Effect of Tillage Methods on Some Physical Properties of Soil and Yield Components Oats (*Avena sativa* L.)

Aqeel J. Nassir[1] Akram A. A. Al-Khalidy[2] Sadq J. Muhsin[3]

[1-3]Department of Machines and Equipment, College of Agriculture University of Basrah, Basrah, Iraq.

[1]E-mail: aqeel.nassir@uobasrah.edu.iq

Abstract. An experiment was conducted on in the field of Agriculture College, University of Basrah, Iraq, during the 2021-2022 season to determine the effect of different tillage strategies on some soil physical characteristics as well as oat growth under three different plowing depths. The experiment was designed according to a randomized complete block design with four tillage methods, namely, moldboard plow following by single pass of disc harrow (MPDH), chisel plow following by one pass of disc harrow (CPDH), two passes of disc harrow (2DH) and one pass of rotary tiller (RP). Three tillage depths 10,15 and 20 cm were used for each primary or secondary implement tillage as a subplot. The results showed that tillage depth and increasing the tillage depth led to significant increases in soil porosity and reducing in MWD (high soil pulverization) and soil bulk density. The plowing depth had a significant effect ($p< 0.05$) on the growth and yield of the oat. Whereas the plowing depth of 20 cm registered the highest values of percentage of emerged seedlings, plant height, leaf area, number of spikes per square meter, thousand kernel weight, and grain yield of oat was 82.83%, 95.05 cm, 23.12 cm2, 251.33 spike m-2, 17.87 g, and 2.98 Mg ha^{-1} respectively. Moreover, the results demonstrated that the tillage methods significantly affected oat growth and production. The 2DH registered the highest value of the percentage of emerged seedlings, plant height, leaf area, number of spikes per square meter, 1000 kernel weight, and grain yield of oat was 85.78%, 102.30 cm, 24.15 cm2, 256.44 g, 19.03spike m^{-2} and, 2.99 Mg ha^{-1} respectively. The optimal operating was at a tillage depth of 20 cm and using DH method followed closely by CPDH method then MPDH and the latest was RT.

Keywords. Tillage methods, Tillage depth, Soil physical properties, Oat growth, Yield components.

1. Introduction

Oat belongs to the Poaceae family and is cultivated in many countries of the world as a two-purpose crop for cereals and fodder. The world cultivated area is 26.5 million hectares and the production is 44.5 million Mgs of grain [1] in Canada and Australia. 74% of the world's production is used for animal feeding in various forms [2], as well as for human feeding [3]. Correct soil preparation was critical in increasing crop yield because soil preparation practices had direct effects on improving the properties of the soil, such as increasing root depth and allowing fertilizer to reach the root zone [4]. The selection of tillage systems or tillage methods depends on soil type and crop type [5]. Around the world, farmers use conservation tillage techniques including minimal tillage, imperfect tillage, reduced tillage, and no-tillage. [6]. The soil physical properties are the most important characteristics of the soil, particularly in agricultural applications. To promote growth and increase the spread of plant roots, the soil should be fragile and soft. To facilitate water and air passage in the plant's root zone, the

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soil's pores must have the right size and form. [7]. In the study conducted by using different tillage systems [8], it was found that the bulk density decreased when using conventional tillage compared to reduced tillage by 17.25%. [9] observed that utilizing a moldboard plow in a single pass had high bulk density and mean weight diameter (MWD) compared to a moldboard plow followed by a disc harrow by 23.44 and 47.65%.

An indication of soil pulverization known as dry mean weight diameter (DMWD) is influenced by operational factors including plowing depth, tillage technology, and soil factors like moisture content and bulk density. The size of the soil cloud must range from 10 to 65 mm. [10]. [11] reported that the increase in the disc harrow passes in the field from one pass to two passes led to a decrease in the dry mean weight diameter (DMWD) by 16%. [12] found that the moldboard plow followed by the chisel plow had the lowest dry mean weight diameter (DMWD) compared with when using only a chisel plow or moldboard plow by 56.47, and 48.90%, respectively.

