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Draft Requirement of Bullock Drawn Mouldboard Ploughs in Sandy Loam Soil of Coastal Odisha

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ABSTRACT: Experiments were conducted in the soil bin to measure the draft requirements of four types of mouldboard ploughs namely CAET, downsize, implement factory and heavy soil mouldboard ploughs in sandy loam soil at two depths (10 and 15 cm) and two speeds (1.25 km/h and 2.0 km/h). The results indicated that ploughing depth had more pronounced effect on the draft of different ploughs than the forward speed. The down size OUAT MB plough was found suitable for a pair of bullocks of body weight of about 400-450 kg (small size bullocks) which can develop a draft of 400-450 N. The other three test ploughs were found suitable for the bullock pair with total body weight of about 700 kg (medium size bullocks) developing a draft of 600-650 N.

Key words: Draft bullock, mouldboard plough, tillage, sandy loam soil, soil bin

Tillage is an energy intensive farm operation consuming about 40% of the total energy input required for crop production (Yadav *et al*., 2006). Accurate knowledge of draft and energy requirement of different implements used for tillage is essential to select matching implements with available power sources and optimum operating conditions (Ademosun, 1990). The draft required for a given implement is also affected by the soil condition and the geometry of tillage implement (Olatunji *et al*., 2009), which is also a function of soil properties, working depth, travel speed and width of the implement (Manuwa, 2009; Naderloo *et al*., 2009). Lift angle of the mouldboard plough also significantly affects the mean draft requirement of the plough (Owende and Ward, 1999). The soil properties that influence tillage energy are moisture content, bulk density, soil texture and soil strength. The ASAE Standards (1999) describes tillage draft as a function of implement type, implement width, depth and speed. Therefore, draft is an important parameter to evaluate the performance of a specific tillage implement for energy requirement in order to select the matching power sources for its efficient operation.

Animal drawn mouldboard plough is one of the most prevailing primary tillage implements used in the Indian farms. The size of mouldboard plough varies from region to region as per the size of the local draft animals. In Odisha, various sizes of bullock drawn mouldboard ploughs are still being in use for tillage operation in majority of the cultivable land (Anonymous, 2008). The bullocks in the state of Odisha are mostly small (pair weight ranging from 300 to 500 kg) and medium (pair weight ranging from 501 to 700 kg) categories. Information on the draft requirement of tillage implements is limited. The lack of information compels the farmers to rely mostly on the past experience for selecting the correct size implements. The farmers' experience may be of little value in selecting the efficient tillage implement if accurate information on the draft requirement of specific tillage implement with respect to a particular farming situation, soil parameters and power sources is not available. Proper selection and use of appropriate matching equipment can enhance the effective utilization of the power source which is more important in general and particularly in case of draft power. Hence, considering draft as an important parameter, the present study was taken up.

Materials and Methods

The experiments for the study were conducted in the soil bin set up of the Department of Farm Machinery and Power, OUAT, Bhubaneswar, Odisha. The study was limited to sandy loam and soil moisture content (11-12% db) as well as normal soil resistance (800-1000 kPa) level which usually prevail in the field condition for operation of bullock drawn tillage implements. Four types of ploughs such as CAET plough, downsize OUAT mouldboard plough, implement factory plough and heavy soil ploughs were selected for the study on the basis of their use under different farming situations. The effects of speed and depth of operation of all four ploughs on their draft requirement were studied in the selected soil conditions during 2012.

Soil Bin

The experimental soil bin (as shown in Figure 1) comprised a stationary bin, a tool carrier to attach desired implement, soil processing trolley, power transmission system, control unit and data acquisition system for recording and display of the collected data in the computer. The bin was 15.0 m long, 1.8 m wide and 0.6 m deep. The two rails, one on top of each side of the bin wall were used for supporting the soil processing as well as implement trolleys. The test soil bed was of 12.0 m long and 1.2 m wide over which all test ploughs were operated for draft measurement. The soil processing trolley consisted of a frame, rotary tiller, leveling blade and roller for leveling and compacting the soil to obtain the desired soil strength. A water sprayer provided in the processing trolley was used to apply water on the soil to maintain the desired average moisture level. Different speeds of operation were obtained by choosing suitable gear of a gear reduction unit coupled with the input shaft of the revolving drum, which was attached to the soil processing trolley with stainless steel rope. A control unit placed outside the soil bin controlled the direction of movement of the soil processing trolley. The testing implement was mounted on the frame of the implement trolley where screw jack arrangements were provided to vary the depth of operation.

