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Impact of the Number of Harrowing Times on Draft Force, Soil Fragmentation, and Bulk Density under Different Forward speeds and Depths

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Abstract

: A field experiment was conducted in one of the fields of the Faculty of Agriculture, Karma Ali site, on clay soil, according to a Randomized Complete Block Design (RCBD). The plowing process was performed with a disk plow and harrowing with a disk harrow once, twice, and three times, while the plowing depth of 15, 20, and 25 cm, and the forward speed levels of 2.58, 4.03 and 5.57 km h^{-1}. The results showed that the draft force required by the disk plow used in the plowing process was higher than the traction force required by the draft ged disk harrow used in the harrowing process by a percentage of 10.11, 10.87, and 11.67% in the case of harrowing once, twice, and three times, respectively. The traction force also decreased with increasing harrowing times, as when Increasing the tillage from once to twice and three times decreased the draft force by 15% and 32% respectively. The number of tillage times, once, twice and three times, was significantly superior in reducing the values of the crumbling index and apparent density compared to the plowing process, as the plowing process recorded the highest draft force and the highest values of the crumbling index and apparent density of 14.95 kN, 42.02 mm and 1.35 Mg m^{-3} respectively. The results also showed the significant interaction between the tillage and the plowing depth in reducing the draft force, crumbling index and apparent density compared to the plowing process. The lowest crumbling index and lowest draft force were at a depth of 15 cm and three times of 14.76 mm and 2.89 kN respectively. The lowest apparent density was 1.09 g.cm^{-3} at a depth of 15 cm and two times of harrowing. As for the interaction between the plowing and harrowing process and the forward speed, the speed was recorded The forward speed of 2.58 km h^{-1} and the three-time harrowing operation recorded the lowest draft force of 2.96 kN and the lowest pulverization index at a forward speed of 5.57 km h^{-1} and three-time harrowing operations of 15.39 mm. The forward speed of 15.57 km h^{-1} and two-time harrowing operations recorded the lowest apparent density of 1.07 Mg m^{-3}.

Keyword: disk plow, disk harrow, harrowing times, bulk density, fragmentation index, draft force

I. Introduction

An extremely significant resource that must be preserved is soil. Careful soil management is essential for sustainable agricultural production. According to Roger-Estrade et al. (2010), soil management plans that do not incorporate tillage activities miss a crucial component. According to Aikins et al. (2012), tillage is the process of mechanically manipulating the soil to get rid of weeds, break up crusts to make it easier for seeds and new crops to germinate, get rid of pests and agricultural waste, and create a proper soil tilth for seeding. In agricultural cultivation, tillage is an essential procedure that can affect the physical characteristics of the soil that are essential for plant growth (Amin et al. 2014; Khan et al. 2017).

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Disk harrows are mainly used for soil softening and breaking up clods after plowing with moldboard and disk ploughs, as they provide acceptable softening and a good seedbed, in addition to their ability to completely bury crop residues and weeds. In this way, a suitable seedbed can be obtained, characterized by a flat, uncompact surface, free of weeds (Nassir et al., 2024). The use of disk harrows in soil softening increases the degree of soil softening, which helps provide suitable conditions for germination. Plowing alone often does not produce a suitable seedbed at all, as it is followed by soil softening operations. The soil may be softened once or more, depending on soil conditions and the type of crop to be planted.

Different tillage tools (such as disk harrows, chisel plows, and moldboard plows) have varying effects on draft force and soil pulverization. Compared to disk harrows, which offer superior pulverization with less energy consumption, moldboard plows usually create larger clods, but need a greater draft force (Chen et al., 2020).

Although more tillage passes often result in better soil pulverization, they also increase energy requirements. A second pass with a disk harrow dramatically increased PI by 15 to 20%, but also increased draft force by 25%, according to research by Aikins et al. (2021). Over pulverization from too many passes can raise the risk of erosion (Soane et al., 2012).

Increased forward speeds may improve soil shattering and require a larger draft. According to Mouazen & Ramon (2006), speeding up from 5 to 8 km/h increased draft force by 18% while improving PI by 12%. However, very high speeds could decrease the effectiveness of pulverization because they shorten the period during which the soil interacts with the implement (Kheiralla et al., 2004).

Although deeper tillage usually results in better PI, it also requires larger draft forces. According to Meselhy (2021), PI improved by 30% while draft increased by 45% when depth was raised from 15 to 25 cm. Although shallow tillage could use less energy, it might not remove the soil enough for the best seedbed preparation.

Research indicates that achieving sufficient PI while consuming the least amount of energy may be accomplished by combining two disk harrow passes, ideal depth (15–20 cm), and moderate speed (6–7 km/h) (Aikins et al., 2021). Further lowering needless draft pressures can be achieved by precision tillage, in which tools are modified according to soil conditions (Godwin et al., 2007).

