Implement Draught and Power Requirement for Tillage operations in Gezira Soil (With Special Reference to Massad Area)

By

Yusuf Elamin Elmadani Akashah
EL Bashir Ali Hammed
Implement Draught and Power Requirement for Tillage operations in Gezira Soil (With Special Reference to Massad Area)

Yusuf Elamin Elmadani Akashah*¹, EL Bashir Ali Hammed²

¹Agricultural Research Corporation, Wad Medani, Sudan.
²Faculty of Agricultural Technology and Fish Sciences, AlNeelain University, Khartoum-Sudan.

*Corresponding Author’s Email: Vonta2010@ gmail. com

ABSTRACT

An experiment was conducted during the year 2011 at Massad Centre for Technology Transfer and Extension (latitude 14° 24′ N and longitude 33° 29′ E) in Gazira Scheme-Sudan to study tractor power requirement for two implements commonly used for tillage operations in Gazira Scheme. The implements were a chisel plough as a primary tillage implement and an offset disc harrow for secondary tillage. Power requirements were studied under wet and dry soil conditions and for two depths of work for each implement (20-30cm, 5-10cm).

Effect of implement draught on the performance of 2WD (120 hp) tractor was investigated in terms of wheel slip (%) under the field conditions of the experiment using different levels of wheel ballast. Draught requirement for the chisel plough was found to be as a range between11 to 15 kN. And for disc harrowing the values ranged between 7 to 10 kN. Maximum power required at a speed of 7 km/h was 29 kW (39 hp).

Optimum performance (with 10 to 15% wheel slip) during chisel ploughing was achieved with water ballast at the rear wheels to 50% of the tyre volume and 50 kg of cast iron weight on each rear wheel. During disc harrowing, optimum performance was achieved with 25% water ballast in the rear wheels with additional 100 kg of cast iron weight on the rear wheels.

Keywords: chisel plough, offset disc harrow.

INTRODUCTION

Gazira Scheme is the largest irrigation Scheme in Sudan. It is located between Latitude13-32 S, 15-30 N and longitude 33-22 W 43-20 E, just southeast of the confluence of the Blue and White Nile rivers at Khartoum. Area of The Scheme is 460,000 ha, with an additional area of around 400 hectare from Managil Extension (considered a part of Gezira Scheme). The two areas account for half of the country's total land under irrigation (World Bank, 2000).

The area of the scheme is generally flat and gently sloping to the north and west, permitting natural gravity irrigation. The soils are fertile cracking clays. Main crops are Cotton, Sorghum, and Wheat.

Tillage operations for land preparation consist of chisel ploughing or disc harrowing followed by levelling and ridging. Power of tractors for the operations range from 80 to 120 hp. Actual power requirements for these operations were rarely measured or recorded. Selection of tractors was mainly based on tradition, experience, and advice of equipment suppliers. Moreover, ballasting of tractors for optimum performance was not receiving necessary attention.

To contribute in improving tractor performance in the largest irrigated scheme in Sudan, the objectives of this study were:

• To determine power requirements for conventional chiselling and harrowing operations in Gazira Scheme.
• To determine the performance of a conventional 2WD tractor with different levels of tire ballast under typical chiselling and harrowing operations adopted in Gazira Scheme.

MATERIALS AND METHODS

The experiment was carried out at Massad Centre near Wad Madani, Sudan. Massad area is located at latitude 14° 24′ N and longitude 33° 29′ E. Climate of the area is that of central Sudan, hot in summer with
an average annual rain fall of 254 mm. Main rainy period is July, August and September. Soil is a heavy clay type (53% clay, 31% Silt and 16% sand), with deep cracks when dry. The area was flat with a gentle slope of about 2%. Main crops grown were cotton and sorghum.

For mechanical analysis and measurement of soil bulk density and moisture content, soil samples were taken from three random locations. A composite sample was treated with HCL. Excess acid was neutralized by NAOH. The soil was then saturated with Na using NaCl for 48 hours and dispersed with calgon. The pipette method was used for clay fraction and wet sieving for the separation of fine and coarse sand fractions (Blake, 1965). Sizes of particles were categorized as follows:

Sand 0.05 - 2 mm  
Silt 0.05 - 0.002 mm  
Clay less than 0.002 mm

RESULTS AND DISCUSSION

Effect of soil condition on implement draught

Fig 1 showed that draught for chisel ploughing at the lower moisture content (6%) was higher compared to the draught at higher moisture content (13%). The effect of soil moisture on draught was similar during disc harrowing; higher in the dry soil (4%) in comparison to that in the wet soil (12%) as could be seen from Fig 2.

Telischi et al. (1956) mentioned that one of the most soil active factors affecting draught, especially when the clay percent is high, is the soil moisture. According to Baver et al. (1972), at low moisture contents the soil becomes hard and very coherent because of the cementation effect between the dried particles. As moisture content increases water molecules are absorbed on the surface of the individual particles and decrease the coherence of the particles and impart friability to soil mass. As friability characterizes the ease of crumbling of soils (or ease to shear), the moisture range in which soils are friable is also the range for conducting tillage operations at optimum power consumption. In agreement with this understanding of the effect of soil moisture content on soil properties, implement draught was higher in the drier soil than in the wetter one.