The test trolley consisted of an extended octagonal ring transducer (EORT) of 1000 N capacity for draft measurement, cone penetrometer with 1 kN load cell with cone diameter of 19 mm for measuring soil resistance and a linear voltage displacement transducer with linear displacement range of 0-200 mm. The data acquisition was done by using HBM Spider 8 data logger with provision for 8 channels recorder.

Soil description and soil bed preparation

Experiments were conducted under controlled conditions in a sandy loam soil (Table 1). The soil was collected from one of the fallow agricultural lands of the Central Farm of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha. To get similar condition of field soil in the laboratory, the collected soil from the farm was filled in the bin up to a depth of 0.6 m with separation in layers of 15 cm each. Each layer of soil in the bin was compacted with roller to achieve similar bulk density as prevailed in the field condition.

Before starting the experiments, the soil bed was prepared to achieve the desired cone index and bulk density. In order to get this, the tiller was initially used to pulverize the soil after spraying water to achieve the required moisture content. Then the soil was leveled with the leveling blade and compacted by the roller to the desired cone index and bulk density in each layer. At the end of each soil preparation, soil cone penetrometer provided in the soil bin set up was used for measuring the soil resistance to a depth of 15 cm in three locations in the soil bin at the interval of 2.5 m, following the procedures outlined in the ASAE Standards (ASAE, 2000).

Test ploughs

The description of mouldboard ploughs selected for the test and their front as well as side views are presented in Table 2 and Figure 2, respectively. These are all right turning ploughs and bullock drawn tillage implements. The width of cut at a particular depth was measured between the projected horizontal distance of the two extreme points at the frontal plane by keeping it in the horizontal position at that depth. Similarly, the depth of operation of test ploughs was maintained by moving the plough bottom up and down along with extended octagonal ring transducer (EORT) and noting the vertical distance with the help of a measuring scale provided in the test trolley.

Experimental layout

The experiment for each tillage implement in a sandy loam soil was conducted with the moisture contents maintaining within 11 to 12% db. Soil strengths were maintained between 800 to 1000 kPa. Two speeds of operation (1.25 km/h and 2.0 km/h) and two depths (10 and 15 cm) were selected for the study except for downsize OUAT mouldboard plough which was tested at only 10 cm as it could not be used beyond 10 cm depth because of its size. After maintaining the desired moisture level and soil strength in the soil bin and fixing the required depth, the implement was moved at a particular speed by selecting the proper gear and keeping the pulling arm horizontal to the soil bed. With the help of the calibrated EORT, the data for draft of test implement were continuously acquired in the data acquisition system. Simultaneously, the time to cover a fixed distance of 10 m was recorded using a mechanical stop watch to calculate the speed of operation.

Results and Discussion

Calibration of extended octagonal ring transducer (EORT)

The EORT was calibrated by applying known weights and recording of respective electrical strains in the data logger. A graph was plotted between the electrical strains and known weights and from the curve, the calibration equation was developed (Figure 3). From the graph between the electrical strain and the load on the EORT, it was observed that the straight line curve represented best fit with high value of coefficient of determination (R^2) 0.9987 which could be satisfactorily used to determine the draft experienced on the test ploughs at various operational conditions.

Effect of depth on the draft requirement

The drafts observed at two depths (10 and 15 cm) and at two different speeds (1.25 and 2.0 km/h) are presented in Table 3. The draft requirement of the downsize OUAT MB plough was minimum among all ploughs but it could be used only up to 10 cm depth due to its size. Among the other three ploughs, the draft requirement of heavy soil plough was least at both the speeds and depths. The increase in draft requirement at 15 cm depth compared to that at 10 cm depth was found to be 11.9% for CAET plough, 11.4% for implement factory plough, and 16.3% for heavy soil plough at speed of 1.25 km/h. Similarly, the increase in draft requirement was 6.7% for CAET plough, 6.7% for implement factory plough and 11.9% for heavy soil plough at speed of 2.0 km/h. Lower draft requirement for heavy soil plough might be attributed to the least value of lift angle compared to the other two ploughs. The increase in the draft requirement of tillage implements with the increase in depth and speed of operation might be because of the higher soil resistance and more volume of soil handled at higher depth and higher force required accomplishing the soil acceleration at a higher speed of operation (Manuwa, 2009).

