EFFECT OF PLOUGHING AND PLANTING DEPTHS ON
DRAFT OF DUAL-PURPOSE MOULDBOARD PLOUGH CUM
PLANTER


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Abstract

This study presents an experimental inquiry into the effects of two independent variables on the
draft force of a mouldboard plough/planter: planting depth (0 – 5 and 6 – 10 cm) and plowing
depth (6 – 10 and 11 – 15 cm). A dual-purpose mouldboard plough/planter was developed to
expedite the cultivation of maize by speeding up the ploughing and planting processes. Based
on planting and ploughing depths, the draft force of the implement was evaluated. Field
experimental procedures were used to conduct the trials, and parametric testing was used to
analyze the data. The final formula for calculating the draft force depends on a number of soils
engineering characteristics, including soil bulk density and type, tool specifications, such as
cutting width and implement weight, and operational factors, such as ploughing depth and
moisture content. The study's findings show that ploughing depth has a greater impact on a
mouldboard plough/planter's draft force; the maximum draft force of 1.5 kN was recorded at
planting depths of 6 to 10 cm and ploughing depths of 11 to 15 cm. The data indicates that the
draft force of the cum planter is significantly (p~0.05) affected by the depth of ploughing. The
ploughing depth and planting depth on draft force were shown to have a strong association in
the linear regression model, with a coefficient of determination (R² = 0.75) for draft force
indicating high correlations among the components. Ploughing depths are always responsible
for explaining the difference in draft force. The results suggest that any change in the plowing
depths provides a considerable forecast of the implement's draft force, since the plowing depth
was the largest predictor of the draft force. The best results from the mouldboard
plough/planter are achieved when planting and ploughing are done at depths of 0–5 cm and
5–10 cm, respectively.

Keywords: Mouldboard plough, planting depth, ploughing depth, bulk density, draft force,
motion content.

1. Introduction

According to McLaughlin et al. (2008), Olatunji et al. (2009), and Khanghah (2009), one criterion used to determine if a
tool is suitable for manipulating soil is the amount of force needed to drag the tool
through the dirt. Tong and Moayad (2006) state that the primary factor influencing
agricultural implement performance is the soil's dynamic response to the tools. Moeenifar et al. (2014) state that the design
and application of tillage tools for soil manipulation are primarily concerned with
the interaction between the tools and the soil. On farms, tillage is the operation that
uses the most energy and electricity. Therefore, in order to evaluate the size of
tractor that could be employed for a certain implement, draft and power requirements
are crucial. The geometry of the tillage implements and the soil conditions will also
have an impact on the draft needed for a particular implement (Naderloo et al.,
2009; Olatunji et al., 2009). It is critical to understand the draught requirements for
various implements in order to minimize tillage. The soil conditions and the design
of the tools had a significant impact on the draft force and power needed for tillage.
Rahman and Chen (2001) found that the working depth of a tillage implement was
more important than the working speed in
terms of its impacts on draft force and soil disturbance. Tillage is one area where a lot of power is utilized, and agricultural mechanization is thought to be the primary element contributing to the total energy inputs in agricultural systems. According to Olatunji and Davies (2009) there are three components to tillage: the soil, the tool, and the power source. Before choosing and matching equipment for a given work, it is important to fully understand the conditions of the soil at tillage time as well as the capacities of the tractors and implements (Okoko and Akpankpuk, 2023). Kheiralla et al. (2004) formulated a draft force model for ploughs based on traveling speed and tillage depth. Abo-Elnor et al. (2004) concluded that the blade cutting width had a significant effect on cutting forces so that the cutting forces increased but not in linear proportion as the cutting width increased. Alele et al. (2018) investigated the effects of depth and speed on power requirements for disc and mouldboard ploughs in silt loam soils and observed that tillage depth and forward speed both led to increase in power requirement for the implements. They reported that the mouldboard plough had highest values of power requirement at all levels of the parameters investigated while the increase in power requirement per unit increase in speed was slightly higher for disc plough. While little to no research has been done on the impact of planting depth and plowing on the draft requirements for an animal-drawn plough/planter, several studies have focused on the effects of depth, rake angles, and speed. This study reports on the impact of the planting depth (P) and plowing depth (D) of a dual-purpose mouldboard plough/planter on the mouldboard plough's draft force.

