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Influence of various tillage systems and tillage speed on some soil physical properties

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ABSTRACT

Soil cultivation techniques can change the physical properties of soil and have the potential to influence the growth and productivity of crops. In the 2022 season, a research study was carried out on Gypsfreous soil in the College of Agriculture fields at Tikrit University. The purpose of the study was to investigate how the physical properties of the soil are influenced by three different plow types and varying plowing speeds. The study was planned using split plots within a Complete Randomized Blocks Design, with three types of plows (moldboard plow, disc plow, and chisel plow) and three tractor speeds (3.8, 5.8, and 7.6 km h^{-1}) as the experimental treatments.

The experiment's findings indicated that the moldboard plow resulted in a greater reduction in bulk density compared to the disc plow. Consequently, the soil's bulk density decreased, and the percentage of porosity increased. On the other hand, the chisel plow had the lowest soil-specific resistance value and the highest soil volume disturbed value. The speed of operation above 3.8 km h^{-1} proved to be the most effective in reducing bulk soil density, increasing soil porosity, and reducing specific soil resistance. However, at a speed of 7.6 km h^{-1}, the soil volume disturbed was significantly higher than at other speeds. Additionally, the experiment's findings demonstrated that the moldboard plow, operating at a speed of 3.8 km h^{-1}, was significantly more effective than other methods in decreasing the soil's bulk density, increasing the porosity percentage, and reducing the specific soil resistance. Conversely, the chisel plow, working at a speed of 7.6 km h^{-1}, had a significant advantage in achieving the highest value for the volume of soil disturbed.

KEYWORDS

tillage, soil, plow, physical properties, moldboard

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INTRODUCTION

Agricultural mechanization has become increasingly important in recent years due to the need to improve efficiency and productivity in agricultural production. Tillage operation has been identified as a process that necessitates significant of energy and management expenses, such as the requirement for powerful tractors that consume a lot of fuel (Damanauskas et al., 2019). Tillage helps to enhance the soil's physical properties, which in turn creates a suitable seedbed for the growth of roots and germination (Lal and Stewart, 2013). Manipulating the soil physically involves eliminating weeds, incorporating crop residues and modifications into the soil, improving water infiltration and reducing evaporation, preparing the seedbed, and loosening compacted layers to facilitate the penetration of roots into the soil (Gbadamosi, 2013). The effects of tillage systems working at different speeds on soil physical properties provide evidence that the method and speed of tillage have a significant impact on soil conditions. Tillage systems can be incredibly effective when used to improve soil quality, but must be used in the right circumstances and with the right speeds to ensure soil quality is improved and preserved (Boydaş and Turgut, 2007; Salem et al., 2015; López-Vázquez et al., 2019; Balsari et al., 2021).

The existing literature may not adequately cover the multitude of tillage systems available and their effects on different soil types and climates. Addressing this gap could involve exploring lesser-known or emerging tillage techniques and their potential benefits. However, the duration and sustainability of the impact of various tillage systems and speed on soil physical properties may be an area that needs more attention. Long-term studies could help fill this gap by providing insights into the durability and persistence of the observed effects.

Conventional tillage systems are becoming more advanced, with features such as speed working components being incorporated. One type of speed-working component is the mouldboard plow, which is designed to move the soil as it is being worked into the required soil type in a fraction of the time usually needed. This is proving to be an effective way of reducing the amount of time typically needed to prepare a field for planting, as well as increasing the speed of complete tilling systems (Isaak, 2011).