Working depth, forward speed, and disk harrow passes all have a big impact on soil bulk density (BD). After three disk harrow passes, Al-aridhee, and Al-Sabagh, A. (2011) found that BD decreased by 29.9%, compared to after the second pass. While Ahaneku and Ogunjirin (2005) noted similar contact-time effects in sandy loam soils, Mahmoudi, Jalali, and Skandri (2015) showed that moderate speeds of 5–7 km h^{-1} decrease BD by lowering tool–soil contact time without creating extra compaction.

Most of the soils in central and southern Iraq are clayey or suffer from drought most of the year. Therefore, when plowing them with primary plowing using traditional plows such as disk plows or rotary plows, this leads to leaving large clods of soil in the field (Amer and Muter, 2023). These clods need repeated harrowing operations until the soil becomes smooth and suitable for seed germination and growth. Therefore, research was conducted to prepare the seed bed and what is the number of times the disk harrow must pass over the field soil to obtain a suitable bed for planting. The research aims to study the effect of harrowing times with the disk harrow on the soil fragmentation index and bulk density of the soil and to determine what the requirements of the disk harrow are in terms of draft force to reach the lowest fragmentation index and prepare a good bed suitable for seed, germination, and growth.

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II. . MATERIALS AND METHODS

Field site and climate of the region

The experiments were carried out in November 2023 at the research station of the college of agriculture, university of Basrah, Karmat Ali District (30° 30′N, 47° 49′ E). This area has a semi-arid climate with an average annual rainfall of 300 mm over the long term (Al-Lami et al., 2021). The majority of the rainfall occurs in the winter. The average monthly temperature varies from a high of 43°C in July to a low of 17°C in January.

Disk Plow (Mounted Disk Plow)

This plow was manufactured by the General Company for Mechanical Industries in Alexandria. It consists of three disks, with a disk diameter of 70 cm and a concave depth of 10 cm. The distance between the disks is 50 cm. Working width of 150 cm. The plow mass is 531.661 kg, and the disk angle can be controlled to 45°.

Disk Harrow

An offset disk harrow was used, consisting of two rows of disks. The front disk has a parabolic section and the rear disks have a soft edge. Each row consists of 12 disks. The disks are inclined at an angle of 17°, with a disk spacing of 22 cm. The disk diameter is 55 cm, the design working width is 2.64 m, and the distance between the front and rear disks is 95 cm.

Tractors used

Massey-Ferguson 440 xtra

The Brazilian-made Massey-Ferguson 440 xtra tractor is equipped with a four-cylinder, four-stroke diesel engine that generates rear-wheel drive or front-wheel assist (MFWD). Its design output power is 65.5 kW. The tractor weighs 3,430 kg.

CASE JX75T

The Turkish-made CASE JX75T tractor is equipped with a 55 kW, six-cylinder, four-stroke diesel engine that generates rear-wheel drive or front-wheel assist (MFWD). The tractor weighs 3,059.15 kg, and its hydraulic system can handle a maximum load of 2,000 kgf. The tractor was used to engage the disk plow using a hydraulic system to control the depth of the machine. The tractor's gearbox was set to neutral, leaving the engine running to operate the hydraulic system without the tractor having any role in pulling the installed machine.

Load cell

An electronic load cell was used to measure the draft force of the disk harrow at the forward speeds and tillage depths used in field trials. The device was manufactured by Futek in the USA in 2010, and is a Cylindrical S-Beam, model LSB 600. The load cell was connected to a laptop via a USB data cable to record and store the measured data in Excel.

Measurement of Draft Force

A load cell was used to calculate the pulling force of the disk harrow. The harrow was connected to the Massey-Ferguson 440 Xtra tractor through a load cell connected to a laptop. The pull force is recorded and stored when the tractor pulls the disk harrow for each tillage treatment. The load cell was used to estimate the draft force of the disk plow by connecting it between a Massey-Ferguson 440 xtra tractor and a CASE JX75T.

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Soil Properties and Texture

Soil moisture content was determined by taking field samples at depths of 0-10, 10-20, and 20-25 cm, with three replicates for different soils using a core. The samples were oven-dried at 105°C for 24 hours, and the moisture percentage was calculated based on dry weight (Equation 1). Soil fractions were measured using a pipette method, according to the method mentioned in Black et al. (1965).

The soil penetrometer (M-0615 SAE Penetrologger, Royal Eijkelkamp Company, Netherlands) was employed. The cone pierces the soil to a predetermined depth when the instrument is pushed down. Up to 80 cm, this gadget can read data on soil penetration every 1 cm. The device's digital screen shows the data either visually or digitally. After sampling, all soil penetration data were stored in the device's memory, and each measurement was made three times for every treatment. All of the captured data was moved to and examined on a computer that was linked to the device. The probe rod is 80 cm long, the top cone angle is 60 degrees, the cone's cross-section is 2 cm², and the soil penetration speed is 2 cm². All results are shown in Table (1).

$$MC = \frac{W_{w} - W_{d}}{W_{d}} \qquad (1)$$

Where: MC is the moisture content of soil (%); W_W is the wet soil sample mass (g); W_d is the dried soil sample mass (g).

