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Adaptation and Performance Evaluation of Animal Drawn Disc Harrow

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Abstract: *Animal traction has not been widely adopted by Ethiopian farmers despite the fact that it is an appropriate technology that can be used to increase agricultural production. One of the reasons for limited use of animal power is the lack of appropriate implements. The objective of this work was, therefore, to design, construct and evaluate a single-acting animal-drawn disc harrow. The harrow consisted of several components fastened together into a unit which could be easily dismantled if necessary. The main parts were the frame; two gangs of three discs, three pneumatic transporting wheels. The total mass of the implement was found to be 100 kg. A well-trained pair of oxen where used to pull the implement during the experiment. The observed data for MMD of seed bed was 10.32 mm. The average theoretical and effective field capacities of the implement were 0.221 ha/h and 0.182 ha/h at a forward speed of 1.85 km/hrespectively. The field efficiency of the implement was found to be 82.21%.*

Keywords: -Disk harrow, soil physical properties, effective field capacity and field efficiency.

1. Introduction

Draft animals can offer farmers advantage of lowinitial investment in farm motive power compared to thepurchase of even relatively small tractor. The firstoperation a farmer has to undertake in growing a crop is touse soil-engaging implement to prepare the land.World-wide, there are an estimated 400 milliondraft animals being used for agricultural operations(Barwell and Ayre, 1982). A review by Mrema andMrema (1993) of the utilization of draft animal power insub-saharan Africa showed that of the 11.3 million draftoxen in use, nearly 80% are found in five countries -Ethiopia (53%), Zimbabwe (7.1%), Kenya (6.2%) andTanzania and Uganda each with 5.3%.

Soil tillage is considered to be one of the important processes affecting of physical and mechanical properties of soil that affect the crop yield and quality(Keshavarzpour and Rashidi, 2008). Tillage method affects the sustainable use of soil resources through its influence on soil properties. Therefore, to insure a good preparation of soil must use primary tillage implements such as moldboard plow and after that use secondary tillage implements such as disk harrow, thereby creating a desirable soil condition for seed germination and growth through improvement the pulverization of soil (Ati*et al*., 2014).

The choice of mechanical, animal or manual power for any work depends up on relative cost of power for doing unit of work for the particular type under consideration. The popular animal-drawn implements available to the Ethiopian farmer are the ARDU plough and spike tooth harrow. The ARDU plough used for primary tillage and spike tooth harrow for secondary tillage implement.However, the use of draught animal needs to be diversified to include more farm operations, additional implements such as disc harrows need to be developed. The disc harrow is extremely useful in pulverizing soil and chopping weeds and trash.

Conventional tillage practices modify soil structure by changing its properties such as soil bulk density, porosity, soil penetration resistance and mean weight diameter (MWD) (Osunbitan*et al*., 2005). The use of tractors in most Ethiopian farm is very limited due to fragmented farmlands and scattered units, farmers find it uneconomical to engage tractor services. Hence, animal traction will be promoted in the farming system; it would contribute positively to agricultural development in the country.

Even though a lot of works has been conducted on the draught ability of bullocks all over the world, there is no information on animal drawn disc harrows in Ethiopia. Therefore, this research project was initiated with the objective of adaptation and evaluation of animal drawn disc harrow under farmer's field condition.

2. Materials and Methods

This section deals with the materials and methods employed for development of animal drawn disc harrow. The workshop facilities of the center were used for implement fabrication. The materials used to develop the harrow and equipment used to test the developed disc harrow should be discussed under respective title.

2.1. Description of the implement

A single-acting disc harrow was developed and constructed to be drawn by a pair of oxen and ensure timeliness in seed bed preparation. The developed disc harrow shown in Figure 1consists of several components fastened together into a unit, which could be easily dismantled, if necessary. The main parts of the frame, two gangs of three discs and depth control wheels. The components and sizes of the materials used were selected based on locally available and affordability.

Figure 1 animal drawn disc harrow

2.2. Construction of the disc harrow

The frame that supports all the components of the implement was constructed from mild steel and forming a T-shaped beam. The two gangs were consisting of four standard plain discs were mounted in series on a shaft. The gangs were attached to the frame of the harrow legs which carried the bearing housing. Each leg was constructed from an angle iron.Three pneumatic wheels were provided, two of which was attached at the front and one at the rear. The rear wheel was mounted to the implement in such a way that lifted up or lowered down depending on depth to operate the harrow. The disc can be above the ground during transport. All other components of the harrow were also made of mild steel.

2.2.1. Hitch and beam

The harrow would be operated parallel to the ground level by a pair of oxen of any height; a circular wood (80 mm dia.) beam was pinned at its end with yoke miran by pin. The height of yoke miran would be adjusted by lengthening or shortening miran.