Tillage techniques alter the soil's physical, chemical, and biological characteristics, which may have an impact on plant development and productivity. [13-15]. [16] The research study conducted by [16] revealed that minimum tillage gave the highest values of the mass of thousand kernels and grain yield of wheat compared to conventional tillage by 5.05 and 25.33%, respectively. [17] On several of the spring crops and using different tillage systems, they found that the highest output of the oat crop was when the traditional plowing by the plow was followed by the disc harrow, where the total grain yield was 1.36 Mg ha-1 while the treatment of low tillage (one pass of disc harrow) and no tillage system had lower grain yields of oats were 1.12 and 1.07 Mg ha-1, respectively. [18] found that deep plowing using a deep digger moldboard plow produced the most tiller number per plant compared to shallow plowing depths when using the disc plow and disc harrow by 18.64 and 11.87% respectively. [19] reported that disc plow, followed by chisel plow, gave plant height higher than reduced tillage by 4.78%. [20] reported that when studying the performance of barley growth and yield parameters, reduced tillage surpassed conventional tillage by increasing height, spike number, seed yield, kernel per spike, and thousand kernel weight by 20.40, 4.05, 26.,37, and 31.1%, respectively. [21] found that the conventional tillage methods increased grain weight compared with the reduced tillage and herbicide tillage systems by 22.47 and 26.71%, respectively. The objectives of this research were (i) investigate the effect of the four tillage methods on soil bulk density, porosity, and dry mean weight diameter (DMWD), as well as their effects on the growth and yield characteristics of the oat crop.

2. Materials and Methods

2.1. Field Operation and Experiment Design

During the 2021–2022 growing season, a field investigation was carried out in the agriculture college's field at Basrah University in Iraq (30° 30' S and 47° 50' E). The soil was silty clay loam. The general authority for meteorological information provided information on precipitation and air temperature (Fig.1). A randomized complete-block design was used in the experiment. The main plots contained four tillage methods that were utilized in the study. The four tillage methods are a moldboard plow followed by a single disc harrow pass (MPDH), a chisel plow followed by a single disc harrow pass (CPDH), two-disc harrow pass (2DH), and a single rotary tiller pass (RP). For each main or secondary implement tillage as a subplot, three tillage depths of 10, 15, and 20 cm were employed. 36 experimental units were present (subplot). The entire set of data was subjected to variance analysis utilizing SPSS Statistics software 22 Applying Fisher's protected least significant difference at a 5% probability

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level, treatment means were separated. After carrying out tillage practices (four tillage methods), the cereal of oats were sown in autumn (18 October) at an equal sowing rate for each tillage method. The germination ratio of oat seeds tested by Petri dishes before sowing was 97 %. Two equal doses of nitrogen fertilizer were added (Urea 46% N) at a rate of 120 kg ha^{-1}, the first dosage was added after two weeks of germination, and the second dosage was added after eight weeks. Before seeding, 80 kg ha^{-1} of phosphorus fertilizer (46% P2O5) was supplied to the soil [22].

