Draft Requirement of Two Animal-Drawn Institute for Agricultural Research (IAR) Weeders

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Draft requirements of two animal-drawn (IAR) weeders operating on loam soil were determined in the study. The implements include a straddle row weeder and an emcot attached rotary weeder evaluated under the same soil conditions, using a pair of white Fulani breed of oxen. The animal draft requirement was first estimated from the animal ergonomics measurements. Using area of 0.054 hectare as experimental plot for each implement the draft requirement of each implement was investigated after taking soil samples for soil moisture content and bulk density determinations. The implements tested showed variation in their average draft requirement. The straddle row weeder had the highest value of 338.15 N respectively while the emcot attached rotary weeder had the lowest value of 188.12 N with 47.03%, respectively. The average soil moisture contents and bulk density were 13.0% and 1.46%/cm³, respectively.

Keywords: Draft; requirement; animal – drawn; IAR; weeders.

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1. INTRODUCTION

Several types of animal draft are used in Nigeria, the most important being the bulls. The white Fulani, Sokoto Gudali and Zebu are the main breeds of cattle employed for traction in northern Nigeria [1,2,3]. Oxen power is relatively cheap compared to alternative farm power from machine, and as the cheapest source of power on the farm draft animal offer farmers advantage of low initial investment in farm motive power compared to the purchase of even relatively small tractor [4]. World – wide an estimated 400 million draft animals are being used for agricultural operations [5,6].

Mrnma [7] reported the utilization of draft animal power in sub-Sahara Africa showed 0.3 Million draft oxen in use, nearly 80% are found in five countries in Africa: Ethiopia (53%), Zimbabwe (7.1%), Kenya (6.2%), Tanzania and Uganda each with 5.3%. Nigeria has a population of approximately 200 million people with an annual growth rate of 6.4%. Almost 80% of the population live in rural areas, earning their living from agriculture on cultivated areas of 8.75 million hectares, of which 5.5% is cultivated using draft animal power. 8.5% using tractor power and the remaining 86% manual labour [8]. Work bulls develop up to 0.4 kW of power for continuous work, which is about five times the human work capacity [9].

Kawuyo, et al. [4] stated that before the introduction of the farm tractor in Nigeria, animal power was already famous among farming communities. In Nigeria the use of animal power is mainly restricted to soil tillage and transportation using different types of implements such as ploughs, harrows, ridges and carts. In addition to oxen, cattle, horses, mules and donkeys are the most commonly used draft animals [10]. Draft and power requirement are important parameters for measuring and evaluating the performance of tillage implements and therefore are considered as essential data when attempting to correctly match tillage implement to a tractor or to animal traction. Many studies have been conducted to measure draft and power requirements of tillage at various soil conditions [11,12]. Animal power is appropriate and sufficient to most needs and in many farming activities particularly in developing countries like Nigeria [13,14]. The need to increase power in Nigerian agriculture to supplement and replace human (manual) labour has been recognised. This has led to the introduction of both animal and mechanical sources of power to boost agricultural production [1,15,16]. Nigerian government has continued to gain acceptance in the used of animal traction technology over the used of agricultural tractors. These is because of the challenges associated with it such as lack of skilled operators and maintenance personal, lack of repairs of suitable implements and spare parts, problem of farm land fragmentation and repairs costs of the tractors may be as high as 1.6 times the purchase price of the tractor. Over 2 million farmers spread across 36 state of the federation are actively involved in the use of animal traction [17].

Factors that are favourable to the use of animals on the farm include:

i. Agricultural labour is easily available;
ii. Adequate draft animals are available in the country;
iii. Little or no foreign exchange in involved due to inflations;
iv. Low initial investment;
v. Little repairs and maintenance of technical knowledge;
vi. Serves as mean of employment.

Because of the above reasons, animal power with its corresponding implements remains the main and best alternative power source as an intermediate technology to attain a sustainable situation and enhance the economic development of any country like Nigeria [13]. Abubakar and Ahmad, [1] attributed the reasons for the frequent breakdown of tractor systems to poor quality of fuel and lubrication use, seasonal nature of tractor use and lack of proper preventive maintenance. In developing countries like Nigeria the most viable alternative to the use of mechanical power is animal power supplied by oxen.