A study (Boydaş and Turgut, 2007) highlighted the significant impact of tillage practices on soil physical characteristics and crop yield. Aggregate sizes and moisture content were found to be key factors influencing attributes like penetration resistance and bulk density. Another research (Rashidi and Keshavarzpour, 2008) analysed the effects of three soil treatments, including no-till and conventional or deep-plow farming. Cultivated soil exhibited lower bulk density due to deeper cracking and fragmentation caused by plowing. In a study by (Turki and Isaak, 2011) rotary plowing speed was investigated. Lowering the tillage speed to 2.5 km h^{-1} decreased bulk density, increased total porosity, reduced penetration resistance, and increased the number of small dirt clumps per square meter. Combining a high-speed tractor with moderate soil moisture improved physical characteristics. Optimal performance was achieved by maintaining soil moisture at 16% and using a general-purpose plow with a high-speed tractor operating at 1.12 m per second, resulting in low bulk density of 0.96 Mg. m^{-3} and high soil porosity of 63.90% (Nassir, 2018).

This study was limited to the effect of tillage systems (types of plows) on some physical properties of the soil. The no-till farming system was not discussed because in this study the focus was on studying the mechanical effect of plows on the physical soil properties.

Based on the above, the importance of agricultural mechanization and tillage operations in improving agricultural efficiency and productivity. This study highlights the influence of tillage method and speed on soil conditions, and the need to use tillage systems appropriate to specific conditions. In addition, the study aims to analyze the effect of plowing methods and its speed on the physical properties of the soil.

MATERIALS AND METHODS

The experiment was conducted to study the effect of plow types and plowing speeds on some physical properties of the soil in gypsiferous soil with a sandy loam texture, whose specifications are shown in Table 1 during the 2022 agricultural season. The first factor of plow types included:

Moldboard plow

The design width of the single share is 35 cm, the overall design width is 105 cm, the weight of the plow is 293 kg (Fig. 1).

Disc plow

Disc plow is a three-discs, the diameter of the disc is 66 cm, the concavity is 10 cm, the angle of inclination is 25 and the angle of the disc is 50, the total design width of the plow is 120 cm, the weight of the plow is 340 kg (Fig. 2).

Table 1. Physical properties of soil

Volumetric distribution of soil particles			Soil texture	Gypsiferous %
Sand %	Clay %	Silt %		
55	43	27	Sandy loam	34.5

Fig. 1. Moldboard plow with three bottoms

Fig. 2. Disc plow with three discs

Chisel plow

Chisel plow has shaves is 15. The type of shave is chisel with two sides, with a total working width of 305 cm. The distance between one shave and another in one row is 65 cm (Fig. 3).

As for the second factor, it was the forward speed of the tractor, and three plowing speeds were chosen, namely 3.8, 7.5, and 7.5 km h^{-1}. The tractor type Massey Ferguson 150 hp was used, and the tractor was driven in the field alone with three speeds and three repetitions. For each speed and for a distance of 50 m, the time for each speed was measured, from which the theoretical speed was calculated. The experiment was conducted using the split-plot design according to Randomized Complete Block Design (RCBD) and with three replications. The area of the experimental unit was 24 m^2, the length was 20 m, and the width was 1.2 m.

The measurements and calculations were made as follows (Fig. 4):

1. Bulk density: It is the ratio of dry soil mass to its total volume. The value of bulk density before the experiment was 1.32 g cm^{-3}.

The bulk density was estimated using the core method, by taking random samples after stirring the soil by plowing, to the depth of plowing for each treatment, and with several replications, and it is calculated according to the following equation:

Fig. 3. Chisel plow with 15 shaves

Fig. 4. Some images showing some measurements and the shape of the soil after plowing

$$Pb = \frac{Ms}{Vt}$$

Pb = bulk density g cm^{-3}, Ms = dry soil mass g, Vt = total volume of soil cm^{3}

2. Porosity: It is the ratio of the size of the pores in the soil. And it is calculated according to the following equation:

$$F = \left(1 - \frac{Pb}{Ps}\right) * 100$$

F = porosity, Ps = the real density is (2.56) g cm^{-3}

The real density is the density of the solid part (the density ratio of the particles) and can be defined as the ratio between the mass of the solid part to the volume of the same part.

