DESIGN, DEVELOPMENT AND EVALUATION OF A POWER TILLER OPERATED BED FORMER

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Technology in Agricultural Engineering

Faculty of Agricultural Engineering and Technology
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DECLARATION

I hereby declare that this thesis entitled "Design, Development and Evaluation of a Power Tiller Operated Bed Former" 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 "Design, Development and Evaluation of a Power Tiller Operated Bed Former" is a record of research work done independently by **Shri. Shaji James, P.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Shri. Shaji James, P.**, a candidate for the degree of Master of Technology in Agricultural Engineering with major in Farm Power and Machinery, agree that the thesis entitled "Design, Development and Evaluation of a Power Tiller Operated Bed Former" may be submitted by Shri. Shaji James, P. in partial fulfilment of the requirement for the degree.

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SHAJI JAMES, P.

To my father

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SYMBOLS AND ABBREVIATIONS USED

agric.	-	Agricultural
AICRPDA	-	All India Co-ordinated Research Project on Dryland Agriculture
AMA	-	Agricultural Mechanisation in Asia, Africa and Latin America
APAU	-	Andhra Pradesh Agricultural University
BBF	-	Broad Bed and Furrow
CIAE	-	Central Institute of Agricultural Engineering
cm	-	centimetre(s)
Co.	-	Company
dia	-	diameter
engg.	-	engineering
et al.	-	and others
FAO	-	Food and Agricultural Organisation
Fig.	-	figure
g	-	gram(s)
ha	-	hectare(s)
HMT	-	Hindustan Machine Tools
hp	-	horse power
hr	-	hour(s)
ICAR	-	Indian Council of Agricultural Research
ICRISAT	-	International Crop Research Institute for Semi Arid Tropics
IIT	-	Indian Institute of Technology
ISAE	-	Indian Society of Agricultural Engineers

IGFRI	-	Indian Grassland and Fodder Research Institute
ISI	-	Indian Standards Institution
JNKVV	-	Jawaharlal Nehru Krishi Viswa Vidhyalaya
KAU	-	Kerala Agricultural University
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kg	-	kilogram(s)
kgf	-	kilogram force
kmph	-	kilometre(s) per hour
Ltd.	-	Limited
m	-	metre(s)
M.B.P	-	Mould Board Plough
mm	-	millimetre(s)
MS	-	Mild Steel
N	-	Newton
No.	-	number
p	-	page
PAU	-	Punjab Agricultural University
pp	-	pages
Pvt.	-	Private
Rs.	-	Rupees
sec	-	second
t	-	tonne(s)
TNAU	-	Tamil Nadu Agricultural University
/	-	per
%	-	per cent

Introduction

INTRODUCTION

World population has been increasing by leaps and bounds and by the turn of the century, it is expected to reach a figure of 6.2 billion. The pressure of population is felt more acutely by the developing countries. As for India the population is projected to reach 935 million by 2000 AD and a corresponding increase in food production is imperative. This can be achieved only by intensive cropping with increased use of inputs.

A large proportion of the agricultural population of our country are small scale agriculturists engaged to produce their own food rather than to amass profit. Hence in our case agriculture is of the subsistence type. There is not much scope for increasing the cultivable area. The only way is to improve on yields per unit area by intensive agriculture, through better inputs and better management. Increased power input for agricultural operations is vital for efficiency and timeliness. So, selective mechanisation has been approved as an important measure to increase agricultural production. A wide range of equipments has been designed and manufactured in our country to serve various agricultural operations.

In the case of developing countries, where agriculture is of the subsistence type, this increased power input can be made available from one, or a combination of the three basic alternatives: hand labour, draught animal, or engine power. The decision as to which of these three and to what extend will vary with the situation. The average power availability of Indian farms is to be raised to about 1 hp/ha from the present level of about 0.6 hp/ha. The country cannot depend fully on human labour and draft animals for filling this wide gap of energy. The mechanical power sources thus become imperative for Indian agriculture.

Four wheel tractors have limitations on Indian farms from the point of view of large number of small and medium farmers, small and fragmented holdings and high initial investment. Power tillers are therefore recognised as an intermediate power source which medium and small farmers could afford.

Since 1975, the total installed capacity of power tiller industry has been only 16,000 and the annual production ranged from 10-15 per cent of the installed capacity. Reasons for low volume of production and sales are many. Power tiller is expensive if seen on the basis of cost per hectare. Initial cost is high because the production volume is low. One of the main reasons for slow acceptance of power tillers by Indian farmers is its low versatility. Besides, the manufacturing of power tillers and a complete range of matching implements have not been organised on a regular basis. The power tillers have not caught up with the Indian farmers due to, the non-availability of matching implements, which results in very low number of hours that a power tiller can be used in a year. Thus the design and development of power tiller operated equipments is imperative for the progress of Indian agriculture.

In high rainfall areas like Kerala, the problem of holding the soil in situ and maintaining soil fertility is acute. The need to conserve moisture from ill distributed rains is great. Prevention of run-off by appropriate mechanical methods are also essential. To prevent water logging raised beds and drainage ditches are necessary in high rainfall areas. In irrigated farming a raised bed and furrow system has been found useful for conveyance and efficient use of irrigation water. Due to these reasons, raised beds, separated by adjacent furrows - commonly known as Broad Bed and Ferrow System (BBF system) has been adopted for various crops both in high rainfall and low rainfall areas. In Kerala, important cash crops like ginger and turmeric are grown always in raised beds. For preparing paddy nursery in dry method, a raised bed is used. In several instances, vegetables are also grown on raised beds.

Manual preparation of beds and furrows is a time consuming, laborious and costly operation. Eventhough there are equipments for forming ridges and furrows, there are only few equipments available for the formation of broad beds. If such an equipment is available as a power tiller attachment, it will be a boon not only to the small and marginal farmers but also to the power tiller industry. Hence a project was taken up with an overall objective to develop a power tiller operated Bed former. The specific objectives of the work were:

1. To study the different soil manipulating tools and cultivation techniques with a view to evolve design parameters to develop a power tiller operated Bed former.

2. To design and develop a prototype power tiller operated Bed former.

3. To evaluate the performance of the above unit towards economic viability and flexibility of operation.

Review of Literature

REVIEW OF LITERATURE

A brief review of cultivation techniques in which a raised bed and furrow system is used, its advantages, development of different equipments for preparing raised beds, development of matching equipments for power tillers, and general design considerations for soil manipulating tools are presented in this chapter.

2.1 Raised bed and furrow system

A seed bed is that layer of soil which has been tilled to a condition to promote germination, emergence and growth of seedlings.

A cultivation system called Broad Bed and Furrow System (BBF system) has been adopted in many regions. In Broad Bed and Furrow system of farming broad beds are formed in between two narrow furrows. The beds are used for growing of crops where as the furrows are used for carrying excessive runoff and also as a track for walking of animals, and wheels of equipments. Furrows are also used as irrigation channels.

Vegetable seedlings are grown in raised out door nurseries of one metre width (Chauhan, 1986). For raising paddy nursery, a dry method is practised in areas where sufficient water is not available. In this method, growth of seedlings can be controlled. Nursery is prepared on raised beds of 1 to 1.5 m width, and 15 cm height and of convenient length. Lemon grass is planted on raised beds of 75-80 cm width with a spacing of 30-35 cm in between and of convenient length (KAU, 1989).

The recommendation for planting ginger is on beds of convenient length, 1 m wide and 25 cm high with 40 cm spacing between the beds (KAU, 1989). For planting turmeric also the same method as that of ginger is used. Raised beds of size 6 m x 1 m x 30 cm are used for cardamom nursery.

2.2 Advantages of broad bed and furrow system

The broad bed and furrow system was found to be advantageous in several ways in the studies conducted by several research stations.

The studies conducted at ICRISAT revealed that the BBF system is the most successful, both to facilitate cultural operation and to control excess water (Kampen, 1979). The broad bed is about 100 cm wide and the sunken furrow about 50 cm. Initial experience with narrow graded ridges of 75 cm amplitudes at ICRISAT indicated instability of this system. Comparisons of flat planting with cultivation on broad beds indicate substantial yield advantages of the broad bed system.

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Kampen reported that values of crop yields in field scale experiments were about Rs.800/ha higher on broad beds at 0.4 to 0.6 per cent slope than under flat cultivation at that slope, during 1976. Operational scale research on water sheds has shown that the broad bed and furrow system has the following advantages.

(i) Reduce soil erosion

(ii) Provides surface drainage

(iii) Concentrates organic matter and fertilizer in the plant zone

(iv) Reduces soil compaction in the plant zone

(v) Is adaptable to supplemental water application

(vi) Can be laid out on a permanent basis

(vii) Is easily maintained with minimum tillage

(viii) Facilities land preparation during the dry season

Under Land Management studies on Vertisols, the BBF system of cultivation was compared with flat system in field size plots for the fifth consecutive year in the 19801-81 crop year (ICRISAT, 1981). The air filled porosity measurements in a 0-15 cm layer in the raised bed zone revealed that the layer in the BBF system was better aerated than the corresponding layer in flat plots. The penetrometer observation showed that the penetration resistance was lower in the raised bed zone of the BBF system than in the flat plots.

A study conducted at ICRISAT to evaluate the influence of surface configuration on run-off and soil loss showed that the run-off rate from both the flat cultivated plots and the raised bedded plots increased with increased rainfall amount. This was also true for increased rainfall intensity. At higher storm intensities or longer rainfall durations a broad bed was more advantageous to control run-off (ICRISAT, 1981).

Palaniappan (1985) has also reported the advantages of the BBF system at ICRISAT. The broad beds are formed on a semi-permanent basis and maintained by minimum tillage. The beds formed in the previous season can be tilled using the multipurpose animal drawn tool bar immediately after the harvest to conserve residual soil moisture. After pre-monsoon rains, the beds can be harrowed to kill the weeds and using a ridger-cum-bed former, the beds can be reshaped. This completes the seed bed preparation in the dry season well ahead of planting time. In this sytem, the excess water received during heavy rainfall is not allowed to run-off but is collected through the furrows, led into the grassy water way and taken to a central tank where the water is stored. The advantages of different land management systems were as shown in Table 1.

Table 1. Run-off, **soil** loss and crop yields for three land management **systems** on a deep vertisol at ICRISAT (ICRISAT, 1980)

Land Management System	Runoff (% of rain)	Soil loss	Maize yield t/ha	Bengal gram yield t/ha
Flat bed	24	2.1	1.78	0.98
Narrow ridges (75 cm)	22	2.0	2.05	0.73
BBF (150 cm)	25	1.4	2.10	1.01

A study of farming sytem at CIAE, Bhopal duing 1982-85 in deep black soils revealed that the production from dry lands could be enhanced to more than 2.5 t/ha/hr from the prevailing level of less than 1 t/ha/yr. Broad Bed and Furrow system of farming yielded 228 kg/ha/hr more grain in comparison to the flat system of farming (Rajput et al., 1985).

A study conducted at the Agricultural Engineering Institute, Raichur, Karnataka to evaluate the BBF farming system revealed that the moisture availability, crop yield and cost-benefit ratio were higher for BBF system compared with flat system (Maurya and Devadattan, 1987).

2.3 Equipments for preparation of raised beds

2.3.1 Need for equipment for carrying out modification of land configuration

Dry land agriculture is the largest sector of Indian rural economy, covering 70 per cent of the cultivated area of the country. Anwar **Alam** (1987) pointed out that in situ moisture conservation is important for dry land agriculture and most of the farmers do not have equipment to carry out modification of land configuration for this.

2.3.2 Small scale equipments for earth-moving

Hopfen (1969) reported the use of different kinds of small scale equipments for earth moving.

2.3.2.1 Shovels

The chief object of a shovel is to move loose soil or similar material over short distances. The essential parts are the blade, the socket and the handle, with grip.

There are long-handled and short-handled shovels for moving material lying on the ground, all operated with both hands, and one-handled scoops (Fig.1). On long-handled shovels the angle between the blade and handle is only slightly less than 180°, whereas this same angle on very short-handled shovels is acute, as will be seen in Fig.1c to 1e. In fact, these shovels, much used in various parts of Africa and the Far East, are sometimes classified as hoes.

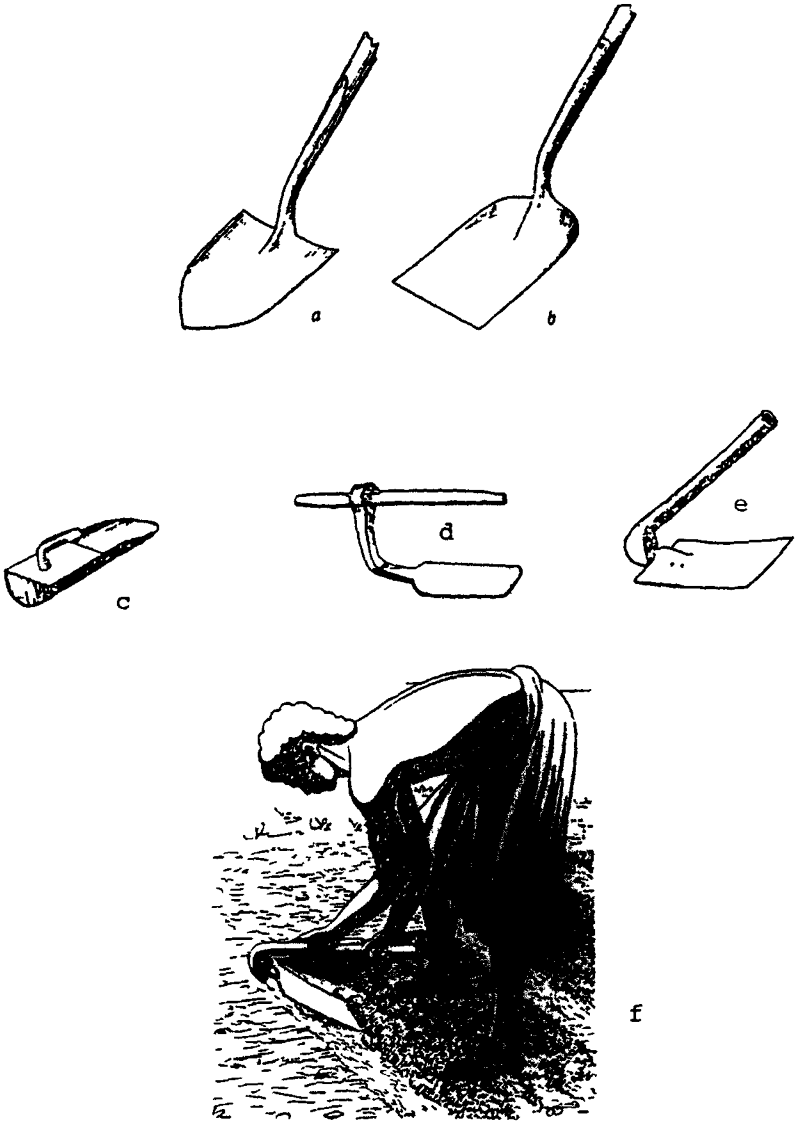


Fig.1 Common types of shovels

(a) Multipurpose type; (b) for use on even ground;
(c) One-handed scoop; (d) Shovel from Nepal;
(e) Ethiopian type; (f) Work with the Ethiopian shovel hoe
Source: Hopfen (1969)

Various types of shovel blades have been developed for different working conditions. A good multipurpose shovel blade is concave and slightly pointed (Fig.1a). Blades with a straight edge and rounded, raised shoulders (Fig.1b) are particularly suitable for picking up material from smooth ground while the pointed ones are better on uneven ground. The handles and the connections between blade and handle are much the same as those used for spades.

The two-man shovel serves to prepare alternating ridges and furrows, to form bunds for irrigated crops, and for other shovel work. It consists of a large, slightly concave, flat-sided blade with two rings on the inside. The rings hold the ends of a rope. In use one man pushes and directs the shovel with the long handle while a second man, facing the first, pulls on the rope. This rhythmic action generally results in an output exceeding that of two men with two shovels. It is widely used in Arabia, Syria, central and northern Iraq, Iran, Afghanistan, parts of India and West Pakistan, Turkestan, China (Mainland and Taiwan) and Korea (Fig.2c).

2.3.2.2 Hand-levelling board

A hand-levelling board may be used in wet paddy fields to give the final touches to the puddling operation by breaking up, levelling and smoothing the soil. It varies greatly in design. It may be a simple solid board with no teeth or, in some cases, with a saw-tooth design on one side of the board.

2.3.2.3 Animal-drawn earth scoop

The earth scoop is used to level land for irrigation and to build small dams, and for any other work involving the transport of soil or similar material over short distances. The construction varies, but a common type has a large scoop of mild steel with a reinforced bottom, the whole being controlled by two wooden handles and drawn by a movable U-shaped steel drawbar. The two points of attachment of the drawbar are at the points of best balance for easy draught, filling and tipping (Fig.2b).

2.3.2.4 Animal-drawn levelling board

The animal-drawn levelling board is used in many countries to prepare rice fields under flooded conditions. It consists of a wooden plank of varying dimensions fitted either with a pole for attachment to yoked animals or with two rings for traces. The operator normally rides on the plank to achieve better penetration into the soil. It is also used for clod crushing under dry conditions.

