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Design and evaluation of bullock drawn maize ridger for Chhattisgarh plain

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Abstract
In Chhattisgarh, maize is a *kharif* season crop and second most important crop next to paddy in terms of both area and production. Ridging of maize crop 30 day after sowing (DAS) is a very important operation as the major chunk of maize acreage of the state is rainfed. Maize ridging is conventionally done by manually which involves extensive labours compared to other operations, this result in higher cost of cultivation and required higher drudgery. There is a need to popularize low cost ridging technology which is suitable for small and medium farmer under stress environments. The crop, machine and operational parameters were identified and selected and the animal drawn maize ridger was developed and evaluated for its performance in actual field conditions. The ridge dimensions were optimized top width, bottom width and ridge height 12.75cm, 43.75cm and 16cm respectively with total volume of soil cover 452.31cm^3 considering plant height and row to row spacing. The average draft of the ridger 69.81 kg-f was observed during ridging operation. The field capacity of the maize ridger was 0.06ha/h with field efficiency of 74.46 percent. The cost of operation of maize ridger for ridging maize was found to be 1737.79 Rs/ha.

Keywords: Maize, ridger, ridging technology, Bullock

Introduction
Maize (*Zea mays* L.) is one of the world-leading cereal crops with the global area under cultivation of183Mha with a production of 1065 MT and productivity of 5.82 tonnes/ha in 2016-17. The United States and China are the largest maize producers followed by Brazil, Argentina, and India, respectively. In India, maize is the third most important cereal crop after rice and wheat, accounting for ~9% of total food grain production. It was cultivated in an area of 9.6 Mha during 2016-17 with a production of 26.00 MT and productivity of 2.71 tonnes/ha (Anonymous, 2017) [1]. Karnataka, Andhra Pradesh, Bihar, Madhya Pradesh, Rajasthan, Maharashtra, Tamil Nadu, Uttar Pradesh and Chhattisgarh are major maize growing states in India. Major sources of farm power include both animate (humans and draught animals) as well as inanimate sources such as diesel engines, tractors and electric motors. Bullock is one of the cheapest and oldest sources of draught power for all types of agricultural operation. Bullocks are mainly used for tillage and sowing operations. Though the population of draught animal is declining but still more than 50 percent net sown area is cultivated by animal power source. Chhattisgarh state of India, which has a large cultivable area, good natural resources, also has very large cattle population. These animals are small to medium size (250 to 450 kg) with a draught ability of 10 to 12 percent of their body weight (AICRP on UAE Report 2008). Most of the marginal and small farmers in this region depend on animal power for farm operations like tillage, sowing and threshing operations.
Khan *et al.* (2010) [5], Thakur *et al.* (2003) [4], Memon *et al*. (2011), Ranawat *et al.* [6] worked on maize tillage management and improves the crop condition as well as yield. **S**owing on ridge may provide better condition for aeration and also require less irrigation water. Labor scarcity delays these agricultural operations which has adverse effects on crop production. Therefore, there is a need to, mechanize the ridging operation of maize and other crops which will result in saving of time, money and labor. Thomas and Kaspar (1997) [] reported that improved understanding of maize (*Zea mays* L.) nodal root response to soil ridging is needed to allow farmers to maximize the benefits of ridge tillage systems. Birkas *et al.* (1998) [3] were carried out study in order to determine the effect of traditional and ridge tillage systems on soil

status yield and weed cover for three years. Ahmad *et al.* (2000) [2] were conducted a field study pertaining to different inter-tillage practices on maize. Ridging of maize crop is an essential operation 30 DAS. This prevents the plant from lodging with better stand ability. Moreover, it also provides anchorage of the lower whorls of adventitious roots above the soil level which then function as absorbing roots. Ridging improves yield but is labour intensive and it is done by hand with a hoe, spade etc. by farmers.

Materials and Methods

The Bullock drawn ridging equipment was designed with various features like provision to vary the spacing of the ridge width, suitable mechanism to maintain the depth of soil penetration to optimize the crop parameter to achieve the desired plant growth. Designs requiring machining processes were generally avoided so as to make the technology accessible to rural artisans and manufacturers, who normally do not have expensive machinery such as lathes and milling machines. No alloy steels were used, but mild steel, which is locally available were used for fabrication of the various parts of implement shown in Table: 1. unnecessary weight, which leads to added strain for the draught animals as well as for the user controlling the implement, was avoided. Enough clearance provided to allow proper ridging and weeding with already established crops up to knee height without plant damage. Adjustments were limited to the practical ones so as to keep the design as simple as possible and easy to use. Designs and technologies associated with high tooling costs, in particular machining, were avoided in order to keep the cost of production. In addition, the bolt sizes chosen were generally the same as those used on the animal drawn mould-board plough so as to avoid the acquisition of extra spanners.
The landside was made of MS plate iron of 5 mm thickness. The landside acts as one side of the wedge, which is formed with the share. It is a long flat metal piece welded to the edge of the frog. It helps to absorb side force caused when furrow slice is turned.

