

## The Role of the Chisel Plow in Loosening the Hardpan Layer and Promoting Crop Growth

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### Abstract

A field experiment was conducted in Karbala Governorate/Tawrij District in 2024 on a silty clay soil to investigate the role of the chisel plow in loosening the hardpan layer and promoting crop growth. A New Holland TD80 tractor was used in this experiment. Two components were examined: operating speed (2.80, 4.65, and 6.15 km/h-1), and plowing depth (50 and 65 cm). Mechanical unit technical metrics such drawing force, slippage percentage, fuel usage, and maize plant output were examined. The experiment used a three-replicate Randomized Complete Block Design (RCBD). The lowest slippage percentage was 6.90% and the lowest traction force was 618.11 kg at 2.80 km/h-1. The lowest fuel usage was 9.99 L/ha and the maximum plant output was 8.05 t/ha at 6.15 km/h-1. A 50 cm plowing depth yielded the lowest pulling force (613.21 kg), slippage (7.57%), and fuel usage (11.91 L/ha). The maximum plant output was 6.76 t/ha at 65 cm. All attributes were significantly affected by the speed-plowing plot interaction. Operating speed, traction force, plant productivity, slippage, Chisel Plow.

**Keywords:** Chisel Plow, Hardpan Layer, Crop Growth

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### Introduction

The operations of soil preparation are important, as they provide the necessary food for the ever-increasing population and supports the economic sector. Control and increasing agricultural production are achieved by reducing the waste and fuel consumption, thus increasing economic returns (Amer, 2019). Because soil is a fundamental resource for economic growth and development, issues with impermeable layers or hardpans contribute to decreased agricultural output. The rising demand for food and the ever-increasing human population highlight the critical need of boosting supply (Al-Ani, 2000). Chisel Plows require very high traction force due to their use in difficult soil conditions. Chisel Plows also require 15 to 35 kN when working in heavy soils (Shippen et al., 1990). drawing forces are the forces required to pull a particular equipment toward the power source. They are considered a factor affecting the stability of the Plow during soil preparation operations (Kepner et al., 1982). McKeys (1985) found that the drawing force increased from 5.65 to 11.35 kN when the Plowing depth increased from 10 to 15 cm in clay soil. Slippage is defined as the asymmetry between the linear distance and the circumferential distance for a fixed number of revolutions of the tractor's drive wheels. The linear distance is usually relatively less than the circumferential distance (Al-Banna, 1990). One key indicator of an agricultural tractor's efficiency is the degree to which its drive wheels slide. According to Swain et al. (2022), the proportion of slippage was significantly affected by raising the plowing depth from 10 to 24 cm while using a plow. The reason behind this was the rise in plowing depth, which caused a rise in pulling force and slippage. According to Al-Mashriqi (1996), the slippage percentage increased from 7.06 to 11.12 to 19.96% when the plowing depth was increased from 15 to 20 and finally 25 cm while maintaining a constant speed lever. The slippage percentage increased significantly from 8.82 to 10.14% when the practical speed was increased from 3.08 to 5.51 km/h, according to Al-Jubouri (2012). This is because a higher practical speed increases drawing resistance and decreases the likelihood of wheel-to-ground adhesion, resulting in a higher slippage percentage.

Primary Plowing is one of the agricultural operations that consumes most of the fuel to complete the assigned tasks (Sing et al., 1989). Fuel consumption varies depending on the soil type, the type of Plow used, the speed of the cultivator, and the Plowing depth (Bukhari and Bolach, 1982). Aday and Hmood (1995) reported that the lowest fuel consumption per unit area was recorded at an engine speed of 1500 rpm, with a forward speed of 0.95 m/sec and a depth of 10 cm. The Plow used was a mouldboard Adding 100 kg of weight to the rear wheel drive tires may have reduced the fuel consumption.

Total grain yield is one of the most important field parameters because it provides the results of field operations (Amer, 2024). The results of Amer and Swain (2019), Muter et al., (2024), and Muter et al., (2025) Significant differences in productivity traits for the fall season were found, ranging from 21% to 17%, when plant densities increased from 40,000 to 65,000 and 75,600 plants/ha.

