical rotors were fixed on the basic cone which was fabricated from 16 gauge MS sheet. The MS sheet was cut as per the dimensions as in Fig. 3.1(a) and rolled to form a cone as in figure and the edges were then welded together to form a cone. The rotor blades, end covers and wear sleeves were welded as in Fig. 3.4 (a). The height of the cone was 194mm and the diameters were 100mm and 260mm for the small and big ends respectively with cone angle of 45 degree.

3.2.1.2.2 Blade pattern

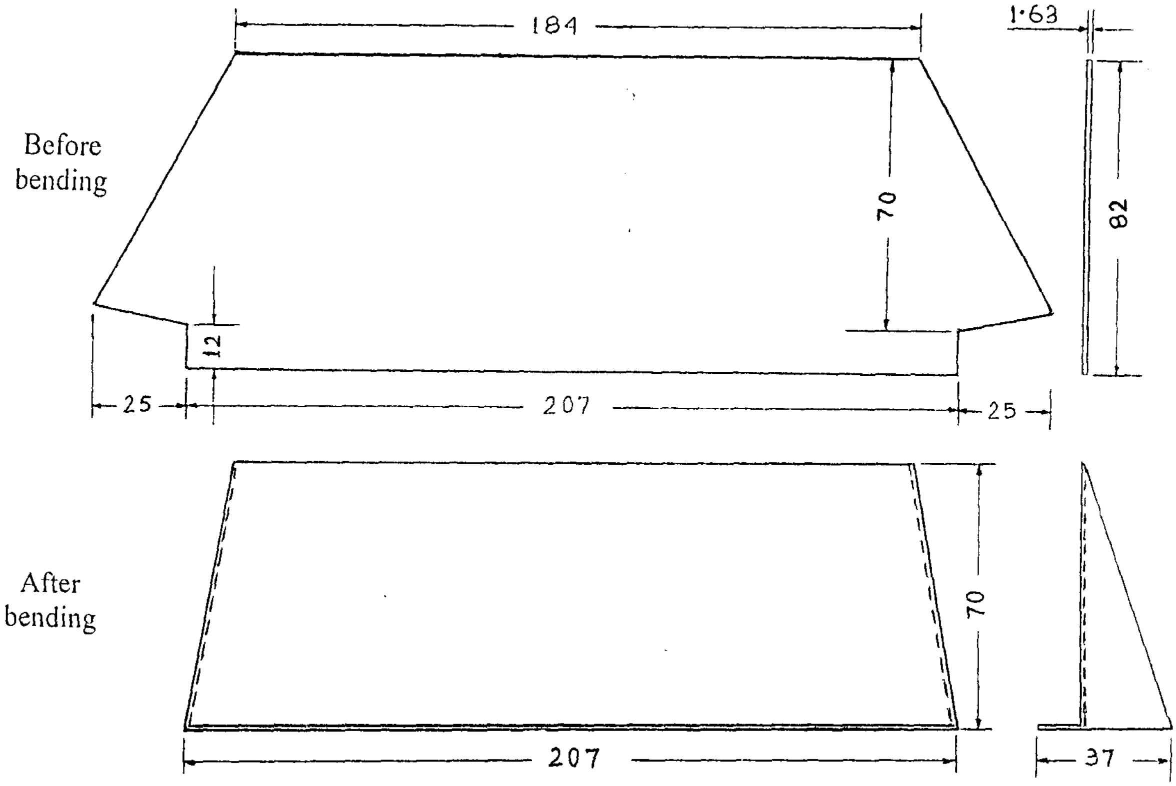
Each conical rotor consisted of six long and six short blades (Fig.3.2(a)& Fig.3.2(b)). They were folded at both ends for better strength and at the bottom to form in to a trapezoidal shape and fixed over the cone. They were alternately welded perpendicular to the cone surface at equal spacing. The height of each blade was 70 mm above the cone surface.

3.2.1.2.3 End covers

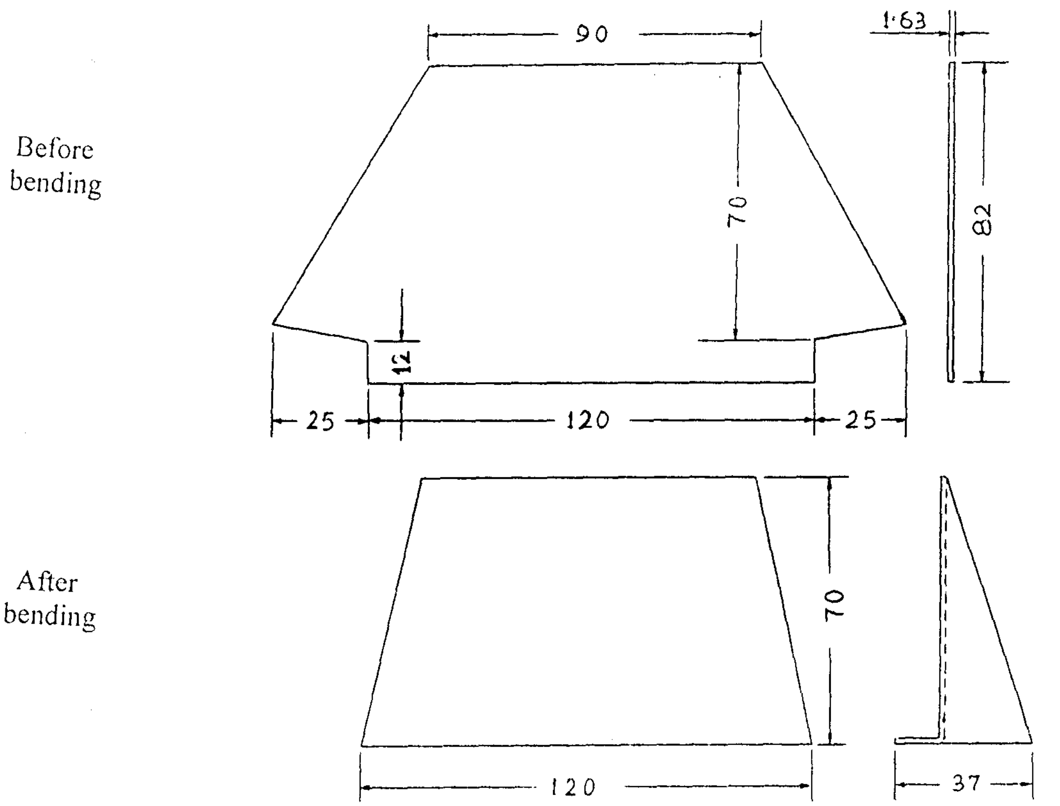
The cone ends were closed with end covers to strengthen at both sides to support loads and to fix the wear sleeve at the centre, so that the rotor shaft could pass through it. End covers were fabricated out of 14 gauge MS sheet having diameters of 258mm and 102mm for the big end and the small end sides respectively. A central hole of 21mm in diameter was drilled for fitting wear sleeve as shown in Fig. 3.3 (a)& 3.3(b).

3.2.1.2.4 Wear sleeve

All of the conical rotors were provided with a central wear sleeve of 200mm long MS pipe of which the inner diameter was 17mm and the outer diameter was 21mm (Fig. 3.3 (c)). Each was passed through the central hole of the end covers and welded along with it.



(a)

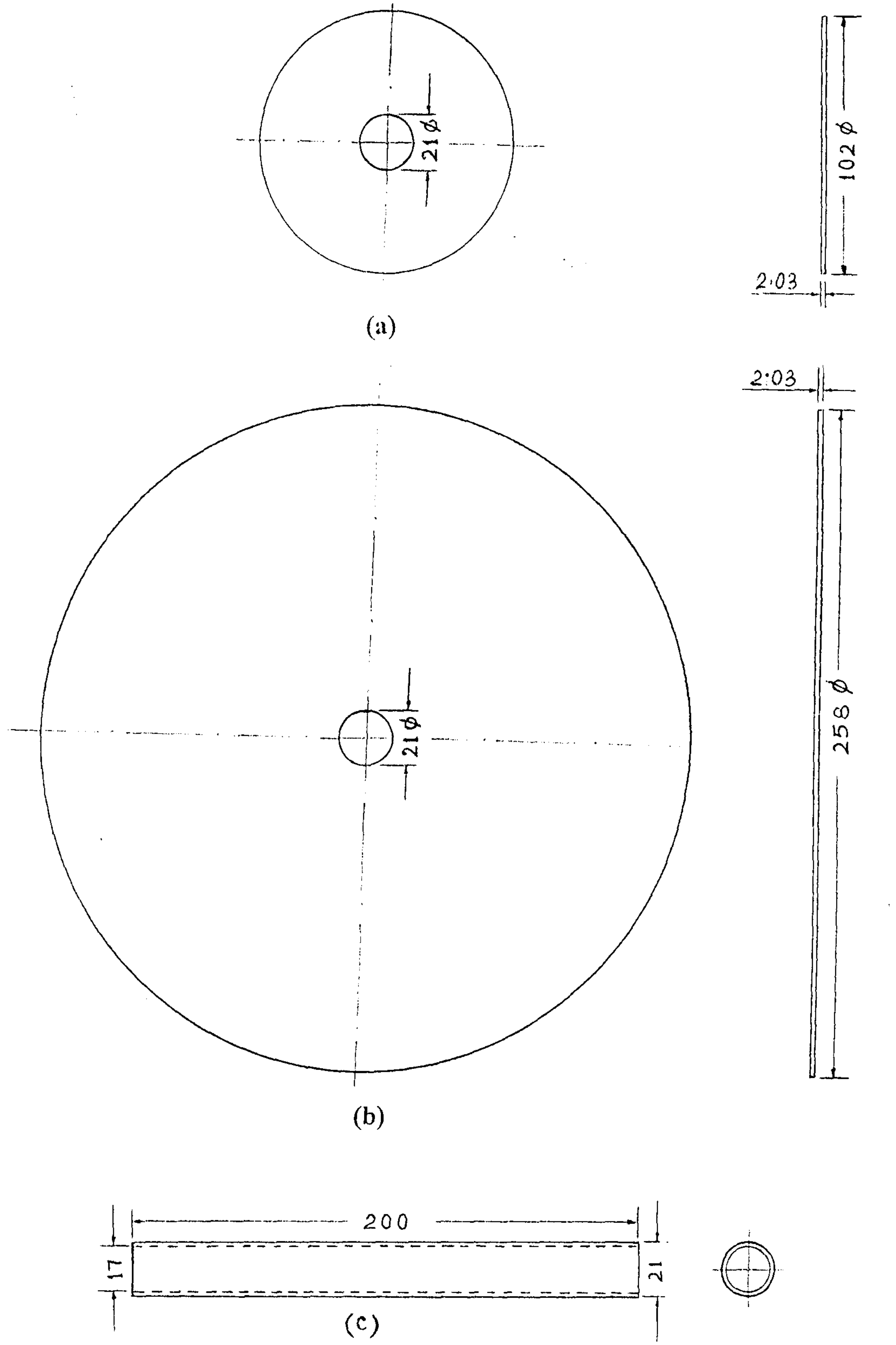


(b)

All dimensions are in mm

Fig. 3.2 (a) Long blade pattern

(b) Short blade pattern



All dimensions are in mm

Fig. 3.3 (a) Small end covers

(b) Big end covers

(c) Wear sleeve

3.2.1.3 Shaft assembly for the conical rotor

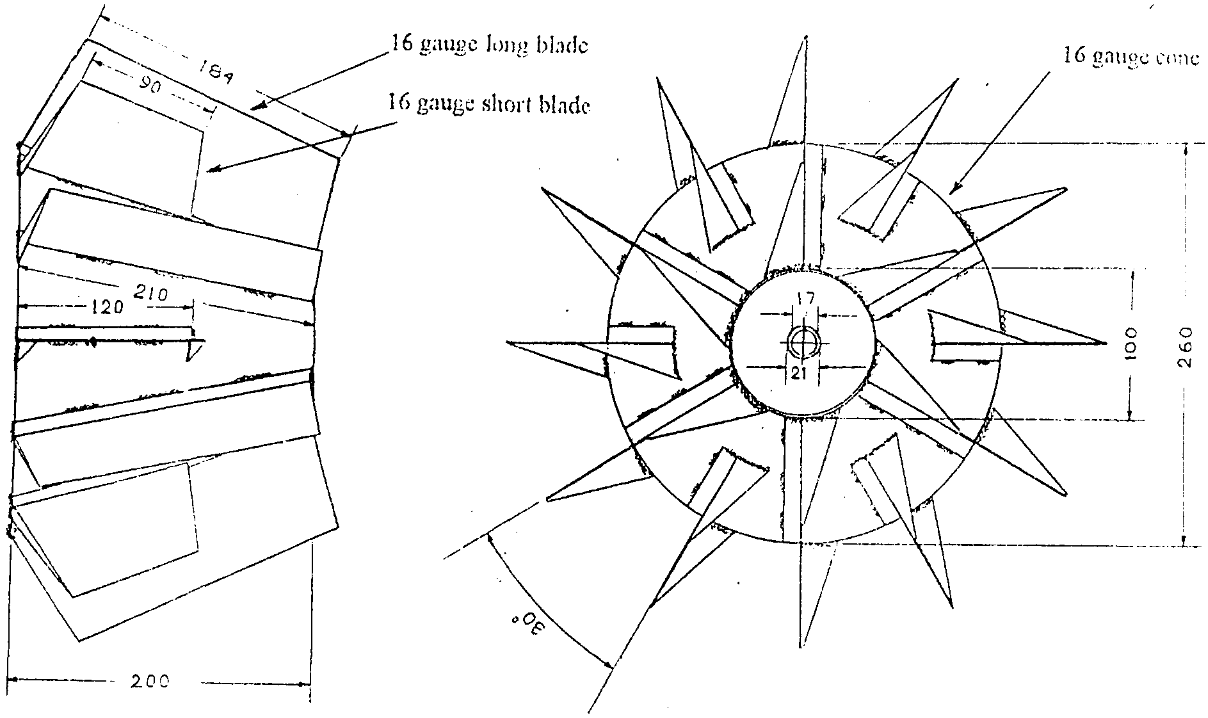
All the conical rotors were rotatably mounted on their individual shaft assemblies using split pins and washers. The shafts were fabricated out of 16mm diameter MS rod on which the rotors rotate freely. The shafts when mounted were inclined at 15 degrees downward from the horizontal and were in the same vertical plane as the tool bar (Fig. 3.4(b)). The 16mm rods were welded to the bottom edge of the vertical rotor shaft arms of 250mm long made out of 30 X 30 X 6 mm MS angle bars. The other ends of the arms had U-clamps welded to them, which were bolted to the tool bar.

3.2.1.4 Power tiller hitch assembly

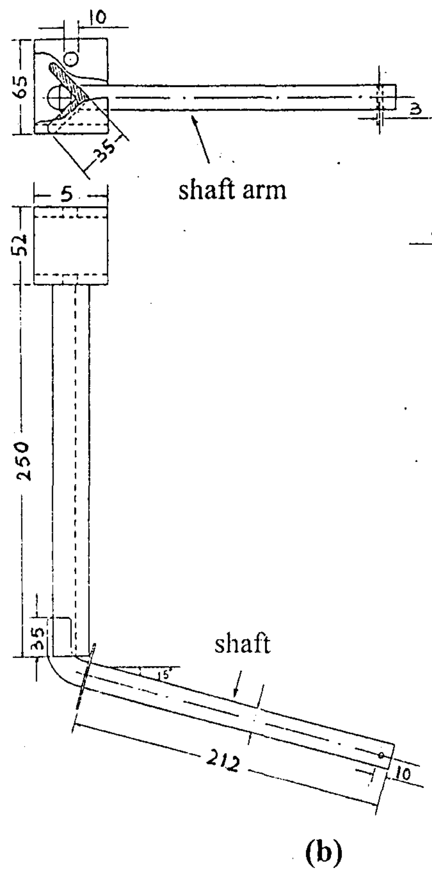
The complete cono-puddler assembly was connected to the power tiller through a hitch assembly. This hitch was fabricated in such a way that the height of the handle of the power tiller and the position of the rotor assembly with respect to the operator were within comfortable limits. The height of the handle was selected as 950mm above the ground in laboratory condition. The rotor assembly was fixed 350mm ahead of the end of the handle to facilitate the operator to walk behind without obstruction. The power tiller hitch assembly consisted of the following parts,

1. four U-clamps
2. two lower and two upper braces and
3. the hitch

Each of the four U-clamps were fabricated out of 50 X 6 mm MS flat on which 10mm diameter holes were drilled to facilitate fastening on the tool bar by bolt and nut (Fig. 3.5(a)). These clamps were welded to the rear ends of the braces, while the front ends of the braces were welded to the hitch member, as shown in figure. The lengths of the upper braces were 580mm and those of the lower braces were 400mm, all fabricated out of 25mm MS pipes.



(a)

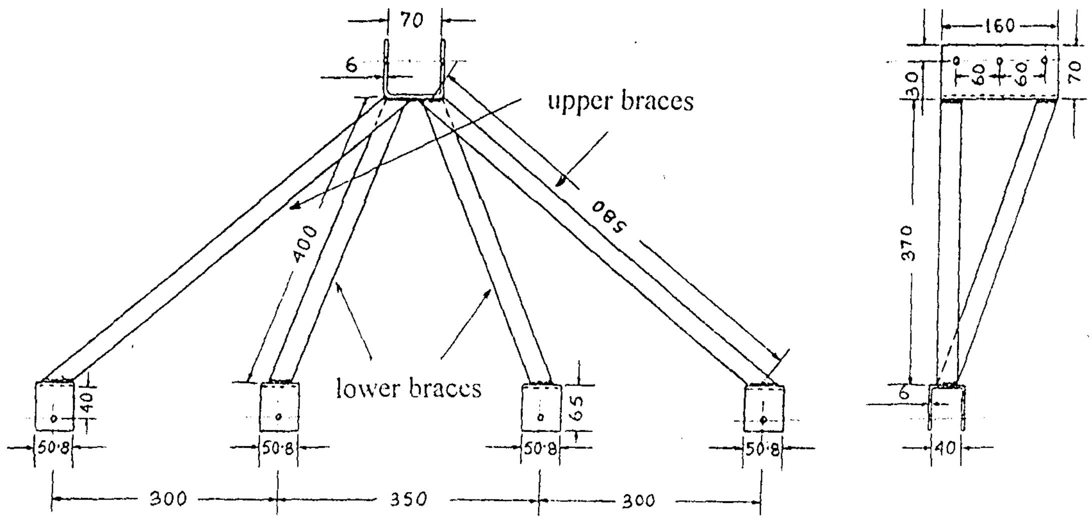


(b)

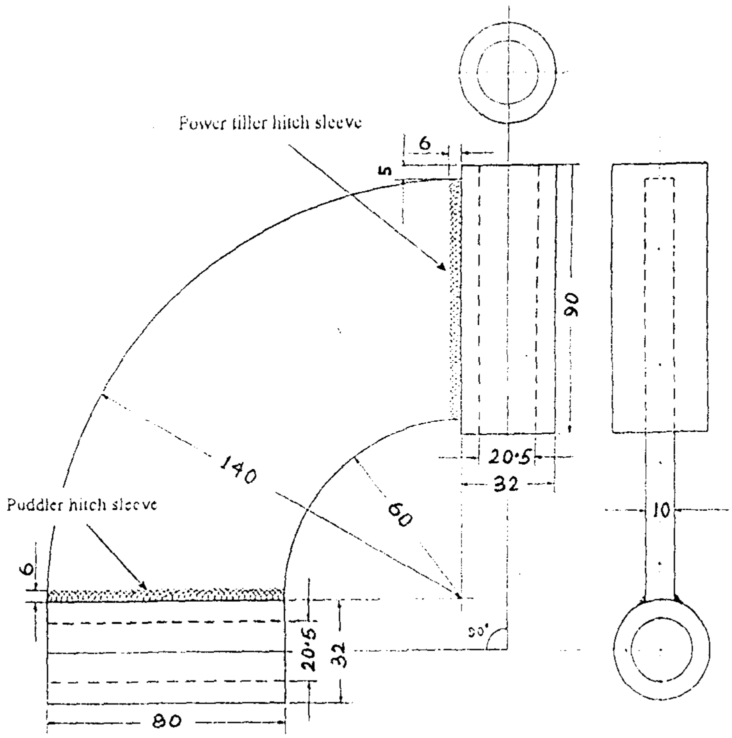
All dimensions are in mm

Fig. 3.4 (a) Conical rotor assembly

(b) Conical rotor shaft assembly



(a)



(b)

All dimensions are in mm

Fig. 3.5 (a) Power-tiller hitch assembly

(b) Power-tiller hitch bracket

The power tiller hitch had the provision of changing the height of the power tiller handle from 950 to 1050mm from the ground level by selecting different holes provided for it.