Table 1: Selection of material for various component of bullock drawn maize ridger

S. No.	Parts	Material	Size, mm
1	Frame	Angle Iron	35x35x5
2	Hitch	MS flat	40 x 5
3	Handle	MS flat	40 x 5
		MS pipe (Dia.)	30
4	Tyne	MS angle Iron	25x25x5
5	Furrow openers		
	a) Mould board	MS sheet	3
	b) Share	MS sheet	5
	c) Frog	MS sheet	3
	d) landside	MS flat	40 x 5
6	Beam	MS pipe	
		i. Dia.	60
		ii. length	3060

The plant height and row spacing were affected the performance of ridging operation which were considered for the design of the maize ridger. The unit was designed to ridging single rows of maize crop with adjustable spacing between two furrow openers (31.5 to 51cm). The machine offers the apparent advantage of timely ridging, weeding, saving of time, and labour costs and therefore, helps reducing the cost of production besides reducing the drudgery of the task. Considering the factors discussed above, an animal drawn maize ridger was developed with a set of functional components including Main frame, share, mould-board and landside-frog assembly. Ridges and furrows can be effectively formed by using animal drawn ridgers. The soil thrown by the wings of the ridgers covers the root and stem zone of the plants. Two opposite mould board bottoms were selected for the formation of ridger.

Constructional Details

The locally available suitable materials were used for the fabrication of different components of the adjustable animal drawn ridging implement. The main components of the adjustable animal drawn ridging implement are as follows:
Mainframe, Handle, Hitch and beam, Tyne, Share, Mould-board, Landside, Frog

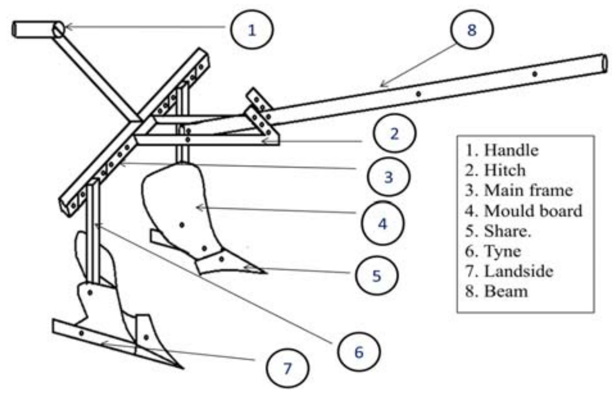

Fig 1: Orthographic view of Developed maize ridger

Design of frame for the ridger:

Draft (D) = Unit draft × cross sectional areas (1)
= Knab

Where,
K = Unit draft, kg/cm^2;
n = Number of bottom = 2;
a = Depth of ploughing, cm = 10 cm; and
b = Width of furrow slice, cm.

$$= \frac{(\text{Top width} + \text{Bottom width})}{2} = \frac{(11+3)}{2} = 7 \text{ cm}$$

For, medium soil K = 0.5 kg/cm^2

Hence, $D = 0.5 \times 2 \times 10 \times 7 = 70$ kgf

Assuming vertical component of pull = 25% for medium soil

$$V = 70 \times 0.25 = 17.5 \text{ kg}$$

Assume the weight of MB (W) = 5 kg × 2 = 10 kg
Weight of soil over MB surface = V-W = 17.5-10 = 7.5 kg
Total pull exerted by the machine is given by

$$P = \{D^2 + (V - W)^2\}^{1/2} \quad (2)$$
$$= \{70^2 + (17.5 - 10)^2\}^{1/2}$$
= 70.40 kg

Horizontal component of soil reaction (Rh) = Ph = D = 70 kg
Vertical component of pull (Pv) = V = 17.5 kg
Vertical component of soil reaction (Rv) = Pv-W = 17.5-10 = 7.5 kg
Rv × 48 - Rh × 48 + Rxx × 48 = 0 (let Rv act at 48cm)
Rx= 62.5 kg