2.3. Estimating the weight of the disc harrow

In order to design tillage implements for animal draught, it is necessary to know or estimate the total weight so that it will not exceed the capability of the animal's pulling power and to perform the expected work. Mckyes (1985) and Ajit*et al*. (1993) reported that the draught force of a standard harrow on a sandy loam soil is:-

$$N = 7.8 \times M \quad (1)$$

$$M = \frac{N}{7.8} \quad (2)$$

Where: -N = draught in N

M = mass of implement in kg.

The draught ability of oxen is about 10 to 12 percent of their body weight (Patrick and Frank, 1995).The designed harrow was pulled by a pair of oxen of an average weight of 9kN. Ten to twelve percent of a pair of bulls weighing 9kN is 0.9kN to 1.080kN. Therefore, from Equation 2.

$$M = \frac{900}{7.8} to \frac{1080}{7.8} = 115 to 138 kg$$

The total weight of implement should, be less than 138 kg for the animals to pull it successfully.

2.4. Performance Test of Developed Disc Harrow

Field performance tests were carried out to obtain actual overall implement performance data and working capacity in the field. The field performance test of animal drawn implements was conducted at Arsi Zone of DodotaWoreda on farmer's field during the rainy season in June of 2021. The performance evaluations of the disc harrow were conducted by FAO (1994) performance parameter of weed destruction, implement field capacity, efficiencyand pulverization index (PI). The following parameters were taken during the field test.

2.4.1. Soil moisture of content

Moisture content (%) on dry basis of the soil was measured by oven dry method. The soil samples from three different locations within a plot were taken at 0 to 15 cm. depth from the surface of soil using core samples 80 mm in diameter and 100 mm in length. The collected soil samples from each location were weighed initially and then kept in an oven for 24 hours at 105ºC for obtaining dry weight of soil. The moisture content was calculated as follows:

$$Moisture content (\% db) = \frac{W_1 - W_2}{W_2} \times 100 \quad (3)$$

Where, W1 = Wet mass of soil, g

W2 = Dry mass of soil, g

2.4.2. Bulk density

The soil samples were collected at depth levels of 0 to 15 cm. before operation. The sample initially weighted before placing into an oven for 8 hours at 105°C. After drying weight of sample are again measured. Bulk density was determined by the following equation (FAO, 1994).

$$\rho = \frac{M}{\pi R^2 L} \qquad 4$$

Where,

M = Mass of the dried sample, g

R = Radius (internal) of cylinder

L= Length of cylindrical sample corrected for any loss of soil as above.

ρ = Bulk density of soil, g / cm3.

2.4.3. Forward speed

Within the experimental plot five random samples were taken to calculate average working speed. The time required to travel the distance of 20 m was recorded and the speed of operation was calculated.

2.4.4. Theoretical field capacity, effective field capacity and field efficiency

The theoretical field capacity is rate of field coverage that would be obtained if the disc harrow was operating continuously without interruptions like turning at the ends and other obstacles. The effective field capacity is the actual average rate of coverage including the time lost in turning at the ends. Theoretical field capacity, effective field capacity and field efficiency were computed by using the following formula (FAO, 1994):-

$$T_C = W_m \times S_m \times 0.0036 \qquad 5$$

$$C_e = \frac{Total\ area cultivated (ha)}{Total\ field time (hr)} \qquad 6$$

$$\eta = \frac{C_e}{T_C} \times 100 \qquad 7$$

Where:-T_C = Theoretical field capacity (ha/h)

W_m = Mean working width (cm)

S_m = mean speed (m/s)

η = Field Efficiency of the implements %

Ce= Effective field capacity, ha/h.

2.4.5. Pulverization index (PI)

To determine the pulverization index, soil samples were taken randomly from the experimental plots of (20 × 20 cm), after disc harrow operationwas completed clod size distribution was determined by sieve analysis, from a representative area 50 cm x 50 cm of the harrowed soil. The soil samples were allowed to air dry at room temperature for twenty days and sieved using a set of (50, 40, 30, 20 and 10) mm. The sieve set was well shaken and the weight of the material retained on each sieve was recorded.The following expression was used to calculatepulverization index (PI): Aday*et al.* (2001).

$$PI = \frac{\sum_{i=1}^{n} Wi \times di}{W_{total}} \qquad 8$$

$$di = \frac{1}{2}\left(d_i + d_{i+1}\right) \qquad 9$$

Where:

PI = Pulverization index (mm)

Wi= The mass of the soil obtained between two sieve openings *di* and *di+1*

W_{total}= Weight of the total mass

n = Number of sieves

*di*willbe calculated using the following equation:-

3. Result and Discussion

Animal drawn disc harrow was designed and fabricated. The performance of developed implement was evaluated in the field. The mean values ofsoil moisture content and bulk density, width of cut, depth of cut and operation speed are discussed in this chapter respectively.