3.2.1.5 Power tiller hitch bracket

The cono-puddler was attached to the power tiller through a hitch bracket (Fig. 3.5(b)). The bracket was fabricated from 10mm thick MS plate on which tiller hitch sleeve and puddler hitch sleeve were welded perpendicularly. Both the sleeves were made out of MS pipes having 20.5mm inner diameter and 32mm outer diameter. The sleeve lengths of the tiller hitch and puddler hitch were 90mm and 80mm respectively. This power tiller hitch bracket facilitates the implement either to turn horizontally about the tiller hitch pin or rotate vertically about the puddler hitch pin.

3.2.1.6 Puddler hitch pin

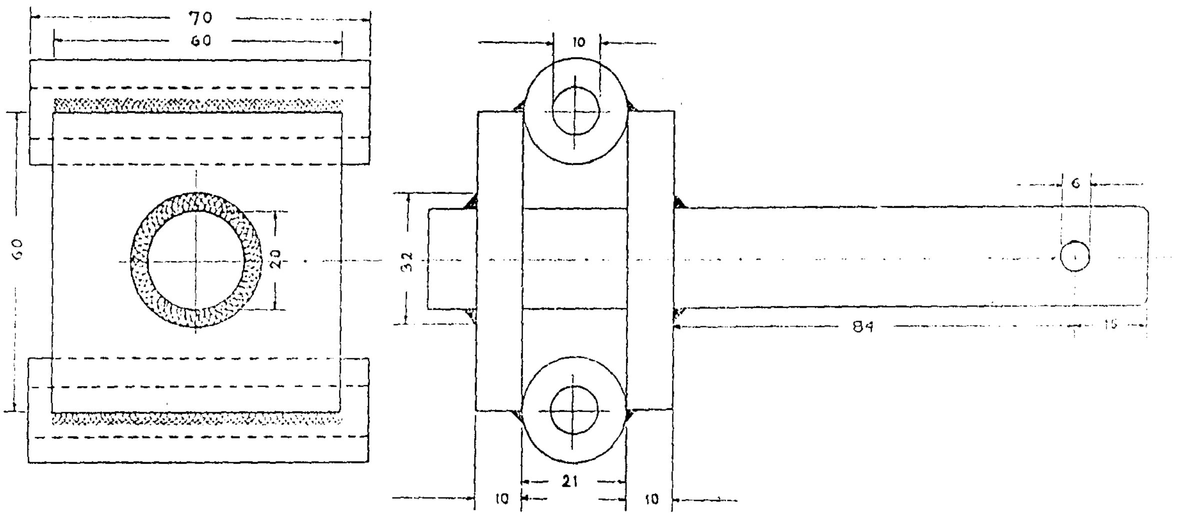
The power to the implement was transferred through the power tiller hitch bracket and puddler hitch pin (Fig. 3.6(a)). The puddler hitch pin was made of 20mm diameter MS rod and was fastened to the power tiller hitch at the desired position by bolt and nut. The hitch pin was inserted to the puddler hitch sleeve and then locked by a cotter pin.

3.2.1.7 Tiller hitch pin

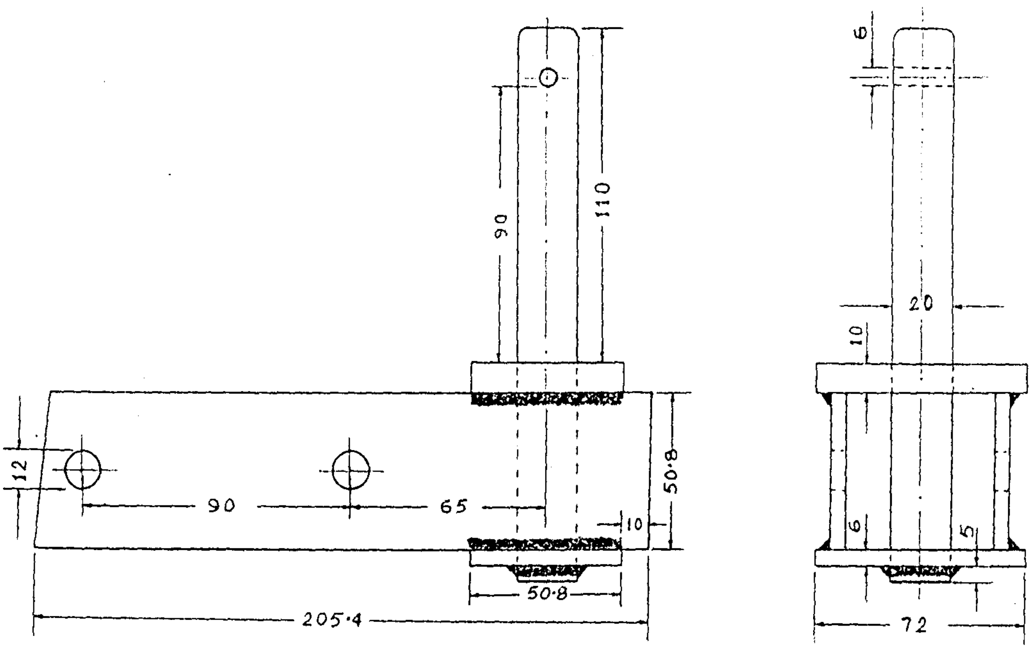
The power tiller hitch pin was fitted to the power tiller hitching point. It was of a 20mm diameter MS rod (Fig. 3.6(b)) fitted on the hitch sleeve of the power tiller hitch bracket and locked by a cotter pin.

3.2.2 Development of modified cono-puddler (model –2)

The cono-puddler fabricated based on the IRRI design (model – 1) was tested at the KCAET instructional farm. From the test results, it was observed that, the depth of puddling was only 10-11mm. To increase the depth of puddling, another six rotors were



(a)



(b)

All dimensions are in mm

Fig. 3.6 (a) Puddler hitch pin

(b) Tiller hitch pin

fabricated by changing the dimensions of the blades. During testing, it was also found that, the puddler hitch pin as well as the tiller hitch pin were bent, and so the dimensions of both the hitch pins were also increased. The dimensions of other parts such as basic cone , end covers and wear sleeves were the same as in the case of first model.

3.2.2.1 Blade pattern

Among the twelve blades on each conical rotor, six were long and six were short. To increase the depth of puddling, the height of the blades were changed from 70mm to 90mm above the cone surface. As the heights of the blades were increased, the overall diameter of the conical rotor was also increased. As a result, the distances between each consecutive blade at the tips were also increased. It was much wider in between two long blades at the position where short blade ended. With the aim to reduce this distance, the lengths of the short blades were increased to 120mm from 90mm at the tip and to 150mm from 120mm at the base. The top and base dimensions of the long blades were kept same as in the case of first model where the heights were changed to 90mm from 70mm.

3.2.2.2 Modification of the diameter of hitch pins

The diameters of the puddler hitch pin and the power tiller hitch pin were changed from 20mm to 32mm respectively.

3.2.2.3 Power tiller hitch bracket

As the dimensions of the puddler hitch pin and tiller hitch pin were changed, the corresponding sleeve diameters were also changed to 32.5mm.

All the other parts used in the first model remained the same for the second model also.

Plate-1 Rear view of the power tiller operated cono-puddler

Plate-2 Conical rotors of model-1, model-2 and model-3


1
2
3

3.2.3 Development of third model of cono-puddler

The second model cono-puddler developed was tested on the field and necessary observations were recorded. In this model, the depth of puddling obtained was 12-14mm.

In this case, a minimum gap of 110mm at the bottom in between two adjacent rotors was observed when fitted on the tool bar which left an uncut portion of the soil in between each rotors. Also there was problem of clogging of soil in between the blades while in operation. So, it was felt that, when the blades were made helical, the problem of clogging would be reduced. By increasing the length of blades, the width of uncut portion of the soil also would also be reduced. To achieve the above conditions, the shape and sizes of the blades were modified again in the third model.

A wooden planker was also attached behind the cono-puddler assembly to get more puddling with the same number of pass and for getting proper levelling of the field after puddling.

3.2.3.1 Blade pattern

Each of the six cones tested already consisted of six long and six short blades welded properly over the cone surface. In the third model, the heights of the long and short blades were same as 90mm, as in the second model. The lengths of the long blades were changed to 220mm at the tip and to 212mm at the bottom. The increase in length was only towards the side big end side of the cone.(Fig. 3.7(a)). For the short blades, the lengths were increased to 190mm at the tip and to 150mm at the bottom as in Fig. 3.7 (b).

All the blades were twisted to get a helical shape and then welded on the cone surfaces perpendicularly making an angle of 10 degree to the axis of the cone.

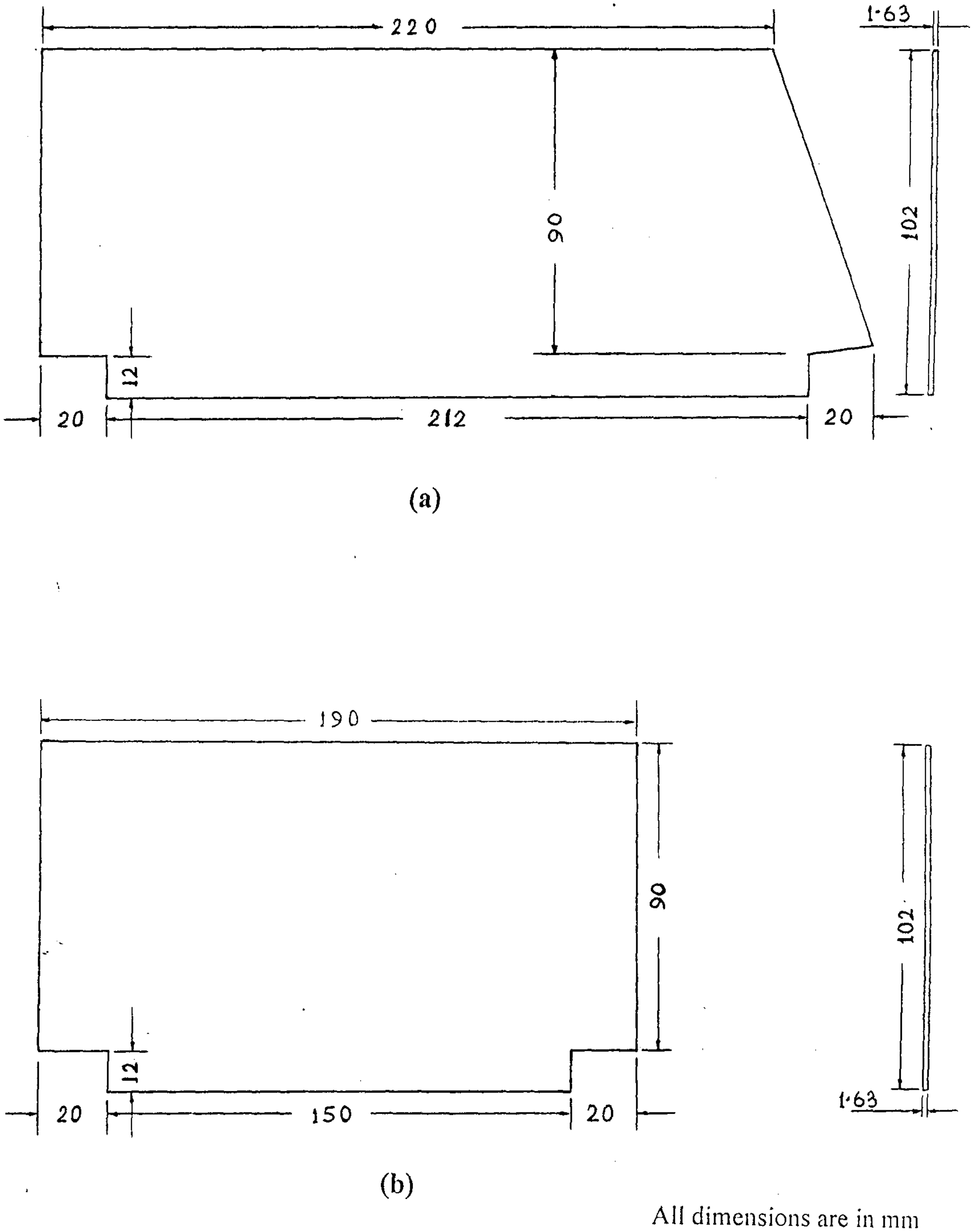


Fig. 3.7 Blade pattern (Model-3)

(a) Long blade pattern

(b) Short blade pattern

3.2.3.2 Wooden planker

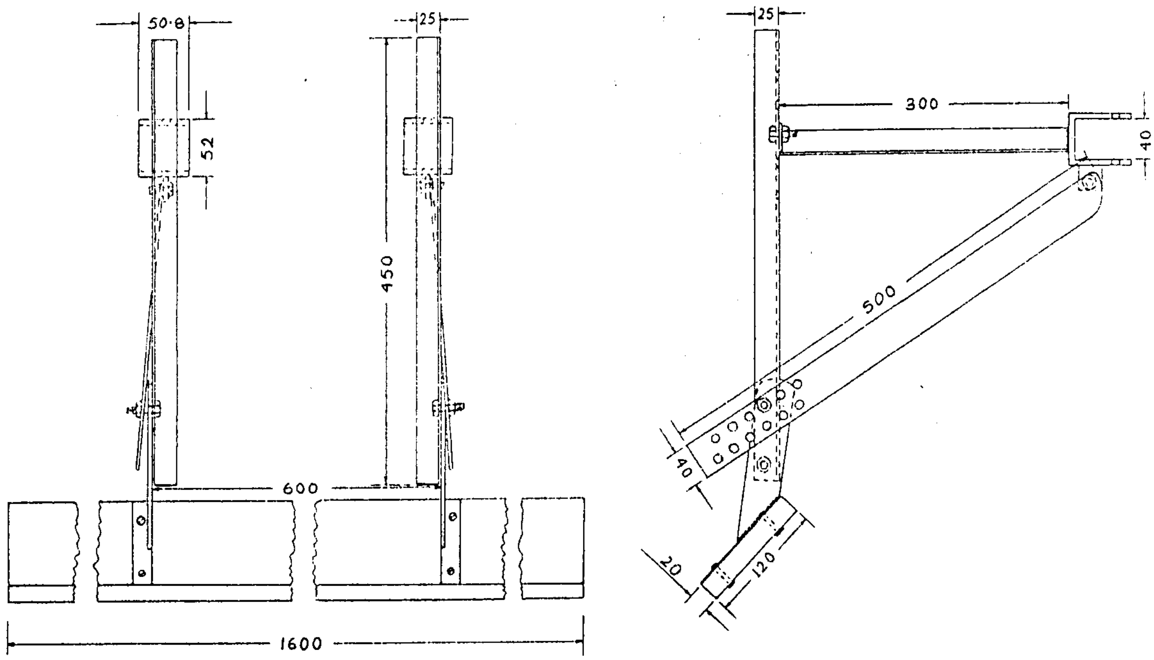
A wooden planker of 1600 X 120 X 20mm size was also fitted on the tool bar of the third model cono-puddler behind the rotors assembly. Provisions were made to facilitate changing of the height of the planker with respect to the conical rotors by providing different optional holes, which can be fixed by bolts and nuts (Fig. 3.8(a)).

3.2.4 Development of fourth model cono-puddler

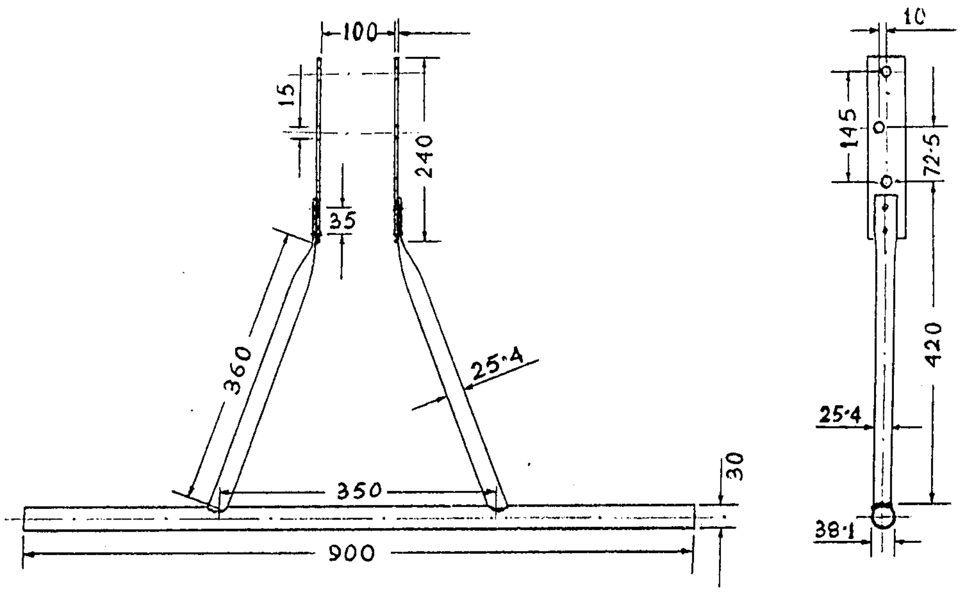
The third model cono-puddler was tested in the field and necessary observations were taken. The performance of the third model was satisfactory for puddling operation in sandy loam soil. With the view to increase the field capacity using the same engine and implement system and at the same speed of operation, trial was conducted by increasing the width of the implement. Two more rotors of the third model were fabricated and attached to the third model cono-puddler so that the total width of the implement became 2.13m. With the same planker of the third model, the cono-puddler(model-4) was then tested in the field.

3.2.5. Development of fifth model cono-puddler

The feasibility of the cono-puddler model-3 with a seating arrangement for the operator to perform the puddling operations comfortably was also tested. A cycle seat was fitted at the center, above the tool bar assembly of the cono-puddler. The height of the seat above the ground was 800mm and that above the tool bar was 300mm. A wooden footrest of 550 X 300X 30 mm was provided over the power tiller hitch assembly. It gave more comfort to the operator and could operate the implement satisfactorily. For this, the handle of the power tiller was modified as in Fig. 3.8 (b).



(a)



(b)

All dimensions are in mm

Fig. 3.8(a) Wooden planker assembly

(b) Modified power tiller handle

The planker of was not used because of the following reasons :

a) insufficient power of the engine
b) limitation of the idler pulley V-belt system
c) over slippage of the ground wheel,

3.3 Field evaluation of the cono-puddler

In this section the methods and procedures followed for the testing of the five models of the cono-puddlers in the field are described.

3.3.1 *Condition of the field*

Testing was conducted at B-block of the college instructional farm, KCAET, Tavanur during March to November, 1999. The type of the soil was sandy loam soil consisting of 65.44 per cent sand, 24.68 percent silt and 9.88 percent clay.

The field was heavily infested with weeds up to 30cm in height. So, the field was initially ploughed by a tractor drawn cultivator. Then the plots were flooded with standing water up to 5-10 cm depth.

3.3.2 Selection of the power source

This research had been taken up to develop a small engine operated machinery for puddling operation where the engine can also be used for multi purposes which will basically be more useful for the marginal farmers having less cultivating area of land. For this research work, modification of IRRI reaper was done. The engine of the IRRI reaper was shifted to the front and the puddler unit was attached at the rear side below the handle of the power tiller. A Greaves engine developing 5hp at 3500rpm range was used. At all conditions, as the implement was heavier than the engine, the implement rested on the ground such that there was no need for applying extra load on the tiller handle for controlling depth of operation.