### Materials and Methods

A field experiment was conducted in the Karbala Governorate/Turij District in 2024, with the aim of investigating the role of the chisel Plow in loosening the impermeable layer and enhancing crop growth. The experimental land was cleaned and levelled, as it had not been planted in the previous season. The soil texture was classified as silty clay (Table No. (1)).

**“Table No. 1: Physical and chemical properties of the soil”**

| “Soil segregation<br>gm kgm <sup>-1</sup> ”   | Texture<br>type | PH   | Electrical<br>conductivity<br>Decemenz<br>m <sup>-1</sup> | Total<br>porosity<br>% |
|-----------------------------------------------|-----------------|------|-----------------------------------------------------------|------------------------|
| Sand      Clay<br>Silt<br>100      160<br>536 | Silty<br>Clay   | 7.62 | 4.01                                                      | 49”                    |

In this experiment, a New Holland TD80 tractor was implemented. A couple of factors have been investigated: the Plowing depth, which comprised 50 and 65 cm, and the operating speed, which had three levels, respectively: 2.80, 4.65, and 6.15 km/h<sup>-1</sup>. Three replicates of a split-block design were used in accordance with a completely randomised design (Sahoki, 1990). Treatment differences were tested using the least significant difference at 5%.

### Studied Traits:

**1-Drawing force:** “Calculated according to the equation proposed by Al-Tahhan (1993)”.

FT = Fpu – PRM (kg).....

Where:

FT: drawing force (kg).

FPU: Total drawing force (pull force) (kg).

FRM: Tractor resistance force (kg).

**2-Slippage percentage:** “Calculated according to the equation proposed by Zoz (1972)”.

“SP = (Vt - Vp)/Vt × 100” .....

Where:

SP: Slippage percentage

Vt: Theoretical speed without load (km/h)

Vp: Practical speed with load (km/h)

**3-Amount of fuel consumed:** “Calculated according to the method used by Al-Jarrah (1998)”.

“Vco = (V × 10000) / (ST × Bp) × 1000 .....

Vco: Amount of fuel consumed per hectare (L/ha-1).

V: Amount of fuel consumed per treatment (mm)

ST: Length of treatment (m)

Bp: Actual tillage width (m)”

### 4-Corn/maize yield:

Measured by marking ten plants randomly from the two median lines of each replicate. Yield was then calculated by multiplying the average yield per gram by plant density. Weight was adjusted based on 15.5% moisture for all weight-related traits according to the equation proposed by Al-Sahouki (1990).

## Results and Discussion

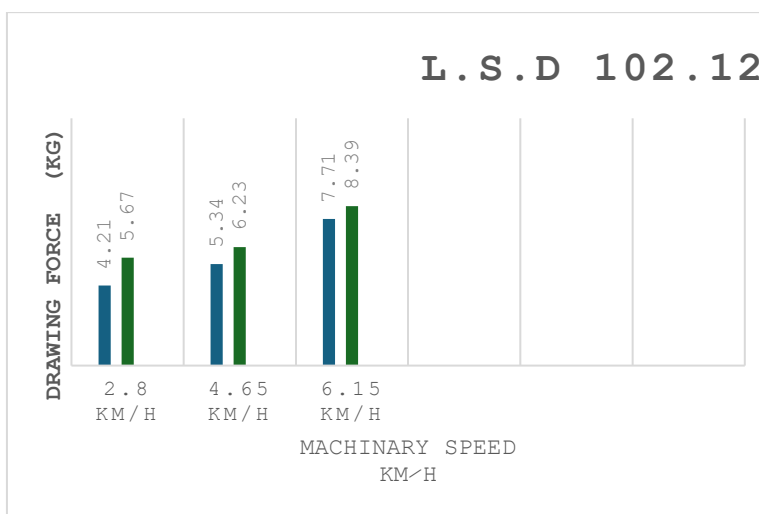
### 1-Drawing Force (kg):

Table (2) and Figure (1) show how operating speed, plowing depth, and interaction affect drawing force. Statisticians found a substantial influence. As speed climbed from 2.80 to 4.65, then 6.15 km/h-1, pulling force increased from 618.11 to 632.22, then 652.39 kg. Due to increased operating speed, soil particles must be accelerated during plowing. This increases soil motion, Plow body load, and pulling force. The pulling force rose from 613.213 to 655.25 kg when the plowing depth increased from 50 to 65 cm. This is due to the increased cross-sectional area of the soil disturbed by the Plow parts. Furthermore, when the plowing depth increased, some soil properties increased, leading to an increased load on the Plow, which increased the drawing force values. This is consistent with the results of Salar et al. (2013) and Amer (2017).