Table 1. Soil properties and texture

Soil depths	**Bulk density (Mg cm^{-3})**	**Soil penetration resistance (Mpa)**	**Soil moisture content (%)**
0-15	1.46	1.5	10.30
15-20	1.50	1.98	15.37
20-25	1.58	2.50	19.24
Soil texture	**Clay**	**Silt**	**Sand**
Clay	(gm.kg^{-1})	(gm.kg^{-1})	(gm.kg^{-1})
	583.52	208.58	206.90

Soil properties studied

Bulk soil density:

The bulk density of soil was determined by taking field samples at depths of 0-10, 10-20, and 20-25 cm using a sample core, with three replicates for each tillage treatment. The samples were oven-dried at 105°C for 24 hours. The bulk density of soil was calculated from Equation (1) according to the method described in Black et al. (1965).

$$\rho b = \frac{ms}{vt} \qquad (2)$$

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Where: ρb: Bulk density of soil (Mg m^{-3}), ms: Mass of dry particles (Mg), vt: Total soil volume (m^{-3}).

Fragmentation index of soil

After conducting experiments using a disk plow at depths of 10, 20, and 25 cm and with forward tractor speeds of 0.468, 0.882, and 11.363 km h^{-1}, samples of the plowed soil were collected after two weeks with an area of 1 m^2 and three replicates for each plowing treatment. After that, harrowing operations were performed. These samples were the result of a plow and disk harrow transferred to the laboratory and left to air dry, then sifted with an electric sifter, which contains a set of sieves with different diameters (170, 100, 50, 30, 20, 8, 2, and 1.7 mm). Then, the percentage of each weight on each sieve was calculated according to the method mentioned in Hillel (1980). The soil fragmentation index was estimated for the first, second, and third passes for each harrowing treatment, as well as for the plowing treatments. The fragmentation index was calculated from Equation 3.

$$PI = \frac{\sum_{i=1}^{n} Wi * \bar{x}i}{W_{total}} \qquad (3)$$

Where: FI: fragmentation Index (mm), wi: Percentage of soil mass remaining on each sieve after sieving (mm), W_{total}: Total soil sample mass (kg), $\bar{x}i$: Average diameter of two consecutive sieves (mm). (For example, if the diameter of the previous sieve is 140 mm and the subsequent sieve is 95 mm, then the average = (100 + 75) / 2 = 97.5 mm.).

Experimental Conduct

The experiment was carried out using a disk plow at three levels of plowing depth (15, 20, 25 cm) and three levels of forward speed (2.58, 4.03, 5.57 km h^{-1}). After completing the plowing operations at various depths and speed levels, the samples were taken randomly in blocks to measure the soil fragmentation index for all tillage treatments. The harrowing operations were carried out using a disk harrow (Figure 1), with one, two, and three harrowing passes. The harrowing was carried out with the first pass perpendicular to the plowing lines, the second pass parallel to the plowing lines and perpendicular to the first pass lines, and the third pass parallel to the first harrowing line and perpendicular to the second harrowing line.

Figure 1. Tractor and disk harrow.

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Statistical analysis of the experiment

The statistical design of the current investigation assesses the impacts of three critical experimental factors on soil preparation (Fig. 2). The factors are four preparation systems, three speeds, and three levels of plowing depth.

The preparation system is characterized as an experimental variable with four levels, as follows.

Plowing by disk plow (no soil harrowing)