3.3.3 Selection of cage wheels

A cono-puddler for wet land paddy cultivation was fabricated based on IRRI design. At the first trial, two steel cage wheel sets one of 457mm diameter and 305mm in width having 50 degree lug angle and one of 457mm diameter and 305mm in width having lug angle 35 degree were tested for the puddling operation along with the power tiller attached cono-puddler. From the preliminary studies it was found that, the slippage of the ground wheel was so high and did not provide enough traction. So, a set of new cage wheels were fabricated for the puddling operation with this machine. The new cage wheels were of 457mm diameter and 305mm in width. The lugs of the wheels were made out of thirteen pieces of 38 X 3mm MS angle bars welded perpendicularly over the frame at equal spacing. Preliminary testing was conducted with the new cage wheels and the result was found satisfactory. The same cage wheels were used for all experiments in this study.

3.3.4 Methods and procedures of testing

All the five models of the cono-puddlers fabricated were tested to evaluate their performances in the field. All the cono-puddlers were tested for,

1. 3 operations (one cross wise and one length wise)
2. 4 operations (two cross wise)

The first four sets of cono-puddlers viz. model-1, model-2, model-3 and model-4 were walking behind type and were operated at engine speed of around 0.800m/sec at no load condition. The fifth model (model-5) which was with a seating arrangement was operated at around 1.00m/sec at no load condition.

For all test conditions, the field was maintained with 5-10cm standing water. After the puddling was over, minimum of 5cm standing water was maintained in the test plots until all the observations were recorded.

3.3.5 Power source

All the power tiller operated cono-puddlers were operated by a Greaves 5hp diesel engine. The power requirement in operation included the power for the implement for operation and the power for traction of the power tiller in puddled soil. The draft of the implement and the power tiller were measured separately to calculate the total power requirement.

3.4 Observations made in the study

The observations were made at appropriate time before, during and after the puddling. The main observations made in the study are

1) percolation rate
2) puddling index
3) percentage burial of weeds
4) depth of puddling
5) cone index
6) field efficiency
7) effective field capacity
8) draft requirement
9) power requirement
10) fuel consumption
11) slippage of the ground wheel

3.4.1 Percolation rate

Percolation loss of water from all the test plots was measured with the procedure cited by Datta (1992). To measure percolation rate, metal cylinder of 100mm in

Plate-3 power tiller operated model-5 cono-puddler in field condition

Plate-4 Measurement of cone index using Vicksberg cone penetrometre

diameter and 200mm long was driven into the saturated soil up to 100mm depth. The cylinders were covered to prevent loss of water due to evaporation and to prevent entry of rainwater. The fall in water level inside the cylinder for every 48hr at a particular time was recorded. The readings were collected from different point of the test plots. Percolation rate was measured,

a. before puddling (initial condition)
b. after puddling (for every 48hr till 20th day after puddling)

3.4.2 Puddling index

Puddling index is a measure to determine the quality of the puddled soil and is the ratio between volume of settled soil and total volume of sample collected (IS code 1985, Sharma *et al.* 1991, Datta 1992).

Samples of the soil water suspension immediately after puddling were collected and then transferred to 1000cc measuring cylinder. Samples were collected at various points of the plots and were allowed to settle for 48hr. The volume of the soil settled were then noted and puddling index were calculated by the following formula,

$$\text{P.I.} = \frac{Vs}{V} \times 100$$

where

P.I. - puddling index (%)
Vs - volume of settled soil (cc)
V - volume of total soil water suspension (cc)

3.4.3 Percentage burial of weeds

The number of weeds buried in the soil is an important factor for a good puddled soil condition. For this the number of weeds before puddling (A) and number of weeds after puddling (B) are counted using a square frame of 500 X 500 mm. The percentage burial of weeds are calculated based on the RNAM test code 1983 using the formula,

$$P.B.W. = \frac{A-B}{A} X\,100$$

where P.B.W. – percentage burial of weeds
A - number of weeds before puddling
B - number of weeds after puddling

The percentage burial of weeds was also calculated based on the dry weight as,

$$PBW = \frac{X-Y}{X} X\,100$$

where X - dry weight of weeds (before puddling)
Y - dry weight of weeds (after puddling)

3.4.4 Depth of puddling

The depth of puddling was measured using a depth scale as given in RNAM (1983). The depth scale consisted of a wooden bar of 1000X30X20mm in size. A metal piece with a 12.5mm diameter hole was attached at one end of the wooden bar where a metal rod of 12mm in diameter could be inserted perpendicularly through the hole. The wooden bar was placed on the puddled soil surface and the metal rod was inserted in the puddled soil up to the puddled sole. The position of the rod was than fixed by tightening a bolt which was provided for this purpose. Then the length of the rod which entered in to the soil below the soil surface was measured using a metal scale graduated in millimeter which was taken as the depth of puddling.

3.4.5 Cone index

Cone index is a measure to define the puddling performance to compare different puddling implements. It is an indication of soil resistance, and is defined as the force required to penetrate the soil at a particular depth per unit area.

Soil resistance was found out using "Vicksberg penetrometer" as shown in Plate-4. The penetrometer consisted of a sturdy handle under which a sensitive proving ring of 200 kg capacity associated with a dial indicator was fixed. An extension piece was fixed to the bottom of the proving ring, which carried a detachable penetrating cone. Two penetration cones of 5 cm^2 and 3.2 cm^2 cross sectional area at the base with 30^0 cone angle were used. The sensitivity of the proving ring was 0.4 kg. with a least count of 0.002mm. The penetration load for the proving ring dial was estimated from the calibration chart. The penetration test was conducted at the following depths,

a. surface of the soil
b. 5 cm depth
c. 10 cm depth and
d. 15 cm depth

The soil resistance at all depths were taken,

a. before ploughing (initial condition)
b. immediately after puddling
c. for every 48 hr for 20 days after puddling

For measuring penetration resistance at surface, 5cm depth and 10cm depth, penetration cone having base area of 5cm^2 was used whereas penetration cone having base area of 3.2cm^2 was used in all cases of 15cm depth of soil. For every measurement five replications were recorded. The cone index in kg/cm^2 was found out by dividing the load applied taken from the calibration chart by the cross sectional area of the corresponding cone.

$$\text{Cone index} = \frac{L}{A}\ \text{kg/cm}^2$$

where

L - load from calibration chart in kg.

A - area of cross section of the cone at the base in cm^2.

3.4.6 Field efficiency

Field efficiency is the ratio of effective field capacity to the theoretical field capacity expressed in percent. Field efficiency was calculated using the expression,

$$F.E. = \frac{EFC}{TFC} \times 100$$

Where F.E - field efficiency in %

EFC - effective field capacity in ha/hr

TFC - theoretical field capacity in ha/hr

3.4.7 Theoretical field capacity

Theoretical field capacity (TFC) is the rate of field coverage that would be obtained if the machine were performing its function 100% of the time at the rated speed and always covering 100% of its rated speed. Theoretical field capacity was calculated by the formula

$$T.F.C = S \times W$$

where T.F.C - theoretical field capacity in ha/hr

S - speed of travel in km/hr

W - rated width of the implement in mm

3.4.8 Effective field capacity

Effective field capacity is the actual field coverage during the actual time of operation. For this the machine was opearted in the test plot until the desired condition was obtained. The time of operation was then noted. The area covered in hectare divided by the time of operation in hours gives the effective field capacity in ha/hr.

3.4.9 Draft requirement

Draft affects the power requirement to operate the implement and soil implement system. To determine the draft, a hydraulic dynamometer fitted with a pressure gauge was connected in between power tiller hitch assembly and hydraulic arms of a tractor such that the entire force was transmitted only through the dynamometer while in operation. The pressure gauge indicated fluid pressure of the dynamometer in terms of kg/cm^2. The cono-puddler was pulled by the tractor for 30m at the operating speed range for the test. While travelling the 30m run, 10 readings of the pressure gauge were noted. The angle of pull from the horizontal was also determined. The pull in terms of kg for the particular pressure gauge reading was determined from the calibration chart where the draft in kg was determined by the formula

$$\text{Draft} = P \times \cos\theta$$

where D - draft in kg.

P - pull in kg. (from the calibration chart)

θ - the angle formed by the line of pull to the horizontal

The draft of the power tiller was also determined in the same manner. The results for all the sets of implements were tabulated in Table 4.7.

3.4.10 Power requirement

The draw bar horse power was calculated by using the expression,

$$D.H.P = \frac{DXS}{75}$$

where D.H.P – draw bar horse power in hp

D - draft of the implement in kg

S - speed of travel in m/sec.

3.4.11 Fuel consumption

Fuel consumption for all test operations were measured by top filling method (Mehta *et al.* 1995). The fuel tank of the engine for which fuel consumption was to be measured was fully filled before the operation started. The machine was operated in the test plot till the desired puddled soil condition was obtained. Then the fuel tank was again refilled with the help of a measuring jar. Care was taken to maintain the engine in nearly horizontal at the same position and not to leave any air space inside the tank while filling the fuel tank. The amount of fuel refilled was noted to determine the fuel consumption of the machine during the operation. The rate of fuel consumption in lt/hr was calculated by dividing the total fuel consumed in litres by the time of operation in hours.

3.4.12 Speed of operation

The speeds of operation of the implement during all the tests were measured. To measure the speed of operation, two poles at 20m apart were placed in the field. Time required to travel the 20m distance was recorded by a digital stopwatch up to one-hundredth of second. Five sets of such readings were recorded for each testing and the average was taken. Readings were recorded for all operations in the testing.

3.4.13 Slippage of the ground wheel

The distance travelled by the machine in a given number of revolutions of the drive wheel decreases when the wheel slips. The distance traveled by the machine for 10 revolutions of the ground wheel for load (with puddler) and no load (without puddler) for all the tests were recorded. To facilitate the counting of the number of revolutions of the drive wheel, a visible mark was given on a point of the drive wheel at the periphery. The slippage of the ground wheel in terms of percentage was calculated by the expression,

$$P.W.S. = \frac{A-B}{A} \text{ X } 100$$

where, P.W.S. - percentage wheel slip

A - distance traveled by 10 revolutions of the ground wheel at no load condition

B - distance traveled by 10 revolutions of the ground wheel at load Condition

3.4.14 Economic analysis

For all sets of the power tiller mounted cono-puddler, the cost of operation on hour basis was calculated using the test data. The fixed cost and variable cost were calculated and added to get the total operating cost. These were compared with that of the conventional methods of puddling (country plough) and tractor operated cage wheel puddler. The cost of operation was calculated as follows

3.4.14.1 Annual fixed cost

1. Depreciation :

$$\text{Depreciation} = \frac{C-S}{L}$$

where C – purchase price in rupees
S – salvage value (10% of purchase price)
L – total life of the implement in years (yr)

2. Interest

$$\text{Interest} = \frac{C+S}{2} \text{ X } \frac{I}{100}$$

where I – interest rate (15%)

3. Insurance = Prevailing rate

4. Taxes = nil

5. Housing

$$\text{Housing} = P \times \frac{h}{100}$$

where h – housing rate (0.5% or 1% of the purchase price)

3.4.14.2 Variable cost

1. Repair and maintenance

$$\text{Repair and maintenance} = C \times \frac{m}{100}$$

where m – repair and maintenance rate (5%)

2. Fuel cost per annum

$$\text{Fuel cost per annum} = H \times R \times P$$

where H – number of operating hours per annum (h)
R – fuel consumption per hour (lt/h)
P – cost of fuel per litre (Rs)

3. Oil cost per annum

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

4. Labour cost per annum

Labour cost per annum = H X labour wages per hour

where H – number of operating hours per annum

Total cost per annum = total fixed cost per annum + total variable cost per annum

Hourly cost of operation was calculated by dividing the total operating cost by the total operating hours per year. The cost of operation of the puddlers for one hectare were also analysed.

RESULTS
AND
DISCUSSIONS

RESULTS AND DISCUSSIONS

Five models of cono-puddlers were fabricated in K.C.A.E.T., Tavanur to identify the puddler suitable for sandy loam soil of the college instructional farm. This chapter deals with the results obtained from the tests of the five models and discussions are presented. The cost analysis of the cono-puddlers comparing with other conventional puddlers is also described. The details of the observations from the field evaluation of the five models are also presented in this chapter.

4.1 Condition of the test plots

Field plots of B-block of the college instructional farm were selected for the testing of the cono-puddlers. The area of each test plot is made of rectangular shape of 15 X 32 m by making bunds. The soil in the test plots is sandy loam consisting of 65.44 per cent sand, 24.68 per cent silt and 9.88 per cent clay.

All the test plots were heavily infested with weeds up to 30cm in height. The average intensity of the weeds was 2580 weeds/m^2 counted up to the smallest of 10cm in height. Each plots were ploughed once cross wise by tractor drawn cultivator before puddling.

4.2 Puddling action on soil

The five models of cono-puddlers fabricated were tested in the field condition. The cono-puddlers were trailing type implement which, was pulled by a 5hp power tiller. Each cono-puddlers consisted of conical rotors having long and short blades around the periphery of the cones. The blades on the rotors cut the soil continuously when the power tiller traveled forward. As the rotors rotate, soils is lifted and thrown out by the blades resulting in the mixing up of soil and water. The soils below the cones are also sheared off under the load of the implement, as well as its forward movement.

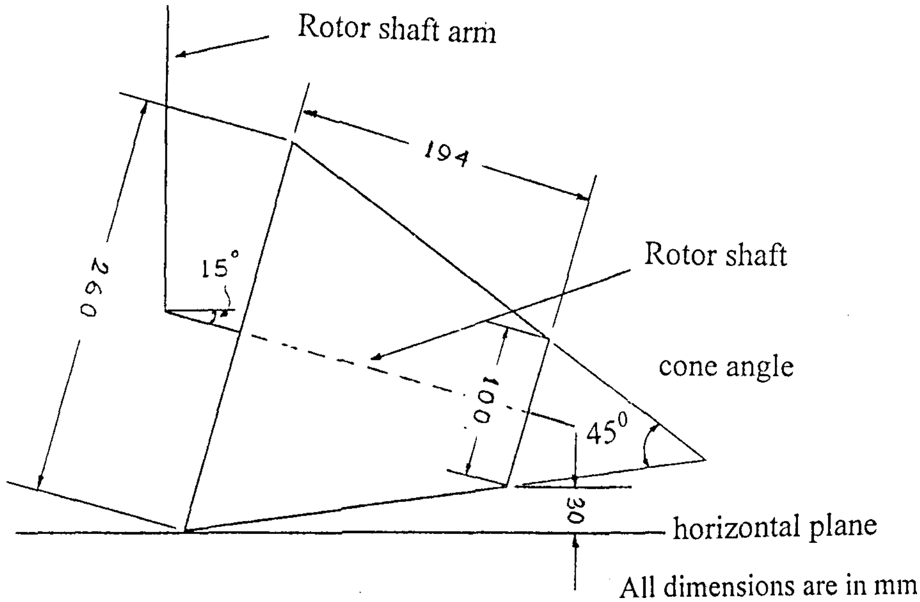
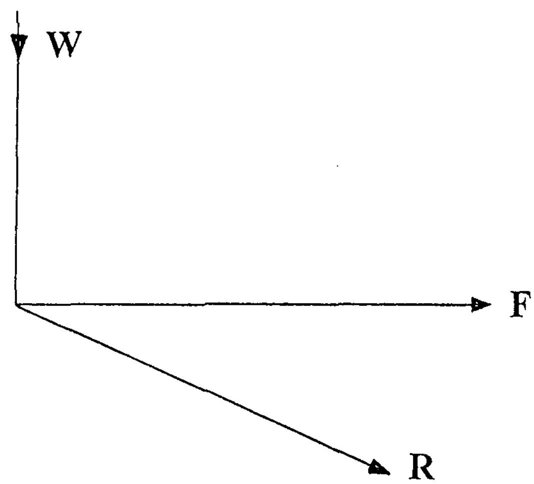


Fig. 4.1 Position of the conical rotor



Where

F - Pull of the power tiller
W - Weight of the implement
R - Resultant force acting on the soil

Fig. 4.2 Forces acting on the puddle soil

As the conical rotor shaft makes 15 degrees downward to the horizontal and cone angle is 45 degree, there is a gap of 30mm at the small end of rotors, its big end touches the soil as shown in Fig. 4.1. Because of the weight of the implement, soil below the cones were compressed and thus, soft soil moved towards the small end of the cone. This also helped in making the soil move sidewise, thus mixing of the soil and water took place.

As the rotors moved forward, soil in front of the rotors were pushed forward because of the resultant force of the weight of the implement and pulling force of the power tiller thus again mixed the soil and water as shown in Fig. 4.2. Thus the combined effect of the cutting and movement mixes the soil with water uniformly.

Because of the action of the weight of the implement and cutting action of the blades, weeds were cut and buried deep into the soil. Thus weeds were destroyed by cutting and decomposing them inside the puddled soil.

As the soil was made into a uniform soil water suspension after puddling, the soil suspension levels automatically, thus a fairly horizontal surface was obtained after puddling.

4.3 Ease of operation of the cono-puddlers

The cono-puddlers were hitched to the 5hp power tiller. Five models were fabricated out of which four were walking behind type and one was riding type with a seat for the operator. Handle of the power tiller was so fabricated for the convenience of the operator.

4.3.1 Model-1

Cono-puddler model-1 was a walking behind type implement. There were six conical rotors attached on a tool bar assembly of the unit and the width of operation is

1600mm. The operator walked behind the implement and controls the unit. The operator was required to walk around 6.25 km to puddle one hectare of land for one operation. The depth of operation is controlled by the weight of the implement itself.

4.3.2 Model-2

In the case of the cono-puddler model-2, the heights of the blades are changed to 90mm from 70mm, which was designed as in 3.2.2.1. The condition of the model-2 in terms of the operator was similar to that of model-1.

4.3.3 Model-3

In case of the model-3, the width of the implement was 1600mm and a wooden planker was also provided behind the rotors. The wooden planker helps in faster puddling and leveling undulated fields easily. There was no extra change of model-3 as compared to model-1 and model-2 in terms of ease of operation.

4.3.4 Model-4

The width of the cono-puddler model-4 was increased to 2130mm by increasing the number of rotors by two, thus making the total conical rotors to eight on the same tool bar. In this case, the control of the handle of the power tiller was found difficult at the headland turning. In this case, when the power tiller starts turning to the left side by engaging the left side clutch, the power tiller tends to turn more and more though the left side clutch is disengaged. This may be due to more soil resistance for a wider distance on the conical rotors. To bring the power tiller and implement in straight position after turning, it is required to engage the right side clutch again. Thus it takes more time and energy for the operator. Thus it requires starting the turning some distance ahead of the point of turning.

4.3.5 Model-5

Another model of the cono-puddler (Model-5) was developed by providing a seating arrangement to operate in riding position. In this a cycle seat was provided as explain under section 3.2.5. This model was tested in the field and observed most convenient to the operator among all the models tested. As the operator could sit and operate the unit, the drudgery of walking behind in the puddle soil was also avoided. As the operator was in sitting position, the speed of operation also could be increased, thus increasing the field capacity. The control of the unit was more easier to the operator and thus the field efficiency is also higher compared to other models.

4.4 Observations recorded

Different observations were made in the study before, during and after the puddling operations. The observations recorded are used directly or indirectly to analyse the performances of the different models of cono-puddlers. The details of the observations are as follows.

4.4.1 Percolation rate

The percolation losses of water from all the test plots were recorded before puddling and for every two days after puddling up to twenty days. The average percolation rate before puddling was 2.1cm/day. The percolation losses observed for different number of operations puddled by different models are presented in Table 4.1 & Fig. 4.2. The variations of the percolation losses for all the five models for different days for three and four operations are shown in Fig. 4.3 & Fig. 4.4.