The table and figure above show the second interaction, where the lowest drawing force was recorded at 2.80 km/h<sup>-1</sup> and the 50 cm depth, and the highest drawing force was recorded at 667.91 kg, resulting from the interaction of the 6.15 km/h<sup>-1</sup> speed and 65 cm depth.

**Table (2) Drawing force (kg) vs. operating speed, plowing depth, and interaction.**

| Speed<br>km/h <sup>-1</sup>                                 | Depth cm |        | average |
|-------------------------------------------------------------|----------|--------|---------|
|                                                             | 65       | 50     |         |
| 2.80                                                        | 643.64   | 592.54 | 618.11  |
| 4.65                                                        | 654.21   | 610.23 | 632.22  |
| 6.15                                                        | 667.91   | 636.87 | 652.39  |
| average                                                     | 655.25   | 613.21 |         |
| L.S.D Speed *78.23 Plowing Depth *61.11 interaction *102.12 |          |        |         |



**Fig.1 shows how operating speed, plowing depth, and interaction affect drawing force.**

## 2-Slippage Percentage (%):

Table (3) and Figure (2) show how operating speed, plowing depth, and interaction affect slippage %. Statisticians found a substantial influence. Slippage percentage rose from 6.90 to 8.33 to 11.87% as speed climbed from 2.80 to 4.65 to 6.15 km/h-1. The reason is that increasing the operational speed led to an increase in the momentum exerted on the soil, which leads to an increase in the load on the Plow body. This leads to an increase in the traction force and, consequently, an increase in the slippage percentage. These findings match Amer and Muter (2023). Slippage rose from 7.57 to 13.50% when plowing depth increased from 50 to 65 cm. Because increasing depth increases Plow weight, drawing resistance, and slippage percentage. These results match Aloush. (2001).

The table and picture above illustrate the second interaction at 2.80 km/h-1 and 50 cm depth. The lowest slippage ratio was 5.13% and the highest 13.18%. This happened at 6.15 km/h-1 and 65 cm depth.

**Table (3) Practical speed, plowing depth, and interaction on slippage percentage.**

| Speed<br>km/h <sup>-1</sup>                             | Depth cm |      | average |
|---------------------------------------------------------|----------|------|---------|
|                                                         | 65       | 50   |         |
| 2.80                                                    | 8.67     | 5.13 | 6.90    |
| 4.65                                                    | 9.01     | 7.65 | 8.33    |
| 6.15                                                    | 13.81    | 9.92 | 11.87   |
| Average                                                 | 10.50    | 7.57 |         |
| L.S.D Speed *4.42 Plowing Depth *3.93 interaction *6.83 |          |      |         |