For known values of drawbar pull (in kN) and speed (in km/h), drawbar power (kW) could be obtained from (1):

\[
\text{Drawbar Power (kW)} = \frac{\text{Drawbar pull (kN)} \times \text{Speed (km/h)}}{(3.6 \text{ km/h})} \quad (1)
\]

Therefore drawbar power requirements for chisel ploughing and disc harrowing for the depths used during this experiment would be as shown in Table (1).

From these values tractor power necessary for the operation of maximum power demand could be calculated in terms of tractor PTO or engine power. PTO power could be calculated from Table (1). A suitable tractor PTO power for the operation from Table (1) would be 37.5/ 0.61 = 61.5 kW (82hp). This, according to Hunt (1997), represents 0.87 of the engine brake power. This PTO power could therefore be obtained from an engine of 71 kW (95 hp). This power however indicated that ploughing to a depth of 30 cm would overload the 80 hp tractor but would suitably be within the capacity of the towing tractor (120 hp engine). This may, at least partially, explain why the two tractor sizes (80 & 120 hp) were in use for the same operations. However, reducing work speed to 7 km/h brings the previous value of highest drawbar power to 29.1 kW (39 hp). This value is approximately 23% lower than the value obtained with higher speed (9 km/h) and would bring down draught power for chiselling to 30 cm depth to the power range of the smaller tractor (80 hp engine).

The final purpose of introducing tractors into the field is to timely complete required key operations. This in turn depends on achievable field capacity with the tractor. For chisel ploughing and harrowing operations, a field efficiency of 0.8 is common. Actual Field capacity could be calculated from (1):

\[
\text{Actual Field Capacity (Feddan/h)} = \frac{\text{speed (km/h)} \times \text{Implement width (m)}}{(4.2 \text{ m/km})} \quad (1)
\]

From this formula, calculated field capacity for the operations would be as shown in the Table (2).
Effect of soil condition and ballast on tractor wheel slip

Optimum tractive performance is normally achievable at rates of wheel slip ranging between 10 to 15%. The purpose of wheel ballasting is to limit slippage to this range. No or light ballast that is less than the adequate level for the tractor power makes the tractor runs out of pull before running out of power. However, it is always advisable to run with low load at a higher speed than running with a high load at slower speed.

No ballast under relatively high load (15 kN) resulted in the maximum slippage reported in this study which was 24% (Fig.5). Highest added weight (ballast) used in this study was 75% of water ballast plus 100 kg of cast iron weights. Under the minimum load encountered in this study (6 kN), this weight represented an over ballasting situation that resulted in 6% wheel slip (Fig.8). Turning attention to the situation of zero ballast (Fig 3 to Fig 10), it could be seen from Fig.3 and Fig 5 that when draught on firm soils increased from 12 to 15 kN (25% increase), wheel slip increased only by 2%. However, an approximately similar increase in drawbar pull on a wet surface (11 kN to 14 kN) resulted in an increase of wheel slip of about 28% (Fig 4 and Fig.6). This could be attributable to the effect of soil moisture content on the cohesive and frictional forces that contributed to the shear strength of the soil.

Disc harrowing is a secondary operation carried out on chiselled soils. Cohesive forces were already greatly reduced by that primary operation. Therefore an increase in drawbar pull from 8 kN to 10 kN (25%) resulted in increasing wheel slip by about 24% on the dry field (Fig.7 and Fig9). On the wet field (Fig 8 and Fig 10) an approximately similar increase in drawbar pull (from 7 kN to 9 kN or 28.6% increase) produced higher increase (30%) in wheel slip (15.5 to 20 % slip). This could be attributable to the effect of moisture content on reducing frictional forces between the soil particles (worked as a lubricant between particles).

Looking at fig. 3 through Fig. 10 it could be seen that when moving from left to right on the horizontal axes we actually move from a side of under ballast (more than 15% of wheel slip) to the side of over ballast (less than 10% wheel slip). High slippage decreases field capacity and increases fuel consumption and tire wear. Over-ballasting is also not good. Addition of weights (ballast) increases total tractor weight and this in turn increases rolling resistance. Increased rolling resistance increases fuel consumption and may result in reducing travel speed and consequently decreases field capacity. Additionally, higher loads accelerate tyre wear. A compromise between the two situations is the optimum ballast that leads to wheel slippage of 10 to 15% and within this range; ballast should be within tyre loading capacity.

On Firm soils (Fig.3 to Fig6) and for the encountered loads (11 kN to 15 KN) addition of 100 kg to each wheel without water ballast represented situations of under ballast while addition of cast iron weights after water ballasting to 75% represented situations of over ballast. Situations of optimum ballast for this soil condition and work load were obtained by filling 50% of the tyre volume (air valve in the horizontal position) with water, in addition to 50 kg weight on each driving wheel. Water ballasting is cheap but need special valve to add water while cast iron weights are easy to attach and detach as required but costly.

Accurate weighing of the tractor with different levels of water ballast could help to use cast iron weights without water ballast.