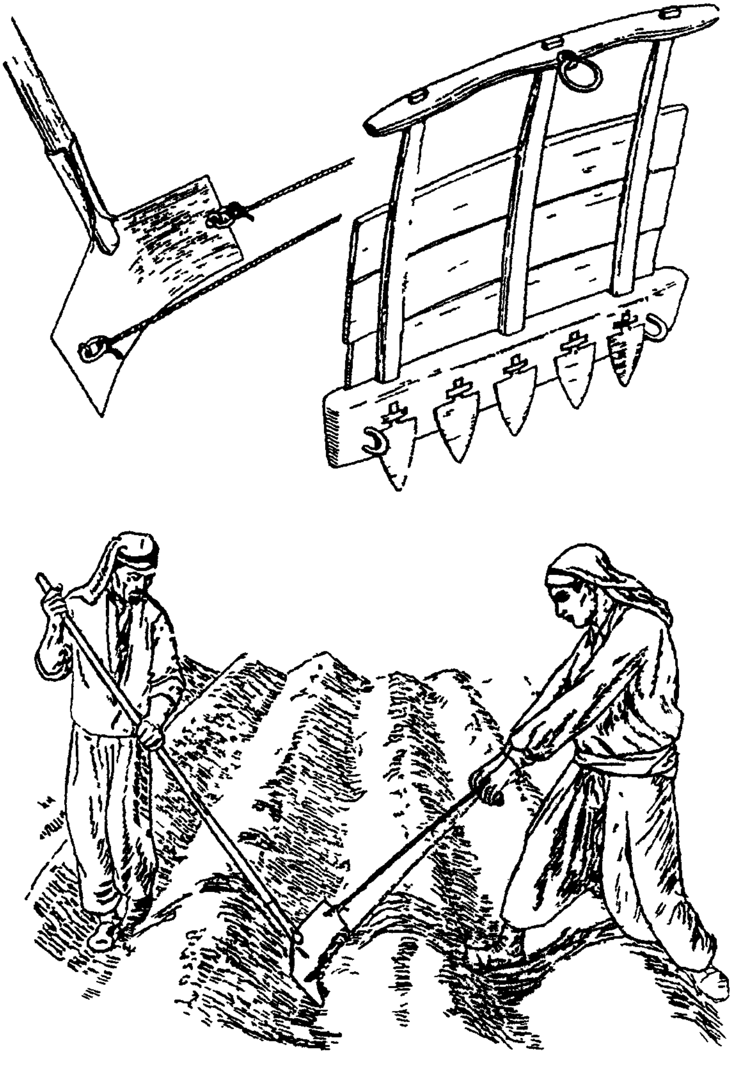


Fig.2 Two-man shovel and its animal drawn version

(a) Two-man shovel; (b) Animal-drawn shovel board
(c) Work with the two-man shovel

Source: Hopfen (1969)

2.3.2.5 Ridgers and ditchers

The ridger plough (Fig.3a) consists of single share and double mould board attached to a short (Steel) or long beam (wooden). There are two handles provided to balance the ridger. The ridges are formed on the return pass of the implement. They are commonly used for making ridges and furrows for potato and sugarcane planting and making field channels for irrigation.

An animal drawn ridger was developed by the Bihar State Department of Agriculture, Patna suitable for maize, Potato and vegetable crops. The working capacity was 0.05 ha/hr. The draft of the equipment was 70 kg, and the cost was Rs.115/-. A larger size of the ridger called Bihar Senior ridger had a size of 550 mm. This ridger was used for sugarcane crop. A ridging attachment to Bakhar was developed at the College of Agricultural Engineering, JNKVV, Jabalpur (Shanmugham, 1982). The animal drawn ridger had a width of operation of 320 mm and its work capacity was 0.1 ha/hr. The unit was a furrower which could be easily mounted on a bakhar and operated between row crops. The cost of the equipment was Rs.30/- and cost of operation Rs.32.50/ha in 1977.

A field Ditcher of double mould board type was developed at IIT, Kharagpur (Shunmugham, 1982). The width of operation of the equipment was 762 mm and the work capacity was 60-70 m^3/hr. The draft of the ditcher was 95 kg.

A power tiller operated trencher was developed at TNAU (TNAU, 1984). The trencher excavated trenches of trapezoidal shape with top width of 53 cm bottom width of 17 cm and total depth of 24 cm. It was also capable of digging circular trenches of a minimum diamter of 3.3 m.

Ridgers for tractors (Fig.3b) are also available with facility of attachment to 3 point linkage (Singh and Bharadwaj, 1985).

2.3.2.6 Bund formers

Bund former is an equipment to form bunds or ridges by gathering soil (Fig.3c). The specification for bullock operated bund former was adopted by the Indian Standards Institution (1965) after the draft finalised by the farm implements and machinery sectional committee had been approved by the Agricultural and Food Products Division Council. A typical design as suggested by the ministry giving complete details was included in the standard for information. ISI recommended three sizes of the bund former, namely, light, up to and including 225 mm; medium, above 225 mm but below 300 mm; and heavy, 300 mm and above but not exceeding 375 mm. Hopfen (1969) reported the use of bullock drawn bund formers in India.

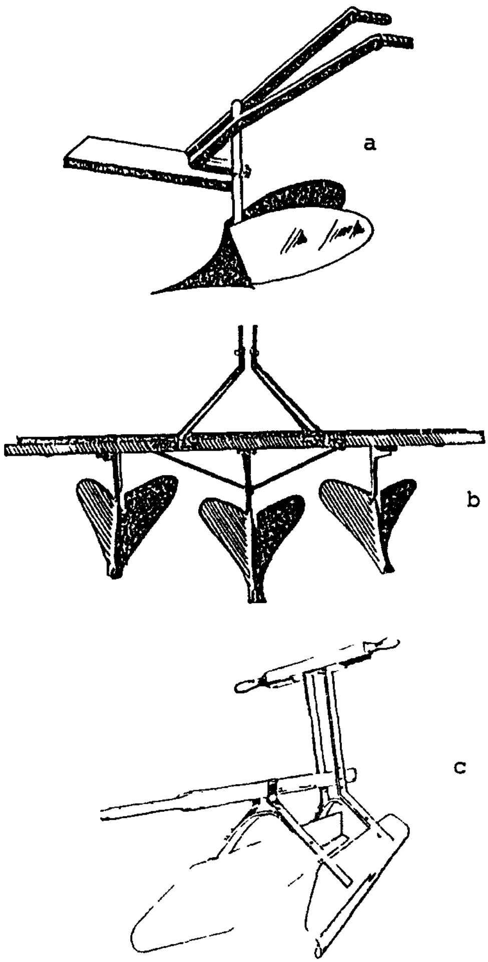


Fig.3 Bullock drawn ridger, Tractor mounted ridger and Bullock drawn Bund former (Shanmugham, 1982)

A tractor operated bund former was developed at the Jawaharlal Nehru Krishi Viswa Vidyalaya, Jabalpur (Shanmugham, 1982). It had a working capacity of 5000 m length/hr in ploughed soil. The bunds formed with the equipment had a base width of 410 mm and a height of 30 to 40 cm.

Shanmugham (1982) reported that an irrigation channel cum bund former was developed by IGFRI, Jhansi for formation of channels and bunds (Fig,.4). The equipment was tractor rear mounted. It had a working capacity of 4000 m/hr for channels and 5500 m/hr for bunds. The cost of operation was Rs.0.75/100 m of channel and Rs.0.55/100 m of bund. The equipment was suitable for all types of soils.

A power tiller operated bund former was developed at TNAU, Coimbatore (1984) to form bunds in the irrigated lands and across the slope of dry lands to conserve soil moisture. It had a capacity of 2.5 ha/day when the bunds are formed at 3 m interval in one direction only. The cost of operation was Rs.35/ha including hire charges of power tiller. The approximate cost of the implement was Rs.350/-. The three sizes of the bunds formed were:

(i)	39 cm	base width and	16 cm	height
(ii)	41 cm	"	16 cm	"
(iii)	45 cm	"	16 cm	"

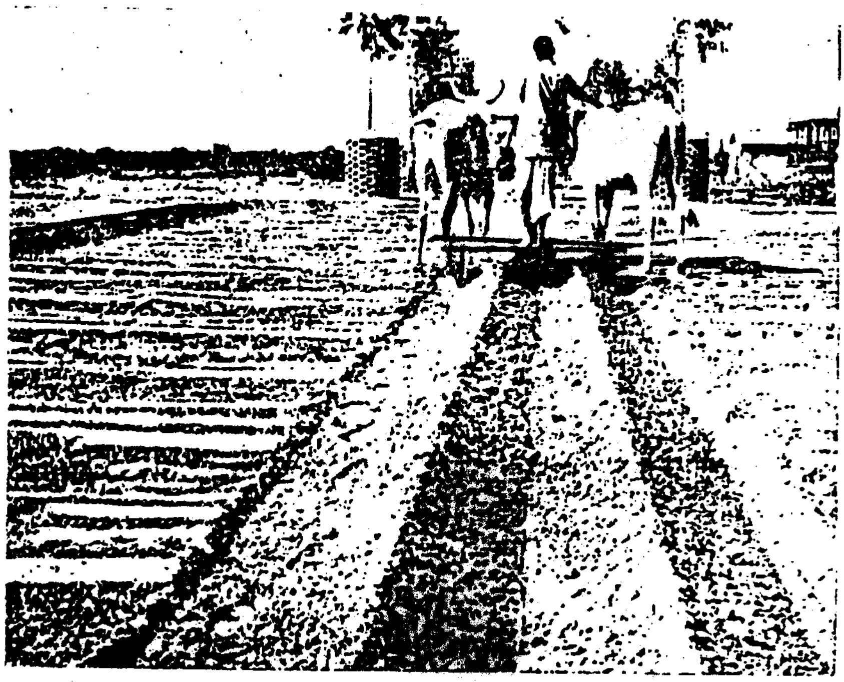


Fig.4 Irrigation channel cum Bund former
(Shanmugham, 1982)

Ojha (1989) reported that bullock drawn bund formers which can form two bunds at a single pass was used in Madhya Pradesh.

2.3.2.7 Multipurpose tool bars used for forming raised beds and bunds

The multipurpose tool carriers basically comprises of a frame on which tools can be mounted and attached to a power source through a tubular beam. On the tool bar, different attachments including bund formers can be fitted for various farming operation to make it a multipurpose.

The multipurpose tool carrier developed at ICRISAT, Hyderabad had three attachments namely mould board plough, ridger and 5 tined sweep cultivator. The wheeled tool carrier had a wheel track of 150 cms (PAU, 1982).

A bullock operated bed former was developed at ICRPDA, Sholapur suitable for all types of soil (Shanmugham, 1982). The working capacity of the equipment was 0.4 ha/hr. The implement was used to form 150 cm wide beds on a predetermined field grade, in terraced land treatments and is used prior to seeding of the crops. The cost of the equipment was Rs.300/- in 1978 and the operating cost was Rs.16/- per ha.

Another multipurpose tool bar, for forming bund along with multipurpose field operations was also developed at TNAU

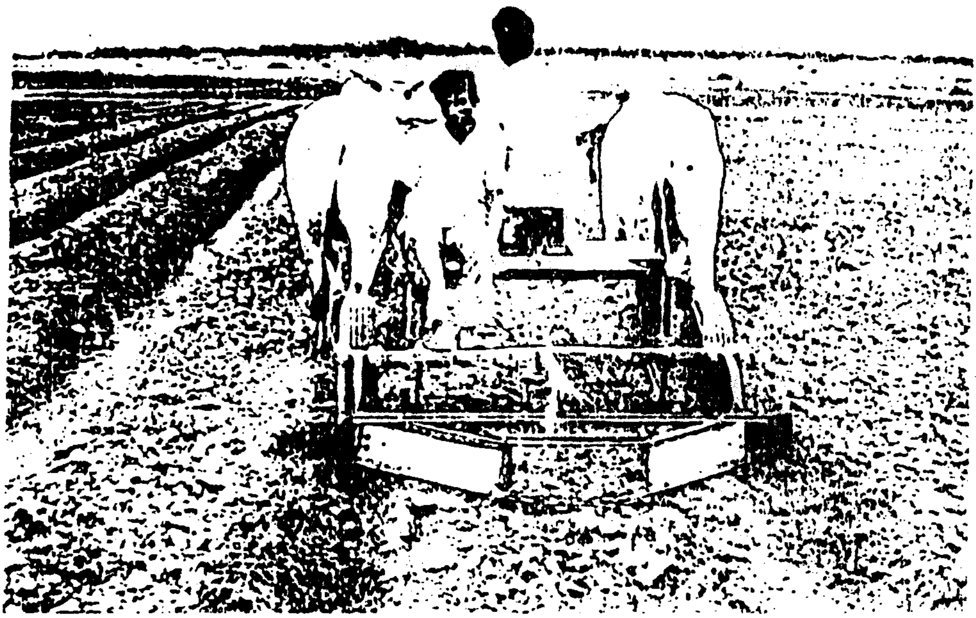
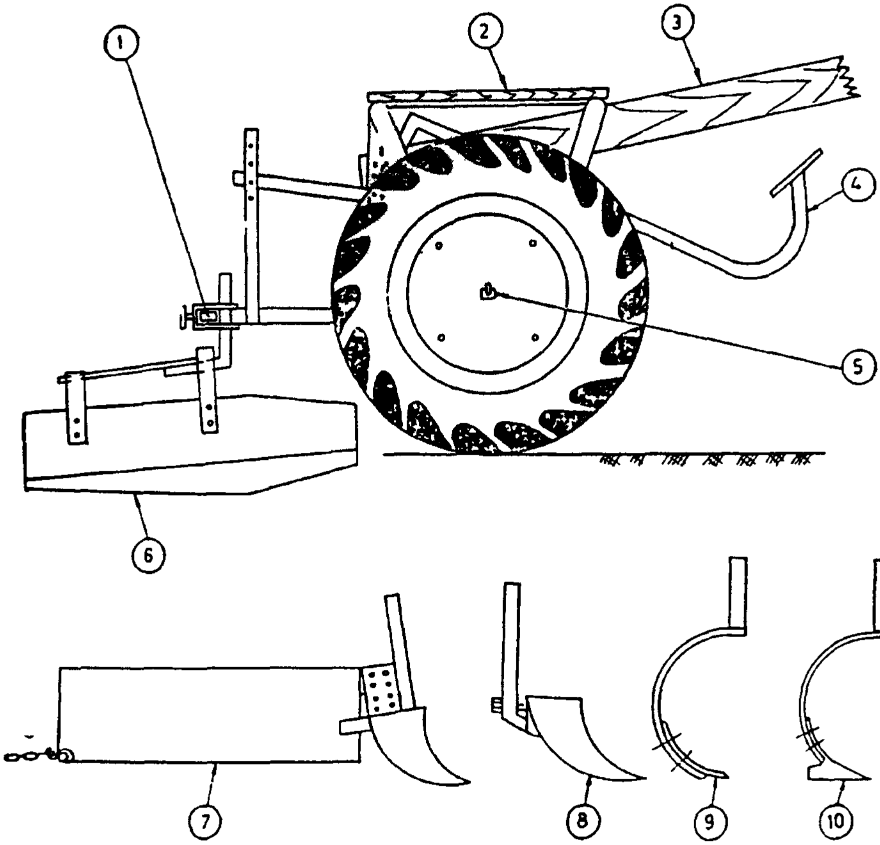


Fig.5 ICRISAT two wheel tool carrier
(Shanmugham, 1982)

(Shanmugham, 1982). This tool carrier had pneumatic wheels and was used for forming broad beds of width 1500 mm. The work capacity was 0.2 ha/hr for bed forming and cost of operation was Rs.21.50/ha.

A wide clearance type tool carrier and attachment similar to ICRISAT design was developed at TNAU Coimbatore (Fig.6). The bullock drawn multipurpose tool carrier developed at TNAU had bund former and bed former as attachments with other attachments like ploughs and cultivator tynes (CIAE, 1983).

Another multipurpose tool carrier was developed at CIAE Bhopal with attachments like M.B. plough, ridger bottom rigid and spring tines with sweeps of different sizes and seeder (CIAE, 1983). A study conducted by Rajput et al. (1985) revealed that the multipurpose bullock drawn tool had a field capacity of 0.3 ha/hr for making broad beds of 150 cm width. The CIAE animal drawn multipurpose tool carriers were evaluated during the years 1983-84 and 84-85 at AEI Raichur (Maurya & Devadattan, 1985). Experiments were conducted involving four treatments consisting of a tropicultor, Krishi ratha, a set of improved implements, and a set of indegenous implements as control. The comparative performances of different equipments involved in the experiment for Broad Bed and Furrow formation was as in Table 2.