3.1. Physical Properties of Soil of Experimental Site

3.1.1. Moisture Content and Bulk Density of Soil

Moisture content on dry basis of soil was measured by oven dry method five soil samples were taken randomly at 5 different depths from surface of soil using core sampler of 8.0 cm diameter and 10cm height. The soil conditions of the experimental field were studied and different parameters were calculated and presented in (Table: 1). The soil of the field was loam and clay sandy loam soil. The results (Table 1) revealed that the average moisture content is as recorded at 0 to 15 cm depth was 17.08%.

Table 1. Moisture content and bulk density of soil

Sample No.	Mass of Wet Soil (gm)	Mass of Dry Soil (gm)	Soil Moisture Content (%)		Bulk Density (g/cm³)
			%Wb	**%Db**	
1	800	661	17.38	21.03	1.32
2	793	657	17.15	20.70	1.31
3	807	671	16.85	20.27	1.34
4	805	668	17.02	20.51	1.33
5	806	669	17.00	20.48	1.33
Average	**802.2**	**665.2**	**17.08**	**20.60**	**1.33**

The mean data on soil density after operations at 0 to 15 cm depth are recorded and presented in Table 1. Average values of bulk density were observed as 1.33g/cm³ for experimental field. Average value of moisture content and bulk density of experimented plot was found 17.08% (Wb) and 1.33 g/cm³ respectively.

3.2. Pulverization Index (PI)

The clod mean-mass-diameter is an index for indirect measurement of tilth of soil. One kg of soil sample was collected and passed it through a different set of sieves with the aperture size 50, 40, 30, 20 and 10 mm. The sieve set was well shaken and the weight of the material retained on each sieve was weighed. The values of pulverization index (PI) were shown in table (2). The observed data for MMD of seed bed was 10.32 mm. It has been indicated that soil aggregates of size 12 to 14 mm in the final seedbed are adequate for sowing crops. This result is in agreement with the findings of Singh *et. al.,* 2002.

Table 2. Mean mass diameter of soil clods

Sieve Opening Size (mm)	**Individual Mass Retained on Each Sieve (*Sx*)**	**% returned on sieve**	**Cumulative % Retained**	**Total Percent Passing (% finer)**
50	332.16	33.22	33.22	66.78
40	59.78	5.98	39.20	60.80
30	83.06	8.31	47.50	52.50
20	99.26	9.93	57.44	42.56
10	71.72	7.17	64.61	35.39
Pan	354.02	35.40	100	

3.3. Field capacity and field efficiency

The field capacity and field efficiency was calculated for animal drawn disc harrow using standard methodology described earlier and results are presented in Table 3. The mean theoretical field capacity was determined as 0.221 ha/h, whereas the actual field capacity of planter was found to be 0.182 ha/h. From the actual and theoretical field capacity the field efficiency of the animal drawn disc harrow was found to be 82.21%.

Table 3: Effective Field capacity and field efficiency of animal drawn disc harrow

Sample No.	**Operating Speed km/h**	**TFC, ha/h**	**EFC, ha/h**	**Field efficiency, %**
1	1.85	0.222	0.183	82.43
2	1.87	0.224	0.186	83.17
3	1.84	0.221	0.181	82.06
4	1.81	0.217	0.175	80.57
5	1.86	0.223	0.185	82.80
Average	**1.85**	**0.221**	**0.182**	**82.21**

3.4. Summery and recommendations

3.4.1. Summery

An animal-drawn disc harrow was designed and constructed to operate at various depths and disc angles. Materials that are readily available were used in its construction. The implement was found to have total weight of 100 kg with a working width of 1 m. The observed data for MMD of seed bed was 10.32 mm. The average theoretical and effective field capacities of the implement were 0.221 ha/h and 0.182 ha/h respectively. The field efficiency of the implement was found to be 82.21%. In general, the disk harrow has shown better results with respect to quality of work. It breaks the clods properly and results in optimum value of clod MWD (10.32 mm) which is preferable for seed bed preparation for sandy loam soil type.

3.4.2. Recommendations

Based on the result obtained from the field test, the following recommendations are made to improve the working efficiency of the implement:

1) Provision should be made to vary the number of discs used to accommodate the variation in the type and size of animals used.

2) It has been suggested to use the disk harrow for seedbed preparationon a sandy loam soil.

3) The implement was tested only on a sandy loam soil. Therefore, it is recommended that it should be tested on other soils.

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