2. Materials and Methods
A pair of bulls, a specially designed dual-purpose mouldboard plough/planter, a spring dynamometer, a stop watch, wooden pegs, survey tape, steel rule, an auger, and a sensitive weighing balance were utilized in the research.

2.1 Experimental site
The field trials were held in Bauchi State, Nigeria, at Sabon Garin Gwallameji, which is across from Federal Polytechnic Bauchi (10° 27′N/ 09° 77′E). The mean temperature of 43°C in the hot season and 29°C in the wet season are used to categorize the climate. The range of the average yearly rainfall is 1200–1300 mm. High humidity is a defining characteristic of the season in the North Guinea Savannah region (Kareem and Sven, 2019). Table 1 displays the features of the soil test and the instrument that were determined.

<table>
<thead>
<tr>
<th>S/NO</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Percentage of clay (&lt;0.002 mm)</td>
<td>15.5 %</td>
</tr>
<tr>
<td>2</td>
<td>Percentage of silt (0.002±0.05 mm)</td>
<td>5.0 %</td>
</tr>
<tr>
<td>3</td>
<td>Percentage of sand (&gt;0.05 mm)</td>
<td>79.50 %</td>
</tr>
<tr>
<td>4</td>
<td>Moisture content</td>
<td>13.59 %</td>
</tr>
<tr>
<td>5</td>
<td>Soil bulk density</td>
<td>1.23 g cm⁻³</td>
</tr>
<tr>
<td>6</td>
<td>Tool width</td>
<td>55 cm</td>
</tr>
<tr>
<td>7</td>
<td>Weight of implement</td>
<td>44.80 Kg</td>
</tr>
</tbody>
</table>

2.2 Draft animal and dual-purpose mouldboard plough cum planter
Two average-sized bulls were purchased from the public market, and they were capable of drawing the moldboard plough/planter combination. The spring dynamometer they were using indicated that they generated an average pulling force of 1.4 KN. Small-scale farmers can implement this technique by employing animal power instead of expensive technology and by using livestock that is readily available in their area. The dual-purpose mouldboard plough/planter was designed with consideration for the forces...
operating on the tool, including the pulling force of the draft animal, the implement's weight, the operator's force, the soil's gravitational force, and the soil resistance. Before the field trial, the following values were obtained: the maximum stress created by share, the total draft of the implement, the maximum shear strength, the torque, the volume of the hopper, the weight of the hopper material, and the shaft diameter. These results are displayed in Table 2 below.

Table 2: Field and calculated data for design of dual-purpose mouldboard cum planter

<table>
<thead>
<tr>
<th>S/N</th>
<th>Calculated Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Average Pulling force applied by pair of draft animals</td>
<td>1200N</td>
</tr>
<tr>
<td>2.</td>
<td>Weight of implement</td>
<td>44.80kg</td>
</tr>
<tr>
<td>3.</td>
<td>Force exerted by the operator</td>
<td>100-250N</td>
</tr>
<tr>
<td>4.</td>
<td>Maximum stress developed by share</td>
<td>9.78Mpa</td>
</tr>
<tr>
<td>5.</td>
<td>Total draft of implement</td>
<td>1809.16N</td>
</tr>
<tr>
<td>6.</td>
<td>Torque</td>
<td>270Nm</td>
</tr>
<tr>
<td>7.</td>
<td>Maximum shear strength</td>
<td>0.0888Mpa</td>
</tr>
<tr>
<td>8.</td>
<td>Volume of hopper</td>
<td>227,848 mm³</td>
</tr>
<tr>
<td>9.</td>
<td>Weight of hopper material</td>
<td>17.89N</td>
</tr>
<tr>
<td>10.</td>
<td>Diameter of shaft</td>
<td>30 mm</td>
</tr>
</tbody>
</table>

2.3 Experimental design
In order to determine how the range of plowing depth affected the dual-purpose mouldboard plough/planters draft when planting maize, experiments were carried out. Two parameters were used for this analysis: planting depths P1 and P2 at two range levels (0 – 5 and 6 – 10 cm) and plowing depths D1 and D2 at two ranges (6 – 10 and 11–15 cm), resulting in a total of four treatments. Using the interquartile range, outliers were removed from the draft dataset derived from the field testing. Statistical metrics of fit, specifically the coefficient of determination (R²), were used to compare the datasets. It was thought of as a factorial idea that was included into a fully randomized block design (CRBD). There were three replications of each test, for a total of twelve experimental plots. Two bulls of a moderate size were employed in the trials to pull the dual-purpose mouldboard plough/planter. Plot dimensions were 10.45 m² and the running length was 19 m. Statistical analysis system (SAS) software was utilized to discover significant differences among treatment means, and ANOVA was employed to investigate the significant and non-significant treatment effects. The LSD means separation method (α < 0.05) was also employed.