(1) TOOL BAR
(2) SEAT
(3) BEAM
(4) PEDAL FOR LIFTING TOOL
(5) SPLIT AXLE
(6) BUND FORMER
(7) BED FORMER
(8) PLOUGH
(9) CULTIVATOR
(10) SWEEP

Fig.6 TNAU multipurpose tool carrier
(Shanmugham, 1982)

Table 2. Comparative performance of equipments in broad bed formation (Maurya & Devadattan, 1985)

Particulars	Treatment	
Operation : BBF formations	Tropicultor	Krishiratha
Total draft kg	155.60	171.10
Speed, kmph	1.44	1.51
Power, hp	0.83	0.96
Eff. field capacity (ha/hr)	0.15	0.15
Field efficiency %	88.30	88.30
Cost of operation Rs/ha	47.92	45.47

The CIAE tool frame was evaluated at the APAU for different tillage operations. It gave a field capacity of 0.06 ha per hr for ploughing, 0.12 ha/hr for seed bed preparation and 0.11 ha per hr for sowing operation (APAU, 1988).

2.3.2.8 Combined tillage bed former

A combined tillage bed former was developed by Nagaiyan (1983) at TNAU. The equipment consists of a rotovator and level board and ridger attachment. The hp requirement of the prime mover was 35. The equipment was found suitable to prepare broad based seed beds of 1.5 m width in rainfed areas.

2.3.2.9 Power tiller operated bed former

A power tiller operated bed former was developed at TNAU Coimbatore (Pandy *et al*., 1983). The equipment was of two row type and was operated with a 8-10 hp power tiller and with one person. The length, width and height of the implement was 160 cm, 110 cm and 70 cm respectively. The equipment weighed 20 kg and the width of coverage was 950 mm. The unit had a working capacity of 0.4 ha/hr. It had a three point linkage system for hitching the unit to the hitch point of power tiller. While in operation it formed a pair of furrows with one bed of 30 cm top width and 65 cm base width.

2.3.2.10 Tractor drawn bed-furrow former

A tractor drawn bed-furrow former was developed at Tamil Nadu Agricultural University during 1980 based on the design of International Maize and Wheat Improvement Centre (TNAU, 1988). The equipment was capable of forming two bunds and three furrows in one pass of the tractor. The furrows were formed at an interval of 75 cm centre to centre (Fig.7). Based on this design a tractor drawn broad bed former cum seeder was developed at TNAU during 1981-82. The implement was capable of, forming broad beds separated by furrows at intervals of 160 cm, and sowing in seven rows in the bed so formed simultaneously. By using this implement an area of about 3.2-4 ha was covered per day. The above unit was

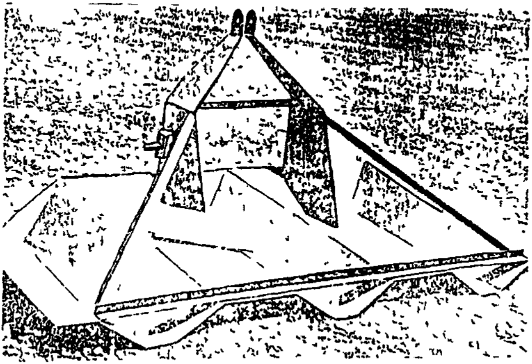


Fig.7 TNAU Bed former
(Shanmugham, 1982)

further modified and an improved Broad Bed Former cum seeder was developed at TNAU consisting 2 numbers of 30 cm wide furrow formers spaced at 160 cm/200 cm apart. The average coverage of the equipment in a day of 8 hours was 3.44 ha.

2.4 Development of matching equipments for power tillers

Power tiller is a multipurpose hand tractor designed primarily for rotary tilling and other operations on small farms (Pandy 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 cannot afford wheel tractors, the power tiller offer a major option to achieve the designed level of mechanisation. Pandy 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 'Humid to Semi-Arid Western Ghats and Karnataka Plateau' the agro-ecological region, which includes Kerala has been identified by them as a conducive region for introduction of power tillers.

Economy of power tiller farming

A study conducted at CIAE (1989) revealed that there was a saving of 48.15 & 45.82 per cent. 45.1 and 78.13 per cent time in seed bed preparation with power tiller system over bullock system in soybean, wheat, sorghum and Bengalgram crops respectively. The cost and benefit analysis showed that the net profit under power tiller system was Rs.693/- per ha as compared to bullock farming system for soybean - wheat crop rotation. In case of sorghum-bengalgram crop rotation, the cost of cultivation was more by Rs.86.00 per ha in power tiller system over bullock systems but the increase in profit in power tiller system was Rs.1901.00 per ha. CIAE (1989) has recommended that though the energy input is more in power tiller system than in bullock system, the yield and net profit favour the use of power tiller in the cultivation of the above mentioned crops.

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 ha of different shapes. The objective was to determine the superiority of one tractor over another for small plots. The two wheel tractor under study consumed about 41 per cent more fuel than the four wheel tractor for an average plot size of 1 ha. On the other hand, for a plot size of 0.25 ha the four wheel tractor consumed 5 per cent 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.

2.5.1 Forces acting upon a tillage tool

Clyde (1934) subdivides the total soil reaction into useful and parasitic forces. He defines useful soil forces as the forces which the tool must overcome in cutting, breaking, and moving the soil. Parasitic forces are those that acts upon stabilizing surfaces such as the land-side and sole of a plough or upon supporting runners or wheels.

The designer is concerned with the forces acting upon a tillage implement from the stand points of total power requirements, proper hitching, designing for adequate strength and rigidity, and determination of the best shapes and adjustments of tools. A tillage implement moving at a constant velocity is subjected to three main forces or force systems, which may be in equilibrium (Kepner et al., 1987). They are,

1. Force of gravity acting upon the implement
2. The soil forces acting upon the implement
3. The forces acting between the implement and the prime mover

2.5.2 Engineering properties of soils

Resistance of soils by crushing by solid bodies, friction at the surface of the implements, internal friction, cohesion, adhesion and plasticity of the soil are the engineering properties of soil which are important during soil working (Klenin *et al.*, 1985).

Resistance of soils to crushing by solid bodies is one of the principal characteristics utilized in evaluating the operating conditions of soil working machines. The specific soil resistance of different soil types are as given in Table 3. The tools of soil working machines wear out at the surface due to soil frictions. The coefficient of friction between soil and steel usually depends upon the mechanical composition and the moisture content of the soil. The calculated values of angle friction and coefficient of friction of soil with steel are given in Table 4.

The coefficient of internal friction in most cases is greater than that between soil and a metal surface. As a consequence, the tools of the soil-working machines are rarely covered by soil.

Soil adhesion on the surfaces of tools disturbs the technological processes, decreases the quality of work and increases the tractive resistance of the machine.

Soil cohesion signifies resistance to mechanical action and largely depends upon the mechanical composition of the soil. Sandy soils are less cohesive than soils with large amounts of silt.

Table 3. Specific **resistance** of soils

Type of soil	N/cm^2
Light (Sandy soil and Sandy loams)	2-3.5
Medium (light and medium loams)	3.5-5.5
Heavy (heavy loams)	5.5-8.0
Very heavy (sod soils and days with high moisture content)	8.0-15

Source: Klenin *et al*. (1985)

Table 4. Calculated values of the angle of friction and coefficient of friction of soil with steel

Soils	Coefficient of friction	Angle of friction
Sandy and loamy soils		
Non-cohesive	0.25 - 0.35	14° - 19°30'
Cohesive	0.50 - 0 70	25°30'- 35°
Light and medium sandy loam soils	0.35 - 0.50	19°30'-20°30'
Heavy sandy loams and days	0.60 - 0.90	31° - 42°

Source: Bosoi *et al*., 1987

2.5.3 Tillage tool design factors

According to Kepner et al. (1987) the three abstract design factors which control or define the the soil manipulation are

1. Initial soil condition
2. Tool shape and
3. Manner of tool movement

The results of these three input factors are evidenced by two output factors, namely

1. Final soil condition and
2. Forces required to manipulate the soil

All the five factors are of direct concern to a tillage tool designer. Of the three input factors, the designer has complete control only of the tool shape.

2.5.4 Mould board plough bottoms

The working surfaces of ploughs, depending upon their geometry, are classified as cylindrical, cylindroid and helicoid surfaces (Klenin et al., 1985) cylindrical and cylindroid surfaces have a profound ability to loosen the soil whereas helicoidal ploughs are designed more for turning the soil over than for loosening it. Cylindrical ploughs crumble the soil but to lesser extent turn the soil over. Essentially, a mould board plough bottom is a three dimensional wedge with the land side and the horizontal plane of the share's cutting edge acting as flat sides and the top of the share and the mould board together acting as a curved side (Kepner _et al._, 1987). The total angle of setting of the share to the furrow bottom is 25-30° for general purpose mould boards (Bosoi _et al._, 1987). For sliding cutting, the blades of the mould board plough and other working tools of soil working machines are usually set at an optimum acute angle to the line of motion (Bosoi _et al._, 1987).

2.5.5 Mounting of implements

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 upon the forces acting on them. The magnitude, the time of action and the nature of change of these forces depends on forces acting on the implements, their method of mounting, the type of machine, its mode of assembly, working conditions and so on (Klenin _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 centre of gravity should be as close to the wheel as possible so that the wheel force is nearer vertical in position to give better traction characteristics.

2.5.6 Factor of safety

An engineering judgement on how safe a product is, can be made by calculating the factor of safety.

$$F.S. = \frac{\text{Yield stress}}{\text{Actual stress}}$$

Krutz et al. (1989) suggested that the numerical value varies between 1 and 4 for agricultural machinery. He remarked that experience accumulated by designing is the best method in choosing the correct factor of safety in engineering design. There are not many rules for determining a suitable value for Factor of Safety.

Materials and Methods

MATERIALS AND METHODS

The development procedure, design details of the prototype power tiller operated bed former and the experimental programme for evaluation and economic analysis are presented in this chapter.

3.1 Fabrication and evaluation of an experimental unit

An experimental Bed former unit was fabricated and evaluated to evolve design parameters to design and develop a prototype power tiller operated Bed former. The functional requirement of the experimental Bed former unit was to form broad beds of upto a maximum width of 1 m with adjacent furrows of 40 cm width. The implement should enable width adjustments and should be attachable to a Kubota power tiller.

An experimental Bed former unit based on the design of a bund former was fabricated at the Kelappaji College of Agricultural Engineering and Technology, Tavanur. The unit consisted of two forming boards of length 70 cm and height 30 cm. They were attached to a rigid frame made of MS sheet reinforced with MS angle iron. The maximum width of the unit at the front was 140 cm and at the rear 100 cm. It was intended to collect soil from a width of 140 cm and form a bed of 100 cm width (Plate I). A hitching unit was also

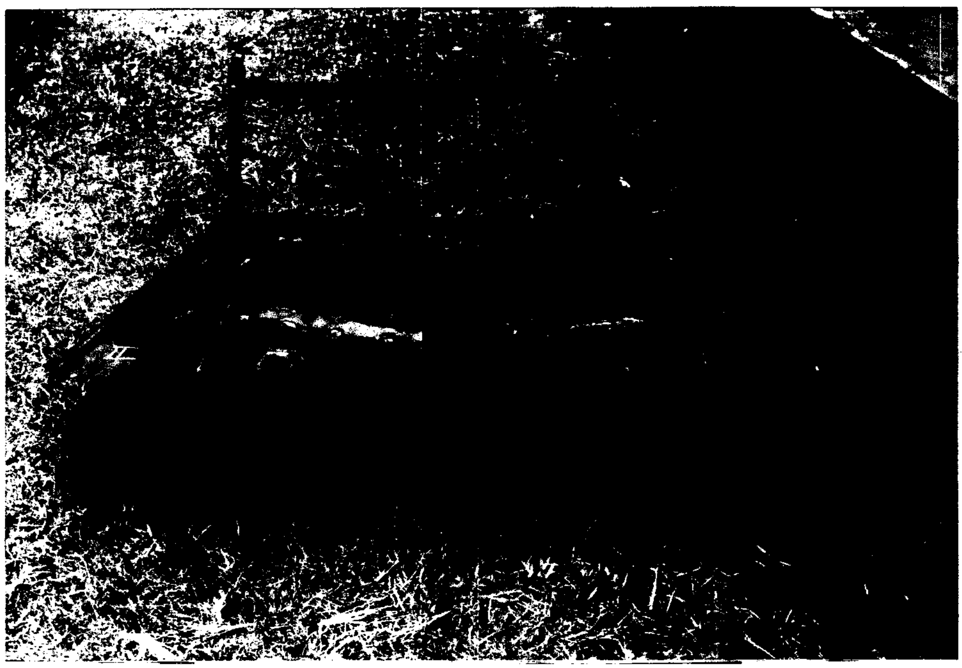


Plate I Experimental unit

fabricated so that the unit is attachable to a Kubota power tiller. The implement had a three point linkage system to attach it with the hitch beam. A modified version of the trailer hitch frame available with the Kubota power tiller was used for attaching purpose. The two forming boards were attached with nuts and bolts in the holes provided on the frame. The forming boards were inclined to the horizontal with an internal angle of 100°. They could be slided inwards to get different widthsof operation.

The fabricated unit was field tested at the Instructional Farm of KCAET, Tavanur. The implement formed only two ridges leaving a depression in between. The furrow formed were of 25-30 cm width. The implement was not found to penetrate into the soil properly. The following conclusions were drawn from the first trial runs conducted with the experimental unit.

1. Two numbers of forming boards were not enough for the formation of 1 m wide beds.

2. The outward inclination of forming boards prevented proper penetration of the implement into the soil.

Trial runs were again conducted by attaching 2 pairs of forming boards with changed angle (Plate I). A better performance was then observed. These observations were used as the guidelines in the design of the prototype unit.

3.2 Design and fabrication of the prototype power tiller operated Bed former

3.2.1 Design consideration

3.2.1.1 Functional requirement

The functional requirement of the power tiller operated Bed former is to prepare seed beds separated by adjacent furrows. The capacity of the Bed former is fixed so as to form beds of 100 cm width and 25 cm height and adjacent furrows of 40 cm width. There should be provision to vary the size of the beds.

3.2.1.2 Principle of operation

The design of a power tiller operated Bed former is based on the working of a bund former. The bund former is an implement used for forming bunds or ridges by gathering soil. The implement consists of two boards which are attached to a frame at a suitable acute angle to the direction of travel of the unit. The front of the equipment is wider than the rear. Because of the reduction in the width at the rear, soil collected by the wider front is transported to the central portion by the forward movement of the equipment to form ridges or bunds.

3.2.1.3 Structural lay out

In order to achieve the above functional requirement the maximum operating width at the front of the equipment is fixed as 140 cm and at the rear as 100 cm. The depth of cut required is calculated as follows.

Consider a unit length of the seed bed

Volume of soil in unit length when the bed

is formed = 1 x 1 x 0.25

$= 0.25\ m^3$

$0.25\ m^3$ soil is to be collected from a width of 1.4 m at the front. A 10 per cent allowance was given for compaction.

Volume of soil to be collected $= 0.25 + \frac{(0.25 \times 10)}{100}$

$= 0.275\ m^3$

Depth of cut required $= \frac{0.275}{1.4 \times 1}$

$= 0.196\ m$

Depth of cut was fixed as 20 cm

3.2.1.4 Factor of safety and strength of the material of construction

The power tiller operated bed former was designed for operation in well ploughed fields at a walking speed of about 1.5 kmph. In this operating condition there was only small chances for sudden over loads. The equipment was to be attached to the rear of the power tiller. A large weight of the equipment would affect the ease of operation especially when taking turns. The reduction of cost was also an important criterion. Considering these factors a large factor of safety was not required. Hence a factor of safety of 2 was adopted. THe material of construction is mild steel having an yield strength of 2000 kg/cm^2.

The design working stress of the material = 2000/2

= 1000 kg/cm^2

3.2.1.5 Specific resistance of soil

The implement was designed for operation in well plouged fields with light to medium soils of low moisture content of about 20 per cent. A maximum specific soil resistance of 0.3 kg/cm^2 is therefore adopted for the design.

The following factors were considered while designing the implement.

a. The implement is to be attached to a Kubota power tiller of 9-12 hp.

b. The speed of operation is 1.5 kmph.

c. It should be simple in construction so that it can easily be manufactured and repaired by local artisans.

d. The implement is operated in well ploughed, light to medium soils with low moisture content.

e. The cost should be around Rs.2000/- so that an average farmer can own a unit.

In order to achieve the functional requirements, the following structural elements are required for the power tiller operated Bed former.

(i) Forming boards

(ii) Forming board supports to support the boards on the main frame

(iii) A levelling board

(iv) A frame to support the above parts

(v) A hitch beam to hitch the equipment to a Kubota power tiller

3.2.2 Forming boards

The cutting and spreading of soil are done by the forming boards. Various aspects of the design of the forming boards are discussed in the following sections.

3.2.2.1 Number of forming boards

Soil collected from a width of 20 cm on either side to a depth of 20 cm is to be spread over the central one metre width of the bed to get a uniform top surface. The equipment is operated at a low speed of 1.5 kmph. So the soil will not be thrown fully over the entire bed. The soil will slide on the sides of the forming boards, resulting in excessive compaction at the sides of the bed and a depression at the centre, if a single pair of forming boards are used. In order to avoid the uneven filling of the seed bed the soil should be cut and spread towards the centre of the bed in two stages. Hence 2 pairs of forming boards are required; one inner and one outer. The inner pair cuts 25 cm width of soil from either side and spreads it to the central 50 cm width. The outer pair cuts 20 cm width of soil from either side and spreads it to the nearby area from where the inner boards have already removed the soil.