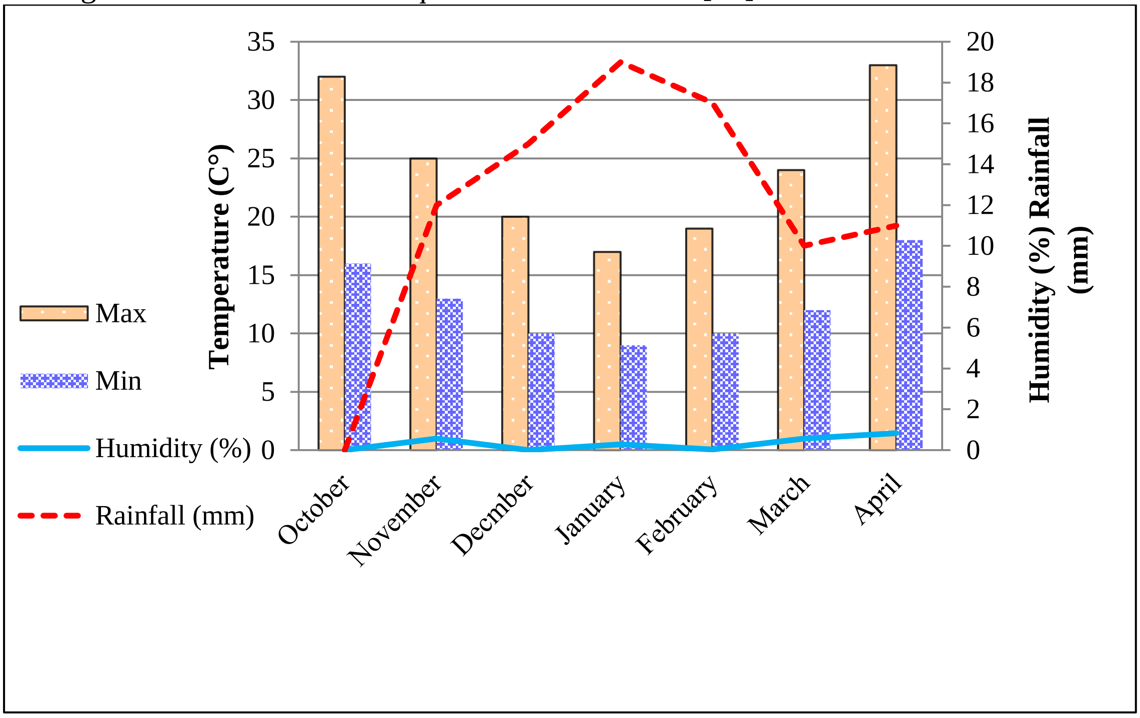

Figure 1. Shows the monthly temperature, air humidity, and total amount of precipitation for the months of October through April in 2021/2022.

2.2. Tillage Implements

Four implements tillage was used in this study were:

2.2.1. Moldboard Plow

General purpose moldboard plow had four moldboards. Work width of the plow was150 cm. Total weight of the plow was 293.50 kg, maximum depth of the plow reached to 30 cm

2.2.2. Chisel Plow

Heavy duty chisel plow had 7 ridge blades in two rows, the work width of the plow was 165 cm. Total weight of the plow was 426.25 kg, maximum depth of the plow reached to 40 cm.

2.2.3. Mounted Disc Harrow

A mounted disc harrow had two groups in the front row and two groups in the rear row, and each group contained 10 discs. The disc diameter is 0.52 m. The disc harrow has a 3.18 m width. Total weight of the plow was 487.55 kg, maximum depth of the plow reached to 25 cm.

2.2.4. Rotary Tiller

2 WD tractor hand drive provider with rotary tiller. The engine working on diesel fuel had power 12 HP. The revolution of the engine speed was 3600 rpm. The rotary tiller consisted of a rotary stainless steel shaft fixed on 24 curved knifed blades. Rotation speed of shaft 525 rpm. The length, width of soil, cutting, and thickness of the blades were 25, 6, and 1.20 cm, respectively. Operating width of the rotary tiller was 80 cm and the maximum

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operating depth reached to 20 cm. Total weight of the equipment was 210 kg.

2.3. Measurement of Growth and Yield Indicators

2.3.1. Emerged Seedlings Percentage (E.P)

It was calculated for each sub-sub plot of all tillage methods as follows equation (1), which is mentioned in [23].

$$P.E. = \frac{\text{total emerged seedlings per meters quare}}{\text{number of seeds planted per meter square}} \times 100 \quad (1)$$

2.3.2. Plant Height(cm)

Six plants from each experimental unit were taken randomly at 50, 75, and 150 days after planting to measure plant height. The plant height was measured as the vertical distance from the ground surface to the peak portion of the plant by tape.

