The Impact of Forward Tractor Speed and Depth of Ploughing in Some Soil Physical Properties

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Abstract. An experiment was carried out at the Agricultural Research and Experiments Station in the Sayyada Region of the College of Agriculture - University of Kirkuk, in order to study the effect of forward tractor speed and depth of ploughing in some technical indicators and physical properties of soil in Loam soils in 2019. Two factors were studied, depths of ploughing (4.63 and 6.30 cm) and the practical speed of the tractor (1.72 and 2.86 km hour-1) and their effect on some of the studied technical indicators, including the practical and theoretical field capacity, the slide percentage, the percentage of porosity, the volume of disturbed soil, the soil particles with less than 5 cm in diameter (5 cm m-2) and practical productivity. The experiment was carried out using the factorial experiment method according to The Randomized Complete Block Design (RCBD) with three replicates. The second speed of the tractor and the second ploughing depth exceeded in achieving the highest rate in practical field capacity of (0.28 and 0.34 ha h-1) and theoretical field capacity (0.41 and 0.49 ha h-1), respectively, and in giving the highest volume of the disturbed soil that were (184.48 and 244.753 m3 h-1) and practical productivity (0.33 and 0.39 ha h-1), respectively. While the lowest rate was in the percentage of slide of the first speed and the depth of the first ploughing (7.56 and 6.31%), respectively. The interference between the second tractor speed and the second ploughing depth was superior in achieving the highest rate in the practical and theoretical field capacity of (0.35 and 0.50 ha h-1) and the highest volume of the disturbed soil and practical productivity reached (254.02 m3 h-1 and 0.40 ha h-1), respectively. The interference between the tractor first speed and the first ploughing depth exceeded the achievement of the lowest rate in the percentage of slide (3.36%).

1. Introduction
The soil ploughing process is described as the process by which the soil is rebuilt and the surface layer is broken down to disintegrate the soil and mix it with the remnants of the previous crop and create appropriate conditions that allow water and air to penetrate through it and prepare a suitable cradle for seeds and provide appropriate conditions for the plant [1]. Choosing the appropriate type of plough is of great importance in determining the quality of the ploughing and improving the characteristics of the soil and then increasing the productivity of the cultivated crop. Despite the many benefits of ploughing, the error in choosing the appropriate machine may lead to negative results that are reflected on the characteristics of the ploughing as soil reclamation, and increase its apparent density and increased soil resistance to penetration [2]. The rototiller has the advantage of reducing the time required to obtain an optimal seed bed by combining the primary and secondary ploughing process [3]. One of the important indicators for determining the efficiency of performance is the actual practical productivity of the mechanical unit, as practical productivity is a key factor in evaluating the performance of ploughs and agricultural machines. The actual practical productivity of the mechanical unit is affected by the type of machine and the equipment, its design, working width, speed of operation, type of soil and its physical characteristics [4].
The speed of ploughing is of great importance in increasing the actual productivity of the mechanical unit as the practical speed of the tractor is directly proportional to the practical productivity of the mechanical unit taking into account that the increase in the practical speed of the tractor is within the permissible range as it works to increase the practical productivity by increasing the speed of the front pull. It is considered that the forward speed of the machine is one of the important and direct factors that affect its productivity in terms of quantity and quality, through which the productivity of agricultural machinery is determined [5].

Al-Tahhan , Al-Jarrah and Abdul Karim [6]; [7]; [8] have showed that the increase in the forward speed from (3.83 km h-1 to 7.58 km h-1) increased the percentage of slide from 9.51 to 16.55, and they say that the reason for that the increase in speed leads to an increase in the strength of the drag resistance and the shortening time of the driving wheels to the ground, ie the short period of time for the wheels to come into contact with the soil surface. Kouchakzadeh [9] explained in a study of three tractor speeds (1.0, 1.5 and 2.0 km h-1) and three rotational speeds of the rototiller (180, 220 and 240 rpm) but the mean cone index and apparent density at the lowest speed (1 km h -1 and 180 rpm) were 28% and 7% less than the corresponding average at the highest speed (2 km h-1 and 240 rpm), respectively.

Taha [10] pointed out that the depth of ploughing 5 cm exceeded the depth of ploughing 10 and 15 cm in achieving the highest rate of practical productivity of 0.562 ha h-1. The lowest rate of tractor force and the increase in the speed of the tractor of 2.65, 4.89 and 6.34 km h-1, led to the increase in the tractor force, the efficiency of conduction capacity, the volume of the disturbed soil, and the practical productivity reached the lowest (1.446 kn and 0.718 307.44 m-3 h-1 and 0.449 km h-1), respectively.