3.2.2.2 Length of forming boards

The following factors were considered in designing the length of the forming boards.

(i) Implement should be confined within the space in between the rotovator axle and the operating handle of the Kubota power tiller.

(ii) The centre of gravity of the implement should be as near as possible to the drive wheels for easy operation and getting enough traction.

(iii) The cut soil is moved to the centre of the bed by sliding. For easy sliding a lesser acute angle of the board to the direction of travel is required.

Considering the above factors the maximum length of the implement was fixed as 80 cm without the hitching unit.

The inner pair of boards is involved in cutting 25 cm width of soil at either sides and spreading it to the centre. An angle of 40° is adopted to the direction of travel.

Length of inner pair of boards,

$$= \frac{25}{\text{Sin } 40°} = 38.89 \text{ cm}$$

A length of 38 cm was adopted.

Angle to the direction of travel = 41°

The outer pair of forming boards are involved in cutting 20 cm width of soil and spreading it to the nearby area. This pair of boards is also involved in stabilising the sides of the seed bed. For this a lesser angle is advisable. Hence an angle of 18° was adopted.

$$= \frac{20}{\text{Sin } 18°} = 64.72 \text{ cm}$$

A length of 64.5 cm was adopted

Angle of the direction of travel = 18°

3.2.2.3 Width of plate for forming boards

The forming boards are to cut soil to a depth of 20 cm at the front and raise the bed to a height of 25 cms. An allowance of 6 cm was provided to avoid clogging and possible curvature of boards. Hence the width of plate for forming boards were taken as 31 cm.

3.2.2.4 Shape of forming boards

To cut the soil with minimum energy, an angle of 25° was adopted for the cutting edge. For smooth sliding and turning of soil a curved shape was selected. Hence the forming boards were designed so that the cutting edge makes an angle of 25° to the ground surface and the board was provided with a smooth curvature.

The inner pair of boards are involved in cutting and spreading the soil only, and hence the same shape was maintained throughout the length of the board.

The outer pair of boards are involved in stabilising the sides of the seed bed in addition to cutting and spreading of soil. So the front end of the boards is given a shape same as those of the inner boards. The curve is gradually straightened towards the rear end so that the board is straight at the extreme rear. At the extreme rear, the board is also made inclined outwards at an angle of 30° to stabilise the sides of the seed bed.

3.2.2.5 Thickness of plates for forming boards

The thickness of plates was designed on the basis of soil resistance acting on it. The calculation is presented in Appendix I.

11 gauge mild steel sheet having a thickness of 3 mm was adopted for the forming boards.

3.2.2.6

The forming boards were fabricated as per the design and shown in Fig.8 and 9. MS sheet of 380 mm x 310 mm x 3mm (11 gauge) was used for the inner forming board. MS sheet of 64.5 mm x 310 mm x 3 mm was used for the outer forming board.

3.2.3 Forming board supports

To attach the forming boards to the main frame , four pairs of supports, one for each forming board are required. The forming board supports consists of a side support and top

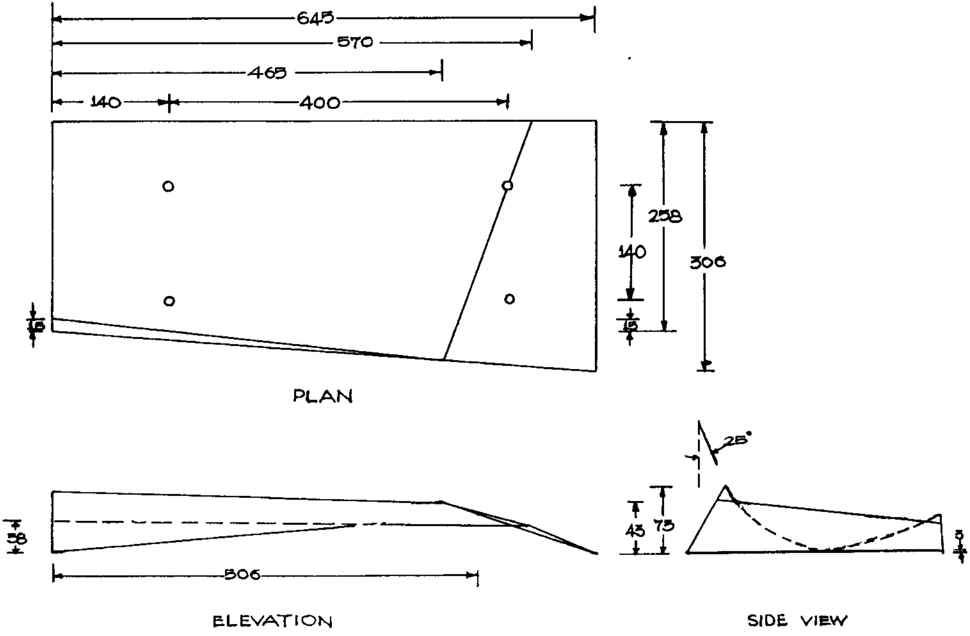


Fig 9. OUTER FORMING BOARD

SCALE 1:5
All dimensions in mm

support which were designed considering the load on them. The calculations are presented in Appendix II. The fabrication was done as shown in Fig.10.

3.2.4 Levelling board

The following considerations are made in the design of the levelling board.

(i) The width and height of the levelling board should be adjustable so as to enable the formation of seed beds of different heights and widths.

(ii) The levelling board should level the top surface of the seed bed with minimum resistance.

(iii) There should not be any clogging of soil in front of the levelling board.

In order to achieve these objectives the following design of the levelling board is adopted.

The load of the levelling board is small. Hence 22 gauge MS sheet of 0.72 mm thickness is adopted as the material for fabrication.

For efficient levelling a minimum effective height of 5 cm is required. For reduced resistance and prevention of soil clogging, the angle of the board to the horizontal should

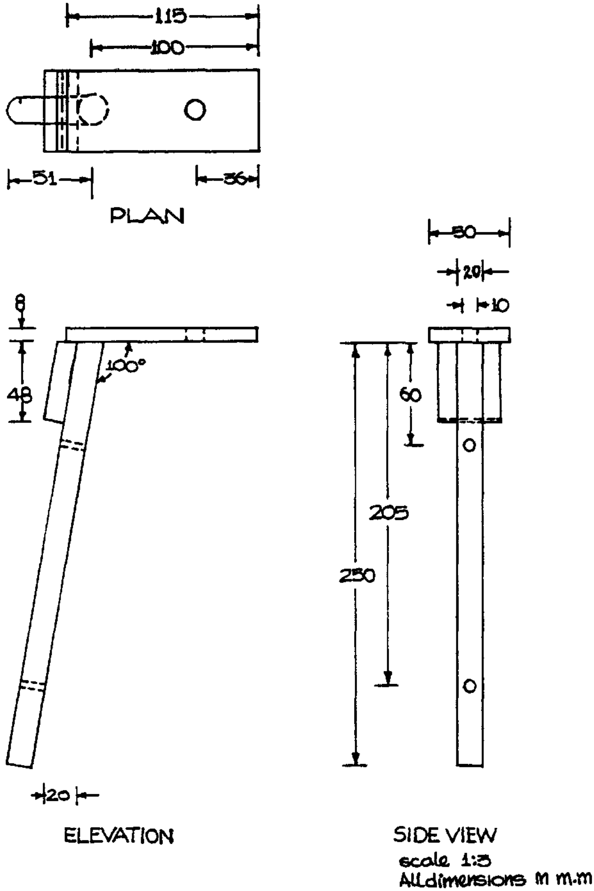


Fig-10. FORMING BOARD SUPPORT

be an acute angle. So the width of the mild steel sheet is adopted as 12 cm which gives an angle of 24.6° to the horizontal. In order to facilitate the width adjustments the levelling board was fabricated as a three piece unit. The central piece is the fixed piece and the two side pieces can be slided inwards and outwards to get the required width. Holes are provided on the sheets to join them together by nuts and bolts.

For height adjustment of the board, the central piece is welded to a suitably bent mild steel rod as shown in Fig. . By raising and lowering the rod in the holder welded to the main frame, heights ranging from 15 cm to 25 cm can be obtained. The rod is fixed using a tightening bolt in the holder. The fabrication was done as per the design and is shown in Fig.11.

3.2.5 Main frame

The following points were considered in designing the main frame.

(i) Strength of the frame should be adequate to support the working parts.

(ii) The forming boards and levelling boards should be easily attachable to the main frame with provision for width and height adjustments.

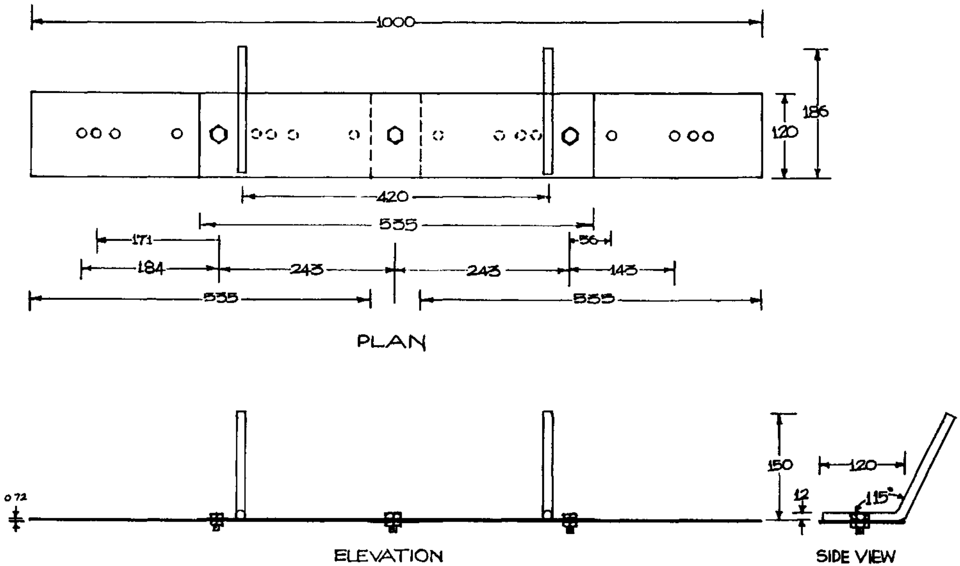


Fig.11. LEVELLING BOARD

scale 1:6
All dimensions in mm

(iii) Easy attachment to the hitch beam

(iv) The forces should be symmetrical about the line of pull

(v) Overall weight of the equipment should be minimum

Considering the above factors the configuration, shown in Fig.12 was adopted for the frame. Design of independent members were done considering the bending moments on them. The members were joined together by welding. The calculations are presented in Appendix III. The fabrication was done as per the design and is shown in Fig.13.

3.2.6 Hitch beam

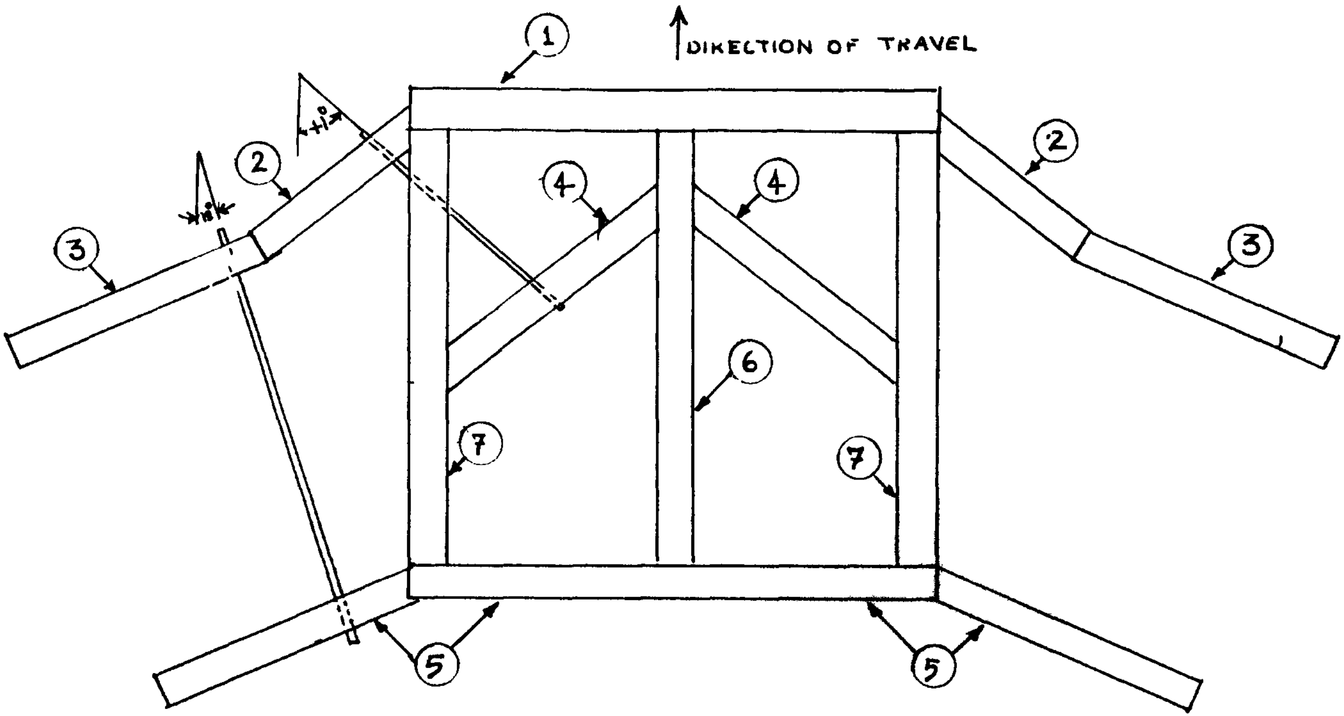
The following factors were considered in the design of the hitch beam.

(i) Easy attachment of the implement to the power tiller

(ii) Ease of operation

(iii) Provision for height adjustments

The trailer hitch frame available with the Kubota power tiller was modified to achieve the above objectives. The angle of bent of the beam of the hitch frame was increased to 160° so as to accommodate the implement. The length of the beam was increased so as to enable the rear hitch support and the depth control cum transport wheel of the implement. The modified hitch beam was fabricated and is shown in Fig.14.



PLAN

Fig.12 STRUCTURAL CONFIGURATION OF MAIN FRAME

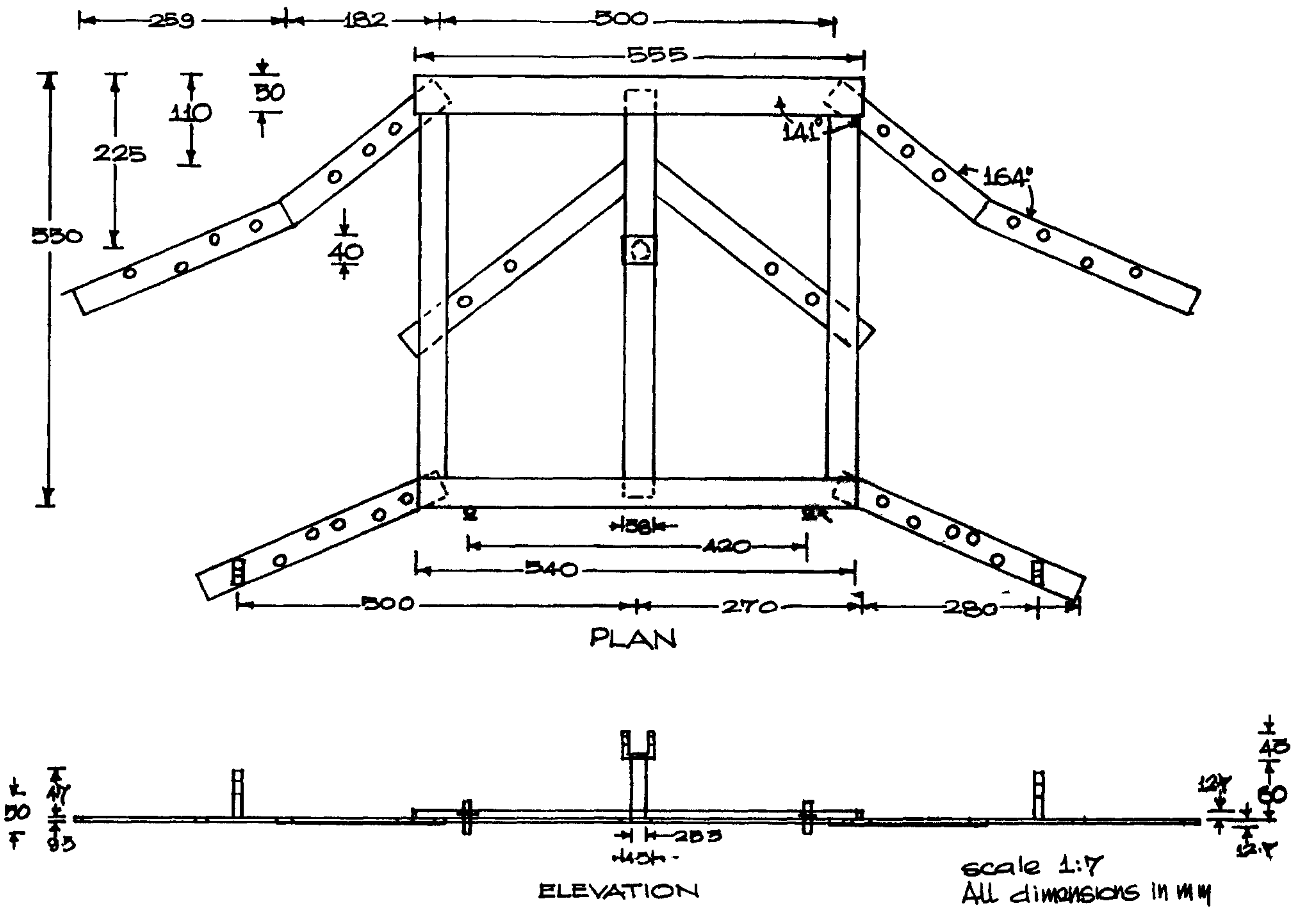
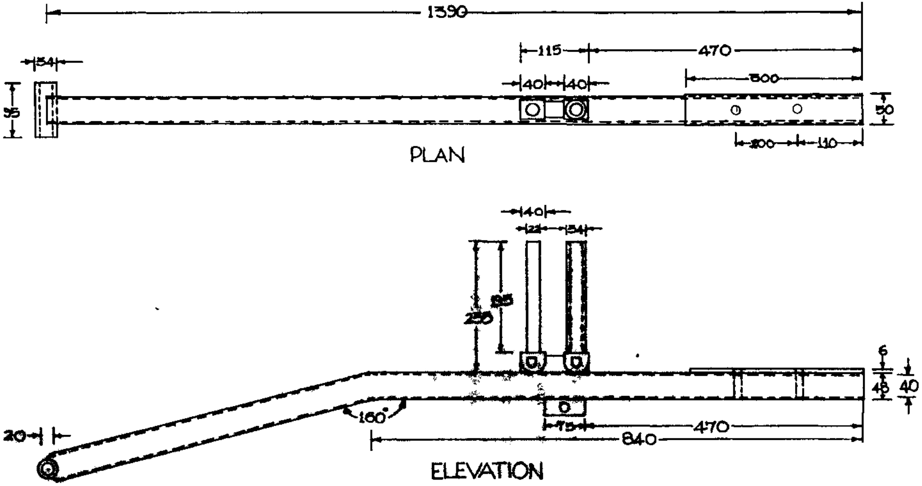