Effect of speed of operation on the draft requirement

The draft requirement increased with increase in speed of operation from 1.25 km/h to 2 km/h. This was mainly because of acceleration of the soil. Accelerated soil exerts more reaction force on the plough resulting in more draft requirement. The increase in draft at 10 cm depth was found to be 10.4% for CAET plough, 6.4% for downsize OUAT MB plough, 7.1% for implement factory plough and 9.8% for heavy soil plough at 2.0 km/h compared to 1.25 km/h speed. However, the increase in draft requirement at 15 cm depth was found to be 5.3% for CAET plough, 2. 6% for implement factory plough and 5.6% for heavy soil plough at 2.0 km/h compared to 1.25 km/h. The above results could be attributed to the fact that the downsize OUAT MB plough was the smallest plough in dimension and among the other three ploughs, the lift angle was minimum (16.7^0) in case of heavy soil plough. Higher lift angle in case of implement factory plough lifts the cut furrow to greater heights thereby increasing the draft requirement.

Obviously, the effect of depth of operation had more pronounced effect on the draft requirement than that of speed. The draft requirement increased in the range of 6.7% to 16.3% when the depth was increased from 10 to 15 cm, compared to that of 2. 6% to 10.4% when the speed was increased from 1.25 km/h to 2 km/h for the test ploughs (Sahu and Raheman, 2006).

Table 1 : Physico-chemical properties of soil used for the study

Parameters	Value
Particle size distribution	
Sand (%)	81.24
Silt (%)	7.80
Clay (%)	10.96
Textural class	Sandy loam
Physical properties	
Bulk density (g/cm^3)	1.54
Particle density (g/cm^3)	2.63
Chemical properties	
Organic matter (%)	0.935
Organic carbon (%)	0.56
Available N (kg/ha)	295
Available P_2O_5 (kg/ha)	20
Available K_2O (kg/ha)	150
pH	5.1

Fig. 1 : Experimental soil bin

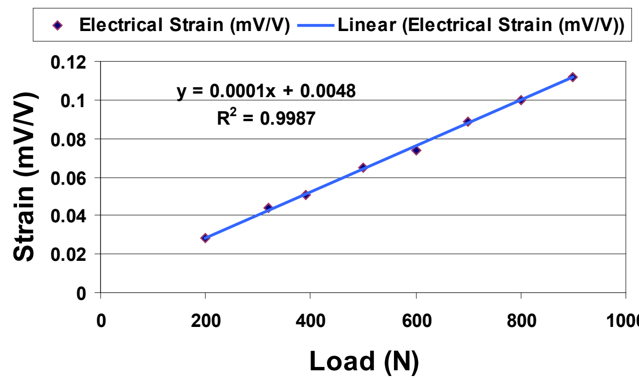

Fig. 3 : Calibration curve of the EORT

Table 2 : Specifications of four types of mouldboard ploughs

Plough	Width of cut (mm) at different depths		Plough height (mm)	Plough length (mm)	Lift angle (degree)	Weight of plough bottom (kg)
	10 cm	15 cm				
CAET plough	195	205	210	377	19.8	4.1
Down size OUAT MB plough	175	-	135	340	10.8	3.5
Implement factory plough	168	175	240	328	21.8	3.6
Heavy soil plough	175	190	230	355	16.7	5.7

Table 3 : Draft requirements (N) of test ploughs with the change of depth and speed of operation

Plough	Speed (1.25 km/h)			Speed (2.0 km/h)		
	Depth 10 cm	Depth 15 cm	% increase	Depth 10 cm	Depth 15 cm	% increase
CAET plough	564.9	632.0	11.9	623.6	665.6	6.7
Down size OUAT MB plough	397.0	-	-	422.2	-	-
Implement factory plough	590.0	657.2	11.4	632.0	674.0	6.7
Heavy soil plough	514.5	598.4	16.3	564.9	632.0	11.9

Front view Side view

CAET mouldboard plough

Front view Side view

Down size OUAT mouldboard plough

Front view Side view

Implement factory mouldboard plough

Front view Side view

Heavy soil mouldboard plough

Fig. 2 : Types of mouldboard ploughs used for study

Conclusions

The draft requirement of downsize OUAT MB plough was found to be 397 N and 422.2 N at the operating speed of 1.25 and 2 km/h, respectively at 10 cm depth of operation. Hence, the downsize OUAT MB plough is suitable for a pair of bullocks of body weight of about 400-450 kg (small size bullocks) which can develop a draft of 400-450 N. The other three test ploughs are found suitable for the bullock pair with body weight of about 700 kg (medium size bullocks) developing a draft of 600-650 N.

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