2.3.3. Leaf Area Index

The number of leaves per plant was estimated by counting the total of leaves on each plant. The area index of the leaf was calculated using equation (2), which was mentioned in [15].

$$\text{Leaf Area Index} = 0.75 * (\text{Leaf length} \times \text{Leaf width}) \quad (2)$$

2.3.4. The Weight of a Thousand Kernels (g)

Ten plants were taken from each sub-subplot after harvest randomly. The weight of a thousand kernels was calculated by an electronic scale (±0.01 g) after passing spikes through a hand-fed thresher. Kernels were weighed based on moisture (15%). To estimate the number of tillers and yield components of oats by harvesting one square meter by sickle for each sub-sub plot. Spike numbers were measured then grains per spike was estimated as an average based on 50 spikes.

2.3.5. Grain Yield (Mg ha^{-1})

One square meter was harvested for each tillage treatment. The harvested grains were weighed by the sensitive scale of moisture (15%). The yields of grain for each one square meter were converted to Mg per hectare.

2.3.6. The Soil Bulk Density

The core sample method was used to estimate soil bulk density. The volume of the core is 83.35 cm^{-3}. Three replications of each treatment of soil samples were collected from the required depths (10,15, and 20 cm). Each sample was dried for 24 hours at 105 °C in an oven. The soil samples were weighed. Equation (3), which was mentioned in [24], was used to calculate the soil bulk density.

$$\rho d = \frac{ms}{vt} \quad (3)$$

Where: ρd: The soil bulk density (Mg m^{-3}), Ms: The mass of the dried soil sample (Mg), Vt: The total the soil sample volume (m^3).

2.3.7. The Soil Porosity (%)

Equation (4), which is mentioned in [24], was used to calculate the porosity of soil. The real density is 2.65Mg m^{-3}.

$$f = 1 - \frac{pd}{ps} * 100 \quad (4)$$

Where: *f*: Soil porosity (%), *ps:* The real density (Mg.m^{-3})

2.3.8. The Mean Weight Diameter

After plowing the soil and implementing all tillage methods at three plowing depths (10,15, and 20cm). The soil was left for two weeks to dry. Soil samples were collected from the surface of the test field and were transmitted to the laboratory and then sifted by using a set consisting of six sieves that had a mesh of 105 mm, 75 mm, 50mm, 25mm, 13mm, and 6.5mm. DMWD for soil was calculated by equation (5), which is mentioned in [25]. The physical and chemical properties of the soils sampled are summarized in Table (1).

$$PI = \frac{\sum_{i=1}^{n} Wi * S\bar{d}i}{W_{total}} \quad (5)$$

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Where:
Wi = The mass of the soil obtained between two
sieve openings *Sdi* and *Sdi+1*
W_{total} = the weight of the total mass
n = The number of sieves

From Equation. 4, *sdi* was calculated using the following equation:

$$\bar{di} = \frac{1}{2}(Sd_i + Sd_{i+1})$$
(6)

Table 1. Initial soil properties for the test field.

Soil characteristics **Texture of soil**	**Unit**	**Values** **Silty clay loam**
Soil bulk density	(mg kg^{-1})	1.52
Soil Cohesion	(kN m^2)	12.58
Organic carbon	(g kg^{-1})	6.13
pH		7.44
EC	(dS m^{-1})	5.11
Elements available in the soil		
P	(mg kg^{-1})	10.75
K	(mg kg^{-1})	168
N	(mg kg^{-1})	35.22
Mn	(mg kg^{-1})	4.14
Zn	(mg kg^{-1})	1.35
Cu	(mg kg^{-1})	0.87