Fig.13.MAIN FRAME



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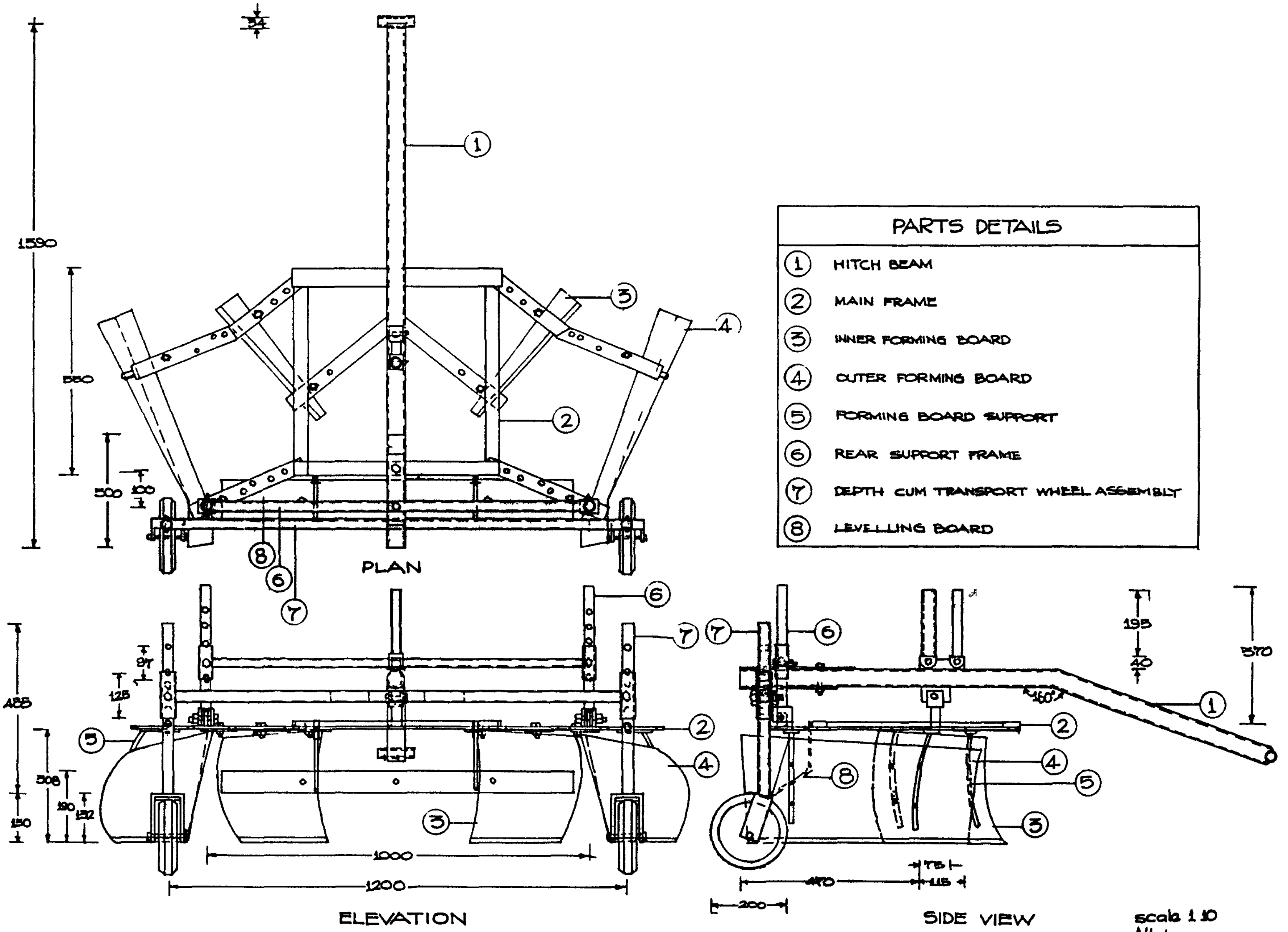
All dimensions in mm

Fig.14. HITCH BEAM



PARTS DETAILS

1	HITCH BEAM
2	MAIN FRAME
3	INNER FORMING BOARD
4	OUTER FORMING BOARD
5	FORMING BOARD SUPPORT
6	REAR SUPPORT FRAME
7	DEPTH CUM TRANSPORT WHEEL ASSEMBLY
8	LEVELLING BOARD

Fig 17 POWER TILLER OPERATED BED FORMER

3.2.7 Rear support frame

The rear support frame is attachable to the hitch beam with nuts and bolts and it provides facility for depth adjustments. The fabrication was done as per the design shown in Fig.15.

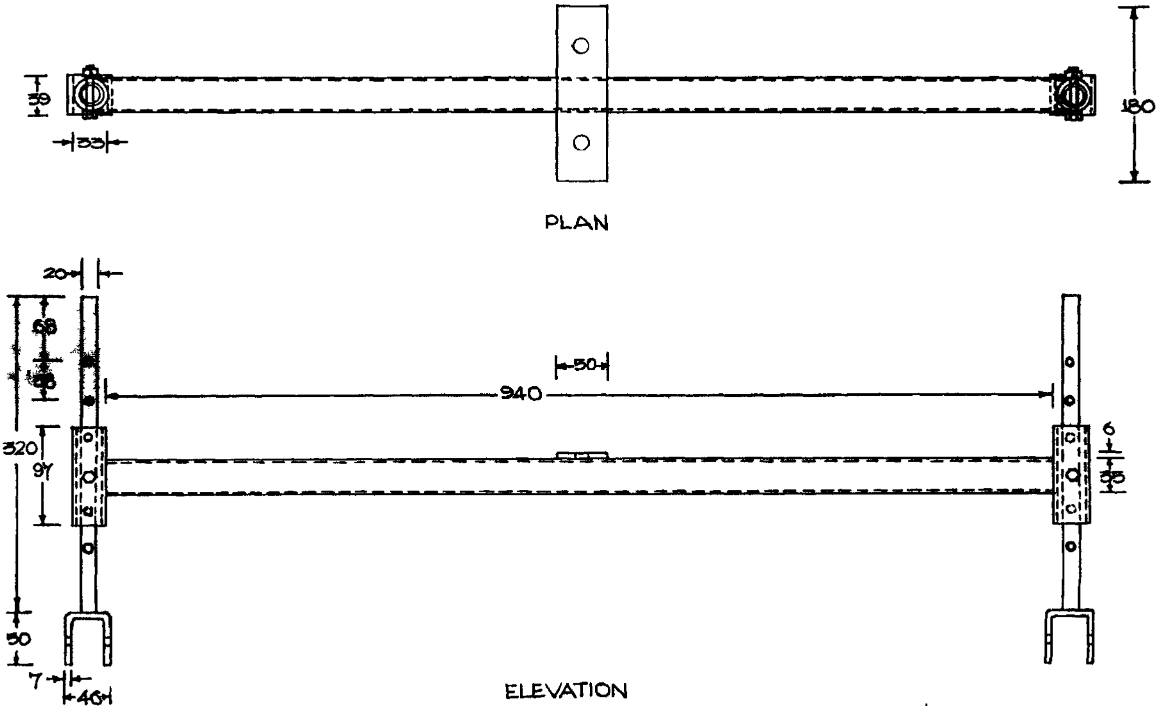
3.2.8 Depth control cum transport wheel

A depth control cum transport wheel was required for the Bed former to enable depth control and transportation of the equipment. Two rubber wheels of diameter 20 cm mounted at a wheel base of 120 cm were used for this. The fabrication was done as shown in Fig.16.

3.2.9 Assembly of parts

The independent parts designed and fabricated were assembled as shown in Fig.17 to get the power tiller operated Bed former.

The prototype power tiller operated Bed former were fabricated and assembled at the Research Workshop, Department of Agricultural Engineering, Mannuthy.



Scale 1:5
All dimensions in mm

Fig 15. REAR SUPPORT FRAME

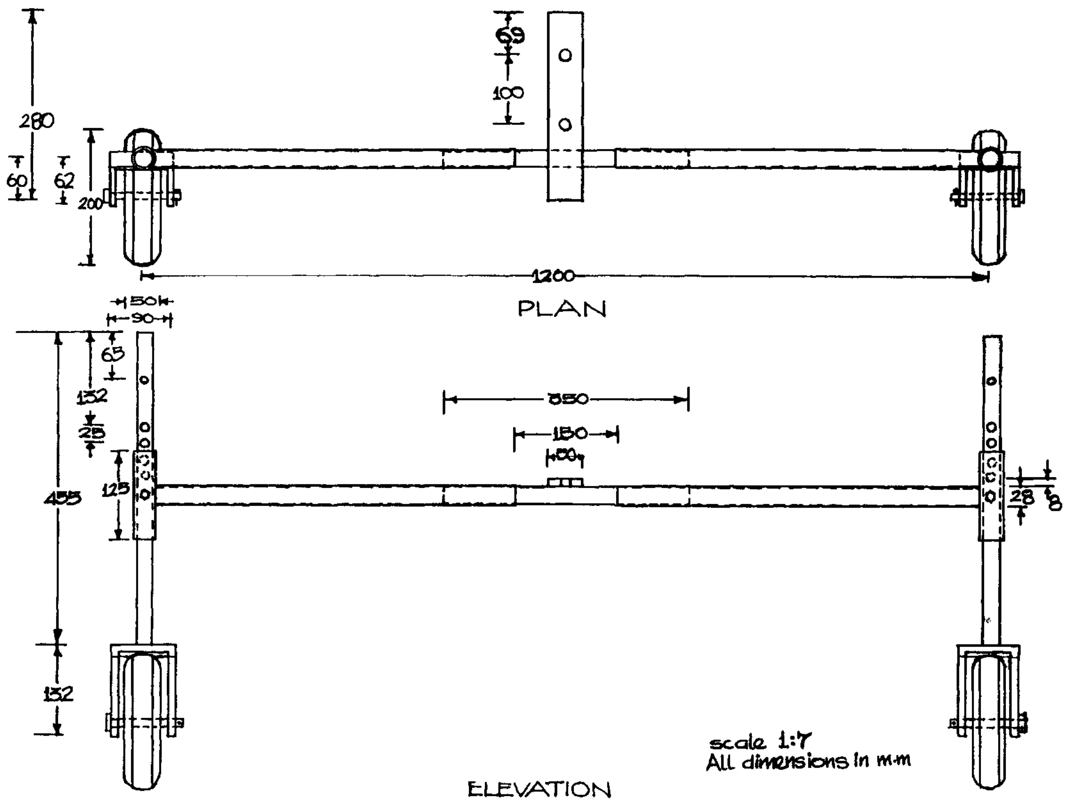


Fig.16. DEPTH CUM TRANSPORT WHEEL ASSEMBLY

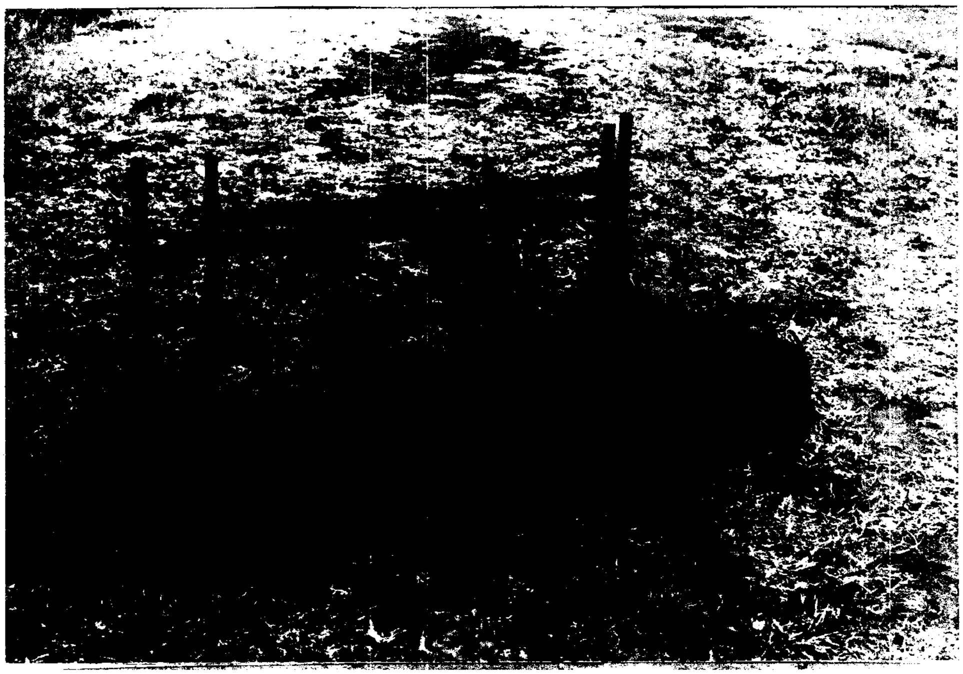


Plate II Power tiller operated bed former

Plate II Power tiller operated bed former

3.3 Evaluation of the prototype power tiller operated Bed former

The evaluation tests were conducted at the farms of the Agricultural Research Station and Fodder Research Station, Mannuthy. The following test procedure was adopted for the evaluation of the power tiller operated Bed former.

3.3.1 Laboratory tests

3.3.1.1 Weight

The Bed former with the hitch was weighed on a platform type physical balance and the weight was noted.

3.3.1.2 Dimensions of the bed former

The dimensions of the Bed former were measured with a steel tape and were noted down.

3.3.1.3 Theoretical field capacity

The theoretical operating widths of the equipment were found at various adjusted widths. The theoretical field capacity was then calculated for an operating speed of 1.5 kmph.

Theoretical field capacity (ha/hr)

$$= \frac{\text{Theoretical speed in kmph} \times \text{Theoretical operating width (m)}}{10}$$

3.3.2 Field tests

The test plots were ploughed with a 2 bottom disc plough and harrowed with a cultivator using 35 hp H.M.T. Zetor tractor. The moisture content and bulk density of the soil where noted down.

3.3.2.1 Dimensions of seed beds and furrows

The implement was tested with various adjustments to get different widths and heights of seed bed. The resulting dimensions of the beds and furrows formed were noted down.

3.3.2.2 Uniformity and straightness of seed beds and furrows

The uniformity and straightness of seed beds and furrows were also evaluated and noted down.

3.3.2.3 Ease of operation and adjustments

Ease of operation and adjustments of the implement were evaluated under field conditions and the observations were noted down. Time required for turning was also noted down.

3.3.2.4 Draft

The procedure used for the draft measurement is as follows.