2.4 Field Experimental Procedure
The chosen effective working width of 55 cm, the range of plowing depths of 6–10 and 11–15 cm, and the range of planting depths of 0–5 and 6–10 cm was all used during the operation. As indicated in Plate I, the range of planting and plowing depths was accomplished by varying the heights of the furrow opener and wheel, respectively. The instrument was pulled across the distance using the draft animals, and the dynamometer was used to record the pulling force and the stop watch Plate II was used to record the time.

Plate I: Adjusting of planting depth of the cum planter using the adjustable furrow opener

Dogara et al.
2.5 Determination of Draft Force
The draft force of the implement was evaluated from the Equation 1 as reported by Omer et al. (2021).

\[ D = P \cos \theta \]  

(1)

Where; \( D \) is draft force (N), \( P \) is pulling force in (N), \( \theta \) is angle between the line of pull and horizontal.

According to Abebe and Yonas (2018) and as shown in Plate III, the pulling power from the draft animal was determined by reading the spring dynamometer that was fastened to the implement's hitch assembly. It was determined what angle the line of pull was from the horizontal.

3. Results and Discussion
The draft force test was carried out by altering the operation speed as well as the planting and plowing depths, the values of which were noted and utilized in the parametric analysis. The study's findings showed that the draft force of a moldboard plow was considerably \((P = 0.01)\) impacted by the plowing depth \((D_1 \text{ and } D_2)\), planting depth \((P_1 \text{ and } P_2)\), and operating speed \((OS)\) of the implement.

3.1 Effect of Ploughing and planting depths on draft of cum planter
An analysis of variance (ANOVA) was performed using statistical methods to determine if the relationship between planting depths and plowing had any significant impact on draft while using the dual-purpose mouldboard plough/planter, as shown in Table 2. From the results of ANOVA, it revealed that the model is statistically significant \((F=6, P = 0.0249 \text{ (P-value) } < 0.05)\) on the draft. It reveals that there was highly significant effect of ploughing depth \((F=24.30, P=0.0026 \text{ (P-value) } < 0.05)\) on the draft. It clearly showed that the variation of ploughing depth had significant effect on draft, meaning draft were not the same amongst ploughing depths while ploughing operation. Planting depth levels while ploughing and planting showed no significant effects on draft with \((F=2.70, P=0.1515 \text{ (P-value) } < 0.05)\). This implies that ploughing and planting can be done at all level of planting depth without showing changes in the draft. The interaction between ploughing and planting depths showed significant effect \((F=1.20, P=0.3154 \text{ (P-value) } < 0.05)\) on the draft. It can be translated that the interaction effect did indicate good relationship between ploughing and planting depths in influencing change in draft. Further analysis using comparison of mean was carried to validate where the difference falls in terms of level and significance.
Table 2: Effect of ploughing and planting depths on draft of cum mouldboard plough planter

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>5</td>
<td>301503.7732</td>
<td>60300.7546</td>
<td>6.00*</td>
</tr>
<tr>
<td>Ploughing depth (D)</td>
<td>1</td>
<td>244219.6540</td>
<td>244219.6540</td>
<td>24.30**</td>
</tr>
<tr>
<td>Planting depth (P)</td>
<td>1</td>
<td>27134.8831</td>
<td>27134.8831</td>
<td>2.70*</td>
</tr>
<tr>
<td>Plough depth (D) x Plant depth (P)</td>
<td>1</td>
<td>12059.3140</td>
<td>12059.3140</td>
<td>1.20*</td>
</tr>
<tr>
<td>Error</td>
<td>6</td>
<td>60302.2763</td>
<td>10050.3794</td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>11</td>
<td>361806.0495</td>
<td>3.216372</td>
<td></td>
</tr>
</tbody>
</table>