The degree of fragmentation can be controlled by the practical speed of the tractor, or the change of the transmission rate in the gearbox of the rototiller, or by changing the number of weapons installed on a plate or by regulating the distance between the cover and the rotating column carrying the weapons [11]. Al-Sharifi [12] concluded that increasing the practical speed of the mechanical unit deteriorates the physical properties of the soil. Al-Badri [13] explained that the increase in the practical speed of the triple-tipped turtle plough from 3.21 to 3.71 km h-2 resulted in a significant increase in both the percentage of slide from 11.86% to 14.42% and practical productivity from 0.21 to 0.24 ha. h-1 and the volume of the disturbed soil from 367.10 to 438.003 m3 h-1.

The depth of ploughing is an important factor affecting the fastening strength, and this effect changes with the change in soil conditions, soil moisture, and the type of instrument used in ploughing [14]. Al Rajbu [15] found that the depth of ploughing (15-20 cm) significantly exceeded the depth (20-25 cm) in its recording of the highest process speed, the lowest percentage of slide, and the highest practical productivity, and the reason for this may be that the increased depth of ploughing was accompanied by an increase in the tractor force with pull force, which led to the increase of the slide of pushing wheels, and the increase in depth decreased the practical productivity due to the decrease in the operation speed. Kankal [16] indicated that the field efficiency of the rototiller gave 77.18-80.60%, and mud depth and mud index were 19.68-20.25 cm and 78.84-80.63%, respectively.

Moitazi [17] found that increasing the depth of ploughing during work leads to an increase in the costs of operating the mechanical unit due to the decrease in the actual field capacity of the machine due to the reduction of the ploughing speed. Jassim [18] concluded that, by increasing the practical speed of the mechanical unit, the percentage of slide, apparent density of the soil, and soil resistance to penetration increased, while fuel consumption and field efficiency decreased. Aday[19] also found that the volume of the soil disturbed for the flip-flop plough was 552.97 m3 h-1, while the flip-disc plough had 470.15 m3 h-1. They also noticed that the volume of the disturbed soil increases with increasing depth. Al-Nima [20] found that practical productivity decreased from 1.423 dun hr-1 to 1.323 dun h-1, with an increase in ploughing depth from 10 cm to 20 cm. The percentage of soil particles with diameters less than 5 cm is a measure of soil fragmentation and smoothing after treatment and is (85%) as a minimum per square meter as evidence of the availability of agricultural technical requirements [21].
Despite the great importance of the rototiller for use in primary and secondary ploughing, studies on this plough are few in terms of operating conditions (depth of ploughing, forward speed of ploughing). This study aims to know the effect of the forward speed of the tractor and depth of ploughing on some characteristics of the physical soil using a rototiller.

2. Materials and Methods

An experiment was carried out at the Agricultural Research Experiments Station that was not cultured with crops in the Sayada region which belongs to the College of Agriculture / University of Kirkuk. The soil texture was Loam soil. The experiment included two factors, the first factor is the forward speed (G1 = 1.72 and G2 = 2.86 km h\(^{-1}\)) of a tractor type of Massey Forksen (MF435), horsepower (72 hp) pulls a rototiller with working width (185 cm). The knives were L-shaped. The second factor was the depth of the ploughing average (D1 = 4.63 and D2 = 6.30 cm). The ploughing distance was determined by (50) metres with leaving a distance of (10) metres between each replicate and another as the machine’s setting distance for the ploughing. A factorial experiment was used according to the design of The Randomized Complete Block Design (RCBD) with three replicates and the differences between the lowest probability level P <0.01 and <0.05 were tested. The following characteristics were measured:

\[\text{T.F.C.} = \frac{W \times S}{10}\]  
\[\text{E.F.C.} = \frac{A}{T_p + T_1}\]  
\[\text{PORO\%} = \left(1 - \frac{P_b}{P_s}\right) \times 100\]  
\[\text{SVD} = 10000 \times P_p \times D_t\]
The ratio of soil particles with diameters less than (5 cm per square meter) was calculated by placing a metal or wooden frame (25 x 25 cm) to take a random sample of the cultivated parameters after which the sample was weighed and then passed using a sieve with holes (5 x 5 cm), thus only allowing with the passage of soil particles, those diameters less than (5 cm), and then weighed for the purpose of calculating the proportion of soil particles with a diameter of less than (5 cm) and the following equation was used [24]:

\[ R = \frac{w_1 - w_2}{w_1} \times 100 \]  
(5)

\[ R = \text{Ratio of soil particles with diameters less than (5 cm m}^{-2}.\]  
\[ W_1 = \text{Sample's total weight.} \]  
\[ W_2 = \text{Weight of the remained amount of sample in the sieve.} \]