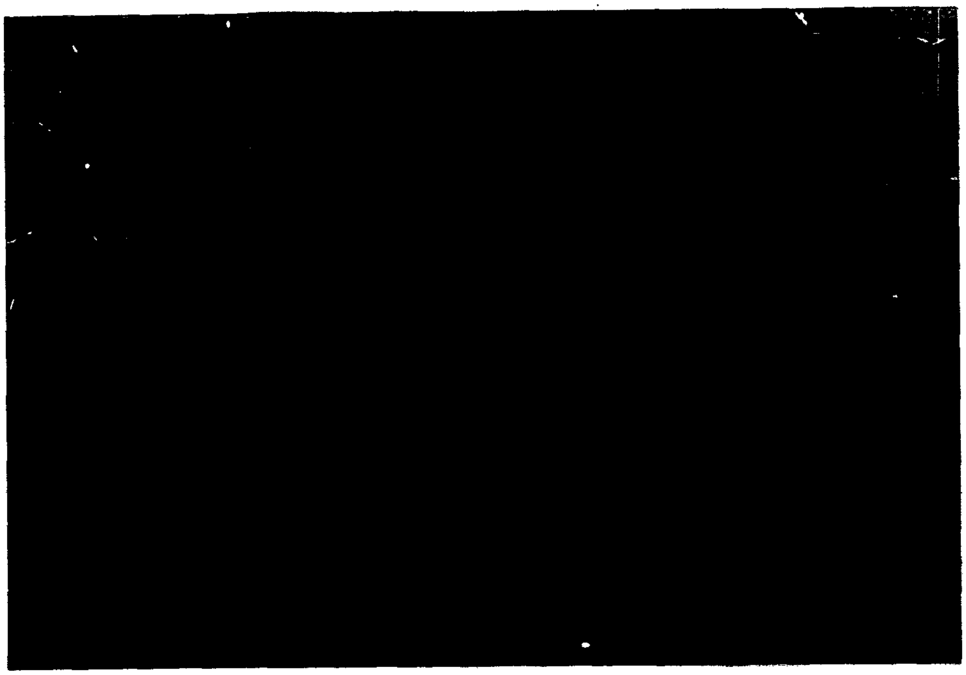


Plate III Power tiller operated bed former in operation (rear view)

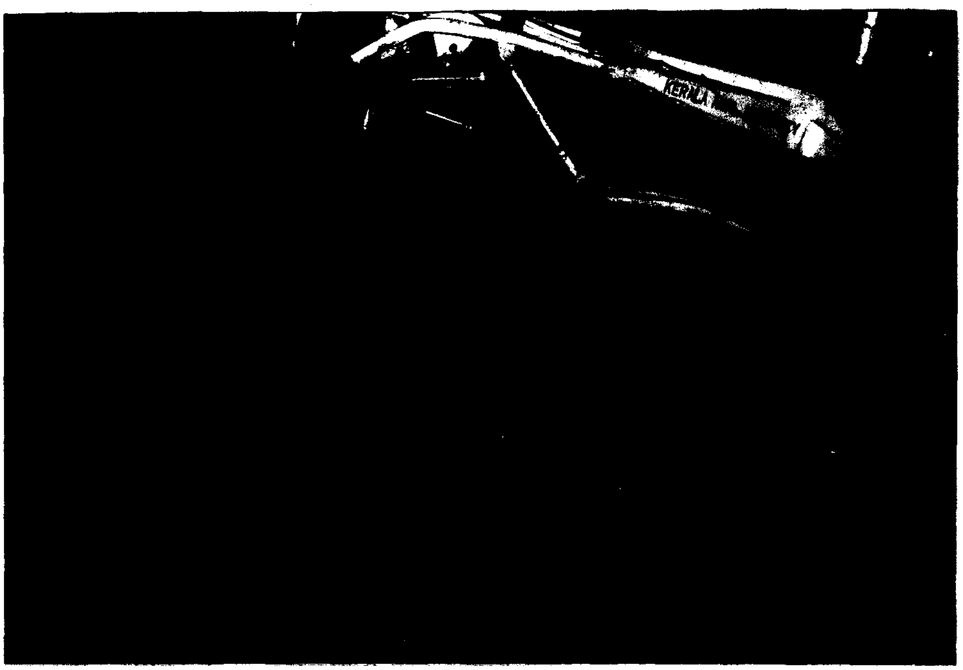


Plate IV Power tiller operated bed former in operation (side view)

The po[illegible] was attached to a spring dynamometer (specification shown [illegible]x VIII) and [illegible] pulled at the design speed of 1.5 km[illegible]e o[illegible] end of the dynamometer by keeping the clutch in [illegible]ition. The angle of inclination of the [illegible] of [illegible] dynamometer reading were noted down. F[illegible] power tiller without the implement [illegible]

Then the implem[illegible] attached [illegible] the power tiller. A hydraulic drawbar dynamometer (specification shown in Appendix VIII) was attached to the front of the power tiller and the other end of the dynamometer was attached to a H.M.T. Zetor tractor. The tractor was moved forward pulling the power tiller with the implement operating at the designed speed. The clutch of the power tiller [illegible] kept at the off position during the test. The [illegible] line of pull to the horizontal and the dyn[illegible] re[illegible] were noted down. The test was repeated [illegible]erent [illegible]usted widths and heights. At instances whe[illegible]ll exceeded the range of the single dynamometer, two d[illegible]ers in parallel were used. The readings of the both [illegible]mometers were added up and noted down.

The drafts were calculated from the dynamometer readings. The difference between the drafts with and without the implement were then calculated. The test set up is shown in Plate V.

The power tiller was attached to a spring dynamometer (specification shown in Appendix VIII) and was pulled at the design speed of 1.5 kmph from the other end of the dynamometer by keeping the clutch in the off position. The angle of inclination of the line of pull and the dynamometer reading were noted down. From these, the draft of the power tiller without the implement was found.

Then the implement was attached with the power tiller. A hydraulic drawbar dynamometer (specification shown in Appendix VIII) was attached to the front of the power tiller and the other end of the dynamometer was attached to a H.M.T. Zetor tractor. The tractor was moved forward pulling the power tiller with the implement operating at the designed speed. The clutch of the power tiller was kept at the off position during the test. The angle of the line of pull to the horizontal and the dynamometer reading were noted down. The test was repeated for different adjusted widths and heights. At instances when the pull exceeded the range of the single dynamometer, two dynamometers in parallel were used. The readings of the both the dynamometers were added up and noted down.

The drafts were calculated from the dynamometer readings. The difference between the drafts with and without the implement were then calculated. The test set up is shown in Plate V.

Plate III Power tiller operated bed former in operation (rear view)

Plate IV Power tiller operated bed former in operation (side view)

Plate V Experimental set up for draft measurement

Plate VI Power tiller operated bed former attached with Kubota power tiller

3.3.2.5 Power requirement

The time required to run a definite distance was noted down and from that the speed of operation was calculated. Then the metric horse power was calculated from the draft and speed for various seed bed dimensions, using the equation,

$$\text{Horse power} = \frac{D \times S}{75}$$

where,

D = Draft in kg

S = Speed in m/sec

3.3.2.6 Slip

The power tiller was operated in the field without the equipment for a known distance. The number of rotations of the drive wheel were counted. Again the number of rotations were counted with the implement operating to cover the same distance. The test was repeated for different heights and widths of seed beds. The slip (%) was calculated using the formula.

$$\text{Slip (\%)} = \frac{n_L - n_O}{n_L} \times 100$$

where,

n_L = number of rotations of the drive wheel with load for a specified distance

n_O = number of rotations at no load

3.3.2.5 Power requirement

The time required to run a definite distance was noted down and from that the speed of operation was calculated. Then the metric horse power was calculated from the draft and speed for various seed bed dimensions, using the equation,

$$\text{Horse power} = \frac{D \times S}{75}$$

where,

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3.3.2.6 Slip

The power tiller was operated in the field without the equipment for a known distance. The number of rotations of the drive wheel were counted. Again the number of rotations were counted with the implement operating to cover the same distance. The test was repeated for different heights and widths of seed beds. The slip (%) was calculated using the formula.

$$\text{Slip (\%)} = \frac{n_L - n_O}{n_L} \times 100$$

where,

n_L = number of rotations of the drive wheel with load for a specified distance

n_O = number of rotations at no load

3.3.2.7 Effective field capacity

The equipment was operated at an average speed, as near as possible to the design speed of 1.5 kmph. The gear selected was low III. Time required to cover a field of known size was noted. The test was repeated for different dimensions of the seed bed.

3.3.2.8 Field efficiency

The field efficiency was calculated from the theoretical and effective field capacities using the following formula,

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

3.3.2.9 Labour requirement

The requirement of labourers for operating the equipment was noted.

3.3.2.10 Economic analysis

(i) The cost of production of the unit was calculated. The calculations are presented in Appendix IV.

(ii) The cost of operation of the implement was calculated and the calculations are presented in Appendix V.

(iii) Cost of preparation of seed bed with the developed bed former was compared with the cost of manual operation. The calculations are presented in Appendix VI.

Results and Discussion

RESULTS AND DISCUSSION

The results of laboratory and field studies conducted and economics of the prototype Bed former are presented and discussed in this chapter.

4.1 Laboratory tests

The laboratory tests were conducted as explained under 3.3.1.

4.1.1 Weight

The overall weight of the Bed former with the hitching unit is 70 kg.

4.1.2 Dimensions

The dimensions of the Bed former are as follows.

Overall length	=	140 cm
Overall width	=	160 cm
Height	=	70 cm

All these measurements includes the hitching unit.

4.1.3 Theoretical field capacity

The theoretical widths of operation of the equipment were measured and the theoretical field capacities were calculated for a design operating speed of 1.5 kmph. The calculated values are presented in Table 3. The mean value for the 3 different settings of the forming boards is 0.2175 ha/hr.

4.2 Field tests

Field tests were conducted in test plots of size 15 m x 10 m with an average soil moisture content of 20.0 per cent (dry basis). The average bulk density of the soil was 1.32 gm/cm^3.

4.2.1 Dimensions of seed beds and furrows

The mean dimensions of the seed beds and furrows for different settings of forming boards and levelling board are presented in Table 4. At the forming board position 3-5, 3-2 (Fig.18) three heights of the seed bed i.e. 22 cm, 18 cm, and 15 cm are possible. The widths obtained were 60 cm, 63 cm and 64 cm respectively with a mean value of 62.33 cm. A slight increase in width can be observed when the height is reduced. This is due to the increase in the width at the rear due to the outward inclination of the boards at the rear. The bottom width of the seed bed remained almost the same at the 3 heights.

Table 5. Theoretical field capacity (Design operating speed = 1.5 kmph)

Sl.No.	Forming board position (*)	Theoretical operating width of implement (m)	Run length required for 1 ha (m)	Time required for 1 ha (hr)	Theoretical field capacity (ha/hr)
1	3-5, 3-2	1.35	7407.4	4.94	0.2025
2	2-4, 2-2	1.45	6896.6	4.60	0.2175
3	1-3, 1-2	1.55	6451.6	4.30	0.2325

* See Fig.18

Forming board position is indicated by the serial number of the hole on the main frame to which the bolt of the forming board support is attached.

The holes are numbered from outer end to inner on both sides separately for outer and inner boards.

The order is, outer board front-outer boarder rear, inner board front-inner board rear.

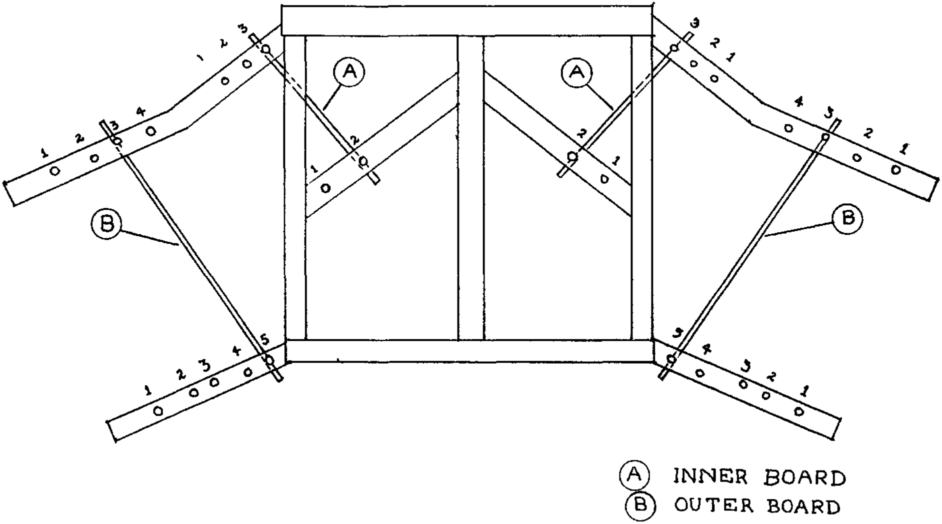

Fig. 18 FORMING BOARD POSITION 3.5.3.2

Table 6. Dimensions of seed beds and furrows for different settings of forming boards and levelling board

Trial No.	Forming board position	Levelling board height (cm)	Dimensions of seed bed (cm)*			Furrow width* (cm)	Theoretical width of operation (cm)	Observed width of operation (cm)
			Top width	Bottom width	Height			
1	3-5, 3-2	22	60	96	22	32	135	128
2	-do-	18	63	94	18	32	135	126
3	-do-	15	64	95	15	31	135	126
4	2-4, 2-2	18	73	102	18	34	145	136
5	-do-	15	75	100	15	35	145	135
6	1-3, 1-2	18	80	104	18	38	155	142
7	-do-	15	81	106	15	39	155	145

* Mean of four observations

At the position 2-4, 2-2 of the forming boards, heights of 18 cm and 15 cm are possible with a width range of 73-75 cm. Eventhough there was a corresponding increase in the bottom width with the increase in the top width, there was no considerable variation with the change in height.

At the position 1-3, 1-2 seed bed heights of 18 cm and 15 cm are got with a width of 80 cm to 81 cm.

The furrow width showed slight increase with the increase in width of the seed beds. The width of furrow did not show any considerable change with the change in heights.

The maximum heights attained were 22 cm, 18 cm, and 18 cm at forming board position (3-5, 3-2), (2-4, 2-2) and (1-3, 1-2) respectively. The design maximum height of the seed bed was 25 cm. But higher seed beds could not be formed with the implement due to the inadequacy of drawbar pull.

A reduction in the observed width of operation from the theoretical width of the implement was also observed. The reason for this reduction of 7-11 cm was the sliding in of uncut soil towards the furrow. Because of this an overlap of the implement was required in each successive run, which reduced the effective operating width of the implement.

Table 7. Draft

Angle of inclination of the line of pull to the horizontal = 19°

Draft of power tiller at no load = 13 kgf

Trial No.	Forming board position	Levelling board height (cm)	Operating width (cm)	Pull * (kgf)	Draft of implement with power tiller (kgf)	Draft of implement (kgf)
1	3-5, 3-2	22	128	193.5	182.96	169.69
2	-do-	18	126	165.5	156.48	143.48
3	-do-	15	126	136.0	128.59	115.59
4	2-4, 2-2	18	136	176.0	166.41	153.41
5	-do-	15	135	144.5	136.63	123.63
6	1-3, 1-2	18	142	188.0	177.76	164.76
7	-do-	15	145	153.0	144.66	131.66

* Mean of four observations

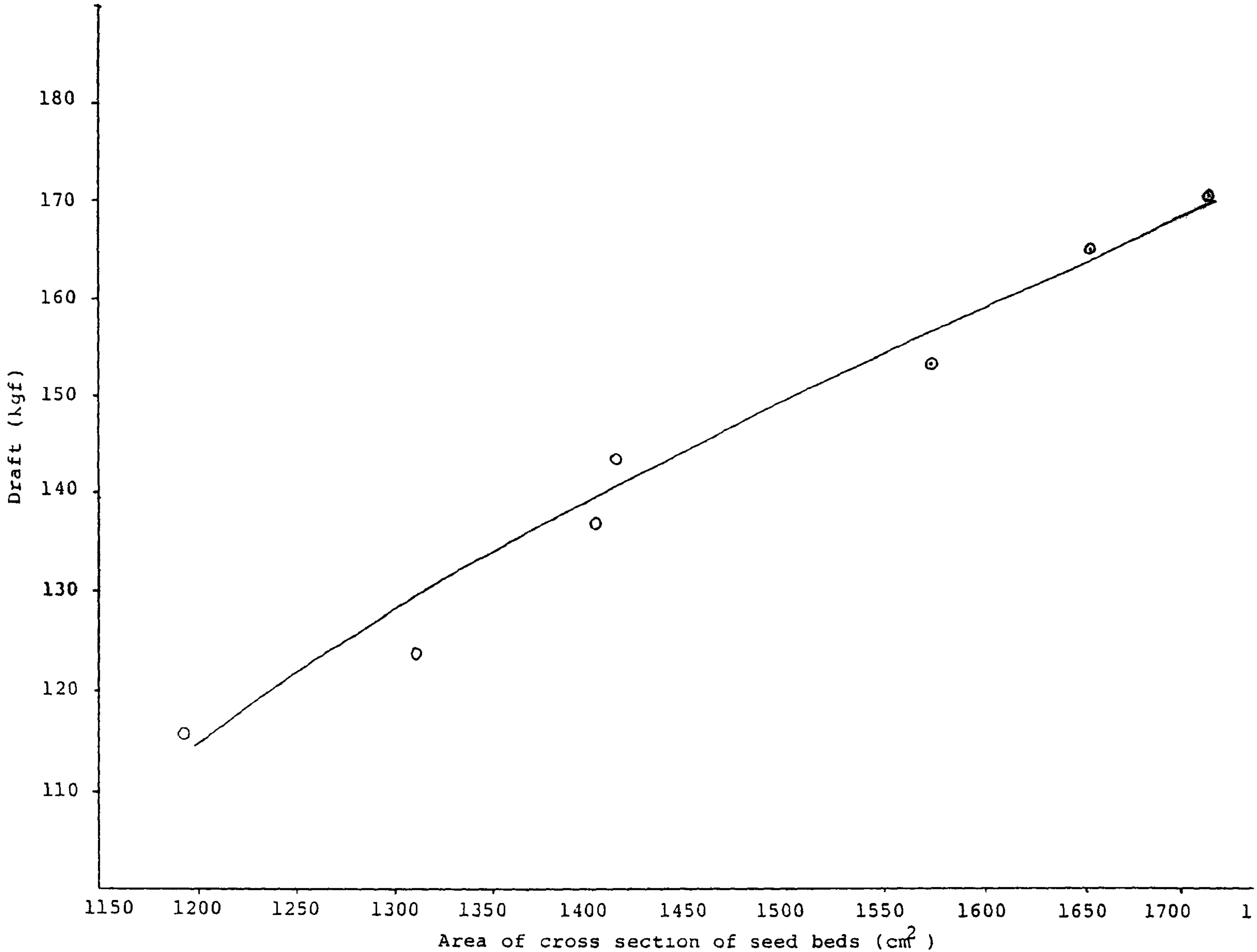

Fig.19 Area of cross section of seed beds Vs draft

4.2.5 Power

The draft measured at a speed of 1.5 kmph was adopted for calculating the power requirements. The speed of operation was found at various adjusted positions of forming boards and levelling board and the power was calculated. The power in hp (metric) is presented in Table 6. A minimum value of the power ie. 0.586 hp was observed at the forming board position 3-5, 3-2 (average width = 62.33 cm) at a levelling board height of 22 cm. The speed of operation at this position was 0.259 m/sec (0.93 kmph). The maximum value of power, 0.771 hp was observed at the board position 3-5, 3-2 at 15 cm levelling board height.