3. Soil specific resistance KN m^{-2}

It represents a portion of the whole resistance per tillage area section, the plow-specific resistance is influenced by the width and depth of the tillage (Siddiq & AL-Obaidi, 2019). This force was calculated using the following equation:

$$SR = \frac{F_t}{(W_P * D_P)}$$

SR = Soil specific resistance, KN m^{-2}.
Ft = Required pulling force, KN.
Wp = Actual tillage width, m.
Dp = Actual tillage depth, m.
4. Soil Volume Disturbed (S.V.D)

It is calculated according to the following equation:

$$S.V.D. = \frac{Pp * 10000 * Dp}{100}$$

$S.V.D.$ = soil volume disturbed m^3 h^{-1}
Pp = effective field capacity ha h^{-1}
Dp = actual tillage depth, cm

RESULT AND DISCUSSION

1. Effect of tillage systems and speed in bulk density

Table 2 shows that the moldboard plow had a statistically significant advantage in providing the lowest bulk density value, which was 1.555 g cm^{-3}, compared to the disc plow and chisel plow, which recorded bulk densities of 1.603 g cm^{-3} and 1.673 g cm^{-3}, respectively. This is because the moldboard plow turns and breaks up soil layers, increasing tilled soil volume without changing soil mass. The disc plow mixes plant residues, reducing texture and increasing bulk density. The chisel plow loosens soil without turning it, resulting in smaller tilled soil volume and higher bulk density. This leads to smaller tilled soil volume and higher apparent density (Al-Tahan and Khan-Baq, 2007; Jassim and Al-Sharifi, 2007; Al-Sharifi, 2009; Isaak and Ahmed, 2009; Ali et al., 2011; AL-Taee et al., 2015).

As shown by the results, the plow speed had a significant impact on bulk density. At a speed of 3.8 km h^{-1}, the lowest bulk density of 1.495 g cm^{-3} was observed compared to higher speeds of 5.8 and 7.6 km h^{-1}, which resulted in bulk densities of 1.616 and 1.720 g cm^{-3}, respectively. Increasing speed reduced the number of large soil masses and led to greater fragmentation, thereby increasing bulk density (AL-Jarrah et al., 2006; Jassim and Al-Sharifi, 2007; Adel Abdullah and Ghazwan, 2012; Al-Sharifi, 2009; Isaak and Ahmed, 2009; Turki and Isaak,

Table 2. Effect of tillage system with speed working in bulk density

Implement	Speed working, km h^{-1}			
	3.8	5.8	7.6	
Moldboard plow	1.419 f	1.576 dc	1.669 b	1.555 c
Disc plow	1.522 e	1.596 c	1.692 b	1.603 b
Chisel plow	1.546 de	1.677 b	1.797 a	1.673 a
	1.495 c	1.616 b	1.720 a	SD = 0.1114

2011; Al-Jubouri, 2012; Alsaady, 2013; Jasim and Alssadi, 2014) that highlighted the relationship between plow speed and soil bulk density.

From Table 2 the interaction between the plowing system and the forward speed has a significant effect on the apparent density after plowing. The interaction between the moldboard plow and the forward speed at 3.8 km h^{-1} gave the lowest value of the apparent density, 1.419 g cm^{-3}, which can be attributed to the superiority of the aforementioned factors in giving the best values for the apparent density. On the other hand, the interaction between the subsoiler plow and the forward speed at 7.6 km h^{-1} gave the highest value of the apparent density, 1.797 g cm^{-3}.

2. Effect of Tillage Systems and Speed in the Porosity

In Table 3, we find that soil porosity was significantly affected by the studied factors and their interactions. When the tillage systems were applied, we found that the moldboard plow had a significant advantage in giving the highest value of soil porosity, which was 41.329%. This is attributed to the fact that this plow gave the lowest value of bulk density, which is inversely related to soil porosity. Meanwhile, the disc plow and chisel plow gave lower values of porosity, which were 39.501% and 36.855%, respectively (Al-Tahan and Khan-Baq, 2007; Al-Sharifi, 2009; Isaak and Ahmed, 2009; AL-Taee et al., 2015).