Plowing + single pass of disk harrow

Plowing + two passes of disk harrow

Plowing + Three passes of disk harrow

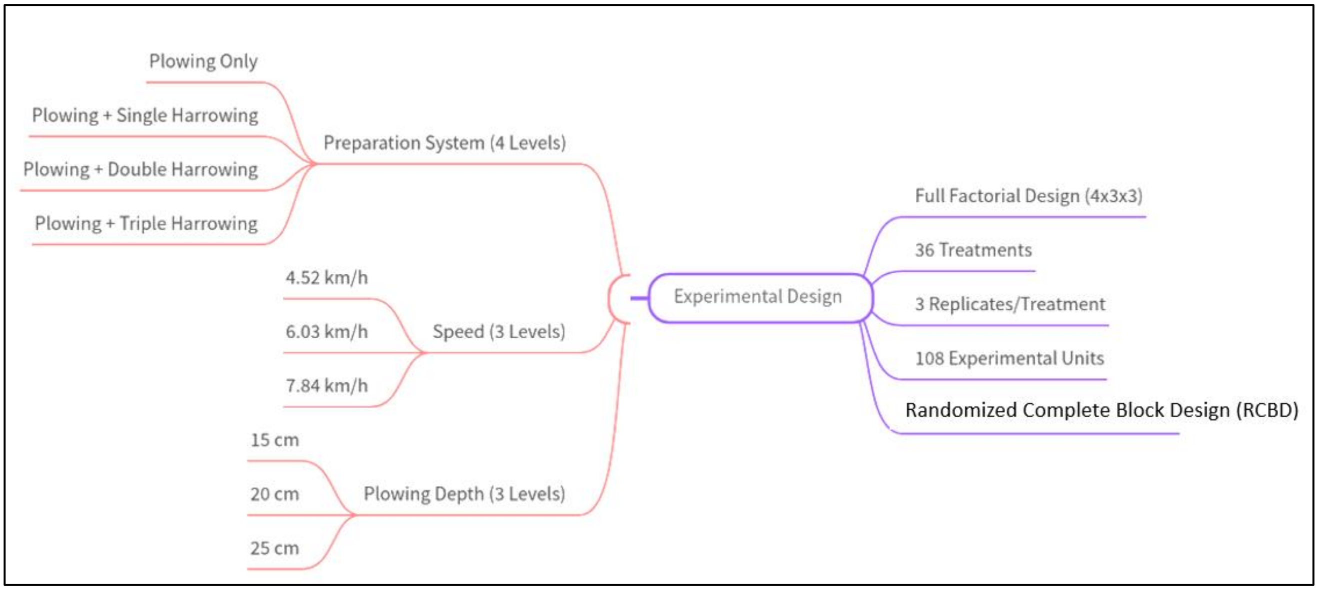
In addition, the design incorporates two other factors:

Speed: Three levels (2.58, 4.03, and 5.57 km h^{-1})

Plowing depth: Three levels (15, 20, and 25 cm).

Plow treatments, namely: 4 (plowing methods) ×3 (forward speed) ×3 (plowing depth) =36. With three replicates per treatment, the total number of experimental units amounts to: experimental units are 36×3=108 experimental units.

This design makes it easier to identify ideal operating conditions by offering a thorough understanding of how these parameters and their relationships affect soil preparation efficiency. Both main effects and higher-order interactions are robustly examined using the factorial technique, and the results are more reliable due to replication. To reduce bias and account for field variability, the experimental setup uses a Randomized Complete Block Design (RCBD). Genstat version 12 was used in statistical analyzes. LSD was used to compare means of treatments at a probability of 0.05.



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III. RESULTS AND DISCUSSOIN

Effect of plowing and harrowing frequency on the fragmentation index:

It is noted from the results in Table (2) that increasing the number of tillage frequencies significantly reduces the values of the fragmentation index. The fragmentation index decreased when plowing with a disk plow compared to tilling with a disk harrow once, twice, and three times by 26.48%, 51.30%, and 58.79%, respectively, as shown in Figures 2, 3, and 4). Meanwhile, the fragmentation index decreased when plowing with a disk harrow increased from one time to two and three times by 33.76% and 43.95%, respectively. The fragmentation index decreased by 15.37% when the number of harrowing frequencies increased from two to three times. The decrease in the fragmentation index values with an increasing number of passes was due to the increase in soil fragmentation. Each time the soil is fined, the fragmentation index decreases until it reaches a point where the possibility of pulverization becomes more difficult, as the fragmentation index decreases slightly after pulverization twice. This happened when fineness was increased from two to three times, as the fragmentation index decreased by only 2.87 mm. This amount is considered very small compared to the economic cost resulting from fuel consumption and other factors, in addition to the increase in soil compaction and the negative effects it causes on soil aeration, water permeability, and the formation of the impervious layer when fineness increases. Aday et al. (2011) found that soil penetration resistance increases with the increase in the number of tractor passes (four and more). These results are consistent with the results obtained by Nassir et al. (2023).

Figure 3. Soil fragmentation for plowing treatment

Plowing and Harrowing Requirements for Draft Force

It is noted in Table (2) that the draft force required by the disk plow used in the plowing process is higher than the draft force required by the disk harrow used in the softening process by 10.11, 10.87, and 11.67% in the case of single, double, and triple harrowing, respectively. It is also showed from the results that the draft force of the disk harrow decreases slightly with increasing number of harrowing, as the harrow is of the pulled type. Its draft force changes slightly depending on the conditions of the soil, the depth of plowing, and the speed of the tillage. This was what happened when the number of harrowing increased, as the soil became less coarse, affecting the friction force. Soil clods also became smaller, requiring slightly less draft force. These results are consistent with those of Nassir (2014).