The average percolation rate for the model-1, model-2, model-3, model-4 and model-5 were 3.979, 3.804, 3.729, 3.737and 3.629 mm/day with standard deviations of 1.261, 1.111, 0.974, 1.239 and 1.081 respectively for three times of operations. The average percolation rate for the model-1, model-2, model-3, model-4 and model-5 are 2.983, 2.732, 2.725, 2.758 and 2.650 mm/day with standard deviations of 1.156, 1.006, 1.119, 1.153 and 0.890 respectively for four times of operations. From the figure, it is observed that, the loss of water due to percolation reduces at higher rate during the first few days and then tends to be stabilised. The same trend is observed for all the models operated for different number

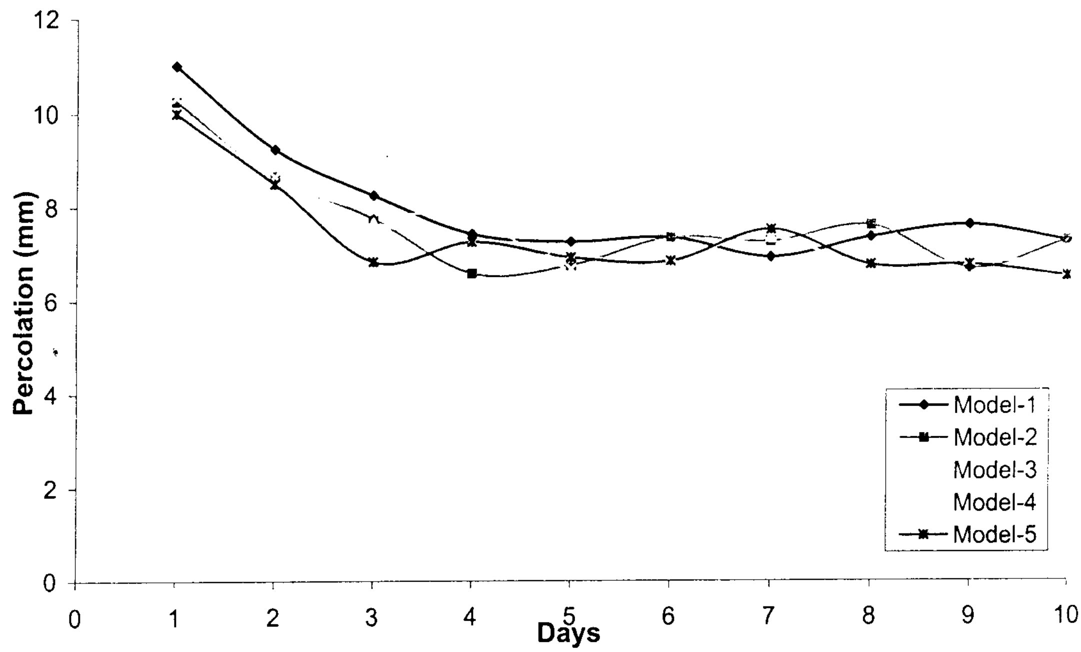


Fig. 4.3 Percolation loss of water for the five models operated three times

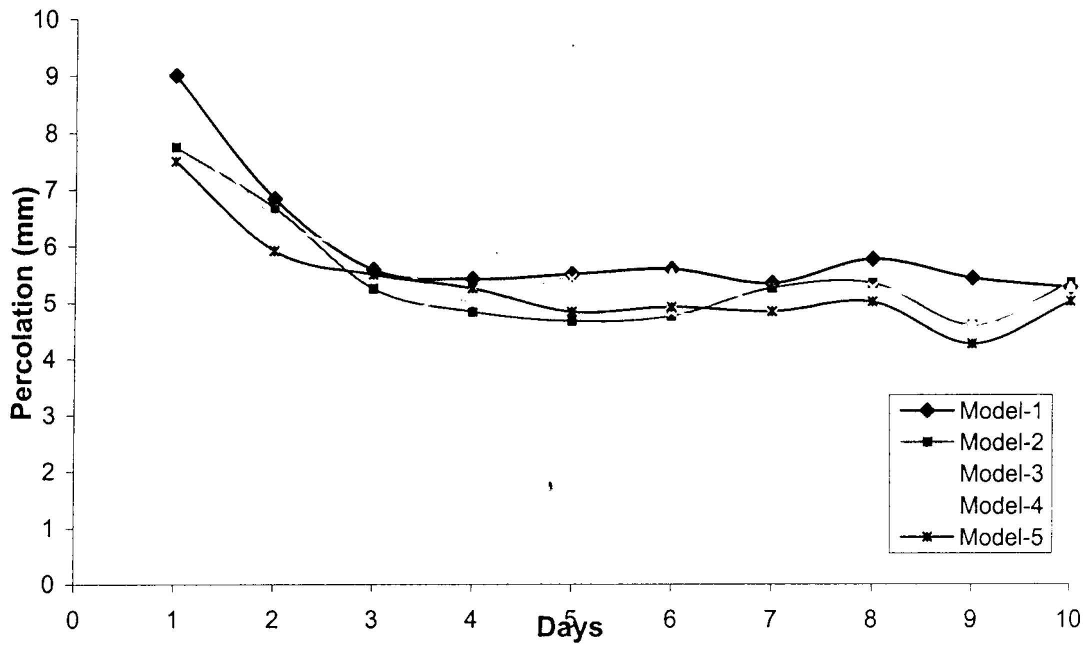


Fig. 4.4 Percolation loss of water for the five models operated four times

Table 4.1 Percolation loss of water for the five models operated for three times

Days	Percolation loss in mm				
	model-1	model-2	model-3	model-4	model-5
2	11.000	10.250	9.750	10.333	10.000
4	9.250	8.667	8.500	8.667	8.500
6	8.250	7.750	7.667	7.916	6.833
8	7.416	6.583	7.250	7.750	7.250
10	7.250	6.750	6.916	6.667	6.916
12	7.333	7.333	6.916	6.833	6.833
14	6.916	7.250	7.333	6.750	7.500
16	7.333	7.583	6.667	6.916	6.750
18	7.583	6.667	6.833	6.500	6.750
20	7.250	7.250	6.750	6.416	6.500
Average mm/day	3.979	3.804	3.729	3.737	3.692
S.D.	1.261	1.111	0.974	1.239	1.081

Table 4.2 Percolation loss of water for the five models operated for four times

Days	Percolation loss in mm				
	model-1	model-2	model-3	model-4	model-5
2	9.000	7.750	8.416	8.333	7.500
4	6.833	6.667	5.916	6.500	5.916
6	5.583	5.250	4.750	5.833	5.500
8	5.416	4.833	5.250	5.000	5.250
10	5.500	4.667	5.250	5.416	4.833
12	5.583	4.750	5.500	4.833	4.916
14	5.333	5.250	4.916	4.667	4.833
16	5.750	5.333	4.667	5.250	5.000
18	5.416	4.583	4.583	4.667	4.250
20	5.250	5.333	5.250	4.667	5.000
Average mm/day	2.983	2.732	2.725	2.758	2.650
S.D.	1.156	1.006	1.119	1.153	0.890

of operations. The average percolation rate, for all the models for four times operations was lower than that for the three times operations.

A minimum average percolation rate of 3.692mm/day for model-5 and a maximum of 3.979mm/day for model-1are observed among the five models operated three times. A minimum average percolation rate of 2.650mm/day for model-5 and a maximum of 2.983mm/day for model-1are observed for the five models operated for four times.

From the statistical analysis, it is found that, there is no significant difference of the percolation rate for the five models for the same number of operations. There is significant difference of the percolation rate for the five models for different number of operations.

4.4.2 Puddling index

Puddling index is the ratio of the volume of soil settled to the volume of soil water suspension collected immediately after puddling and was measured as explained in section 3.4.2. The average puddling indices obtained from all the test plots puddled by the five models for different operations are presented in Table 4.3. Puddling indices for model-1, model-2, model-3, model-4 and model-5 for three times operations are 55.14%, 56.31%, 59.52%, 58.33% and 59.34% respectively. The puddling indices for model-1, model-2, model-3, model-4 and model-5 for four times operations are 63.72%, 63.46%, 66.36%, 64.42% and 68.89% respectively. From the table, it is observed that, the puddling indices for the five models for the four times operations are higher than that of the three times operations. It is due to more mixing of the soil with water as the puddler was operated more number of times. Minimum puddling index of 57.14% in case of the model-1 operated three times and maximum puddling index of 68.89% in case of model-5 operated four times are observed. There are no significant variations of the puddling indices for the five models operated for same number of times.

4.4.3 Percentage burial of weeds

The degree of burial of weeds due to puddling are measured based on the number of weeds and also based on the dry weight as described in section 3.4.3. The number of weeds obtained for all the experiments were noted by using a quadrant frame. The average number of weeds before puddling was 645 with dry weight of 1754.4gm. in the area measured. The details of the percentage burial of weeds are presented in Table 4.4 and Appendix–V.

The percentage burial of weeds for the model-1, model-2, model-3, model-4 and model-5 for three times operations are 99.38, 98.54, 98.76, 98.60 and 98.79 per cent respectively in terms of number of weeds and 99.09, 99.24, 99.35, 99.23 and 99.34 per cent respectively in terms of dry weight basis. The percentage burial of weeds for the model-1, model-2, model-3, model-4 and model-5 for four times operations are 98.94, 99.35, 99.50, 99.50 and 99.69 per cent respectively in terms of number of weeds and 99.40, 99.63, 99.72, 99.44 and 99.83 per cent respectively on the dry weight basis.

From the table, it is evident that, the percentage burial of weeds are more in case of four times operations than that of the three times operations.

A minimum of 98.38 per cent in terms of number of buried weeds and 99.09 per cent on the dry weight basis was observed in model-1 operated three times. A maximum of 99.69 per cent in terms of number of buried weeds and 99.83 per cent on the dry weight basis was observed in model-5 operated four times. The cono-puddler model-1 had blades of less height and hence, the burial of weeds could not be achieved more effectively since some of the weeds floats on the surface. In case of the model-5, because of the weight of the operator and higher height of the blades, the burial of weeds was more efficient than the other models.

Table – 4.3 Puddling indices of the different models for different number of operations

Puddling indices in percent					
Sl. No.	Model	No. of operation	Volume of soil settled (cc)	Volume of total soil (cc)	Puddling index (%)
1	Model- 1	3	420	735	57.14
2	Model–2	3	290	515	56.31
3	Model–3	3	375	630	59.52
4	Model–4	3	315	540	58.33
5	Model–5	3	365	615	59.34
6	Model–1	4	360	565	63.72
7	Model–2	4	330	520	63.46
8	Model–3	4	365	550	66.36
9	Model-4	4	335	520	64.42
10	Model-5	4	365	530	68.89

Table 4.4 Average percentage burial of weeds from different test plots

	For three operations			For four operations		
Sl. No.	Model	% burial of weeds		Model	% burial of weeds	
		in nos.	dry wt. basis		in nos.	dry wt. basis
1	Model-1	98.38	99.09	Model-1	98.94	99.40
2	Model-2	98.54	99.24	Model-2	99.35	99.63
3	Model-3	98.76	99.35	Model-3	99.50	99.72
4	Model-4	98.60	99.23	Model-4	99.50	99.74
5	Model-5	98.79	99.34	Model-5	99.69	99.83

Weeds before puddling : Number – 645
Dry weight – 1754.4gm

Table – 4.5(a) Depth of puddling of the puddled field with different models for three times operations

Sl. No.	Machine	Depth in cm.		
		Min	Max	Average
1	Model-1	10.0	10.8	10.42
2	Model-2	12.2	13.5	12.99
3	Model-3	12.2	13.8	12.89
4	Model-4	12.2	13.4	12.96
5	Model-5	13.4	14.9	14.10

Table – 4.5(b) Depth of puddling of the puddled field with different models for four times operations

Sl. No.	Machine	Depth in cm.		
		Min	Max	Average
1	Model-1	10.2	11.0	10.70
2	Model-2	12.6	13.8	13.49
3	Model-3	12.6	13.9	13.50
4	Model-4	12.7	13.9	13.47
5	Model-5	13.5	14.9	14.36

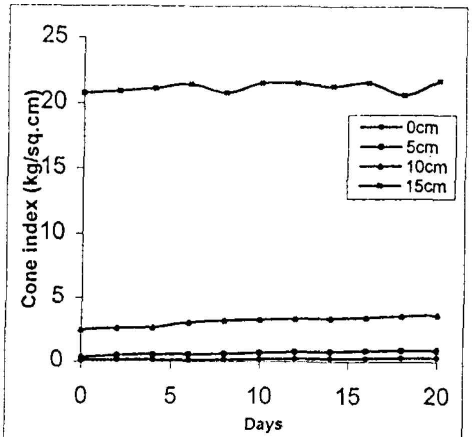
4.4.4 Depth of puddling

The depths of puddling of different test plots were measured as described in section 3.4.4. Minimum, maximum and average depths of puddling for different operations were given in Table 4.5 (a) & 4.5 (b). The minimum and maximum depths of puddling of model-1, model-2, model-3, model-4 and model-5 were 10-11, 12.2-13.8, 12.2-13.9, 12.2-13.9 and 13.4-14.9cm respectively. The average depths of puddling for the model-1, model-2, model-3, model-4 and model-5 for three operations were 10.42, 12.99, 12.89, 12.96 and 14.10cm respectively. The average depths of puddling for the model-1, model-2, model-3, model-4 and model-5 for four operations were 10.70, 13.49, 13.50, 13.42 and 14.36cm respectively.

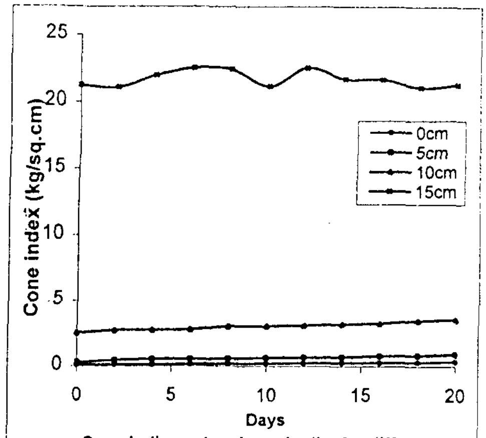
From the table, it is seen that, the average depth of puddling of model-1 is lower than that of other models which is due to its lower blade height. There is increase in average depth of puddling from model-1 to model-2, but no significant change among model-2, model-3 and model4. The average depth of puddling of model-5 observed was observed higher than that of the other models in all operations. It may be due to the additional weight of the operator acting directly over the conical rotors.

4.4.5 Cone index

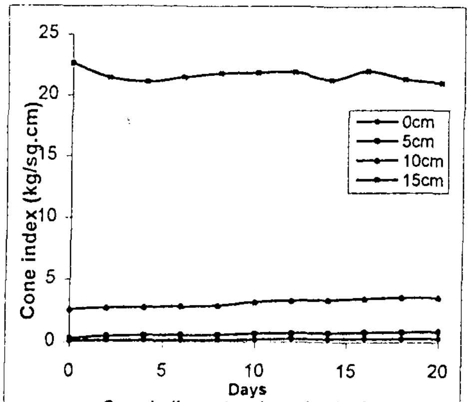
The cone indices from all the test plots corresponding to the five models operated for different number of times were measured at 0.0cm, 5.0cm, 10.0cm and 15.0cm depths from the field surface as described in section 3.4.5. The average cone indices obtained for the five models operated three and four times of operations are presented in Appendix–VI and Appendix-VII. The average cone indices at 0.0cm, 5.0cm, 10.0cm and 15.0cm depths before puddling were 2.78, 4.59, 7.90 and 23.66kg/cm^2. The cone indices at 0.0cm, 5.0cm and 10.0cm depths are found to reduce immediately after puddling. Whereas there is no significant difference at the 15.0cm depth, which may be due to the fact that, the depths of puddling of all the cases are less than 15.0cm. The cone indices at 0.0cm, 5.0cm and 10.0cm depths are found to increase gradually with



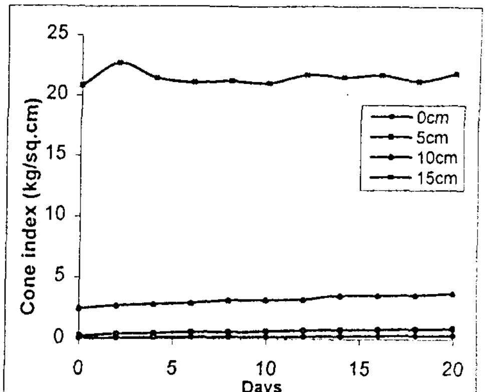
Cone Indices at various depths for different days of model-1



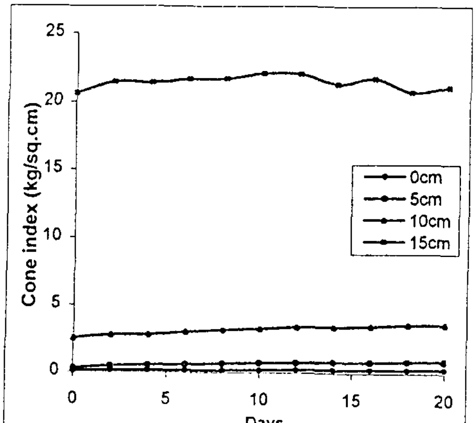
Cone Indices at various depths for different days of model-2



Cone Indices at various depths for different days of model-3

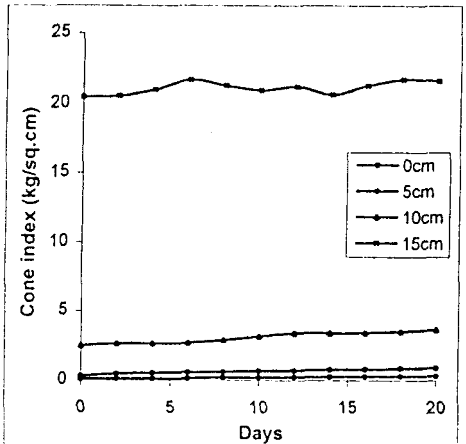


Cone Indices at various depths for different days of model-4

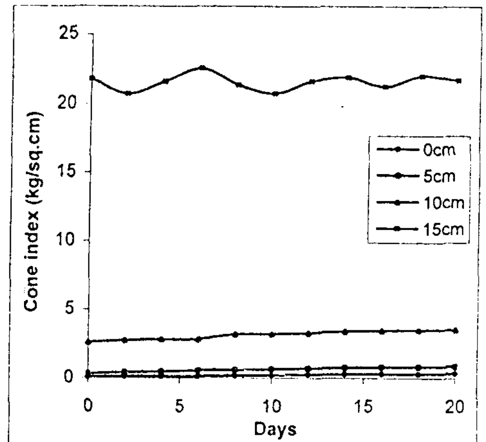


Cone Indices at various depths for different days of model-5

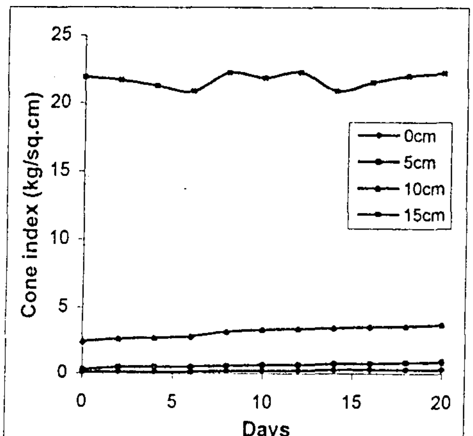
Fig. 4.5 Variation of cone indices at different depths with time for three times operations



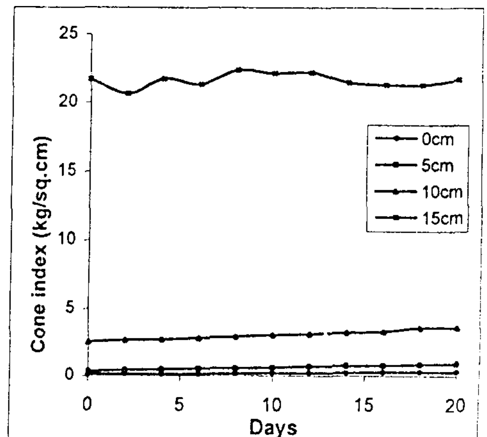
Cone indices at various depths for different days of model-1



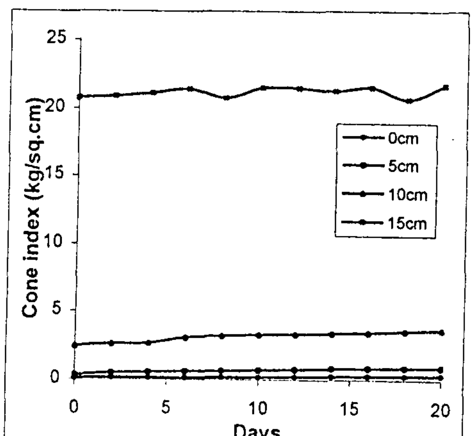
Cone indices at various depths for different days of model-2



Cone indices at various depths for different days of model-3



Cone indices at various depths for different days of model-4



Cone indices at various depths for different days of model-5

Fig. 4.6 Variation of cone indices at different depths with time for four times operatios