The effect of forward speed was also significant in soil porosity, where the forward speed of the tractor recorded the highest value of porosity, which was 43.568%, compared to the other speeds of 5.8 and 7.6 km h^{-1}, which gave porosity values of 39.006% and 35.111%, respectively. The reason for the superiority of the slower forward speed resulted in the highest soil porosity value, mainly due to its lower bulk density. There is an inverse relationship between plowing speed and porosity, as higher tractor speed increases soil clod fragmentation and reduces pore spaces (Jasim and Alssadi, 2014; Al-Rubaie, 2012; Kadhim and Subr, 2012), (A. Abdullah and Hilal, 2014) that observed similar relationships between speed and porosity.

Table 3 shows that the interaction between tillage systems and forward speed significantly influenced soil porosity after tillage. The moldboard plow combined with a forward speed of 3.8 km h^{-1} resulted in the highest porosity value of 46.465%. Conversely, the chisel plow combined with a forward speed of 7.6 km h^{-1} yielded the lowest porosity value of 32.189%.

3. Effect of tillage systems and speed on the soil's specific resistance property

From the data in Table 4, we notice the significant effect of the study factors on the soil's specific resistance, where the moldboard plow gave the least resistance in plowing, which was 41.349 kN m^{-2}. This is due to the narrow width of its blade compared to the other plows and the

Table 3. Effect of tillage system with speed working in porosity

Implement	Speed working, km h^{-1}			
	3.8	5.8	7.6	
Moldboard plow	46.465 a	40.516 cd	37.006 e	41.329 a
Disc plow	42.579 b	39.786 d	36.138 e	39.501 b
Chisel plow	41.660 bc	36.717 e	32.189 f	36.855 c
	43.568 a	39.006 b	35.111 c	SD = 4.211

Table 4. Effect of tillage system with speed working in soil specific resistance

Implement	Speed working, km h^{-1}			
	3.8	5.8	7.6	
Moldboard plow	93.501 c	103.975 b	114.901 a	104.126 a
Disc plow	71.032 e	84.284 d	98.514 bc	84.610 b
Chisel plow	35.860 g	40.517 fg	47.669 f	41.349 c
	66.798 c	76.259 b	87.028 a	SD = 29.306

fact that it does not invert the soil, which reduced its specific resistance. On the other hand, the disc plow gave a specific resistance of 84.610 kN m^{-2}, while the highest specific resistance was recorded by the chisel plow at 104.126 kN m^{-2}, due to its heavy weight and high ability to invert the soil (Al-Sharifi, 2009).

According to Table 4, we find a significant effect of speed on the specific resistance property of the soil, and there was a direct relationship between them. With an increase in speed from 3.8 km h^{-1} to 7.6 km h^{-1}, the specific resistance increased from 66.798 kN m^{-2} to 87.028 kN m^{-2}. This is because the increase in speed leads to an increase in the pulling force, and therefore, the specific resistance of the plow increases (Al-Sharifi, 2009; Ramadhan, 2012; Tahir and Jarad, 2017; Siddiq & AL-Obaidi, 2019).

The interaction between the type of tillage system and speed had a significant effect on the specific resistance of the soil, as shown in Table 4. The interaction between the moldboard plow and the speed of 3.8 km h^{-1} recorded the lowest resistance value, which was 35.860 kN m^{-2}. This is because the two factors individually had the least effect. On the other hand, the highest specific resistance value was recorded for the interaction between the chisel plow and the speed of 7.6 km h^{-1}, which was 114.901 kN m^{-2}.