On the loose surfaces encountered during the harrowing operations drawbar loads ranged from 7 to 10 kN. Water ballast at 25% of the tyre volume (air valve in the lowest vertical position above ground surface) and 100 kg of cat iron weight was the optimum ballast for that situation.

1. Effect of soil condition on drawbar pull

Fig 4.1 shows the effect of soil condition on drawbar pull (kN) for the chisel plough and Fig 4.2 shows the effect for the disc harrow. The details results are shown in A appendix (A).
For chisel ploughing, drawbar pull was higher in FD in comparison to that in FW. Also, for disc harrowing drawbar pull was higher in PD in comparison to PW.

2 Effect of wheel ballast on wheel slippage on firm surfaces

Figure 3, 4, 5 and 6 shows graphically the effect of ballast on wheel slippage under different drawbar loads on firm surfaces. The details results are shown in appendix (B).
Fig. 3: Wheel slip on firm dry surface under 12 kN of drawbar pull and different levels of wheel ballast.

Fig. 4: Wheel slip on firm wet surface at 11 kN of drawbar pull and different levels of wheel ballast.
Fig. 5: Wheel slip on firm dry surface at 15kN of drawbar pull and different levels of wheel ballast.

Fig. 6: Wheel slip on firm wet surface at 14 kN of drawbar pull and different levels of wheel ballast.
3 Effect of ballast on wheel slippage on loose surfaces

Figure 7, 8, 9 and 10, shows the effect of ballast on wheel slippage under different drawbar loads on loose (chiselled) surfaces. Table 2 in appendix shows the details of the results.

![Bar graph showing wheel slip on loose (chiselled) soil and dry surface under 8 kN of drawbar pull and different levels of wheel ballast.](image1)

Fig. 7: Wheel slip on loose (chiselled) soil and dry surface under 8 kN of drawbar pull and different levels of wheel ballast.

![Bar graph showing wheel slip on loose (chiselled) wet soil surface at 7 kN of drawbar pull and different levels of wheel ballast.](image2)

Fig. 8: Wheel slip on loose (chiselled) wet soil surface at 7 kN of drawbar pull and different levels of wheel ballast.
Fig. 9: Wheel slip on loose (chiselled) soil dry surface at 10 kN of drawbar pull and different levels of wheel ballast.

Fig. 10: Wheel slip on loose (chiselled) and wet soil surface at 9 kN of drawbar pull and different levels of wheel ballast.
Table (1): Drawbar Power for chiselling & harrowing operations at 9km/h

<table>
<thead>
<tr>
<th>Operations</th>
<th>Drawbar pull (kN)</th>
<th>Drawbar Power (kW)</th>
<th>Drawbar Power (hp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisel ploughing (20 cm)</td>
<td>12</td>
<td>30</td>
<td>40.5</td>
</tr>
<tr>
<td>Chisel ploughing (30 cm)</td>
<td>15</td>
<td>37.5</td>
<td>50.5</td>
</tr>
<tr>
<td>Disc Harrowing (5 cm)</td>
<td>8</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>Disc harrowing (10 cm)</td>
<td>10</td>
<td>25</td>
<td>33.7</td>
</tr>
</tbody>
</table>

Table (2): Field capacity for chiselling & harrowing operations

<table>
<thead>
<tr>
<th>Operations</th>
<th>Implement width (m)</th>
<th>Operations speed</th>
<th>Field Capacity (Feddan/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisel ploughing</td>
<td>1.9</td>
<td>7</td>
<td>2.53</td>
</tr>
<tr>
<td>Disc harrowing</td>
<td>2</td>
<td>9</td>
<td>3.42</td>
</tr>
</tbody>
</table>

Table (3): Basic physical properties of the experimental site

<table>
<thead>
<tr>
<th>Field Condition</th>
<th>Bulk density (g/cm³)</th>
<th>Soil Moisture Content (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>Field Capacity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm dry</td>
<td>1.7</td>
<td>6</td>
<td>13</td>
<td>16</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>Firm wet</td>
<td>1.6</td>
<td>13</td>
<td>4</td>
<td>31</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Loose dry</td>
<td>1.6</td>
<td>13</td>
<td>4</td>
<td>31</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Loose wet</td>
<td>1.5</td>
<td>12</td>
<td>16</td>
<td>31</td>
<td>53</td>
<td>50</td>
</tr>
</tbody>
</table>

3: CONCLUSIONS

Draught requirement for conventional chisel ploughing ranged between 11 to 15 kN. For disc harrowing values ranged between 7 to 10 kN. Values in both cases were depending on soil moisture and depth of work.

Maximum drawbar power for chisel ploughing at 7km per hour was 29 kW (39 hp). This power could adequately be supplied by the 80 hp tractor if properly ballasted.

Field capacity for chisel ploughing would be 2.53 feddan per hour while for disc harrowing field capacity would be 3.42 feddan per hour.

Ballast for optimum performance for the 80 hp tractor was obtained with 50% of water ballast and 50 kg of cast iron on rear wheels for chisel ploughing. For disc harrowing adequate ballast was obtained by filling driving tyres with water to 25% of the tyre volume and addition of 100 kg of cast iron on each rear wheel.

REFERENCES