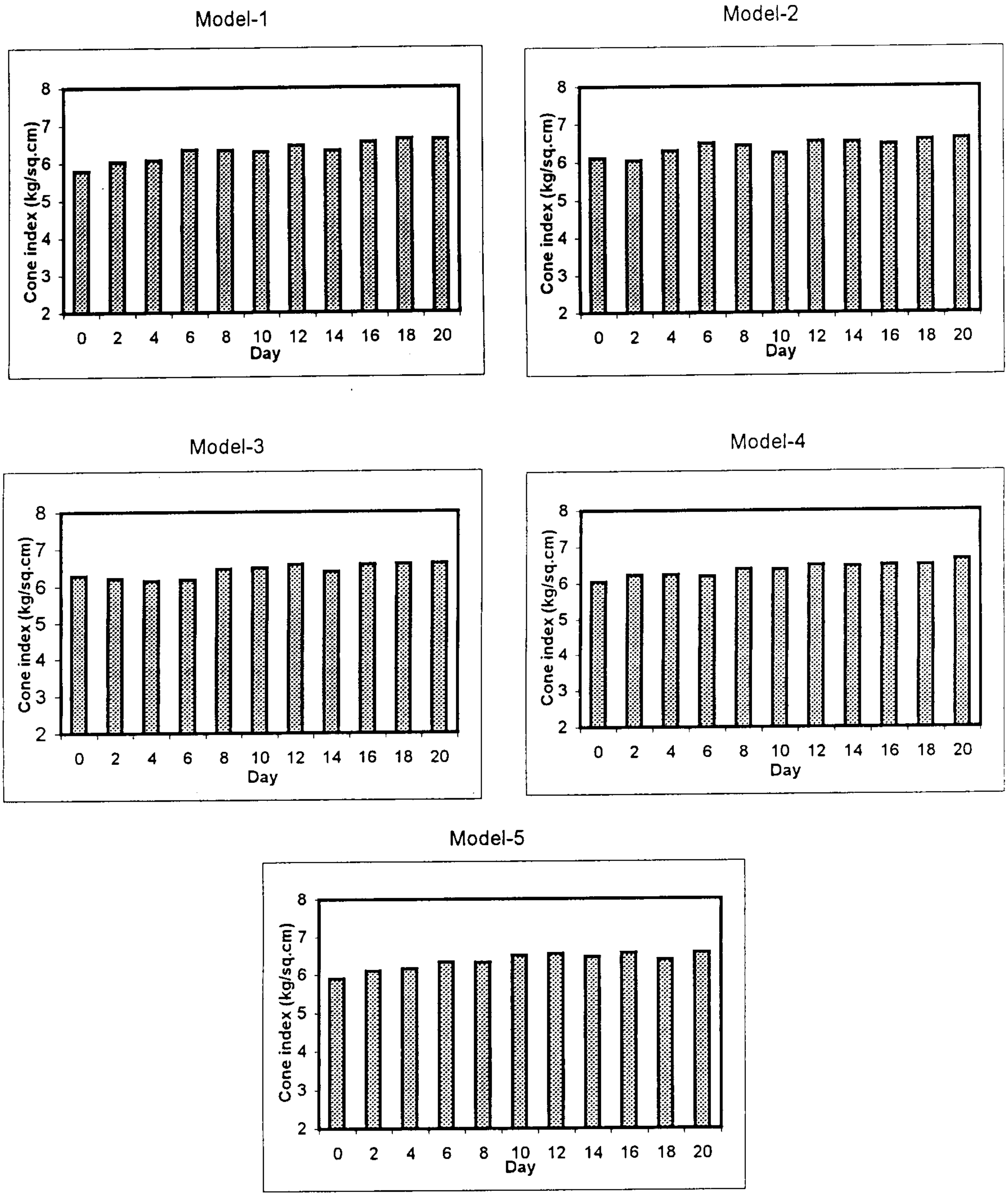


Fig. 4.7 Least square means of cone indices for the five models for different days

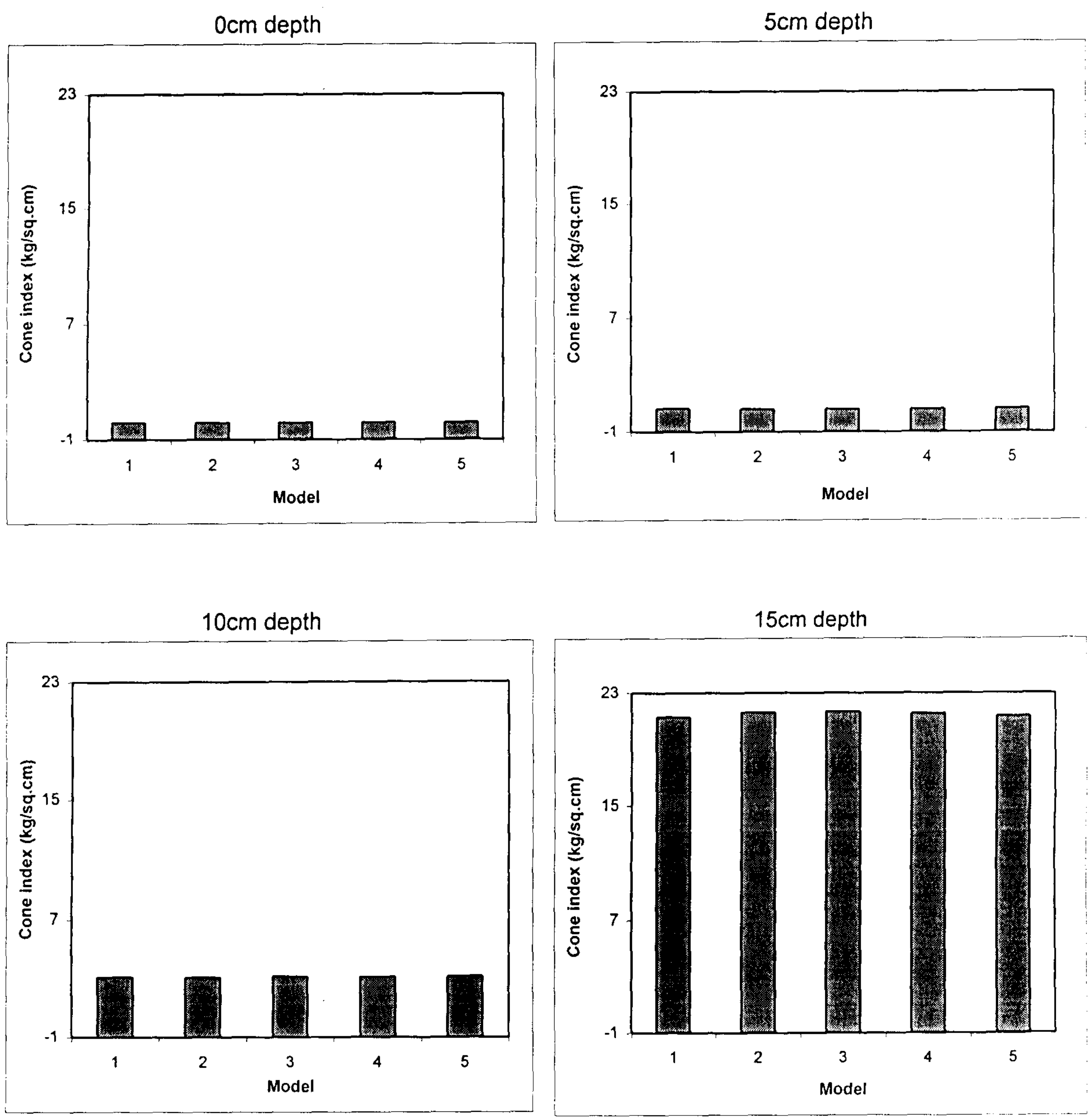


Fig. 4.8 Least square means of cone indices for the five models at different depths

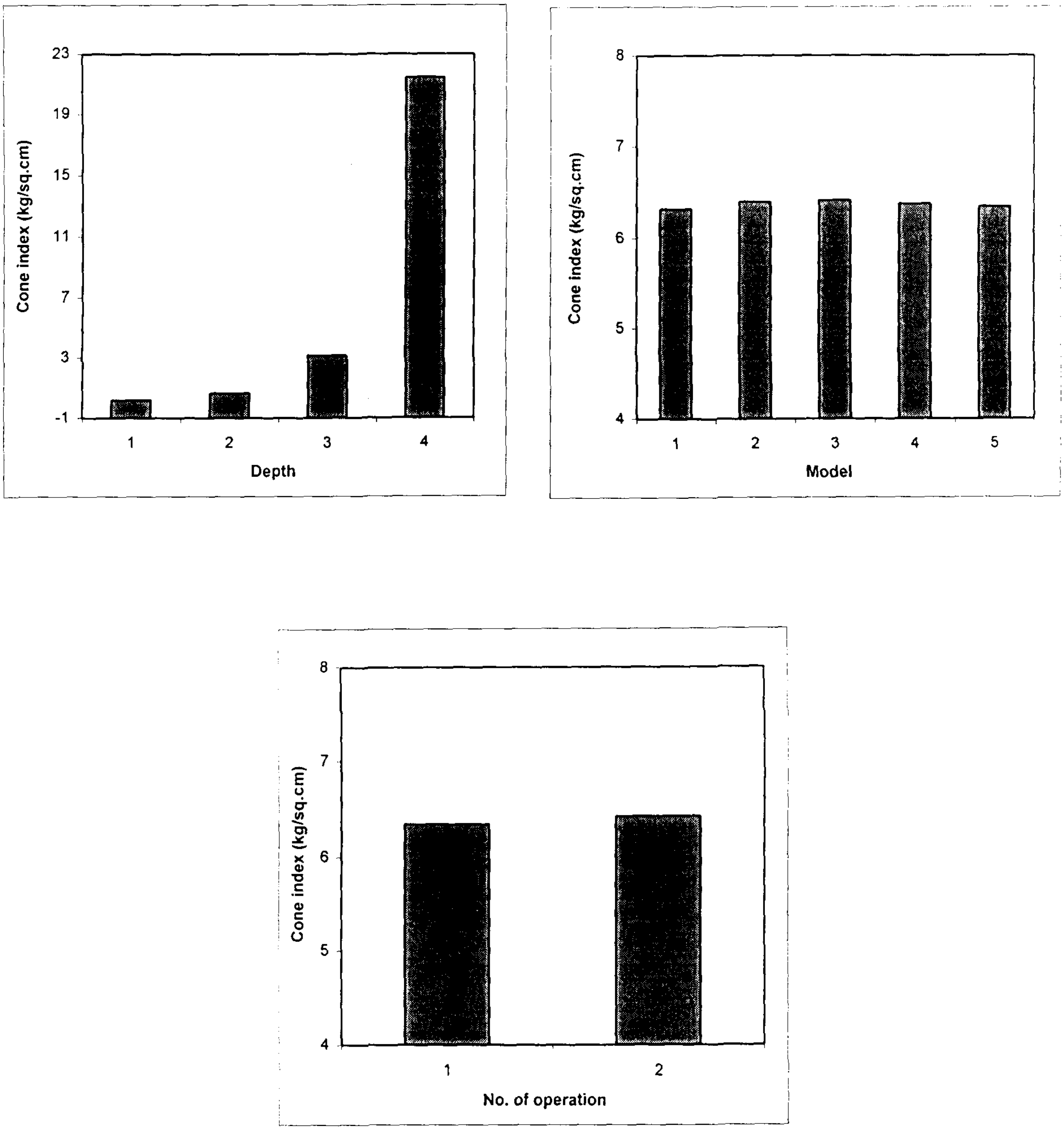


Fig. 4.9 Least square means of the cone indices verses depths, different models and different number of operations

time up to the twenty days measured. The variations of cone indices at different depths with time are represented in Fig. 4.5 & Fig. 4.6.

The data recorded are analysed statistically using SYSTAT 8.0 of WINDOWS package. The least square means of the cone indices for the five models for different days are presented in Fig. 4.7. There is significant difference among the cone indices for the different days. The least square means of the cone indices for different depths of all the five models for different number of operations are presented in Fig. 4.8. From the statistical analysis, it is revealed that, the cone indices at different depths are significantly different. The least square means of the cone indices verses depths, cone indices verses different models and cone indices verses different number of operations are presented in Fig. 4.9. From the analysis, there is no significant difference of the cone indices for the different models and for different number of operations.

4.4.6 Effective field capacity and field efficiency

Effective field capacities and field efficiencies of all the five models operated for different number of times are calculated based on the time taken for the operation and with respect to the speed of operation. The effective field capacities and related field efficiencies of the five models operated for different number of times are presented in Table 4.6.

The effective field capacities for model-1, model-2, model-3, model-4 and model-5 were 0.826, 0.790, 0.843, 0.826 and 1.053ha/day of eight hours respectively with field efficiencies of 67.02, 64.91, 69.455, 52.58 and 70.11 per cent respectively for three times operations. The effective field capacities for model-1, model-2, model-3, model-4 and model-5 are 0.618, 0.598, 0.613, 0.643 and 0.799ha/day respectively with field efficiencies of 66.80, 65.52, 67.21, 54.50 and 72.20 per cent respectively for four times operations.

Table 4.6 Effective field capacities and field efficiencies observed in different field operations

Sl. No.	Model	No. of operations	Area of plot (m^2)	Time taken (min)	Speed of (m/sec)	TFC (ha/day)	EFC (ha/day)	Field efficiency (%)
1	Model-1	3	480	27.88	0.803	1.232	0.826	67.02
2	Model-2	3	480	29.15	0.793	1.218	0.790	64.91
3	Model-3	3	480	27.32	0.790	1.214	0.843	69.45
4	Model-4	3	480	27.90	0.768	1.570	0.826	52.58
5	Model-5	3	480	21.89	0.970	1.490	1.053	70.61
6	Model-1	4	480	37.26	0.804	0.926	0.618	66.80
7	Model-2	4	480	38.53	0.792	0.913	0.598	65.52
8	Model-3	4	480	37.58	0.792	0.912	0.613	67.21
9	Model-4	4	480	35.82	0.769	1.180	0.643	54.50
10	Model-5	4	480	18.83	0.961	1.107	0.799	72.20

The effective field capacities for the three operations are higher than that of the four operations for all models. Lowest field capacity of 0.790ha/day in case of model-2 and highest of 1.053ha/day in case of model-5 were observed for the three times operations. In case of the four operations, lowest field capacity of 0.598ha/day for model-2 and highest of 0.799ha/day for model-5 were observed.

The field efficiencies of the model-4 was lower than that of the other models for all the operations. It is due to difficulty in controlling the system by the operator which took extra unproductive time to complete the operation. The field efficiencies of the model-5 is higher in both three and four times operations with 70.61 per cent in three operations and 72.20 per cent in four operations. It is due to the easier control of the implement system by the operator compared to other models, using the time of operation more effective.

4.4.7 Draft of the implement

The draft of all the models were measured using a hydraulic dynamometer as described in section 3.4.9. The average draft of the power tiller was 74.85kg at 0.786m/sec speed of travel and 80.38 kg at 0.964m/sec speed of travel. The drafts of all the models were measured are presented in Table 4.7.

The drafts of model-1, model-2, model-3 and model-4 measured at the speed of 0.786 m/sec were 40.68, 45.03, 46.81 and 48.19kg respectively. The draft measured for the model-5 at 0.964m/sec speed of travel was 58.06kg. The drafts measured are observed increased gradually from model-1, model-2, model-3, model-4 and model-5 because of the structural difference of the different models. As the height of the blades of the conical rotors increased, there is increase in draft. In case of model-4, the number of conical rotors is increased, the draft is also increased. In the model-5 due to the additional weight of the operator, the draft of the implement also increased.

Table 4.7 Draft and draw bar horse power for different models of cono-puddler

Power required in hp				
Sl.No.	Machine	Speed of travel (m/sec)	Draft (Kg.)	Draw bar horse power (hp)
1	Model – 1	0.786	40.68	0.426
2	Model – 2	0.786	45.03	0.472
3	Model – 3	0.786	46.81	0.491
4	Model – 4	0.786	48.19	0.505
5	Model – 5	0.964	58.06	0.746

4.4.8 Power requirement

The power requirements for all the five models and the power tiller without the implement were calculated based on the speed of travel and draft of the unit and are presented in Table 4.7. The draw bar horse power of the power tiller was 0.784hp when operated at the speed of 0.786m/sec and 1.033hp when operated at the speed of 0.964m/sec. The draw bar horse power requirement of the model-1, model-2, model-3 and model-4 were 0.426 hp, 0.472 hp, 0.491 hp and 0.505 hp respectively at forward speed of 0.786m/sec. The draw bar horse power requirement for the model-5 was 0.746 hp at forward speed of 0.964m/sec. Lowest power requirement of 0.426 hp in case of model-1 and highest power requirement of 0.746 hp was observed in case of model-5.

4.4.9 Fuel consumption

Fuel consumption rate for all the models for different operations were measured as described in section 3.4.11and are presented in Table 4.8. Fuel consumption rate for model-1, model-2, model-3, model-4 and model-5 for three times operations were 0.495, 0.525, 0.538, 0.613 and 0.658lt/h respectively. Fuel consumption rate for model-1, model-2, model-3, model-4 and model-5 for four times operations were 0.507, 0.529, 0.551, 0.628 and 0.666lt/h respectively. Fuel consumption rate of the five models tends to increase as the power required increases. Lowest fuel consumption rate of 0.495lt/h was observed in model-1 operated for three times and highest of 0.666lt/h in case of model-5 operated for four times. The fuel consumption rate for the same implement increased with increase in number of operations. This is because of the draft is higher in the puddle soil condition where the implement had to travel for longer distances in the puddle soil in case of the four times operations than that of three times operations.

Table 4.8 Fuel consumption of different models for different operations

Sl. No.	Machine	No. of operation	Area of plot (m^2)	Time taken (min)	Fuel consumed (lt.)	Rate (lt / hr)
1	Model-1	3	480	27.88	0.230	0.495
2	Model-2	3	480	29.15	0.255	0.525
3	Model-3	3	480	27.32	0.245	0.538
4	Model-4	3	480	27.90	0.285	0.613
5	Model-5	3	480	21.89	0.240	0.658
6	Model-1	4	480	37.26	0.315	0.507
7	Model-2	4	480	38.53	0.340	0.529
8	Model-3	4	480	37.58	0.345	0.551
9	Model-4	4	480	35.82	0.375	0.628
10	Model-5	4	480	28.83	0.320	0.666

Table – 4.9 Percentage wheel slip for different models for different operations

Percentage slippage of the ground wheel					
Sl.No.	Model No.	No. of operations	Distance at no load (m)	Distance at load (m)	wheel slip (%)
1	1	3	14.298	14.182	0.811
2	2	3	14.298	14.168	0.909
3	3	3	14.298	14.123	1.224
4	4	3	14.298	13.990	2.154
5	5	3	14.298	13.813	3.392
6	1	4	14.298	14.171	0.888
7	2	4	14.298	14.155	1.000
8	3	4	14.298	14.120	1.245
9	4	4	14.298	13.983	2.203
10	5	4	14.298	13.785	3.588

- Distances are which were covered by the wheel in 10 revolutions.

4.4.10 Ground wheel slippage

The ground wheel slippage was measured as mentioned in section 3.4.13. The slippage of the ground wheels for model-1, model-2, model-3, model-4 and model-5 for three times operations were 0.811, 0.909, 1.224, 2.154 and 3.392 per cent respectively as presented in Table 4.9. The slippage of the ground wheels for model-1, model-2, model-3, model-4 and model-5 for four times operations were 0.888, 1.000, 1.245, 2.203 and 3.588 per cent respectively. The ground slippage increased as the draft of the implement increased. A lowest ground wheel slippage of 0.811 per cent was observed in case of the model-1 operated for three times and a maximum of 3.588 per cent in model-5 when operated four times.

4.4.11 Cost analysis

The economic analysis were conducted by comparing the cost of puddling using tractor drawn cage wheel puddler, country plough and cono-puddler. The detailed calculations of the cost of operation for different implements are presented in Appendix – XII. The cost indicator for the cono-puddler is given in Table 4.10.

From the cost analysis, it is found that, the cost of puddling by tractor cage wheels for one hectare of land is Rs. 776.65. The total cost of operation for the country plough is found to be Rs. 2442.68 per hectare of land. The cost of puddling of one hectare of land with cono-puddler model-3 and model-5 are Rs. 534.39 and Rs. 432.83 when operated for four times.