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The effect of plowing and harrowing times on the bulk density of the soil

Table 2 shows significant differences in the bulk density values between the plowing operation and the harrowing operation, as the bulk density decreases with increasing harrowing times compared to the plowing process. The bulk density decreased with increasing harrowing times compared to the plowing process, from 1.35 to 1.18, 1.13, and 1.15 Mg m^{-3} when harrowing once, twice, and three times, respectively. This was because the harrowing process increases the fragmentation of the plowed soil clods, which increases the pores between the soil clods, making the soil volume after harrowing larger than its volume after the plowing operation, as the bulk density decreases according to equation (2). These results are consistent with the results obtained by Isaak (2024). However, when comparing the harrowing times with each other, we note that the bulk density values decrease significantly with increasing harrowing times. The bulk density decreased from 1.18 Mg m^{-3} after one harrowing to 1.13 and 1.15 Mg m^{-3} after two and three harrowing, respectively. The results also showed that the third harrowing increased the bulk density from 1.13 to 1.15 Mg m^{-3} compared to the one-time harrowing. The increase in the bulk density with the increase in the harrowing times to three times is due to the compaction and compression of the soil with the increase in the harrowing once to three times, which reduces the pores between the soil blocks, as the soil volume decreases. According to equation (2), the bulk density values decrease.

Table 2. Effect of the number of times of harrowing and plowing on the studied treatments

Harrowing times	Fragmentation index (mm)	Draft force (kN)	Bulk density (Mg cm^{-3})
Plowing without harrowing	42.02	14.95	1.35
Once harrowing	30.89	4.83	1.18
Twice harrowing	20.46	4.08	1.13
Thrice harrowing	17.31	3.27	1.15
LSD (0.05)	0.81	0.46	0.018

The effect of the interaction between plowing depth and number of harrowing operations on the draft force

Table 4 shows the increase in the draft force and the fragmentation index with the increasing depth of the plowing and harrowing process. When the plowing depth increased from 15 to 25 cm, the draft force increased from 12.92 to 17.47 kN, or 11.48%. The pull-out force increased with single, double, and triple harrowing by 37.05%, 46.72%, and 49.14%, respectively. The reason for the increase in the draft force with increasing depth of plowing and harrowing is due to the increase in the volume of soil cut by the plow disks, in addition to the increase in the friction force between the disks and the soil blocks, which increases the draft requirements necessary for plowing and harrowing. The plowing operations required a higher draft force than the draft force necessary for the crushing at all depths of the plowing. For example, when plowing at a depth of 15 cm, the lowest depth in this study, the draft force was 12.92 kN, while the harrowing operations once, twice, and three times at a depth of 25 cm, which is the greatest depth in this study, required a draft force of 5.66, 5.25 and 4.24 kN, respectively. This is due to the disk plow fact that the plowing process requires a higher draft force because the plow works in previously unplowed soil, so the force required to cut the soil, loosen it, and overcome the soil strength is high, while the harrowing operations with the disk harrow required a lower draft force because The harrow works on previously plowed soil, so its strength is weak and the harrowing process does not require cutting the soil slice from the mother soil body, but rather requires the process of breaking up the soil clods left in the field from the various plowing operations, which makes the pulling force required for the harrowing process less than the pulling force required for the plowing process. These results are consistent with the results obtained by Okoko (2022).

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The effect of the interaction between plowing depth and the number of harrowing operations on the fragmentation index:

Table 4 shows an increase in the fragmentation index values with increasing plowing or tillage depth. When the plowing depth increased from 15 to 25 cm, the fragmentation index increased for the plowing process and for the single, double, and triple tillage processes by 22.16, 51037, 28.42, and 34.75%, respectively. The highest fragmentation index (lowest fragmentation) was 45.81 mm when plowing at a depth of 25 cm. The three-time plowing process and a 15 cm plowing depth recorded the lowest fragmentation index (highest fragmentation) of 14.76 mm. This is due to the increased breaking and fragmentation of soil clods with increasing tillage times. These results are consistent with the results obtained by Wang et al., (2022).

The effect of the interaction between plowing depth and the number of harrowing operations on the bulk density of the soil.

Table 4 shows a decrease in the bulk density values of the soil when the harrowing operations were carried out once, twice, or three times compared to the plowing operation at all the plowing depths. The bulk density also increased significantly with increasing depth for the plowing operation and all harrowing operations. When the depth increased from 15 to 25 cm, the bulk density increased from 1.30 to 1.39 g cm^{-3}, while for the harrowing operations, once, twice and three times, it increased from 1.15 to 1.19 g.cm^{-3}, from 1.09 to 1.17 g.cm^{-3}, and from 1.12 to 1.20 g cm^{-3}. This is due to the increase in soil weight with increasing depth, which increases the cohesion of the soil masses. This reduces the presence of voids and pores in the soil, increasing the bulk density values with increasing depth. These results are consistent with Amer and Swain (2021) showing that the depth of 15 cm and the two-time harrowing were superior in recording the lowest bulk density of 1.09 Mg m^{-3}, while the plowing process and depth of 25 cm recorded the highest bulk density values of 1.39 Mg m^{-3}. The bulk density also increased with the third harrowing compared to the two-time harrowing for all plowing depths. For example, at a depth of 25 cm and three and two-time harrowing, the bulk density increased from 1.17 to 120 Mg m^{-3}. This is due to the increase in soil compaction with the increase in harrowing times more than twice, as the soil pores decrease, leading to a reduction in the soil volume. According to Equation (2), the bulk density increases in this study.