The objectives of this study were to:-

i. Estimate the power output of two pair of work bulls, white Fulani breed;
ii. Evaluate the draft requirement of two animal – drawn IAR rotary weeders.

2. MATERIALS AND METHODS

2.1 Experimental Site

The test was conducted at Institute for Agricultural Research, Ahmadu Bello University experimental site in Samaru – Zaria, located at
Latitude N11°11' and longitude E7°38'. The altitude is 689 m above the mean sea level. The region is considered to be within the Northern guinea savannah ecological zone while the climate is described as semi-arid [18]. The experiment was conducted during 2007/2008 irrigation season, spanning the months of February to April. The study was designed to utilize the irrigation season at the Irrigation Research Farm.

2.2 Field Layout and Experimental Design

The experimental field size was 0.054 hectare with dimensions 60 × 9 m. The site was divided into four blocks. The dimension of each block was 20 × 2.25 m. Each block was further divided into 14 ridges in equal parts, the sides of each ridge (60 × 0.75 m) planted with maize. The four blocks were separated from each other a distance of 0.75 m apart. The test was carried-out in ridge type of cultivation. The plot was ploughed, harrowed and finally prepared into ridge on the field layout.

2.3 Devices Used for Data Collection

Measuring devices were used in carrying out the test. These include measuring tape; stop watch, digital dynamometer, weighing balance, sample cane (container for collecting sample), core sampler and pegs for plot demarcation.

2.4 Field Evaluation

The work bulls used for the field evaluation were of age 9-9.5 years and are white Fulani breed which is the most widely distributed type throughout Northern Nigeria. They are white in colour with medium horns curving outward and upwards from the head with relatively muscular shoulder and moderate neck and legs.

2.5 Soil Moisture Determination

Soil sample was collected each from three different locations within the experimental field. Each of samples was transferred to sampling can of known weight (W₁) and weighed immediately (W₂). The samples were oven dried at 105°C for 24 hours and reweighed. The soil moisture content was calculated (in percent by weight of the even dried soil) as used by Isiaka, [19].

\[ M_c = \frac{W_2 - W_3}{W_1 - W_2} \times 100 \]  

where,

\[ M_c = \text{percent moisture content (dry weight basis)} \]
\[ W_1 = \text{Weight of container.} \]
\[ W_2 = \text{Weight of container + wet soil.} \]
\[ W_3 = \text{Weight of container + dried soil.} \]

2.6 Bulk Density

Bulk density was determined before and after the field irrigation. Soil cores were collected using hollow steel cores 5 cm diameter and 5 cm high. The samples were oven dried at 105°C for 24 hours.

\[ B_B = \frac{M_d}{V} \]  

where:

\[ B_B = \text{Bulk density (gcm}^{-3}\text{)} \]
\[ M_d = \text{Mass of oven-dry soil (g)} \]
\[ V = \text{Volume of soil core (cm}^3\text{)} \]

The volume of the core samples is equal to the volume of the oven dry soil and given as:

\[ V = \pi r^2 h \]  

where,

\[ V = \text{Volume of core sample (cm}^3\text{)} \]
\[ r = \text{radius of core sampler (cm)} \]
\[ h = \text{height of core sampler (cm)} \]

2.7 Draft Measurement

The unit draft along the line of pull was measured using a dynamometer place at the middle of the draft chain. Values obtained were then used in equation 5 below to calculated the total draft force as done by Isiaka [20]:

\[ F = B \cos \theta \text{ and } \theta = \sin^{-1}\left(\frac{H-h}{L}\right) \]  

Therefore \[ F = B \cos \left(\sin^{-1}\left(\frac{H-h}{L}\right)\right) \]  

where,

\[ F = \text{Draft force (parallel to the ground level) (N)} \]
\[ B = \text{Draft force a long line of pull (N)} \]
\[ \theta = \text{angle of pull} \]
\[ H = \text{Vertical distance from ground surface to harness point (cm)} \]
\[ h = \text{Vertical distance from ground surface to draft load hitch point (cm)} \]
L = Distance between the harness point and draft load hitch point (cm).

2.8 Working Principles of the Two Implement

Proper hitching and adjustment are important factors that will determine high or poor performance of the above implements. If high performance into be attained, the implements should be hitched properly to the source of power, and the gangs and lines should be adjusted to conform to the ridge profile see Appendix 1.