Thus there is saving of Rs. 242.26 which is 31.19 per cent when model-3 is operated for four times compared to the tractor drawn cage wheels and saving of Rs. 1908.29 per hectare which is 78.12 per cent compared to country plough. A saving of Rs 343.82 per hectare which is 44.27 per cent compared to tractor cage wheels and Rs 2001.85 per hectare which is 82.28 per cent compared to country plough are observed when model-5 is operated for four times.

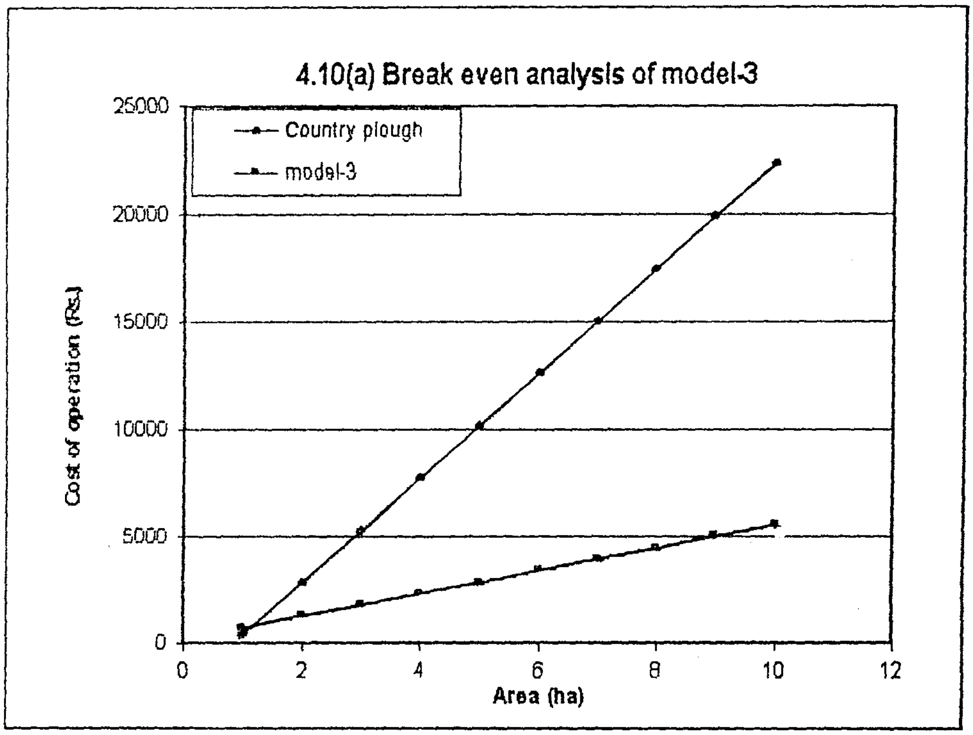
Table - 4.10. Cost indicators for power tiller operated cono-puddler

Sl. No.	Items	Observations
	1. 5hp power tiller	
a)	Cost of power tiller	Rs. 33000
b)	Useful life	10 yr
c)	Hours of use per year	1000 hr
d)	Fixed cost per annum	
	i) Annual depreciation	Rs. 2970
	ii) Annual interest on investment	Rs. 2722.5
	iii) Housing cost per annum	Rs. 330
	iv) Total fixed cost per annum	Rs. 6022.5
e)	Variable cost per annum	
	i) Repair and maintenance	Rs. 1650
	ii) Fuel cost for model-3	Rs. 7280
	iii) Fuel cost for model-5	Rs. 9240
	iv) Cost of oil for model -3	Rs. 2426.67
	v) Cost of oil for model -5	Rs. 3080
	vi) Total variable cost per annum of model-3	Rs. 11356.67
	vii) Total variable cost per annum of model-5	Rs. 13970
	f) Total cost of operation of power tiller for model-3	Rs.17379.17
	g) Total cost of operation of power tiller for model -5	Rs. 19992.5
	h) Operating cost per hour for model-3	Rs. 17.379
	i) Operating cost per hour for model -5	Rs. 19.92

2) Cono-puddler

a) Cost of cono-puddler	Rs. 2800
b) Life in years	5 yr
c) Operating hours per year	300 hr

d) Fixed cost per annum	
i) Annual depreciation	Rs. 504
ii) Interest on investment per annum	Rs. 231
iii) Housing cost per annum	Rs. 28
iv) Total fixed cost per annum	Rs. 763
e) Variable cost per annum	
i) Repair and maintenance	Rs. 140
ii) Weight of operator per annum	Rs. 5625
iii) Total variable cost per annum	Rs. 5765
f) Total operating cost per annum	Rs. 6528
g) Operating cost per hour	Rs. 21.76
h) Operating cost of power tiller with model-3 for three times operations per hour	Rs. 324.46
i) Operating cost of power tiller with model-3 for four times operations per hectare	Rs. 436.00
j) Operating cost of power tiller with model-5 for three times operations per hectare	Rs. 278.07
k) Operating cost of power tiller with model-5 for four times operations per hectare	Rs. 367.00


4.10(a) Break even analysis of model-3
Country plough
model-3
Cost of operation (Rs.)
25000
20000
15000
10000
5000
0
0
2
4
6
8
10
12
Area (ha)

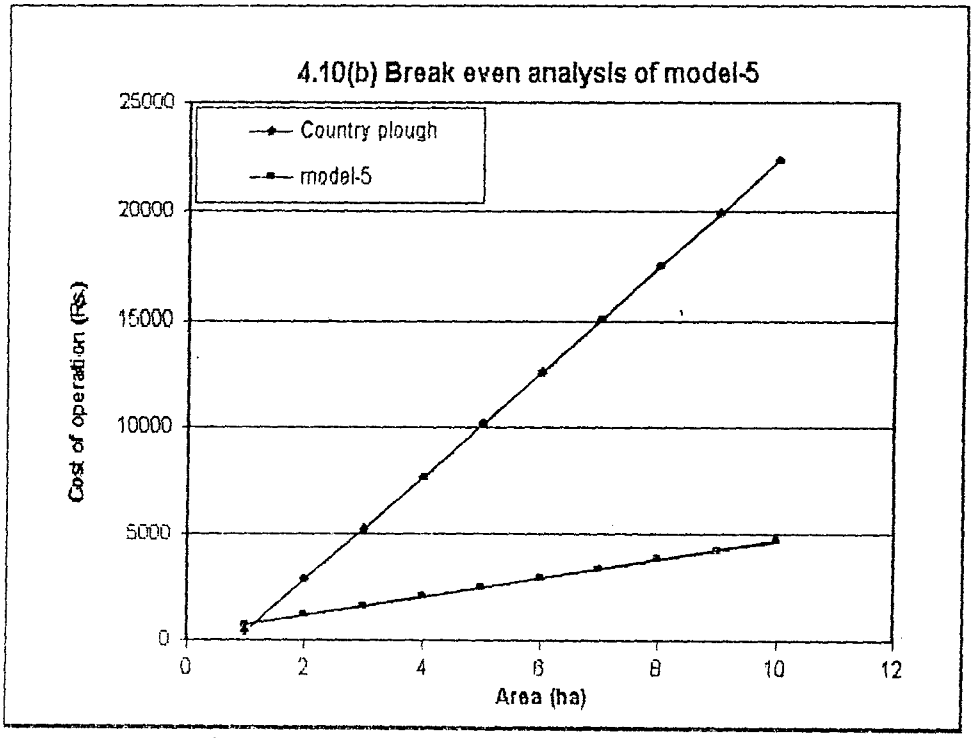

4.10(b) Break even analysis of model-5
Country plough
model-5
Cost of operation (Rs.)
25000
20000
15000
10000
5000
0
0
2
4
6
8
10
12
Area (ha)

Table 4.11(a) Break even analysis of model-3

Area (ha)	Cost of operation: Country plough	Cost of operation: Model-3
1	408.75	763.00
2	2851.43	1297.39
3	5294.11	1831.78
4	7736.79	2366.17
5	10179.47	2900.56
6	12622.15	3434.95
7	15064.83	3969.34
8	17507.51	4503.73
9	19950.19	5038.12
10	22392.87	5572.51

Table 4.11(b) Break even analysis of model-5

Area (ha)	Cost of operation: Country plough	Cost of operation: Model-3
1	408.75	763.00
2	2851.43	1195.83
3	5294.11	1628.66
4	7736.79	2061.49
5	10179.47	2494.32
6	12622.15	2927.15
7	15064.83	3359.98
8	17507.51	3792.81
9	19950.19	4225.64
10	22392.87	4658.47

The break even analysis was carried out for puddling by country plough and puddling by cono-puddler model-3 and model-5 operated for four times. This analysis had been carried out with the assumption that, some expenditure will be incurred for puddling even if the cono-puddler is not used for puddling because of the fixed cost of the unit. Fig. 4.10 shows the break even analysis and Table 4.11 shows the calculations of the break even analysis. It is found that, for the power tiller operated cono-puddler (model-3 and model-5) the break even point are 1.2 ha when operated for four times. It means that, the power tiller operated cono-puddler has to be operated at least for 1.2 ha per annum, otherwise the cost of operation will be more than the cost of puddling by country plough.

SUMMARY

Mechanization is the backbone of agriculture. Rice is one of the most important crops in the world. It normally grows in wetland area with standing water of 5 to 10 cm on the field. It is generally transplanted in puddled soil which is the most widely accepted method of cultivation of rice.

It requires good water management practices which are generally found efficient in a well prepared soft soil bed, which is obtained by puddling. Adequate puddling of soil is important from the point of view of reducing loss of water and nutrients from the soil due to deep percolation of water.

Research had been taken for the development of a cono-puddler attachment for a 5 hp tiller. This will be more useful for wet land preparation of paddy field for the marginal farmer having low investing capacity and having low land holding.

A cono puddler (Model-1) was fabricated in KCAET, Tavanur based on the IRRI design. The width of the implement was 1600mm which consisted of six conical rotors fitted on a tool bar of the main assembly. The depth of puddling obtained from the field test was 10-11cm only. To improve the depth of puddling, another set of rotors (Model-2) was fabricated by increasing the height of the blades to 90mm from 70mm. The depth of puddling from the field test was satisfactory with 12-14cm.

From the second model, It was found that there was a gap of 110mm in between the rotors which leaves that much gap of soil uncut. Also there was problems of clogging of soil in between the blades while in operation. So, another set of six rotors (Model-3) was fabricated by modifying the blade size and shape to helical. The gaps in between the rotors were reduced to 5 cm and the problem of clogging of the soil was removed.

A wooden planker was also provided in the Model-3 behind the conical rotor assembly. With the use of the wooden planker more puddling and better levelling of the field was observed.

Another model (Model-4) was also tested in the field by increasing the width of operation to 2130 mm by adding two more conical rotors on the same tool bar. It was found from the field test that, the working with the Model-4 was not convenient to the operator because of difficulties at the time of turning. Another model (Model-5) with a seat for the operator and modified handle of the power tiller to suit the condition was also tested. This model could be operated at a faster rate as the operator need not walk behind the implement. In terms of the operator, this model was most convenient among the models tested.

Necessary observations were made before, during and after puddling operations. All the models were tested for three and four number of passes of the implement.

Percolation rate

The average percolation loss of water from the field before puddling was 2.1 cm/day. The average percolation loss of water obtained for 20 days were 3.979, 3.804, 3.729, 3.737 and 3.692mm\day for three times operations and 2.938, 2.732, 2.725, 2.758 and 2.650mm/day four times operators for the model-1, model-2, model-3, model-4 and model-5 respectively. From statistical analysis, it was found that there was no significance difference among the different models but there was significance difference between three and four number of operations.

Puddling index

The puddling indices observed were 57.14, 56.31, 59.52, 58.33 and 59.34 per cent for three times operations and 63.72, 63.46, 66.36, 64.42 and 68.89 per cent for four times operations for the model-1, model-2, model-3, model-4 and model-5 respectively. Higher puddling index were observed for four times operations than that of the three times operators.

Percentage of burying of weeds

The percentage burial of weeds for the model-1, model-2, model-3, model-4 and model-5 for three times operations were 98.38, 98.54, 98.76, 98.60 and 98.79 per cent in number of weeds and 99.09, 99.24, 99.35, 99.23 and 99.34 per cent respectively in dry weight basis. The percentage burial of weeds for the model-1, model-2, model-3, model-4 and model-5 for four times operations were 98.94, 99.35, 99.50, 99.50 and 99.69 per cent in number of weeds and 99.40, 99.63, 99.72, 99.74 and 99.83 per cent respectively in terms of dry weight basis.

Depth of puddling

The depth of puddling for the model-1 varied from 10-11cm. For model-2, model-3 and model-4 the depth of puddling was between 12 and 14cm. Higher depth of puddling of 13-15cm was observed for model-5, which may be because of the weight of the operator. The average depth of puddling was 10.42, 12.99, 12.89, 12.96 and 14.10cm for three times operations and 10.70, 13.49, 13.50, 13.47 and 14.36cm for the model-1, model-2, model-3, model-4 and model-5 respectively.

Cone index

The cone indices at 0, 5, 10 and 15cm depths before pudding were 2.78, 4.59, 7.90 and 23.66kg/cm^2. The cone indices for all the models and for all operations were observed reduced immediately after puddling at 0, 5 and 10cm depths. Then it was observed to increase gradually for the depths 0, 5 and 10cm depths till the 20 days. For the 15cm depth the cone indices were not affected by the pudding operation. There was no significance difference of the cone indices among he models and between the different number of operations. But, there was significant difference of cone indices among different days and at different depths.

Effective field capacity and field efficiency

The effective field capacities obtained from the field tests for model-1, model-2, model-3, model-4 and model-5 were 0.826, 0.790, 0.843, 0.826 and 1.053ha/day. The field efficiencies obtained from the field tests for model-1, model-2, model-3, model-4 and model-5 were 67.02, 64.91, 69.45, 52.58 and 70.61 per cent respectively for three times operators. The effective field capacities for model-1, model-2, model-3, model-4 and model-5 were 0.618, 0.594, 0.613, 0.643 and 0.799 ha/day. . The field efficiencies for model-1, model-2, model-3, model-4 and model-5 were 66.80, 65. 52, 68.64, 54.50 and 72.20 per cent respectively for the four times operators. In both cases, the field efficiency of the model-4 was less than that of others where as the field efficiency of the model-5 was observed higher.

Draft and power requirement

The draft of the power tiller was 74.85 kg at and 80.38 kg at travel speed of 0.786m/sec and 0.964m/sec respectively. The drafts of the model-1, model-2, model-3 and model-4 were 40.68, 45.03, 46.81, and 48.19kg respectively at travel speed of 0.786m/sec. The draft of the model-5 was 58.06kg at travel speed of 0.786m/sec. The draw bar horse power requirement for model-1, model-2, model-3 and model-4 and model-5 were 0.426hp, 0.472hp, 0.491hp, 0.505 hp and 0.746hp respectively with their respective speed of travel.

Fuel consumtion

The rate of fuel consumption obtained from the testing for model-1, model-2, model-3 and model-4 and model-5 were 0.495, 0.525, 0.538, 0.613 and 0.658 lt/h for three times operations and 0.507, 0.529, 0.551,0.628 and 0.666 lt/h respectively for four times operations. The fuel consumption rate was least in case of model-1 and highest in case of model-5.

Ground wheel slippage

The ground wheel slippage of the power tiller operated cono-puddler for model-1, model-2, model-3 and model-4 and model-5 for three times operation were 0.811, 0.909, 1.224, 2.154 and 3.392 per cent respectively. The ground wheel slippage for model-1, model-2, model-3 and model-4 and model-5 for four times operation were 0.888, 1.000, 1.245, 2.203 and 3.588 per cent respectively. The ground wheel slippage was observed increased as the load of the implement increased.

Cost economics

The cost of operation of the cono-puddler developed and the cost of puddling using country plough and tractor drawn cage wheels are compared. The cost of puddling one hectare of land using country plough is Rs. 2442.68. The cost of puddling one hectare of land using tractor drawn cage wheels is Rs. 776.65. The cost of puddling one hectare of land using model-3 and model-5 are Rs. 388.61 and Rs. 328.19 when operated for three times and Rs. 534.39 and Rs. 432.83 when operated for four times. The break even point of the cono-puddler is 1.2 ha compared to country plough.

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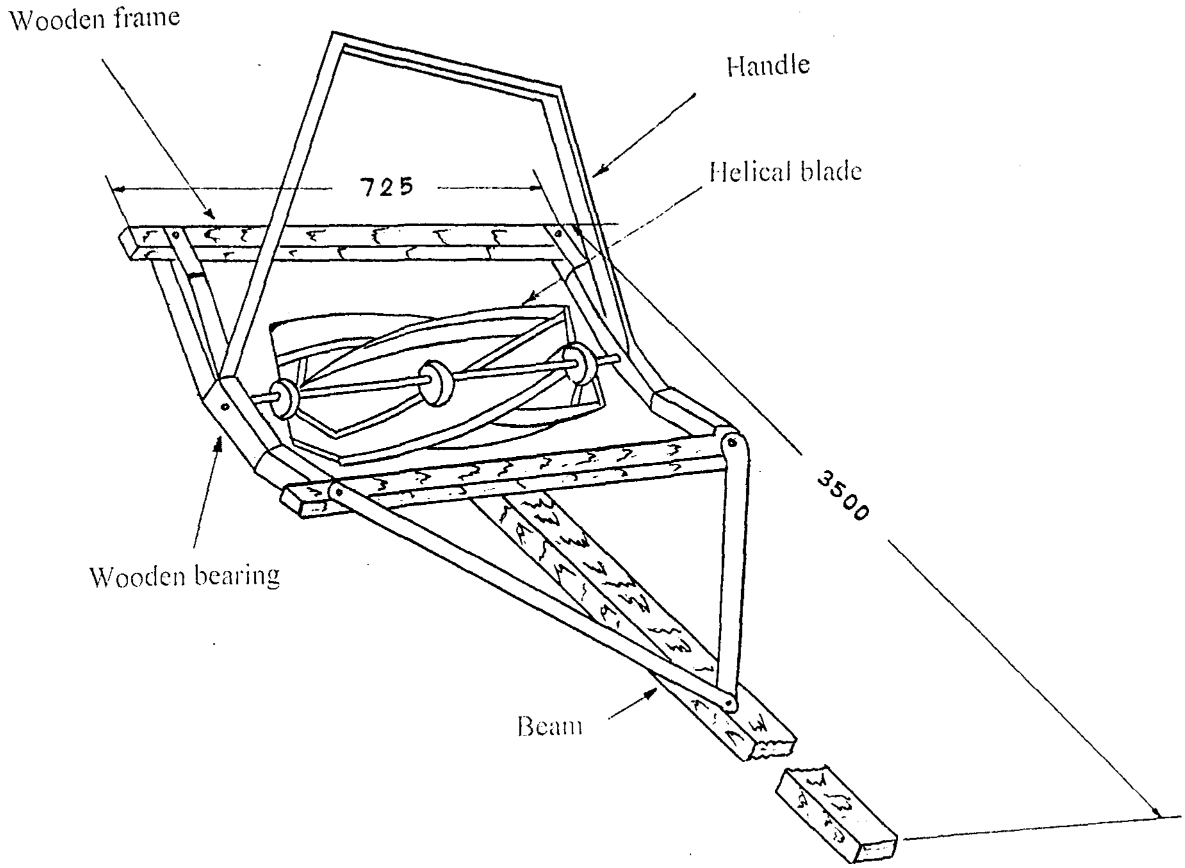
* Originals not seen.