**highly significant *significant

3.2 Effect of ploughing depths on draft of moldboard dual-purpose cum planter

Figure 3 displays the average comparison for the effects of plowing depths on draft using the LSD mean separation method. Significant differences were seen between the average drafts of 1.5 kN and 1.2 kN at ploughing depths of D2 and D1, respectively. This suggests that as the depth of the ploughing grows, so does the implement's draft force. The outcome concurs with Abebe and Yonas's (2018) report, which indicated that the draft increases as the plowing depth increased.

![Figure 2: Effect of ploughing depths on draft of moldboard dual-purpose cum planter](image)

3.3 Effect of planting depth on draft of moldboard dual-purpose cum planter

Figure 4 illustrates how planting depth variations during plowing and planting operations significantly impacted draft. There were differences in the averages between the planting levels. The mean values of 1.3 and 1.4 kN of draft for planting depths P1 and P2 showed a significant difference from the norm. The field evaluation's findings indicated that when planting depth was increased from 0 to 10 cm, draft rose by 0.095 KN. This is comparable to the Van Muysen, *et al.* (2000).

![Figure 2: Effect of planting depth on draft of moldboard dual-purpose cum planter](image)

3.4 Effect of ploughing and planting depths on draft of moldboard dual-purpose cum planter

With averages of 1.1 and 1.5 kN, respectively, the planting depth (P1) average values (Figure 5) at all ploughing depths demonstrate considerable variances during the plowing and planting procedure. Additionally, there are notable variations in the planting depths (P2) at both ploughing depths of D1 and D2, with means of 1.3 and 1.5 kN, respectively. The outcome shows that the draft of the tool increases with planting and plowing depth, which may be connected to the characteristics of the soil and the geometry of the tool. Veerangouda and Shridhar (2010) found that ground...
wheel slip and draft on a planter were similar.

![Figure 3: Effect of ploughing and planting depths on draft of moldboard dual-purpose cum planter](image)

3.5 Linear regression on the effect of implement parameters on draft of cum planter

The mean values of the draft were analyzed using linear regression to see if planting and plowing depths were significantly predicting the draft. The influence of the independent variables or functional operational implement parameters (planting and plowing depths) on draft force was predicted using the linear regression model, as Table 3 illustrates. The linear regression's p-value is 0.0020, meaning that it is statistically significant and suggests that one of the implement parameter indicators or factors has a substantial impact on the draft force of the implement. This is below the α-level of 0.05. The planting depth, for which the selected α-level of 0.05 is exceeded by the p-value of 0.1348. Therefore, compared to planting depth, plowing depth has a greater impact on the dual-purpose mouldboard plough/planter's draft force. $R^2$, the coefficient of determination, has a value of 0.750. This suggests that a linear regression with a high determination coefficient is the best-fit regression equation. There was a significant association found by the linear regression model between the implement and draft's parameters. As a result of the model's extremely high $R^2$ (determination coefficient) value, precise predictions can be made using it. Equation (2) below shows the linear model that was developed to forecast the draft force in relation to the independent variables or functional operating parameters (planting and plowing depths):

$$D_f = 760.84417 + 285.31833D + 95.10500P$$

Where:

- $D_f$ is draft force, (N)
- $D$ is ploughing depth, (cm)
- $P$ is planting depth, (cm)

<table>
<thead>
<tr>
<th>Model</th>
<th>$F$</th>
<th>$R^2$</th>
<th>Adj $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft</td>
<td>13.50</td>
<td>0.7500</td>
<td>0.6944</td>
</tr>
</tbody>
</table>

Conclusion

According to this study, it is technically possible to create an integrated tool that may be used for small-scale maize farming by adding planting and plowing units to an already-existing mouldboard plough beam. The results of a study on the impact of planting and plowing depth on draft force in a dual-purpose mouldboard plough/planter prototype show that as planting and plowing depth grew, so did the draft level. It is determined that the draft needs of a dual-purpose mouldboard plough/planter are consistent with the draft capacity of an average pair of oxen currently utilized by small-scale maize farmers based on the significant specific draft decrease as well as lower values of the actual draft.

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