Table 3. Effect of the interaction of the number of times of harrowing and plowing depth on the studied treatments

Harrowing times	Plowing Depth (cm)	Fragmentation index (mm)	Draft force (kN)	Bulk density (Mg cm^{-3})
Plowing without harrowing	15	37.50	12.92	1.30
	20	42.76	14.45	1.36
	25	45.81	17.47	1.39
Once harrowing	15	25.63	4.13	1.15
	20	38.54	4.71	1.18
	25	38.54	5.66	1.19
Twice harrowing	15	18.05	3.52	1.09
	20	20.16	4.15	1.14
	25	23.18	5.25	1.17
Thrice harrowing	15	14.76	2.89	1.12
	20	17.30	3.00	1.17
	25	19.89	4.24	1.20
LSD (0.05)		1.32	0.77	0.12

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The effect of the interaction between the number of harrowing operations and forward speed on the draft force:

Table 4 shows the increase in draft force with the increase in forward speed. During the plowing process, the forward speed increased from 0.45 to 2.58 km h^{-1} and the draft force increased by 19.57%. The draft force increased by 30.71%, 16.44% and 20.60% for the single, double and triple harrowing processes, respectively. This is due to the increased movement of soil clods and their friction with each other and with the harrow disks, which causes momentum for these clods in front of the harrow disks, resulting in an increase in the draft force required to break up the soil clods by the disk harrow with increasing forward speed. The results also show that the draft force of the disk plow is higher than that of the disk harrow at different forward speeds and numbers of tillage passes. For example, the lowest draft force for the disk plow was 13.69 kN at a forward speed of 2.58 km h^{-1}, while the highest draft force recorded for the disk harrow was 5.49, 4.39, and 3.57 kN at a forward speed of 5.57 km h^{-1} when tilling once, twice and three times, respectively, at 5.49, 4.39, and 3.57 kN at a forward speed of 2.58 km h^{-1}. This indicates that the draft force requirement for the tillage process is less than the draft force requirement for the plowing process, as the ploughing process requires additional draft force resulting from cutting and turning the soil, while the disk harrow requires less draft force because it breaks up soil clods through the passage of the disks over the plowed land, making the draft force required for the disk harrow less than for the disk plow. The above results are consistent with those obtained by Sadek et al. (2021).

The effect of the interaction between the number of harrowing operations and forward speed on the fragmentation index:

Table 4 shows a decrease in the fragmentation index with increasing forward speed. The pulverization index decreased from 44.42 to 39.92 mm for the plowing operation and increased with forward speed from 2.58 to 5.57 km h^{-1}. Meanwhile, the pulverization index decreased from 28.10 to 24.20 mm from 22.14 to 19.04 mm, and from 18 to 15.39 mm for single, double and triple tillage operations, respectively. The highest pulverization index, 44.24 mm, was recorded during plowing at a forward speed of 2.58 km h^{-1}, and the lowest fragmentation index, 15.39 mm, was recorded during three-time tillage at a forward speed of 5.57 km h^{-1}. The reason for the decrease in the fragmentation index with increasing forward speed is due to the increase in forces. Collision of the harrow disks with the loosened soil clods during the plowing process, in addition to increasing the acceleration and movement of the soil clods and their collision with each other, increases the chance of self-disintegration of the soil clods. Additionally, increasing the harrowing times to three times makes the soil clods smaller in size, increasing the harrowing and fragmentation of the soil and thus reducing the fragmentation index. The above results are consistent with those obtained by Nasser et al. (2023).

The effect of the interaction between forward speed and the number of harrowing operations on the bulk density of the soil.

Table 4 shows that the bulk density decreases with increasing forward speed of the plowing process and for all harrowing operations. When the forward speed increases from 2.58 to 5.57 km h^{-1}, the bulk density decreases. The bulk density of the tillage operation decreased from 1.39 to 1.30 Mg m^{-3}, while the bulk density of the harrowing operations decreased once, twice and three times from 1.22 to 1.15 Mg m^{-3}, from 1.17 to 1.07 Mg m^{-3} and from 1.19 to 1.15 $g.cm^{-3}$, respectively. This is because increasing the forward speed increases the soil fragmentation, which increases the soil volume, and thus the bulk density increases according to equation (2). These results are consistent with the results of Meselhy (2021), and the forward speed of 5.57 km and harrowing twice achieved a lower bulk density of 1.07 Mg m^{-3}, while harrowing three times at the same forward speed achieved a higher bulk density of 1.16 Mg m^{-3}. It is noted that increasing the harrowing times to three times increases soil compaction due to the increased passage of the tractor and the tillage and harrowing equipment over the surface of the field soil, which causes the bulk density values to increase, albeit slightly, due to the proximity of soil particles to each other, as the pores decrease, which negatively affects soil aeration, water permeability, and root spread in the soil (McGarry et al. (2000); Zhang et al. 2006 and Balsari et al. 2021