APPENDIX

Appendix – I

Common puddlers used in India

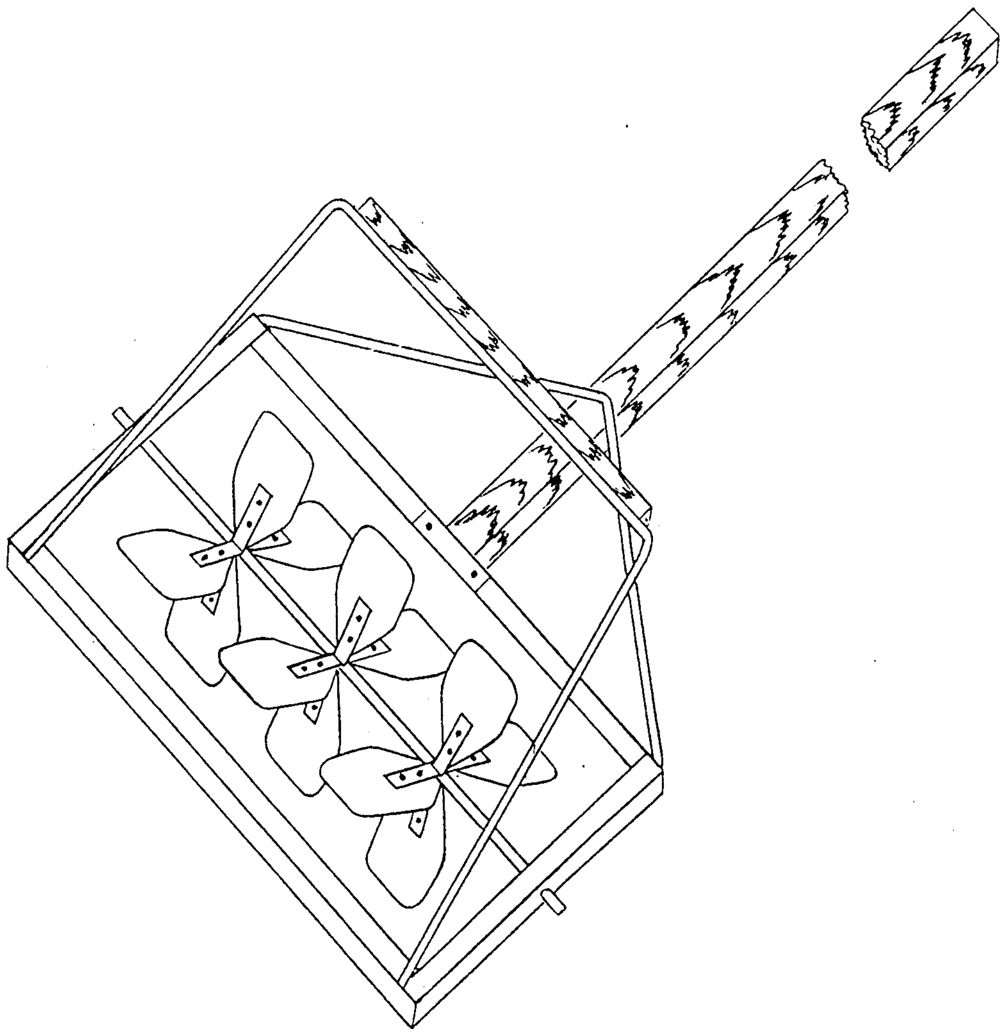


1. Bullock drawn helical blade puddler

Specification :

Type	:	Animal drawn, rolling
Power requirement	:	A pair of bullock and one person
Length	:	1020 mm (3500 mm including beam)
Height	:	1055 mm
Total width	:	725 mm
Width of cut	:	650 mm
Field capacity	:	0.075 ha/hr
Draft	:	50 kg

Source : Training Course for Research on Agricultural Implements/Machines (CIAE) 12th February.

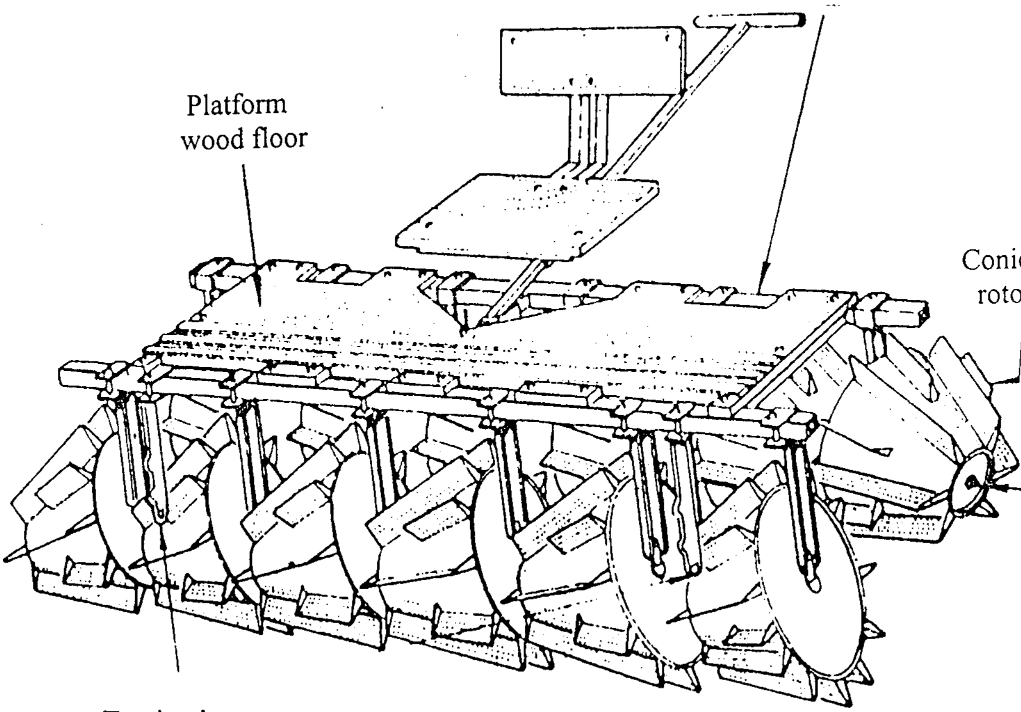


2. Bullock drawn rotary blade puddler

Specification :

Power requirement	: One pair of bullock and one person
Nunber of gangs	: One
Number of blades	: 3 sets of 4 blades
Width of cut	: 780
Size of blade	: 200 x 150 x 3 mm
Distance between two sets of blades	: 250-275 mm
Blade angle	: 45^0
Field capacity	: 0.112 ha/hr
Draft	: 45-60 kg

Source : AMA (1991) vol. 22, No. 1, pp : 30.

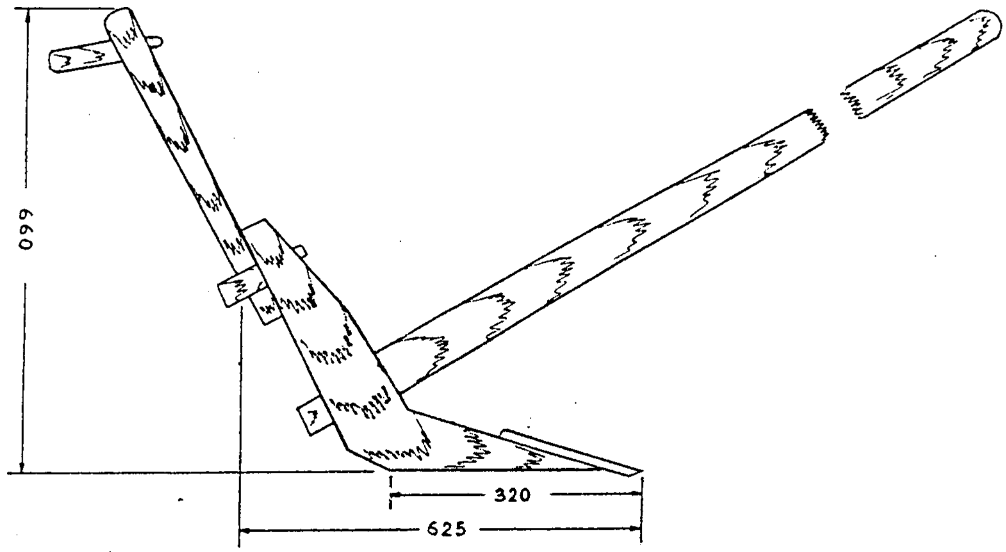


3. Animal drawn IRRI cono- puddler

Specification :

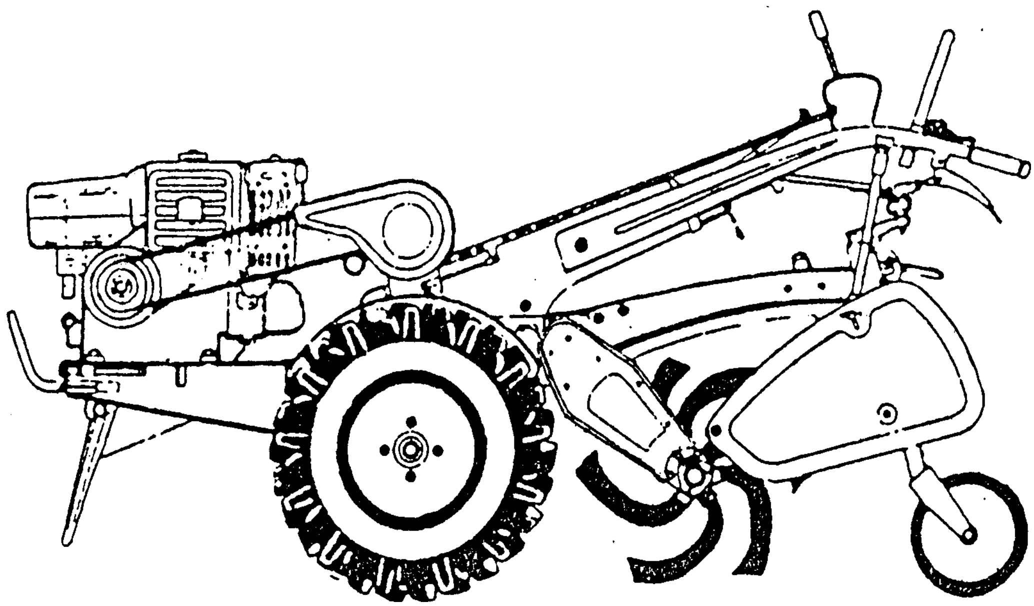
Power requirement	: One draft animal
Number of gangs	: 2
Number of rotors	: 6 rotors in each gang
Width of cut	: 1600 mm
Puddling depth	: 100-150 mm
Weight	: 64 kg (with operator seat)
	: 59 kg (without operator seat)
Field capacity	: 1 ha/da
Draft requirement	: 30-70 kg

Source : IRRI Engineering (1993) pp : 7.



All dimensions are in mm

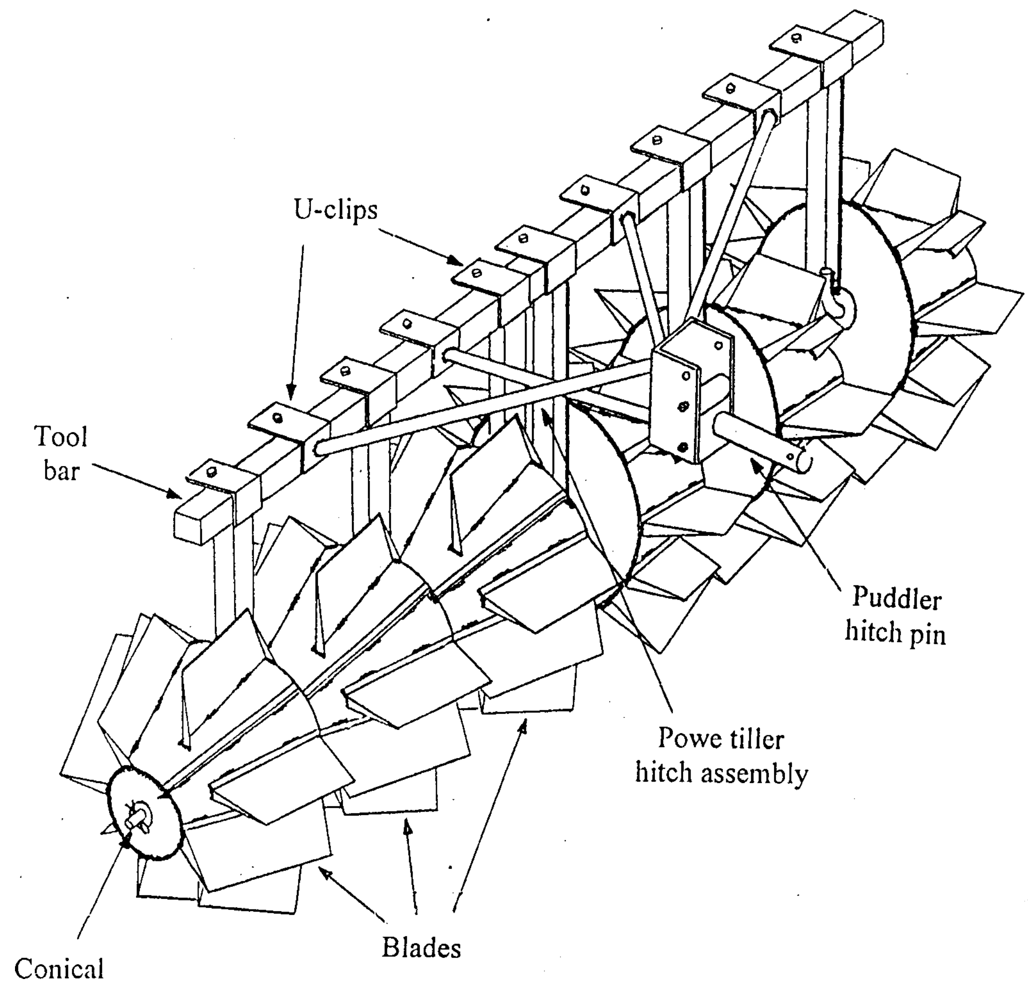
4. Bullock drawn country (Desi) plough



5. Power tiller mounted rotavator

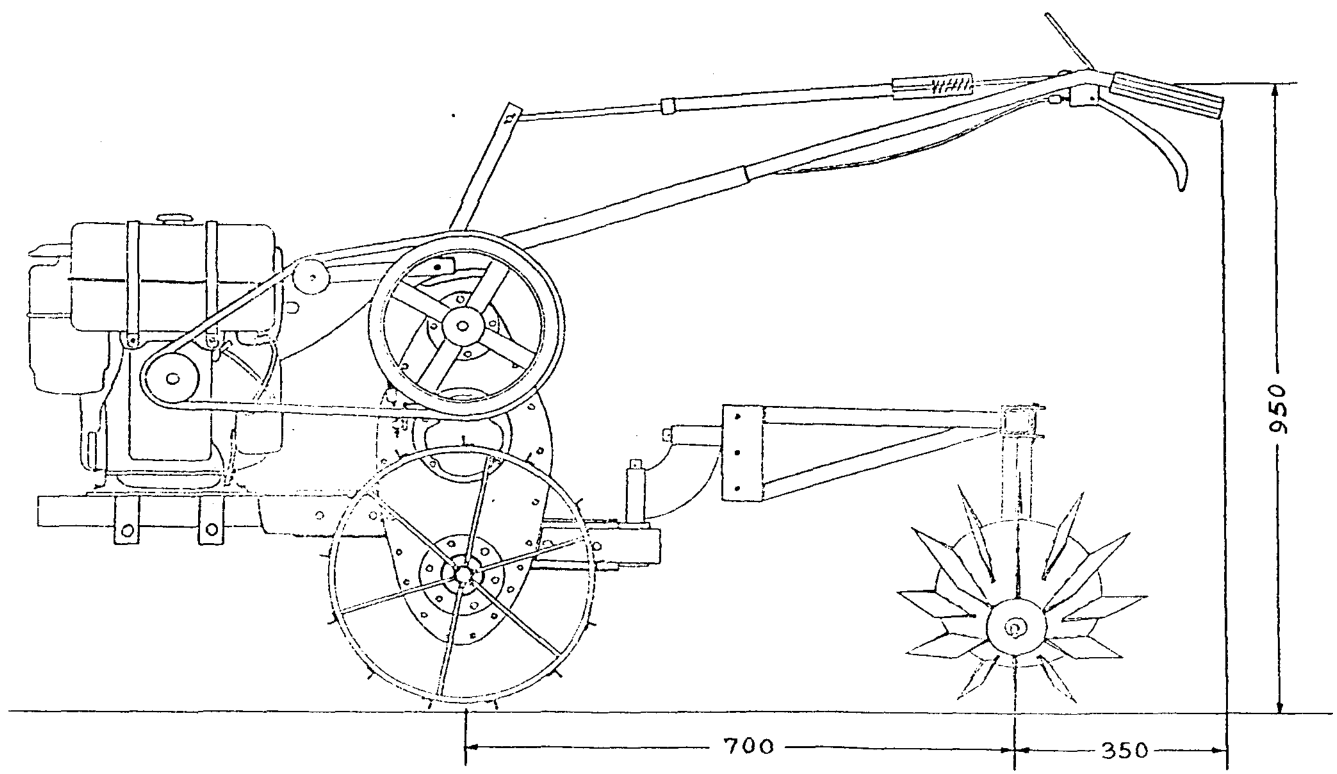
Appendix – II

Isometric view the cono-puddler main assembly (Model-1, Model-2)



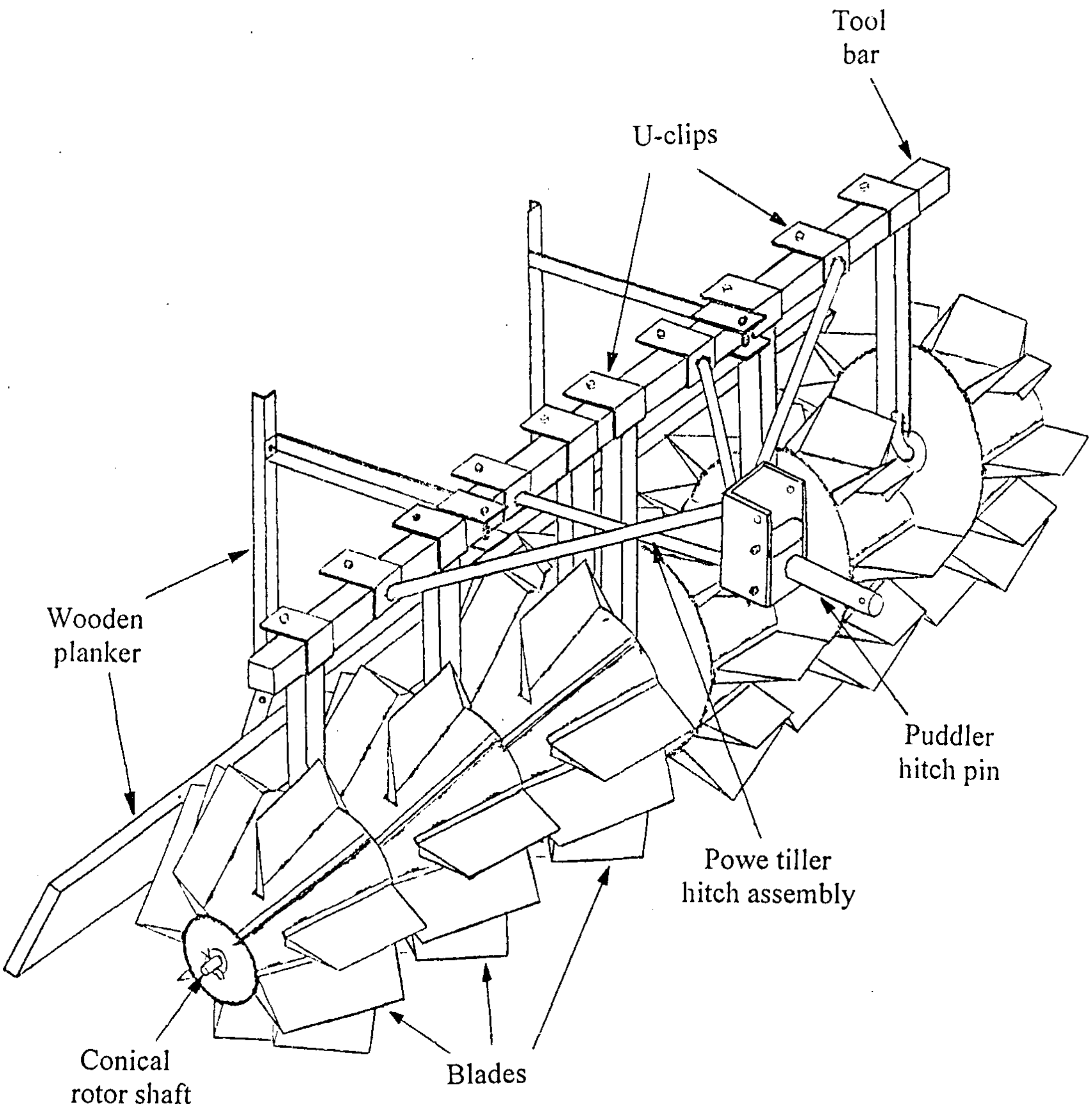
Appendix – III

Side view of 5hp power tiller drawn cono-puddler (Model-1&Model-2)



Appendix-IV

Isometric view of the cono-puddler main assembly (Model-3)



Appendix - V

Percentage burial of weeds for different puddling operations of different models

Percentage burial of weeds for three times operations measured in $0.25m^2$ area

Sl. No.	Machine	Before puddling		After puddling		Burial (%)	
		In nos.	Dry Wt. (gm)	In nos.	Dry Wt. (gm)	In nos.	Dry Wt. (gm)
1	Model-1	645	1754.4	10.4	15.91	98.38	99.09
2	Model-2	645	1754.4	9.4	13.38	98.54	99.24
3	Model-3	645	1754.4	8.0	11.89	98.76	99.35
4	Model-4	645	1754.4	9.0	13.50	98.60	99.23
5	Model-5	645	1754.4	7.8	11.62	98.79	99.34

Percentage burial of weeds for four times operations measured in $0.25m^2$ area

Sl. No.	Machine	Before puddling		After puddling		Burial (%)	
		In nos.	Dry Wt. (gm)	In nos.	Dry Wt. (gm)	In nos.	Dry Wt. (gm)
1	Model-1	645	1754.4	6.8	10.47	98.94	99.40
2	Model-2	645	1754.4	4.2	6.42	99.35	99.63
3	Model-3	645	1754.4	3.2	4.89	99.50	99.72
4	Model-4	645	1754.4	3.2	4.52	99.50	99.74
5	Model-5	645	1754.4	2.0	2.92	99.69	99.83

Appendix - VI

Cone indices observed at different days for different models after three times operations (kg/sq.m)

Depths (cm.)