$$\frac{S_s}{Y} = \frac{T_e}{I} \quad (3)$$

Ss = 250 kg assume

$$I = \frac{bd^3}{12} = \frac{d^4}{12}\ (as\ b = d) \quad (4)$$

$$I = \frac{d^4}{12} \times Y = \frac{d^4}{12}(d/2)$$

$$\frac{S_s}{Y} = \frac{P}{I}$$

$$\frac{I}{Y} = \frac{P}{S_s}$$

$$\frac{d^4/12}{d/2} = \frac{P}{S_s}$$

$$d^3 = \frac{6P}{S_s}$$

$$d^3 = \frac{6 \times 70.40}{350}$$

d = 1.06 cm

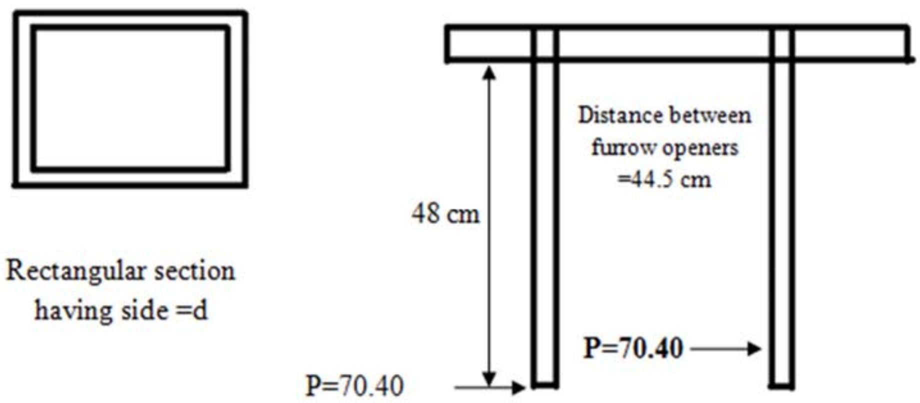

Fig 2: Calculation of Forces acting on frame

Taking factor of safety the d may be increased to 2.5 times and according to availability of material the angle iron having size 2.5 x 2.5 x 0.5 may be taken as square section.

Experimental Details

The field performance tests were carried out obtains actual data on overall implement performance and work capacity in the field. The field trials of animal drawn implements were conducted in the field of I.G.K.V., Raipur, which is situated at the south-eastern part of Chhattisgarh and lies between 21016'N latitude and 81036'E longitudes with an altitude of 298m above the mean sea level. The soil of the experimental field was clay loam in texture. The average initial bulk density and moisture content were observed as 1.85 t/m3 and 14.98% (db), respectively, for the depth of 0-150 mm.

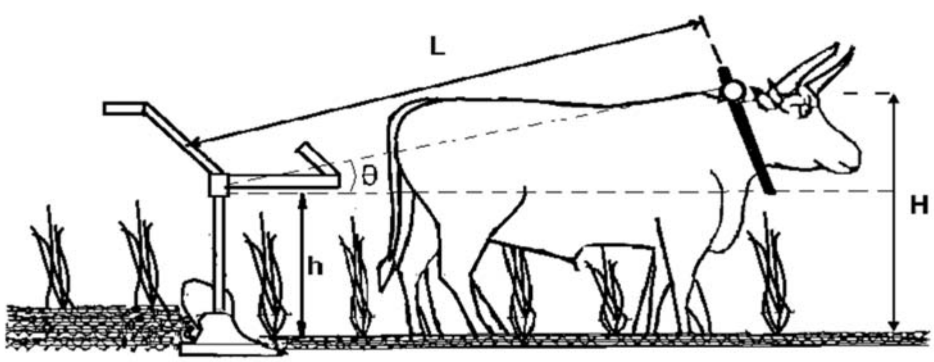

Fig 3: Functional requirement of developed maize ridger

Results and Discussion

The performance of designed and fabricated maize ridger was tested in the laboratory as well as in the actual field condition for maize crop, to examine the performance of maize ridger. A pair of bullock/buffalos was used to draw the implements throughout the experiment. During the field trial proper spacing between two furrows openers to obtain proper ridge dimensions with minimum plant damage through the implement were optimized. During field trail it was observed that higher ridge dimensions bottom width (43.5 cm), top width (12.75 cm), ridge height (16.88 cm) was obtained with T3 (inclined mould-board with 44.50 cm spacing between two furrow openers of developed ridger). The dimension of the ridge at various spacing and with different treatments were measured during field trial and presented in Table: 2 and suitable spacing for ridging was optimized.

Table: 2 Height, width and soil handled obtained by different types of mould board with different furrow spacing.

Parameter	T1=SMB*			T2=STMB**			T3=IMB***		
	Height, cm	Width, cm	Volume, cm^3	Height, cm	Width, cm	Volume, cm^3	Height, cm	Width, cm	Volume, cm^3
S1=31.50	12.5	30.63	239.48	13.88	30.88	267.34	17.63	30.75	347.54
S2=38.00	11.88	36.38	273.09	13.75	36.5	316.61	16.88	36.38	393.88
S3=44.50	11.13	43.38	335.12	13.25	43.63	373.59	16.88	43.5	482.48
S4=51.00	10.75	49.75	328.04	12.63	50.13	387.51	15.5	49.88	477.6
Mean	**11.56**	**40.03**	**293.93**	**13.38**	**40.28**	**336.26**	**16.72**	**40.13**	**425.37**