2.6. Slide percentage:
The percentage of slide was calculated according to the method proposed by [25], as following:

\[ S\% = \frac{V_t - V_p}{V_t} \times 100 \ldots (\%) \]  
(6)

\[ V_t = \text{Theatrical speed (km h}^{-1}.\]  
\[ V_p = \text{Effective speed (km h}^{-1}.\]  

2.7. Effective productivity:
The effective productivity has been calculated according to the method suggested by [14 and 26] which is as following:

\[ P.p = 0.1 \times B.p \times V.p \times F_t \]  
(7)

\[ P.p = \text{Process’s productivity (ha h}^{-1}.\]  
\[ B.p = \text{Width of worker (cm).} \]  
\[ V.p = \text{Practical speed (km h}^{-1}.\]  
\[ F_t = \text{Coefficient of time consumption (0.8).} \]

3. Results and Discussion

The table of variance analysis (Table 1) shows the presence of significant effects of forward speed, depth of ploughing, and the interaction between them in the characteristics, effective field capacity (ha h\(^{-1}\)), theoretical field capacity (ha h\(^{-1}\)), and volume of disturbed soil (m\(^3\) h\(^{-1}\)), slide percentage (%) and effective productivity (ha h\(^{-1}\)). At the level of significance p <0.01. The differences did not have a significant effect on the two characteristics of the porosity ratio (%) and the percentage of soil particles with diameters less than (5 cm m\(^{-2}\)).

It is clear from Table (2 and 3) that there are significant effects of forward speed and depth of ploughing and their interactions in the characteristics of the theoretical and effective capacities (ha h\(^{-2}\)), as the second forward speed exceeds (G2 = 2.86 km h\(^{-1}\)) and the second ploughing depth (D2 = 6.30 cm) in giving the highest effective field capacity of (0.28 and 0.34 ha h\(^{-1}\)) and the theoretical field capacity of (0.41 and 0.49 ha h\(^{-1}\)), respectively. The highest interference capacity between the second

| S.O.V         | d.f | Effective field capacity E.F.C (ha h\(^{-1}\)) | Theoretical field capacity T.F.C (ha h\(^{-1}\)) | %Porosity | Soil Volume Disturbed SVD (m\(^3\) h\(^{-1}\)) | Ratio of soil particles with diameters less than (5 cm m\(^{-2}\)) | %Slip (%S) | process’s productivity P.p (ha h\(^{-1}\)) |
|---------------|-----|---------------------------------------------|---------------------------------------------|-----------|---------------------------------------------|---------------------------------------------|-----------|-------------------------------------------|
| Rep           | 2   |                                             |                                             |           |                                             |                                             |           |                                           |
| Treat.        | 3   |                                             |                                             |           |                                             |                                             |           |                                           |
| G             | 1   | 0.000338**                                 | 0.000691**                                 | 0.604354  | 195.6137**                                  | 19.168119                                  | 18.661681** | 0.000442**                                |
| D             | 1   | 0.043649**                                 | 0.089079**                                 | 0.308375  | 49630.372**                                 | 0.4511736                                  | 74.760645** | 0.057011**                                |
| GxD           | 1   | 0.000686**                                 | 0.001400**                                 | 13.96873  | 328.2172**                                  | 25.429331                                 | 34.975133** | 0.000896**                                |
| Error         | 6   | 0.0000103                                 | 0.0000221                                 | 17.54159  | 3.7850936                                  | 15.045302                                 | 1.0695072  | 0.0000135                                 |
| LSD           | G   | 0.0058                                     | 0.0083                                     | n.s       | 3.5307                                     | n.s                                        | 1.8766     | 0.0067                                    |
| LSD           | D   | 0.0058                                     | 0.0083                                     | n.s       | 3.5307                                     | n.s                                        | 1.8766     | 0.0067                                    |
| LSD           | GxD  | 0.0082                                    | 0.0118                                     | n.s       | 4.9931                                     | n.s                                        | 2.6539     | 0.0094                                    |

n.s not significant; * significant at p <0.05; ** significant at p <0.01.
forward speed and the second ploughing depth reached (0.35 and 0.50 ha h-2) respectively. This is consistent with the findings of [19].