Days	0	5	10	15	0	5	10	15
	Model-1				Model-2			
0	0.085	0.316	2.507	20.461	0.076	0.301	2.606	21.817
2	0.113	0.485	2.649	20.543	0.116	0.442	2.768	20.718
4	0.134	0.541	2.679	20.985	0.137	0.479	2.834	21.622
6	0.153	0.585	2.705	21.665	0.147	0.566	2.846	22.557
8	0.202	0.615	2.926	21.274	0.174	0.590	3.197	21.385
10	0.218	0.689	3.191	20.944	0.227	0.658	3.204	20.764
12	0.227	0.713	3.407	21.190	0.267	0.719	3.290	21.643
14	0.255	0.775	3.413	20.636	0.295	0.763	3.401	21.899
16	0.276	0.812	3.438	21.263	0.301	0.806	3.462	21.262
18	0.313	0.869	3.549	21.735	0.310	0.849	3.512	22.022
20	0.344	0.923	3.691	21.632	0.332	0.874	3.537	21.725
	Model-3				Model-4			
0	0.079	0.282	2.433	21.901	0.091	0.298	2.526	21.705
2	0.110	0.491	2.630	21.694	0.119	0.430	2.667	20.656
4	0.119	0.523	2.710	21.293	0.125	0.479	2.705	21.715
6	0.134	0.535	2.827	20.872	0.147	0.535	2.826	21.334
8	0.181	0.584	3.167	22.238	0.178	0.572	2.926	22.362
10	0.224	0.645	3.340	21.848	0.218	0.621	3.037	22.125
12	0.239	0.664	3.401	22.279	0.221	0.720	3.105	22.197
14	0.295	0.741	3.450	20.893	0.248	0.750	3.228	21.458
16	0.304	0.775	3.549	21.519	0.276	0.788	3.302	21.283
18	0.316	0.837	3.604	21.992	0.301	0.862	3.586	21.283
20	0.309	0.880	3.728	22.208	0.310	0.892	3.598	21.694
	Model-5				Cone indices before puddling			
0	0.085	0.325	2.464	20.749				
2	0.116	0.467	2.593	20.880				
4	0.141	0.553	2.661	21.098	2.780	4.590	7.900	23.660
6	0.153	0.603	3.081	21.417				
8	0.171	0.634	3.222	20.759				
10	0.196	0.707	3.302	21.499				
12	0.236	0.763	3.357	21.488				
14	0.267	0.818	3.401	21.273				
16	0.282	0.849	3.475	21.540				
18	0.316	0.899	3.598	20.656				
20	0.329	0.911	3.685	21.694				

Appendix - VII

Cone indices observed at different days for different models after four times operations (kg/sq.m)

Depths (cm.)

Days	0	5	10	15	0	5	10	15
		Model-1				**Model-2**		
0	0.082	0.291	2.415	20.225	0.088	0.304	2.519	21.191
2	0.119	0.504	2.599	21.314	0.119	0.473	2.754	21.047
4	0.128	0.559	2.661	21.252	0.125	0.528	2.766	21.930
6	0.144	0.566	2.815	22.156	0.141	0.566	2.809	22.464
8	0.196	0.609	3.167	21.632	0.187	0.584	3.037	22.382
10	0.211	0.683	3.210	21.252	0.218	0.658	3.074	21.118
12	0.248	0.757	3.222	21.909	0.236	0.683	3.111	22.495
14	0.267	0.781	3.401	21.067	0.282	0.713	3.228	21.653
16	0.289	0.849	3.567	22.002	0.301	0.818	3.284	21.642
18	0.307	0.862	3.684	21.756	0.316	0.830	3.499	21.026
20	0.313	0.898	3.703	21.488	0.359	0.935	3.592	21.232
		Model-3				**Model-4**		
0	0.085	0.288	2.612	22.595	0.089	0.301	2.513	20.821
2	0.125	0.473	2.735	21.417	0.107	0.442	2.742	22.670
4	0.134	0.535	2.766	21.078	0.141	0.479	2.852	21.427
6	0.153	0.572	2.883	21.478	0.150	0.566	2.938	21.067
8	0.196	0.590	2.933	21.789	0.187	0.590	3.179	21.191
10	0.221	0.683	3.210	21.827	0.202	0.658	3.235	20.995
12	0.255	0.713	3.321	21.899	0.215	0.719	3.253	21.694
14	0.267	0.734	3.389	21.252	0.258	0.763	3.561	21.519
16	0.288	0.800	3.518	21.992	0.289	0.806	3.604	21.694
18	0.301	0.824	3.605	21.345	0.310	0.849	3.623	21.201
20	0.307	0.870	3.624	21.006	0.325	0.874	3.746	21.827
		Model-5						
0	0.088	0.295	2.513	20.615		**Cone indices before puddling**		
2	0.116	0.461	2.754	21.458				
4	0.147	0.523	2.778	21.406	2.780	4.590	7.900	23.660
6	0.178	0.590	3.000	21.653				
8	0.187	0.676	3.173	21.715				
10	0.211	0.732	3.272	22.094				
12	0.242	0.763	3.413	22.033				
14	0.258	0.806	3.432	21.324				
16	0.276	0.824	3.512	21.735				
18	0.295	0.874	3.617	20.769				
20	0.304	0.899	3.642	21.118				

Appendix – VIII

Cost analysis

1. Cost of operation of tractor operated cage wheel puddler

1(A) Operating cost of tractor :

Cost of a tractor (C)	: Rs. 1,90000
Life in years (L)	: 10 yr
Salvage value (S)	: 10% of purchase value
Operating hours per annum	: 1000 h
Fuel consumption	: 4.5 lt/h
Cost of diesel per litre	: Rs. 16
Labour wages per hour	: Rs.18.75

Fixed cost of tractor :

1. Annual depreciation $= \frac{C-S}{L}$ $= \frac{190000-19000}{10}$

   = Rs. 17100

2. Annual interest $= \frac{C+S}{2} \text{ X } \frac{I}{100}$ $= \frac{190000+19000}{2} X \frac{15}{100}$

   @ Interest rate of 15% = Rs.15675

3. Insurance = Rs. 120
4. Tax = nil
5. Housing $= 190000 \text{ X } \frac{1}{100}$

   @ 1% of purchase value = Rs.1900

Total fixed cost per annum = 17100 + 15675 + 120 + 1900

= Rs. 34795

Variable cost of tractor :

1. Annual repair and maintenance $= 190000 \text{ X } \frac{5}{100}$

   @ 5% of the purchase value = Rs. 9500

2. Fuel cost = 1000 X 4.5 X 16

= Rs. 72000

3. Oil cost $= \frac{1}{3}$ X 72000

= Rs. 24000

Total variable cost per annum = 9500 + 72000 + 24000

= Rs. 105500

Total operating cost per annum = 34795 + 105500

= Rs. 140295

Operating cost of tractor per hour $= \frac{140295}{1000}$

= Rs. 140.295

1(B) Operation cost of cage wheel :

Cost of the cage wheels (C)	:	Rs. 8000
Life in years (L)	:	10 yr
Operating hours per annum (H)	:	300 h
Salvage value (S)	:	10% of purchase value
Labour cost per hour	:	Rs. 18.75

Fixed cost of cage whhel :

1. Annual depreciation $= \frac{C-S}{L}$ $= \text{Rs } \frac{8000-800}{10}$

= Rs. 720

2. Annual interest $= \frac{C+S}{2} \text{X} \frac{I}{100}$ $= \frac{8000+800}{2} \text{X} \frac{15}{100}$

@ interest rate 15% = Rs. 660

3. Insurance = nil

4. Tax = nil

5. Housing $= 8000 \text{ X } \frac{1}{100}$

@ 15 of purchase value = Rs. 80

Total fixed cost per annum = 720 + 660 + 80

= Rs. 1460

Variable cost of cage wheel :

1. Repair and maintenance $= 8000 \times \frac{5}{100}$

$= \text{Rs } 400$

2. Wages of operator $= 300 \times 18.75$

$= \text{Rs.}5625$

Total variable cost per annum $= 400 + 5625$

$= \text{Rs. } 6025$

Total operating cost of cage wheel per annum $= 1460 + 6025$

$= \text{Rs. } 7485$

Operating cost of cage wheel per hour $= \frac{7485}{300}$

$= \text{Rs.}24.95$

Operating cost of tractor drawn cage wheel per hour $= 140.295 + 24.95$

$= \text{Rs.}165.245$

Time required for puddling one hectare of land = 4.7 h

Cost of puddling of one hectare $= 4.7 \times 165.245$

$= \text{Rs.}776.65$

2. Cost of operation of power tiller operated cono-puddler

2(A) Operating cost of 5hp power tiller :

Cost of the 5hp power tiller	:	Rs. 33000
Life in years	:	10 yr
Cost of fuel per litre	:	Rs. 16
Cost of oil	:	one third of fuel cost
Operating hours per annum	:	1000 h
Salvage value	:	10% of the purchase value
Operating hour for puddling	:	300 h

Fixed cost of power tiller :

1. Annual depreciation $= \frac{33000 - 3300}{10}$

$= \text{Rs. } 2970$

2. Interest $= \frac{33000 + 3300}{2} X \frac{15}{100}$

@ 12% interest rate = Rs. 2722.5

3. Insurance = nil

4. Tax = nil

5. Housing $= 33000 X \frac{1}{100}$

@ 1% of the purchase value = Rs. 330

Total fixed cost per annum = 2970 + 2722.5 + 330

= Rs. 6022.5

Variable cost of power tiller :

1. Repair and maintenance $= 33000 X \frac{5}{100}$

@ 5%of the purchase value = Rs. 1650

2. Fuel cost (Model-3) = 1000 X 0.54 X 16

= Rs. 8640

Fuel cost (Model-5) = 1000 X 0.66 X 16

= Rs.10560

3. Cost of oil (Mode-3) $= 8640 X \frac{1}{3}$

= Rs. 2880

Cost of oil (Model-5) $= 10560 X \frac{1}{3}$

= Rs. 3520

Total variable cost per annum (Model-3) = 1650 + 8640 + 2880

= Rs.13170

Total variable cost per annum (Model-5) = 1650 + 10560 + 3250

= Rs. 15460

Total cost of operation of the power tiller per annum (Model-3) = 6022.5 + 13170

= Rs.19192.5

Operating cost per hour (Model-3) $= \frac{19192.5}{1000}$

= Rs. 19.19

Total cost of operation of the power tiller per annum (Model-5) $= 6022.5 + 15460$

$= \text{Rs. } 21482.5$

Operating cost per hour (Model-5) $= \frac{21482.5}{1000}$

$= \text{Rs. } 21.48$

2(B) Operating cost of cono-puddler :

Cost of the puddler	: Rs. 2800
Life in years	: 5 yr
Operating hours per annum	: 300 h
Salvage value	: 10% of purchase value

Fixed cost of cono-puddler :

1. Annual depreciation $= \frac{2800 - 280}{5}$

$= \text{Rs. } 504$

2. Interest $= \frac{2800 + 280}{2} \text{ X } \frac{15}{100}$

@ 12% of the purchase value $= \text{Rs } 231$

1. Insurance = nil
2. Tax = nil
3. Housing $= 2800 \text{ X } \frac{1}{100}$

@ 1% of the purchase value $= \text{Rs } 28$

Total fixed cost per annum $= 504 + 231 + 28$

$= \text{Rs. } 763$

Variable cost of cono-puddler :

1. Repair and maintenance $= 2800 \text{ X } \frac{5}{100}$

@ 5% of the purchase value $= \text{Rs. } 140$

2. Wages of operator $= 300 \text{ X } 18.75$

$= \text{Rs.} 5625$

Total variable cost per annum $= 140 + 5625$

$= \text{Rs.} 5765$

Total operating cost per annum	= 763 + 5765
	= Rs. 6528
Operating cost cono-puddler for puddling per hour	$= \frac{6528}{300}$
	= Rs. 21.76
Operating cost of power tiller drawn cono-puddler	= 19.19 + 21.76
(Model-3)	= Rs. 40.95
Operating cost of power tiller drawn cono-puddler	= 21.48 + 21.76
(Model-5)	= Rs. 43.24
Time required for puddling one hectare	= 9.49 h
(Model-3, three operation)	
Cost of puddling one hectare	= 40.95 X 9.49
	= Rs. 388.61
Time required for puddling one hectare	= 13.05 h
(Model-3, four operation)	
Cost of puddling one hectare	= 40.95 X 13.05
	= Rs. 534.39
Time required for puddling one hectare	= 7.59h
(Model-5, three operation)	
Cost of puddling one hectare	= 43.24 X 7.59
	= Rs. 328.19
(Model-5, three operation)	
Time required for puddling one hectare	= 10.01h
(Model-5, four operation)	
Cost of operation one hectare	= 43.24 X 10.01
	= Rs. 432.83

3. Cost of operation of country (desi) plough

3(A). Cost of use of a pair of bullock

Cost of a pair of bullock	: Rs.12000
Useful life in years	: 7 yr
Maintenance cost	: Rs.80 per day
Hours of use per annum	: 1200 h
Cost of a pair of bullock after 7 years	: Rs.16000

Gain in price of a pair of bullock per annum $= \frac{16000-12000}{7}$

$= Rs. 571.43$

Feed per annum $= 80 X 365$

@ Rs.80 per day $= Rs. 29200$

Housing cost $= \frac{2X12000}{100}$

@ 2% of initial cost $= Rs. 240$

Operating cost of a pair of bullock per annum $= 29200 + 240 - 571.43$

$= Rs.28868.57$

Operating cost of a pair of bullock per hour $= \frac{28868.57}{1200}$

$= Rs.24.05$

3(B). Operating cost of country plough

Cost plough (C)	:	Rs.1500
Life of plough (L)	:	5 yr
Operating hours per annum (H)	:	700h
Operating hours for puddling	:	300 h
Salvage value (S)	:	10% of purchase value

Fixed cost of country plough :

1. Annual depreciation $= \frac{C-S}{L} = \frac{1500-150}{5}$

   $= Rs. 270$

2. Annual interest on investment $= \frac{C+S}{2} X \frac{I}{100} = \frac{1500+150}{2} X \frac{15}{100}$

   @ 15% interest rate $= Rs. 123.75$

3. Housing $= 1500 X \frac{1}{100}$

   @ 1% of purchase value $= Rs. 15$

Total fixed cost of country plough per annum $= 270 + 123.75 + 15$

$= Rs. 408.75$

Variable cost of country plough :

1. Repair and maintenance = $1500 \times \frac{5}{100}$

   @ 5% of purchase value = Rs.75

2. Labour cost for puddling = 300 X 18.75

   = Rs. 5625

Total variable cost per annum = 75 + 5625

= Rs. 5700

Total operating cost of country plough per annum = 408.75 + 5700

= Rs. 6108.75

Operating cost of country plough per hour = $\frac{6108.75}{300}$

= Rs.20.36

Cost of operation of bullock drawn country plough per hour = 24.05 +20.36

= Rs.44.41

Time required for puddling one hectare of land = 55 h

Cost of puddling one hectare of land = 44.41 X 55

= Rs. 2442.68

DEVELOPMENT OF A CONO-PUDDLER ATTACHMENT FOR A 5HP TILLER

By

PH. TEJENDRA SHARMA

ABSTRACT OF A THESIS

Submitted in partial fulfillment 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 &TECHNOLOGY

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2000

ABSTRACT

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A 5hp power tiller operated cono-puddler was fabricated based on the IRRI design and tested. Based on the test result, four more models of cono-puddlers were fabricated and tested.

Out of the five models, four were walking behind type implement and were tested at travel speed of around 0.786 m/sec whereas one was of riding type (model-5) and was operated at travel speed of around 0.964 m/sec. All the models were tested for three and four times operations.

The depth of puddling of the model-1 was 10-11cm. Another set of conical rotors was fabricated by increasing the blade height to 90 mm from 70mm (model-2). The depth of puddling obtained was 12.2 to 13.8 cm. Because of the problem of clogging of soil in between the blades and due to a wide gap in between the rotors which leaves the soil uncut, another set of rotors was fabricated by increasing and modifying the shape of the blades to helical and tested (model-3).

The above three models consisted of six conical rotors clamped individually on a toolbar assembly. Another model,(model-4) was tested by increasing the number of rotors of model-3 to eight numbers. The maneuverability of this model was not good as it was difficult at the time of headland turning.

The average percolation loss of water for the five models measured for 20 days after puddling varied from 3.692 to 3.979 mm/day for three time operations and 2.650 to 2.983 mm/day for four times operations. The least percolation loss of water was observed in case of model-5 and highest in case of model-1 in both numbers of operations.

The puddling indices for the five models varied from 56.31 to 59.34 per cent for three times operations and 63.46 to 68.89 per cent for four times operations. The highest puddling index was observed in case of model-5 in both numbers of operations.

The average percentage burial of weeds from different test plots varied from 98.38 to 98.79 per cent in terms of number of weeds and 99.09 to 99.34 per cent in terms of dry weight basis for three times operations. The variation was from 98.94 to 99.69 per cent in terms of number of weeds and 99.40 to 99.83 per cent in terms of dry weight basis for four times operations.

The effective field capacities for model-1, model-2, model-3, model-4 and model-5 were 0.826, 0.790, 0.843, 0.826 and 1.053 ha/day respectively for three times operations and 0.618, 0.598, 0.613, 0.643 and 0.799 ha/day respectively for four times operations. The field efficiencies of the five models for different number of operations varied from 52.58 to 72.20 per cent where field efficiency of model-4 was observed least in both number of operations. In both cases, field capacity and field efficiency of the model-5 was highest.

The draft of model-1, model-2, model-3 model-4 and model-5 were 40.68, 45.03, 46.81, 48.19 and 58.06 kg and draw bar horse power requirement were 0.426, 0.472, 0.491, 0.505 and 0.746 hp respectively.

The power required for the model-5 was higher than the other models. The fuel consumption rate for the five models operated at different number of operations varied from 0.495 lt/h in case of model-1 operated three times to 0.666 lt/h in case of model-5 operated for four times.

The slippage of the ground wheel for the five models varied from 0.811per cent to 3.588 per cent. Lowest ground wheel slippage of 0.881 per cent was observed in model-1 operated three times and highest of 3.588 per cent in model-5 operated 4 times.

The cost of puddling one hectare of land using model-3 and model-5 are Rs. 534.39 and Rs. 432.83 when operated for four times and break even point is 1.2 ha compared to animal drawn country plough.