4. Effect of tillage systems and speed on the volume of disturbed soil

From Table 5, it is evident that the plowing system has a significant effect on the characteristic of the disturbed soil volume, where the excavator plow recorded the highest value of the disturbed soil volume at 1857.65 m^3 h^{-1}, while the disc plow and the reversible moldboard plow recorded the lowest values of the disturbed soil volume at 880.43 and 704.88 m^3 h^{-1}, respectively. The reason for this is attributed to the higher productivity of the excavator plow due to its larger working width, which results in a larger disturbed soil volume. These results are consistent with those reported in (Isaak and Ahmed, 2009).

Plowing speed had a significant impact on disturbed soil volume, with higher speeds resulting in greater volumes. At speeds of 3.8, 5.8, and 7.6 km h^{-1}, the disturbed soil volumes were

Table 5. Effect of tillage system with speed working in soil volume disturbed

Implement	Speed working, km h^{-1}			
	3.8	5.8	7.6	
Moldboard plow	492.42 g	703.79 f	918.43 e	704.88 c
Disc plow	633.25 f	935.61 e	1072.44 d	880.43 b
Chisel plow	1386.39 c	1932.42 b	2254.13 a	1857.65 a
	837.35 c	1190.61 b	1415.00 a	SD = 601.174

837.35, 1190.61, and 1415.00 $m^3 h^{-1}$, respectively. The relationship between speed and disturbed soil volume was positive and linear, indicating that increasing tractor speed increases the breaking up and throwing of soil clods. Speed is recognized as a key factor in calculating disturbed soil volume (Ashour and Safi, 2015; Al-abiedi et al., 2016).

The interaction between the two factors, tillage system, and field speed, had a significant effect on the bulk soil volume. The highest value of the bulk soil volume, 2254.13 $m^3 h^{-1}$, was recorded when the moldboard plow was used with a field speed of 7.6 km h^{-1}. On the other hand, the lowest value of the bulk soil volume, 492.42 $m^3 h^{-1}$, was recorded when the disc plow was used with the lowest field speed of 3.8 km h^{-1}. As previously mentioned, this is due to the wider working width of the moldboard plow, which gave the highest productivity with the use of the highest tillage speed and thus produced the highest volume of disturbed soil.

CONCLUSIONS

The study investigated the impact of different tillage systems and plowing speeds on various soil properties, including bulk density, soil porosity, specific resistance, disturbed soil volume, and bulk soil volume. The significant advantage of the moldboard plow in achieving the lowest bulk density is attributed to its ability to turn and break up soil layers, increasing tilled soil volume without changing soil mass. The plow speed also played a crucial role, with slower speeds resulting in lower bulk densities due to increased soil clod fragmentation.

The interaction between plowing systems and forward speed further influenced the apparent density after plowing, emphasizing the importance of choosing the right combination for optimal results. The moldboard plow combined with a forward speed of 3.8 km h^{-1} yielded the lowest apparent density, while the subsoiler plow at 7.6 km h^{-1} resulted in the highest. The moldboard plow stood out again by providing the highest soil porosity, attributed to its ability to reduce bulk density. The slower forward speed of the tractor also contributed to higher porosity values due to lower bulk density. The interaction between tillage systems and forward speed significantly influenced soil porosity after tillage, with the moldboard plow at 3.8 km h^{-1} resulting in the highest porosity. The soil-specific resistance was influenced by the type of tillage system and speed. The moldboard plow exhibited the least resistance, while the chisel plow had the highest, attributed to its heavy weight and soil-inverting capability. Higher speeds led to increased specific resistance, emphasizing the need for a balanced approach when selecting plowing speeds. The chisel plow records the highest volume due to its larger working width. Plowing speed had a direct and positive relationship with disturbed soil volume, indicating that higher speeds resulted in greater volumes. The interaction between tillage systems and field speed significantly affected bulk soil volume, with the moldboard plow producing the highest volume at 7.6 km h^{-1}.

In summary, the study provided valuable insights into the influence of different tillage systems and plowing speeds on soil properties, highlighting the importance of selecting the right combination to achieve desired outcomes in terms of soil structure and productivity.

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