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Table 4. Effect of the interaction of the number of times of harrowing and forward speed on the studied treatments

Harrowing times	Forward speed (km h^{-1})	Fragmentation index (mm)	Draft force (kN)	Bulk density (Mg cm^{-3})
	2.58	44.24	13.69	1.39
Plowing without harrowing	4.03	41.90	14.79	1.35
	5.57	39.92	16.37	1.30
	2.58	29.20	4.20	1.22
Once harrowing	4.03	28.86	4.81	1.17
	5.57	24.61	5.49	1.15
	2.58	22.14	3.77	1.17
Twice harrowing	4.03	20.20	4.07	1.13
	5.57	19.04	4.39	1.07
	2.58	18.00	2.96	1.19
Thrice harrowing	4.03	17.55	3.28	1.15
	5.57	15.39	3.57	1.16
LSD (0.05)		1.25	0.78	0.16

IV. . CONCLUSIONS

1. Soil pulverization increases with increasing number of harrowing. The fragmentation index values decrease with one, two, and three harrowing compared to plowing by 26.48%, 51.30%, and 58.79%, respectively.

2. Three harrowing reduce the fragmentation index by only 15%. This indicates that increasing the fragmentation index more than twice results in a slight decrease in fragmentation index values compared to the damage caused by soil compaction, as well as increased fuel consumption due to the tractor passing more than once through the field.

3- The traction force required for plowing with a disk plow is higher than the traction force required for harrowing with a towed disk harrow.

4- The bulk density is best achieved when harrowing is performed twice, at a forward speed of 5.57 km h^{-1}, and a plowing depth of 15 cm. The bulk density increases with three harrowings.

5- The traction force increases with increasing forward speed and depth.

6- The pulverization index decreases with increasing forward speed, and the pulverization index increases with increasing depth.

It can be recommended

1- Limit harrowing to one or two times to reduce tractor travel through the field while achieving adequate harrowing, minimizing soil compaction, and reducing fuel consumption.

2- Use a disk harrow at a forward speed of .84 km h^{-1} and a plowing depth of 15 to 25 cm to achieve optimal soil harrowing.

3- Use this disk harrow for harrowing with plows other than the disk plow.

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V. . REFERENCES

Aday, S. H., Aldosary, S. H., & Hassan, J. C. (2011). The effect of the tractor-implement passes on the soil penetration resistance of plowed silty clay soil. *Basrah Journal of Agricultural Sciences*, *24*(1), 2011.

Ahaneku, I. E., & Ogunjirin, O. A. (2005). Effect of tractor forward speed on sandy loam soil physical conditions during tillage. *Nigerian Journal of Technology*, *24*(1), 51–57.

Aikins, K. A., Antille, D. L., Jensen, T. A., & Blackwell, J. (2021). Influence of tillage speed and depth on soil physical properties and cotton emergence. Biosystems Engineering, 204, 1-12. https://doi.org/10.1016/j.biosystemseng.2021.01.013

Al-aridhee, J., & Al-Sabagh, A. (2011). *Effect of tractor type, speed, and tillage depth on some technical indicators of machine units and physical characteristics of the soil* (Master's thesis, University of Baghdad).

Al-Lami, A. M., Y. K. Al-Timimi, and H. K. Al-Shamarti. 2021. Spatiotemporal analysis of some extreme rainfall indices over Iraq (1981–2017). Scientific Review Engineering and Environmental Studies (SREES), 30(2): 221-235.

Alwan, A. A. (2019). A Field Study of Soil Pulverization Energy by using Different Moldboards Types Under Various Operating Condition. *Basrah Journal of Agricultural Sciences, College of Agriculture, University of Basrah*, *32*, 373–388. https://doi.org/10.37077/25200860.2019.284

Amer, K. Z., & Muter, S. A. (2023). The impact of two types of tillage machines on the tillage dates and numbers of durum wheat, Triticum durum yield (Waha Iraq). International Journal of Agricultural & Statistical Sciences, 19(1), 231–237. https://doi.org/10.59467/IJASS.2023.19.231

Amer, K. Z., & Swain, K. H. (2021). The impact of plowing depth and soil moisture on some technical indicators at using disk plow. International Journal of Agricultural & Statistical Sciences, 17(1). https://doi.org/10.1016/j.still.2021.105202

Amin, M., Khan, M. J., Jan, M. T., Rehman, M. U., Tariq, J. A., Hanif, M., & Shah, Z. (2014). Effect of different tillage practices on soil physical properties under wheat in semi-arid environment. Soil Environ, 33(1), 33-37.

Balsari, P., Biglia, A., Comba, L., Sacco, D., Alcatrao, L. E., Varani, M., ... & Aimonino, D. R. (2021). Performance analysis of a tractor-power harrow system under different working conditions. *Biosystems Engineering*, *202*, 28-41.https://doi.org/10.1016/j.biosystemseng.2020.11.009

Black, C.A.; Evans, D.D.; White, J.L.; Ensminger, L.E. & Clarck, F.E. (1965). Methods of Soil Analysis. Part 1. Physical Properties. Am. Soc. Agron. Inc. Pub., Madison, Wisconsin, 770pp.