*SMB = Steep mould-board, **STMB = Standard mould-board, ***IMB = Inclined mould-board and S1 to S4 spacing of furrow openers in cm

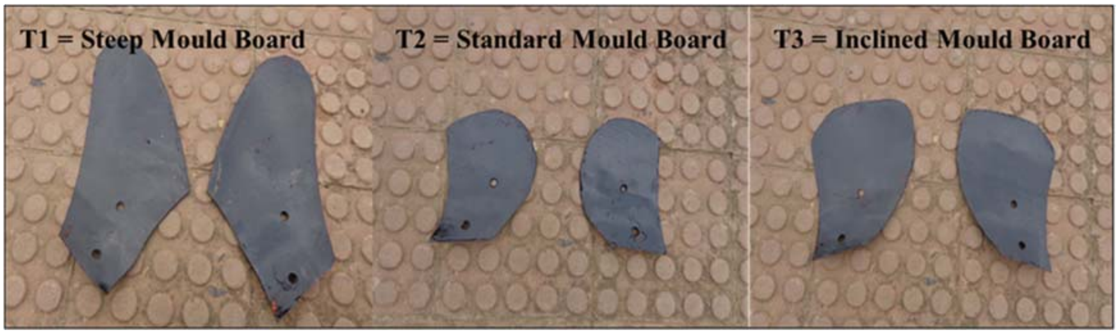

Fig. 4 Different types of mould board designed for optimization of developed maize ridger for ridging

Fig. 5 Field Test of developed maize ridger

The field test of developed ridger was carried out at an average plant height of 35.54 cm. The average moisture content at 2.5 to 20 cm depth was 16.69 % at dry basis, 14.30% at wet basis and the bulk density during trail was found to be 1.85t/m^3. The height of plant of maize crop, moisture content and bulk density of soil during ridging operation is presented in Table: 3.

The maximum theoretical field capacity was observed with S4–51cm (0.09 ha/h) followed by S3–44.5 cm (0.08 ha/h), S2–38 cm (0.07 ha/h) and S1–31.5 (0.05 ha/h) cm respectively. It was also observed that variation in effective field capacity of the developed ridger during field test with respect to different spacing. The maximum effective field capacity was observed with S4–51cm (0.06 ha/h) followed by S3–44.5 cm (0.060 ha/h), S2-38 cm (0.051 ha/h) and S1–31.5 (0.042 ha/h) cm respectively. The detailed data were shown in Table: 4.

Table: 3 Plant height, moisture content and bulk density of soil during testing

S .No.	Plant height, cm	Moisture content, % wb*	Moisture content, % db**	Bulk density, t/m^3
Range	34-38	13- 15.25	14.94-18.20	1.79-1.91
Mean	35.54	14.3	16.69	1.85
SD	25.70	32.42	7.18	0.043

*wb = wet basis, **db = dry basis

Table: 4 Field capacity and field efficiency of developed ridger at different spacing

Parameter	EFC- Effective field capacity	TFC- Theoretical field capacity	FE- Field efficiency
S1=31.50	0.04	0.05	72.49
S2=38.00	0.05	0.07	
S3=44.50	0.06	0.08	74.46
S4=51.00	0.07	0.09	74.74
Mean	0.05	0.07	73.87

Note- S1 to S= Spacing in cm

Table: 5 Draft and power requirement of developed ridger at different spacing

S. N	Parameters	Draft, kg-f	Power requirement, hp
1	S1=31.50	68.54	0.48
2	S2=38.00	69.12	0.48
3	S3=44.50	70.15	0.49
4	S4=51.00	71.42	0.5
5	Mean	69.81	0.49

The cost of operation of developed maize ridger was carried out as shown in Table: 6. The total cost of operation of developed bullock drawn maize ridger 30 DAS was found 1737.79 Rs/ha.

Table: 6: Cost of operation of developed maize ridger

S. No.	Particular	Maize ridger
1	Cost of machine, Rs	2960
2	Life of the machine (year)	5
3	Annual use (h)	240
4	Depreciation, Rs/year @10%	532.8
5	Interest, Rs/year @12%	195.36
Total (4+5)	Fixed cost (Rs/Year) annual use is 240 h	728.16
A	Fixed cost (Rs/h)	3.03
B	Operational cost	
1	Wage of 1 operator (200 Rs/day*), Rs/h	25
2	Hiring charges of bullock (300 Rs/day*), Rs/h	75
3	Repair and maintenance, Rs/h	1.23
Σ(1 to 3)	Total operational cost, Rs/h	101.23
(A+B)	Machinery cost, (Rs/h)	104.27
	Machine capacity	0.06
Total machinery cost in, (Rs/ha)		**1737.79**

*1 day i.e. 8 hour of work

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