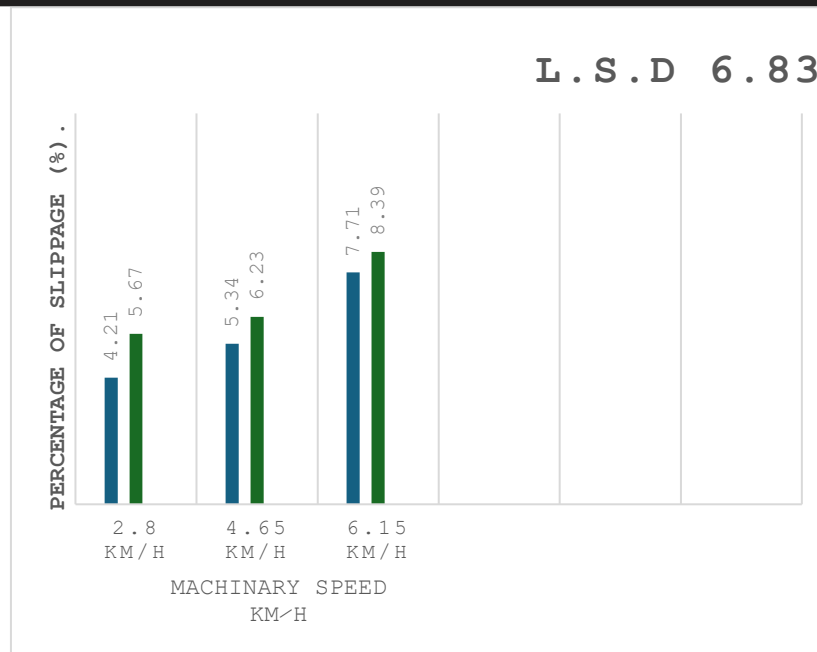


Fig.2. elaborates the effect of operational speed and plowing depth and their interaction on the slippage percentage

### 3. Amount of fuel consumed (Liters/hectare).

Table (4) and Figure (3) demonstrate how operating speed, plowing depth, and interaction affect fuel use. Statisticians found a substantial influence. When speed climbed from 2.80 to 4.65, then 6.15 km/h-1, fuel consumption increased from 15.21 to 11.74, then 9.99 Liters/hectare. This is because increasing forward speed reduces fuel consumption and sluggish speeds lose energy by not using full capability. In agreement with Alloush (2001) and Amer et al (2025), working at high speeds uses this energy, reducing operation time.

Fuel usage rose from 11.91 to 12.71 Liters/hectare when plowing depth increased from 50 to 65 cm. Because deeper plowing disturbs more soil. This unsettling procedure increases fuel consumption and effort. The table and figure above depict the second interaction, where fuel usage was lowest at 6.15 km/h and 50 cm depth. The speed of 2.80 km/h and depth of 65 cm produced the maximum fuel usage of 15.51 Liters/hectare.

**Table (4) Fuel consumption (Liters/hectare) by operating speed, plowing depth, and interaction.**

| Speed<br>km/h <sup>-1</sup>                         | Depth cm |       | average |
|-----------------------------------------------------|----------|-------|---------|
|                                                     | 65       | 50    |         |
| 2.80                                                | 15.51    | 14.91 | 15.21   |
| 4.65                                                | 12.02    | 11.46 | 11.74   |
| 6.15                                                | 10.61    | 9.37  | 9.99    |
| Average                                             | 12.71    | 11.91 |         |
| L.S.D Speed *1.03 Plowing Depth *0.71 Overlap *1.61 |          |       |         |

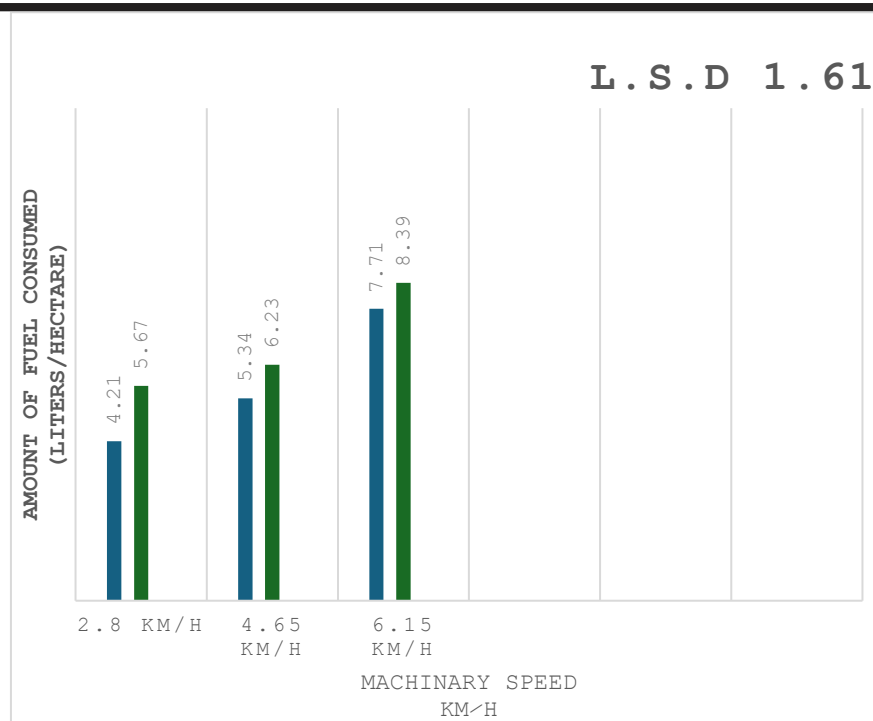


Fig.3 shows how operating speed, plowing depth, and interaction affect fuel use.