It was observed that only a small fraction of the total power could be utilised by the implement because of the low drawbar power availability. The maximum drawbar power available was 0.771 hp, which is only a small fraction of the engine power of 9-12 hp. This is a clear indication of the incapability of the drive wheels of the power tiller to utilise the full engine power to work a soil working drag implement.

4.2.6 Slip

The slip of the power tiller in percentage of various adjusted positions of the implement is presented in Table 7.

Table 8. Power

Gear selection - Low III

Trial No.	Levelling board height (cm)	Forming board position	Length of run (m)	Time taken (sec)*	Speed (m/sec)	Draft (kgf)	Power (hp)
1	22	3-5, 3-2	15	58	0.259	169.69	0.586
2	18	-do-	15	45	0.333	143.48	0.637
3	15	-do-	15	30	0.500	115.59	0.771
4	18	2-4, 2-2	15	49	0.306	153.41	0.626
5	15	-do-	15	34	0.441	123.63	0.727
6	18	1-3, 1-2	15	53	0.283	164.76	0.622
7	15	-do-	15	38	0.395	131.66	0.693

* Mean of four observations

The maximum slip of 77.1 per cent was observed when the seed bed of larger cross sectional area was prepared. The minimum slip of 46.76 per cent was observed while preparing the seed bed of the smallest cross section. The slip of the drive wheels were found to increase with the increase in area of cross section of the seed beds (Fig.20). Slip as great as 77.1 per cent was observed when pulling the implement with a draft of 169.69 kg. The power was reduced to 0.586 hp due to the reduction in speed caused by slip. This indicates the insufficiency of the area of contact of drive wheels to transmit the engine power.

4.2.7 Effective field capacity

Seven numbers test plots of 15 m x 10 m size were selected for the test. The observations are given in Table 3.

The effective field capacity of the implement ranged between 0.0786 ha/hr to 0.1154 ha/hr. Since the field capacity is a function of both the operating speed and width, there is no direct relation to the cross sectional area of the seed bed formed. The minimum effective field capacity was observed at the forming board position 3-5, 3-2 at a levelling board height of 22 cm. The maximum was observed at the forming board position 1-3, 1-2 when the levelling board height was 15 cm. The mean effective field capacity for the

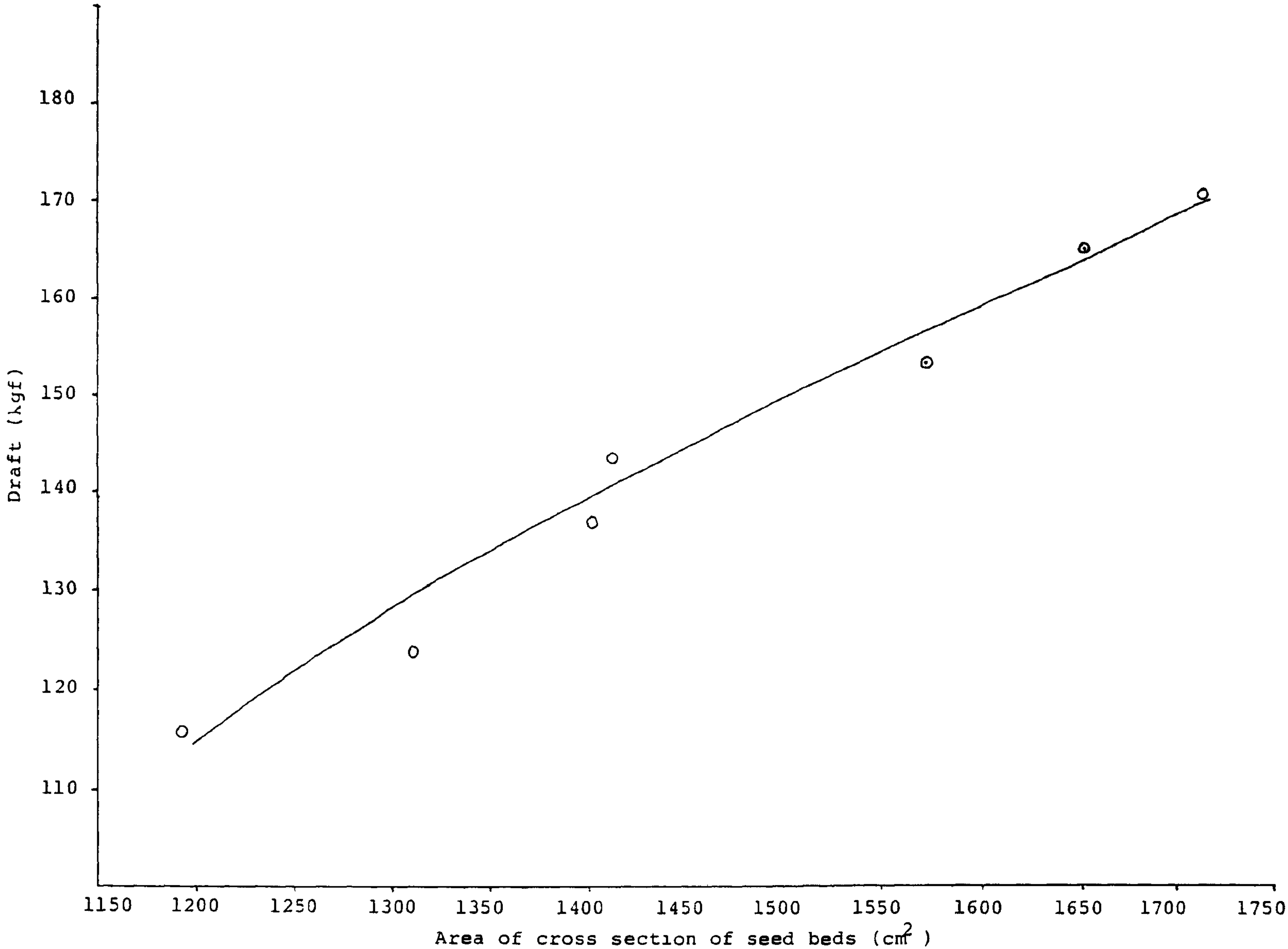

Fig.19 Area of cross section of seed beds Vs draft

4.2.5 Power

The draft measured at a speed of 1.5 kmph was adopted for calculating the power requirements. The speed of operation was found at various adjusted positions of forming boards and levelling board and the power was calculated. The power in hp (metric) is presented in Table 6. A minimum value of the power ie. 0.586 hp was observed at the forming board position 3-5, 3-2 (average width = 62.33 cm) at a levelling board height of 22 cm. The speed of operation at this position was 0.259 m/sec (0.93 kmph). The maximum value of power, 0.771 hp was observed at the board position 3-5, 3-2 at 15 cm levelling board height.

It was observed that only a small fraction of the total power could be utilised by the implement because of the low drawbar power availability. The maximum drawbar power available was 0.771 hp, which is only a small fraction of the engine power of 9-12 hp. This is a clear indication of the incapability of the drive wheels of the power tiller to utilise the full engine power to work a soil working drag implement.

4.2.6 Slip

The slip of the power tiller in percentage of various adjusted positions of the implement is presented in Table 7.

Table 8. Power

Gear selection - Low III

Trial No.	Levelling board height (cm)	Forming board position	Length of run (m)	Time taken (sec)*	Speed (m/sec)	Draft (kgf)	Power (hp)
1	22	3-5, 3-2	15	58	0.259	169.69	0.586
2	18	-do-	15	45	0.333	143.48	0.637
3	15	-do-	15	30	0.500	115.59	0.771
4	18	2-4, 2-2	15	49	0.306	153.41	0.626
5	15	-do-	15	34	0.441	123.63	0.727
6	18	1-3, 1-2	15	53	0.283	164.76	0.622
7	15	-do-	15	38	0.395	131.66	0.693

* Mean of four observations

Table 9. Slip of the power tiller

Length of run = 15 m

Number of rotations of the drive wheel at no load = 8

Trial No.	Forming board position	Seed bed dimensions (cm)		Observed total width of operation (cm)	Number of rotations of drive wheel *	Slip (%)
		Top width	Height			
1	3-5, 3-2	60	22	128	35	77.1
2	-do-	63	18	126	26	69.2
3	-do-	64	15	126	15	46.7
4	2-4, 2-2	73	18	136	29	72.4
5	-do-	75	15	135	18	55.6
6	1-3, 1-2	80	18	142	33	75.8
7	-do-	81	15	145	21	61.9

* Mean of four observations

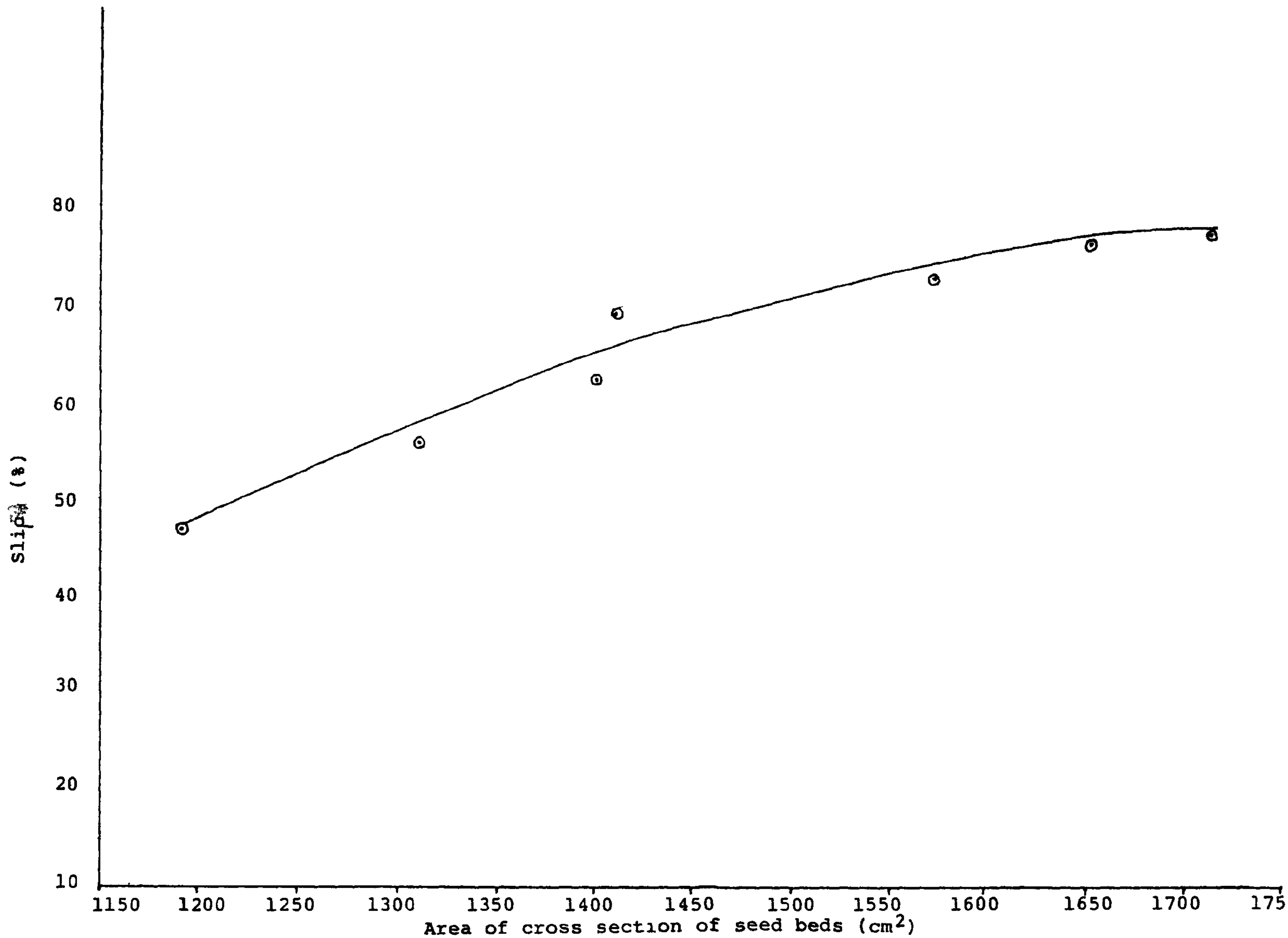

Fig.19 Area of cross section of seed beds Vs draft

Table 10. Effective field capacity

Test plot size = 10 m x 15; Area = 150 m^2

Trial No.	Forming board position	Dimensions of seed bed (cm)			Furrow width (cm)	Width of operation	Time taken to cover the area (sec)	Effective field capacity (ha/hr)
		Top width	Bottom width	Height				
1	3-5, 3-2	60	96	22	32	128	687	0.0786
2	-do-	63	94	18	32	126	595	0.0908
3	-do-	64	95	15	31	126	476	0.1134
4	2-4, 2-2	73	102	18	34	136	580	0.0931
5	-do-	75	100	15	35	135	474	0.1139
6	1-3, 1-2	80	104	18	38	142	585	0.0923
7	-do-	81	106	15	39	145	468	0.1154

Mean = 0.0996 ha/hr

7 different settings was 0.996 ha/hr. Compared with similar power tiller drawn equipments, the mean effective field capacity observed is appreciable.

4.2.8 Field efficiency

The field efficiencies of the implement for different adjusted positions are presented in Table 9. A maximum field efficiency of 56.0 per cent was observed when the implement was preparing seed beds of 64 cm top width and 15 cm height. The minimum field efficiency of 38.8 per cent was observed while preparing seed beds of top width 60 cm and height 22 cm. The mean field efficiency was 46.3 per cent. The main reason for lowering of field efficiency is the time loss in turning and time loss due to the slip of drive wheels. The actual speed of operation was always lower than the design speed of 1.5 kmph due to slip. Another factor is the reduction in effective width of the implements as discussed in 4.2.1.

The field efficiency can be further improved by providing front weights to the power tiller, so that the turning becomes more easy.

4.2.9 Labour requirement

One man, in addition to the power tiller operator is required to operate the implement during turning, and also to keep the straightness when seed beds of larger cross sections are prepared.

Table 11. Field efficiency

Trial No.	Forming board position	Dimensions of seed bed (cm)		Total width of operation (cm)	Theoretical field capacity at same board position (ha/hr)	Effective field capacity (ha/hr)	Field efficiency (%)
		Top width	Height				
1	3-5, 3-2	60	22	128	0.2025	0.0786	38.8
2	-do-	63	18	126	0.2025	0.0908	44.8
3	-do-	64	15	126	0.2025	0.1134	56.0
4	2-4, 2-2	73	18	136	0.2175	0.0931	42.8
5	-do-	75	15	135	0.2175	0.1139	52.4
6	1-3, 1-2	80	18	142	0.2375	0.0923	39.7
7	-do-	81	15	145	0.2325	0.1154	49.6

Mean = 46.3%

4.2.10 Economic analysis

(i) Cost of production

The total cost of production of the unit is Rs.2000/-. Out of this total cost, Rs.1550/- is the cost of materials and Rs.400/- is the fabrication charges. The details are shown in Appendix IV.