Chen, Y., Tessier, S., & Rouffignat, J. (2020). Soil bulk density and porosity under different tillage systems. Soil Science Society of America Journal, 59(3), 724-731. https://doi.org/10.2136/sssaj1995.03615995005900030015x

Godwin, R. J., O'Dogherty, M. J., Saunders, C., & Balafoutis, A. T. (2007). A machine for assessing the mechanical properties of soil. Journal of Agricultural Engineering Research, 76(2), 161-171. https://doi.org/10.1006/jaer.2000.0538

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 14, Issue 1 (2025) PP 260-272
https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

Hillel, D. (1980). Fundamentals of Soil Physics. Academic Press Inc. New York, U.K.

Isaak, M., Azawi, A., & Turky, T. (2024). Influence of various tillage systems and tillage speed on some soil physical properties. Progress in Agricultural Engineering Sciences, 20(1), 37-47. https://doi.org/10.1556/446.2024.00070

Khan, S., Shah, A., Nawaz, M., & Khan, M. (2017). Impact of different tillage practices on soil physical properties, nitrate leaching and yield attributes of maize (Zea mays L.). Journal of soil science and plant nutrition, 17(1), 240-252. http://dx.doi.org/10.4067/S0718-95162017005000019

Kheiralla, A. F., Yahya, A., Zohadie, M., & Ishak, W. (2004). Modelling of power and energy requirements for tillage implements operating in Serdang sandy clay loam, Malaysia. Soil and Tillage Research, 78(1), 21-34. https://doi.org/10.1016/j.still.2004.02.006

McGarry D, Bridge B J & Radford B J (2000). Contrasting soil physical properties after zero and traditional tillage of an alluvial soil in the semi-arid subtropics. Soil and Tillage Research 53(2): 105-115

Meselhy, A. A. E. (2021). Effect of variable-depth tillage system on energy requirements for tillage operation and productivity of desert soil. International Journal of Applied Agricultural Sciences, 7(1), 38. DOI:10.11648/j.ijaas.20210701.13

Mouazen, A. M., & Ramon, H. (2006). Development of on-line measurement system of bulk density based on on-line measured draught, depth and soil moisture content. Soil and Tillage Research, 86(2), 218-229. https://doi.org/10.1016/j.still.2005.02.028

Nassir A.J (2014). Requirements of pulverization Energy of a tandem Disk Harrow At different . Pulverization depth And forward speed Basrah J. Agric. 27(1):301-315.

Nassir, A. J., Ramadhan, M. N., Alwan, A. A., & Muhsin, S. J. (2024). Optimisation and Modelling of Soil Pulverisation Index Using Response Surface Methodology for Disk Harrow Under Different Operational Conditions. *Acta Technologica Agriculturae*, *27*(2), 76–83. https://doi.org/10.2478/ata-2024-0011

Nassir, A. J., S. J. Muhsin, A. A. Mishall, and F. M. Almusawi. 2023. The impact of the tillage systems on input-output energy, soil pulverization, and grain yield of barley. Agricultural Engineering International: CIGR Journal, 25(4): 68-83.

Okoko, P. (2022). Draft Force Determination for an Offset Disk Harrow in a Sandy Loam Soil. *Adeleke University Journal of Engineering and Technology*, *5*(2), 140-146. DOI:10.4314/jasem.v25i5.9

Roger-Estrade, J., Anger, C., Bertrand, M., & Richard, G. (2010). Tillage and soil ecology: partners for sustainable agriculture. *Soil and Tillage Research*, *111*(1), 33-40. https://doi.org/10.1016/j.still.2010.08.010

Sadek, M. A., Chen, Y., & Zeng, Z. (2021). Draft force prediction for a high-speed disk implement using diskrete element modelling. *Biosystems engineering*, *202*, 133-141.https://doi.org/10.1016/j.biosystemseng.2020.12.009

Soane, B. D., Ball, B. C., Arvidsson, J., Basch, G., Moreno, F., & Roger-Estrade, J. (2012). No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment. Soil and Tillage Research, 118, 66-87. https://doi.org/10.1016/j.still.2011.10.015

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 14, Issue 1 (2025) PP 260-272

https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

Wang, Y., Jin, Y., Liang, X., Liu, X., Tan, B., He, S., ... & Zhang, Y. (2022). Fragmentation of soil-root complexes in sloping landscapes during tillage and soil translocation. Biosystems Engineering, 223, 116-128.https://doi.org/10.1016/j.biosystemseng.2022.08.014

Zhang S, Grip H & Lövdahl L (2006). Effect of soil compaction on hydraulic properties of two loess soils in China. Soil and Tillage Research 90(1-2): 117-125