#### 4-Maize production (tons/hectare).

Table (5) and Figure (4) asserts the effect of practical speed, plowing depth, and their interaction on plant productivity. The results of the statistical analysis expressed a significant effect. When the speed increased from 2.80 to 4.65, then to 6.15 km/h<sup>-1</sup>, maize productivity increased from 4.94 to 5.79, then to 8.05 tons/hectare. This is due to increasing productivity leads to increasing plant density, this is in consistent with Shuwailih and Bakr (2001).

When plowing depth increased from 50 to 65 cm, productivity increased from 7.71 to 8.39 Liters/hectare, respectively. The table and figure above show the second interaction, where the speed of 2.80 km/h<sup>-1</sup> and the depth of 50 cm recorded the lowest plant productivity of 4.21 tons/hectare, and the highest plant productivity of 8.39 tons/hectare, with the interaction of the speed of 2.80 km/h<sup>-1</sup> and the depth of 65 cm.

Table (5) Maize plant productivity (tons/hectare) by practical speed, plowing depth, and interaction.

| Speed<br>km/h <sup>-1</sup>                             | Depth cm |      | average |
|---------------------------------------------------------|----------|------|---------|
|                                                         | 65       | 50   |         |
| 2.80                                                    | 5.67     | 4.21 | 4.94    |
| 4.65                                                    | 6.23     | 5.34 | 5.79    |
| 6.15                                                    | 8.39     | 7.71 | 8.05    |
| average                                                 | 6.76     | 5.75 |         |
| L.S.D Speed *2.45 Plowing Depth *1.96 interaction *3.42 |          |      |         |

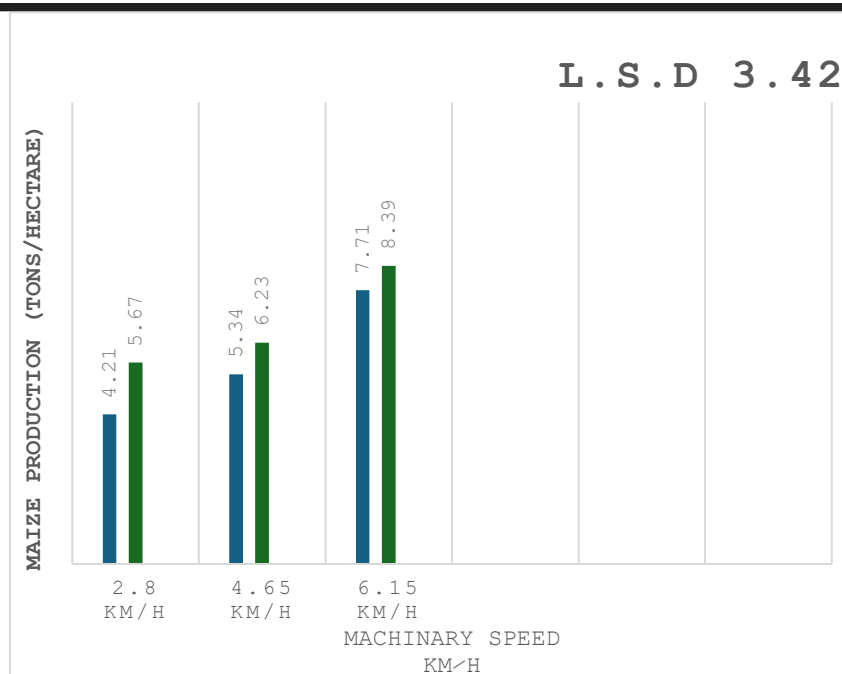


Fig.4 shows how practical speed, plowing depth, and interaction affect plant production.

### Conclusions and Recommendations

According to the aforementioned findings, raising the operating speed led to a notable rise in plant yield, drawing force, slippage percentage, and fuel consumption. The drawing force, slippage percentage, fuel consumption, and plant yield are all increased as the depth increased. For best results, we suggest a depth of 65 cm and a speed of 6.15 km/h-1z

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