(ii) Cost of operation

The cost of operation of the equipment for different adjusted positions of the implement is presented in Table 10. The cost is maximum for preparing seed beds of 60 cm top width and 22 cm height. The minimum cost is for preparing seed beds of 81 cm top width and 15 cm height. The average cost of operation of the implement is Rs.777/- per ha.

Table 12. Operating cost of bed former

Cost of operation per hour = Rs.75.93

Sl. No.	Forming board position	Levelling board height (cm)	Effective field capacity (ha/hr)	Operating cost per ha (Rs.)
1	3-5, 3-2	22	0.0786	966.00
2	-do-	18	0.0908	836.00
3	-do-	15	0.1134	670.00
4	2-4, 2-2	18	0.0931	816.00
5	-do-	15	0.1139	667.00
6	1-3, 1-2	18	0.0923	823.00
7	-do-	15	0.1154	658.00

Mean = Rs.777.00

(iii) Comparison with manual operation

The cost of preparation of seed beds by manual operation is Rs.2250/- per hectare. The calculation is presented in Appendix VI. Saving in the cost of seed bed preparation using the power tiller operated Bed former is Rs.1473/- per ha. The percentage saving in the cost of seed bed preparation by using the implement is 52.7 per cent. Even if it is considered that more ploughing is required before the use of the Bed former, the large saving justifies the use of Bed former.

Summary

SUMMARY

A broad bed and furrow system of cultivation has been found efficient for many crops and manual preparation of beds is very laborious. In order to increase the versatility of power tillers, design and development of power tiller operated equipments is imperative. Hence it was decided to design and develop a power tiller operated Bed former.

An experimental Bed former unit was fabricated and field tested at the Kelappaji College of Agricultural Engineering and Technology, Tavanur. The observations made in the field trials with this experimental unit were used to design the prototype Bed former.

A prototype unit of the power tiller operated Bed former was designed and fabricated at the Research Workshop, Kerala Agricultural University, Mannuthy. The following are the features of the unit.

1. It was designed to operate at a maximum width of 140 cm and to form seed beds of maximum dimension 100 cm x 25 cm.

2. The widths and heights of operation can be adjusted to form seed beds of different dimensions.

3. It consists of a main frame, two pairs of forming boards, 4 pairs of forming board supports, a levelling board, a hitching unit, a rear support frame and a depth control cum transport wheel.

The prototype unit was field tested in the fields of the Agricultural Research Station and Fodder Research Station, Kerala Agricultural University, Mannuthy. The results obtained are summarised below.

1. The dimensions of seed beds formed were as follows:

Width (range)	Height
60-64 cm	22 cm, 18 cm and 15 cm
73-75 cm	18 cm and 15 cm
80-81 cm	18 cm and 15 cm

2. The uniformity and straightness of seed beds and furrows were good at the minimum width setting and were badly affected at larger widths.

3. The ease of operation also showed the same trend as above. The ease for field adjustments was found good.

4. The minimum draft of the implement was 115.59 kgf when seed beds of 60 cm x 15 cm size was prepared and the maximum draft was 169.69 kgf when seed beds of 64 cm x

22 cm size was prepared. Draft was found to increase with the area of cross section of seed beds.

5. The power utilisation of the equipment varied from the minimum value of 0.586 hp to the maximum value of 0.771 hp. The power utilisation was found to decrease with the increase in area of cross section of the seed bed due to the decrease in speed of operation caused by slip.

6. The slip of the power tiller varied between 46.76 per cent to 77.1 per cent. The slip was also found to increase with the increase in area of cross section of seed beds.

7. The effective field capacity of the implement ranged between 0.0786 ha/hr to 0.1154 ha/hr. The mean effective field capacity of the implement is 0.0996 ha/hr.

8. The field efficiency of the implement ranged between 38.8 per cent to 56.0 per cent with a mean value of 46.3 per cent.

9. One man in addition to the power tiller operator is required for operating the implement.

10. The total cost of production of the unit is Rs.2000/-. The cost of operation including power tiller hire charges is Rs.777/- per ha. There is a saving of Rs.1473/- per ha when compared with manual operations.

The loss of straightness of the seed beds formed is the major disadvantage of the implement. Another disadvantage was the inadequate drawbar power of the power tiller. The performance of the implement was found good when seed beds of minimum cross section was prepared. It was seen that the implement cannot be turned smoothly. The performance of the implement can be further improved by providing front weights to the power tiller.

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Appendices

Appendix I

Design of thickness of plates for forming boards

Maximum of depth cut required	= 20 cm
Maximum width of cut per board	= 25 cm
Area of cut = 25 x 20	= 500 cm^2
Specific soil resistance	= 0.3 kgf/cm^2
Total soil resistance on a single board	= 0.3 x 500
	= 150 kgf

This load is considered as uniformly distributed over the entire effective area of the forming boards.

Effective width of forming board ie. height of the bed	= 25 cm
Length of board	= 38 cm

(Length of the inner boards is considered)

Effective area on which the load of 150 kgf acts	= 25 x 38
	= 950 cm^2
Unit working load on surface	= $\frac{150}{950}$
	= 0.158 kgf

The theory of bending of plates is applied for the design.

Maximum bending stress developed,

$$S = \frac{BWb^2}{t^2}$$

where,

W = uniformly distributed load

b = width of plate

t = thickness of plate

B = a constant depending on the length-breadth ratio of plate

For a length-breadth ratio of 1:1, the constant B may be taken as 0.5. Here the ratio is 380:310 Hence the value of B is taken as 0.5.

$$S = 1000 \text{ kgf/cm}^2$$

$$1000 = \frac{0.5 \times 0.158 \times 30^2}{t^2}$$

$$t = 0.267 \text{ cm}$$

Therefore 11 gauge MS sheet having a thickness of 3 mm is used for the forming boards. The outer forming boards have more length and the unit working load on the surface is lesser than the inner boards. Hence 3 mm thick MS sheet is safe for the outer forming boards also.

Appendix II

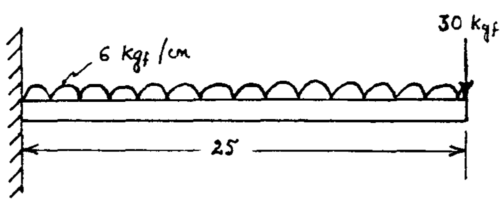
Design of forming board supports

A. Side supports

The total load on the forming boards is considered to act at the bottom 25 cm height.

$$\text{Load/cm depth of the board} = \frac{150}{25} = 6 \text{ kgf}$$

Load on the bottom 5 cm depth of the board acts as point load at the bottom end of the rod since the end of the support rod is 5 cm above the ground surface. The rest of the load acts as uniformly distributed load on the entire length.



$$\text{Point load} = 5 \times 6 = 30 \text{ kgf}$$

Maximum bending moment due to point load, (a)

$$= P \times L = 30 \times 25 = 750 \text{ kg cm}$$

Maximum bending moment due to distributed load, (b)

$$= \frac{WL^2}{4} = \frac{6 \times 25^2}{4} = 937.5 \text{ kg cm}$$

Total B.M. = (a) + (b) = 750 + 937.5

= 1687.5 kg cm

This total bending moment of 1687.5 kg cm has to be borne by 2 side supports.

Bending moment on each support

$$= \frac{1687.5}{2} = 843.75$$

$$M = \frac{I \times f_b}{y}$$

where,

M = maximum bending moment

I = moment of inertia

f_b = yield stress

y = distance from neutral axis

For circular section, $I = \frac{d^4}{64}$ and $y = \frac{d}{2}$

where,

d = is the diameter

$$\frac{I}{y} = \frac{M}{f_b} \quad \text{i.e.} \quad \frac{d^3}{32} = \frac{843.75}{1000}$$

d = 2.0 cm

Hence MS rod of 2 cm diameter is used for the fabrication of side support. A top supporting plate is also required for the side support to attach it to the main frame. A MS flat of 1/4" x 2" (0.635 cm x 5.08 cm) size is used for that.

Appendix III

Design of main frame

Maximum load on each forming board = 150 kgf (see Appendix I)

Member I

This member experiences a bending moment due to the load on the forming board when the implement is in operation.

Load on outer forming board = 150 kgf

Half of this load is taken by the member I (Fig.12).

The forming board surface is inclined at an angle of 18° to the line of travel. The load causing bending moment on member I is the horizontal component of this load parallel to the line of travel.

$$= \frac{150}{2} \times \sin 18° = 23.18 \text{ kgf}$$

This load acts at a maximum distance of 65 cm from the centre.

Maximum bending moment due to outer board (a)

$$= 23.18 \times 65 = 1506.7 \text{ kg cm}$$

The inner boards are inclined at 41°

Load due to inner board causing bending moment

$$= \frac{150}{2} \times \sin 41°$$

$$= 49.20 \text{ kg}$$

Maximum distance from centre to the point of application of this load = 40 cm

Maximum bending moment due to inner board (b)

$$= 40 \times 49.20 = 1968 \text{ kg cm}$$

Total bending moment on member I

$$(a) + (b) = 1506.7 + 1968$$

$$= 3474.7 \text{ kg cm}$$

Maximum bending moment,

$$M = \frac{I \times f_b}{y}$$

I for rectangular section is

$$I = \frac{db^3}{12}$$

$$y = \frac{b}{2}$$

$$\frac{I}{y} = \frac{db^2}{6}$$

where,

d = depth (thickness)

b = width

If 1/2" (1.27 cm) thick MS flat is used for the member

$$M = 1000 \text{ kgf}$$

Width of flat required, $b = \dfrac{6 \times 3474.7}{1000 \times 1.27}$

$= 4.05$ c,

$= 40$ mm

Cosidering the weakest section at the hole for bolts and nuts MS flat of 1/2" (1.27 cm) thickness and 2" (5.08 cm) wicth is used.

Member 2

Maximum bending moment acts at the junction point of member I with member 2.

Load from outer forming board = 23.18 kg
Maximum distance to junction point = 40 cm

Maximum bending moment due to outer forming board on member 2m (a) = 23.18×40

= 927.2 kg cm

Load from inner forming board = 49.20 kg

Maximum distance to junction point = 15 cm

Maximum bending moment due to inner forming board (b)

= 49.20×15

= 738 kg cm

Total bending moment, (a) + (b)

$$= 927.2 + 738$$

$$= 1665.2 \text{ kg cm}$$

Width of 1/2" (1.27 cm) thick MS flat required

$$b = \frac{1665.2 \times 6}{1000 \times 1.27}$$

$$= 2.80 \text{ cm}$$

MS flat of 1/2" (1.27 cm) thickness and 1½" (3.81 cm) width is used.

Member 3

Load is applied on number 3 by outer forming board only.

Maximum load causing bending moment = 23.18 kg

Maximum bending moment occurs at the junction point with member 2

Maximum distance to the junction point = 20 cm

Maximum bending moment = 23.18 x 20

$$= 463.60 \text{ kg cm}$$

Width of 3/8" (0.9525 cm) thick MS flat required, b

$$= \frac{6 \times 463.60}{1000 \times 0.9525}$$

$$= 1.71 \text{ cm}$$

MS flat of 3/8" (0.9525 cm) thickness and 1¼" (3.175 cm) width is used.

Member 4

Load is applied on member 4 by inner forming board only.

Load causing bending moment = 49.20 kg

Maximum bending moment occurs at the junction point with member 6.

Maximum distance	=	25 cm
Maximum bending moment	=	49.20 x 25
	=	1220 kg cm

Width of 3/8" (0.9525 cm) MS flat required, b

$$= \frac{1230 \times 6}{1000 \times 0.9525}$$

$$= 2.78 \text{ cm}$$

MS flat of 3/8" (0.9525 cm) thickness and 1¼" (3.175 cm) width is used.

Member 5

Load is applied by outer forming board only on this member.

Load causing bending moment = 23.18 kg

Maximum distance to centre = 52 cm

Maximum bending moment = 23.18 x 52

= 1205.36 kg cm

Width of 3/8" (0.9525 cm) thick MS flat required, b

$$= \frac{1205.36 \times 6}{1000 \times 0.9525}$$

= 2.76 cm

MS flat of 3/8" (0.9525 cm) thickness and 1½" (3.81 cm) width is used.

Member 6

This member connects all other members and forms the backbone of the main frame, with member 7. This member partly carries the weight of the implement and also experiences bending moments due to the soil resistance transmitted through other members. The front hitch of the hitch beam is attached to this member. The exact direction and magnitudes of loads on this member. The exact direction and magnitudes of loads on this member is therefore uncertain. Hence, MS flat of 3/8" (0.9525 cm) thickness and 1½" (3.81 cm) width is used for this member.

Member 7

This member provides additional reinforcement to the main frame. MS flat of 3/8" (0.9525 cm) thickness and 1¼" (3.175 cm) width is used for this member.

Appendix V

Calculation of operating cost of power tiller operated Bed former

Investment cost of the bed former	= Rs.2000.00
Working hours per year	= 250
Average life in years	= 10
Salvage value (10% of the Investment cost)	= Rs.200.00

1. Fixed cost per hour

Depreciation/hr $= \frac{P-S}{L}$

$= \frac{2000-200}{2500}$ = Rs.0.72

Interest on average investment/hr $= \frac{P+S}{2} \times \frac{12}{100} \times \frac{1}{250}$

= Rs.0.528

Total fixed cost/hr = Rs.1.248

2. Variable cost per hour

Power tiller hire charge (@ Rs.70.00 per hr) = Rs.70.00

(Wages for the power tiller operator is included in the power tiller hire charges)

Wages for additional operator @ Rs.40.00 $= \frac{40}{8}$

Rs.5.00

Appendix IV

Cost of production of Bed former

a. Materials

		Rs.Ps.
Cost of 25 kg MS flat	=	360.00
Cost of 25 kg MS sheet	=	400.00
Cost of trolley wheels (2 nos.)	=	200.00
Cost of 2" MS pipe 3 m	=	200.00
Cost of 1¼" MS pipe 2 m	=	100.00
Ccst of 1" MS pipe 3 m	=	110.00
Cost of 7 kg 1" MS rod	=	80.00
Cost of nuts and bolts	=	50.00
Cost of paints	=	50.00
Total (a)	=	1550.00

b. Total fabrication charges	=	400.00
c. Over head charges	=	50.00
Total production cost (a+b+c)	=	2000.00

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(Wages for the power tiller operator is included in the power tiller hire charges)

Wages for additional operator @ Rs.40.00 $= \frac{40}{8}$

= Rs.5.00

Repair and maintenance charges per hour
(@ 4% of the original price per year)

$$= 2000 \times \frac{4}{100} \times \frac{1}{250}$$

= Rs.0.32

Total variable cost per hour

= 70.00 + 5.00 + 0.32

= Rs.75.32

3. Total operating cost per hour

= 1.24 + 75.32

= Rs.76.568

Say Rs.77.00

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Appendix VI

Cost of manual operation for seed bed preparation

(Bed formation only)

Area covered by a single man for seed bed preparation per day	=	200 m^2
Man days for covering 1 ha	=	50
Labour cost for 1 ha bed formation @ Rs.45.00 per day	=	Rs. 50 x 45
	=	Rs.2250.00

Appendix VII

Specification of power tiller

Make	:	Kubota
Model	:	ER 90 Engine
Horse Power	:	9 continuous
	:	12 maximum
Engine revolution	:	2000 rpm
Type of engine	:	Single cylinder, 4 stroke, horizontal, diesel
Total weight of tiller	:	485 kgs
Overall length x width x height of tiller	:	225 x 82 x 103
Diesel consumption	:	1.25 x 1.5 lit/hr
Fuel tank capacity	:	12 lit.
Tyres	:	6.00 x 12 power tiller
Minimum ground clearance	:	203 mm
Number of speeds	:	Forward 6 Reverse 2
Minimum forward speed	:	1.5 kmph

Appendix VIII

Specification of dynamometer

(i) Hydraulic dynamometer

Make	:	Scientific, India
Range	:	0-28 kg/cm^2
		0-400 lb/in^2
Least count	:	0.8 kg/cm^2
		10 lb/in^2
Inside diameter	:	28 mm
Outside diameter	:	47 mm
Stroke length	:	50 mm

(ii) Spring dynamometer

Make	:	Salter
Range	:	0-100 kgf
Least count	:	0.5 kgf

DESIGN, DEVELOPMENT AND EVALUATION OF A POWER TILLER OPERATED BED FORMER

By

SHAJI JAMES P.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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1991

ABSTRACT

A power tiller operated Bed Former was developed and evaluated. The main components of the prototype unit of the power tiller operated Bed Former are, a main frame, two pairs of forming boards, a levelling board, a hitching unit and a depth control cum transport wheel. The equipment was found capable of forming seed beds of heights 22 cm, 18 cm and 15 cm at a width range of 60-64 cm. Heights of 18 cm and 15 cm were possible at width ranges of 73-75 cm and 80-81 cm. The draft of the implement ranges from 115.59 kgf to 169.69 kgf. The power utilisation of the implement varies from 0.586 hp to 0.771 hp and the wheel slip between 46.76 per cent and 77.1 per cent. The mean effective field capacity of the implement is 0.0996 ha/hr and the mean field efficiency is 46.3 per cent. The total cost of production of the unit is Rs.2000/- and the cost of operation per hectare is Rs.777/-. The amount that can be saved by using the implement is Rs.1473/- per hectare.

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