Table 1. Technical specification

| Implement | Weight (kg) | Length (m) | Width (m) | Height (m) |
|-----------|-------------|------------|-----------|------------|
| SRW       | 72.1        | 1.1        | 1.0       | 1.2        |
| EAW       | 98          | 2.1        | 0.6       | 0.7        |

2.9 Field Operation

After proper adjustment in the field, the implement should be attached by means of harness to the power source which is a pair of work bulls. The operator should insure that the centre of load, the hitch point and the centre of power pass through a straight line. The operator can now set the work bulls in motion, pull the implement for a short distance and examine the work done. If satisfactory, the operation should continue.

3. RESULTS AND DISCUSSION

The result obtained on the ergonomics measurement of a pair of oxen, with their body weights and tractive efforts estimated according to Abubakar, et al. [13] are presented in Table 2. The results collected on soil moisture content before operation of each treatment and draft requirement are presented in Table 3.

The two oxen made up a pair of work bulls which were white Fulani breed with their age and estimated average weight of 9 to 9.5 years; 2700.24 and 2651.27 N, respectively. The total draft forces of the two weeders were obtained to be statistically significantly at P ≤ 5% probability levels. This indicates that SRW has a higher force than EAW. The average combined total draft force was 541.52 N. The soil moisture content and bulk density of the four experimental plots were not different for the experimental treatments. The mean soil condition for which these implement were tested (SRW and EAW) are statistically same at P ≤ 5% probability levels. Okoko, et al. [11] reported that by increasing the tillage depth and implement speed, more power is need to cut and transfer the soil.

The average draft requirement of the two implement were further analysed using Duncan multiple range test (DMRT). From the above results the observed differences in total draft were not attributable to the soil moisture condition in the different experimental plots, but were caused by the implement properties. The SRW had the highest draft requirement of 338.51 N, or 44.62N of the maximum available oxen total draft force. The EAW had a unit draft requirement and total draft of 188.12 N and 47.03N, respectively.

Table 2. Summary of the ergonomic data and draft force

| Estimated work bull | Breed | Age (years) | Body dimension | Unit draft (N) | Total draft force (N) |
|---------------------|-------|-------------|----------------|----------------|-----------------------|
| B₁                  | WFB   | 9.0         | L(m) 1.98      | H(m) 3.50      | G (m) 1.15           | 2800.24               | 265.40                |
| B₂                  | WFB   | 9.0         | L(m) 1.97      | H(m) 3.30      | G (m) 1.20           | 2651.27               | 276.12                |
| Average             | WFB   | 9.3         | L(m) 1.98      | H(m) 3.40      | G (m) 1.17           | 2725.75               | 270.76                |
| Combined pair       | WFB   |             | L(m) 5.453.51  | H(m) 5.455.2   | G (m) 5.455.2        | 5453.51               | 541.52                |

$B₁$ & $B₂$ = work bull, $L$ = length, $H$ = Height, $G$ = Girth

Table 3. Average field experimental results

| Treatment | No of reading | $Mₚ$ (%) | $B₉$ (%) | Unit draft (N) | Total draft (N) |
|-----------|---------------|----------|----------|----------------|-----------------|
| SRW       | 4             | 13.3a    | 1.49a    | 338.51a        | 84.62a          |
| EAW       | 4             | 13.0a    | 1.46b    | 188.12b        | 47.03b          |

SRW = Straddle row weeder, EAW = Emcot attached rotary weeder, $Mₚ$ = Moisture content, $B₉$ = Bulk density
4. CONCLUSION

Field tests were performed to determine the draft requirements of the two locally used animal drawn IAR rotary weeder, which were evaluated and found to be different. The straddle row weeder had the highest draft requirement, of 338.51 N while the emot attached rotary weeder had the lowest draft requirement of 188.12 N, respectively. The rotary weeder were design to work in a ridge till system with a flat growing surface of about 0.75 m and to utilized two pair of work bulls white Fulani breed as source of power. All the weeder were equally good in weeds control.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

Fig. 1. Emcot attached rotary weeder

1. Operating handle
2. Ridger frame
3. Ridger
4. Rotor bracket (gang)
5. Tine
6. Roller wheel
7. Hitch point

Fig. 2. Straddle row weeder

1. Straddle frame
2. Operator’s seat
3. Hitch Ring
4. Rotor bracket (gang)
5. Tine