Table 2. Effect of forward speed and depth of ploughing on the characteristic of field capacity (ha h-2).

| G/D | G1  | G2  | Mean-G |
|-----|-----|-----|--------|
| D1  | 0.22| 0.22| 0.22   |
| D2  | 0.33| 0.35| 0.34   |

Table 3. Effect of forward speed, depth of ploughing and their interventions on the theoretical field capacity (ha h-2).

| G/D | G1  | G2  | Mean-G |
|-----|-----|-----|--------|
| D1  | 0.32| 0.31| 0.31   |
| D2  | 0.47| 0.50| 0.49   |

Table No. (4 and 5) show significant effects of forward speed, depth of ploughing and their interventions on the characteristics of the disturbed soil volume (m³ h-2) and effective productivity (ha h-2), as it exceeded the second forward speed (G2 = 2.86 km h-1) and the second ploughing depth (D2 = 6.30 cm) in giving the highest volume of the disturbed soil amounted to (184.48 and 244.753 m³ h-2) and effective productivity (0.33 and 0.39 ha h-2) respectively. The highest capacities of interference between the second forward speed and the second ploughing depth were (254.02 m³ h-2 and 0.40 ha h-1) respectively. This indicates that with increasing speed the effective productivity increases and the reason for this is that the speed is one of the factors involved in calculating effective productivity. These results are consistent with results of [27] and [28]. With increasing speed, the volume of disturbed soil increases exponentially [29].

Table 4. Effect of forward speed, depth of ploughing and their interventions on the volume of the disturbed soil (m³ h-2).

| G/D | G1  | G2  | Mean-G |
|-----|-----|-----|--------|
| D1  | 117.32| 114.94| 116.13 |
| D2  | 235.49| 254.02| 244.75 |

Table 5. Effect of forward speed, depth of ploughing and their interventions on effective productivity (ha h-2).

| G/D | G1  | G2  | Mean-G |
|-----|-----|-----|--------|
| D1  | 0.25| 0.25| 0.25   |
| D2  | 0.37| 0.40| 0.39   |

Table (6) show significant effects of forward speed and depth of ploughing and their interventions on the percentage of slide ratio (%), as the first forward speed exceeds (G1 = 1.72 km h-1 and depth of the first ploughing (D1 = 4 63 cm), in giving the lowest percentage of slide which was (7.56% and 6.31%), respectively. The lowest percentage of slide was for interference between the first forward speed and the first ploughing depth (3.36%). This may be due to that the increase in the practical speed of the mechanical unit reduces the chance that the wheel will stick to the ground leading to increased slide [8]. The highest percentage of slip was for interference between the second forward speed and the second ploughing depth (11.76%).
Table 6. Effect of forward speed, depth of ploughing and their interference on the percentage of slide (%).

| G/D | D1  | D2  | Mean-G |
|-----|-----|-----|--------|
| G1  | 3.36| 11.76| 7.56   |
| G2  | 9.27| 10.84| 10.06  |
| Mean-D | 6.31| 11.30|        |

G = Forward speed (Km hr⁻¹), D = Ploughing depth (cm).

Tables (7 and 8) indicate that there were no significant differences for the characteristics of the porosity ratio (%) and the percentage of soil particles with diameter less than (5 cm m⁻²).

Table 7. Effect of forward speed, depth of ploughing and their interventions on porosity (%).

| G/D | D1  | D2  | Mean-G |
|-----|-----|-----|--------|
| G1  | 33.73| 31.25| 32.49  |
| G2  | 31.12| 32.96| 32.04  |
| Mean-D | 32.42| 32.10|        |

G = Forward speed (Km hr⁻¹), D = Ploughing depth (cm).

Table 8. Effect of forward speed, depth of ploughing and their interference on the ratio of soil particles with diameter less than (5 cm m⁻²).

| G/D | D1  | D2  | Mean-G |
|-----|-----|-----|--------|
| G1  | 88.27| 85.74| 87.00  |
| G2  | 82.83| 86.13| 84.48  |
| Mean-D | 85.55| 85.93|        |

G = Forward speed (Km hr⁻¹), D = Ploughing depth (cm).

4. Conclusion
Can be conclude from the study that achieving the highest rate in the theoretical and effective field capacities, the highest volume of disturbed soil and effective productivity, were at high speeds and big depths and the lowest slide was at low speeds and depths. We recommend using another combination at different speeds and depths.

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