3. Results and Discussions

3.1. Effect of Tillage Methods on Soil Properties

The effect of tillage methods on soil properties was shown in Table 2. There were significant ($P < 0.05$) differences in soil bulk density values for tillage methods, with 2DH having the lowest soil bulk density value of 1.22 Mg m-3. whereas CPDH and MPDH recorded soil bulk density values of 1.24 and 1.25 Mg m^{-3} respectively, higher than 2DH. However, the RT had the greatest soil bulk density value of 1.32 Mg m^{-3}. These results, because of differences in tillage tools, led to obtaining different roughness of the soil surface due to the result of soil clouds of different sizes. These findings concur with that of [9] and found that tillage methods had an impact on soil bulk density, with conventional tillage having a 16.67% higher bulk density than minimum tillage. Moreover, the results from table 2 showed that the 2DH significantly surpassed in obtaining the highest soil porosity, at 53.95% compared to other tillage methods CPDH, MPDH, and RT, which recorded the low porosity of soil, were 52.83, 53.21, and 50.19% respectively. That was because the tillage operation distributes soil and increases the soil porosity, particularly when using the 2DH tillage method. Similar results were obtained by [8] which showed that moldboard plow had lower soil porosity than disc harrows by 32.47%. The results indicated that tillage methods had a significant ($p < 0.05$) influence on the mean weight diameter (MWD) (Table 2). RT showed a lower MWD of 8.05 mm when compared with other tillage methods, CPDH, MPDH, and 2DH, which recorded MWD of 14.85, 13.08, and 12.02 mm respectively. This was because RT breaks down the soil by the rotation of curved blades, which operated to cut the soil and throw soil clouds into the blade cover where pulverized into small pieces. Thus, the MWD was low when utilizing RT [7,8,12].

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Table 2. Effect of tillage methods on soil properties.

Tillage methods	Bulk density (Mg m^{-3})	Porosity (%)	MWD (mm)
MPDH	1.25	53.21	13.08
CPDH	1.24	52.83	14.85
2DH	1.22	53.95	12.02
RT	1.32	50.19	8.05
LSD $_{(0.05)}$	0.009	0.435	0.793

3.2. Effect of Tillage Depth on Soil Properties

Table 3 demonstrates the effects of plowing depth on the physical properties of soil. The results indicated that the soil bulk density was significantly affected by the plowing depth. The lowest bulk density value was 1.22 Mg m-3 at plowing depth of 20 cm, while the maximum value was 1.28 Mg m-3 at plowing depth of 10 cm. These results might be explained by the fact that high plowing depth increased the soil loosening, thus increasing the soil volume plowed. This was consistent with [9], who found that increasing from 10 to 20 cm of plowing depth resulted in a reduction in soil bulk density of 1.22 to 1.64 Mg m-3 (25.61%).

The data shown in Table 3 demonstrates the significant effect of tillage depth on soil porosity (table 3). Increasing plowing depth from 10 to 20 led to an increase in the soil porosity from 51.70 to 53.95% (4.35%). This was because of increasing soil pulverization, which resulted in a considerable number of pores in the body of soil (high porosity). This result was similar to that of [10].

Tillage depth had a significant (p0.05) impact on MWD (table 3). The MWD was considerably reduced from 14.95 to 12.43 and 9.01 mm, respectively, when the tillage depths were increased from 10 to 15 and 20 cm. This indicates that MWD improved when tillage depths were increased. Reduced plowing depth increased soil fragmentation, due to a decrease in the volume of soil plowed. resulting in reduced MWD. Similar findings were reported by [12].

Table 3. Effect of tillage depth on soil properties.

Plowing depths (cm)	Bulk density (Mg m^{-3})	Porosity (%)	MWD (mm)
0-10	1.28	51.07	9.01
10-15	1.27	52.08	12.43
15-20	1.22	53.95	14.59
LSD $_{(0.05)}$	0.007	0.363	0.687

3.3. Effect of Tillage Methods on Plant Growth Parameters

3.3.1. Seed Emergence Ratio

The seed emergence ratio was affected significantly ($p < 0.05$) by tillage method. Data in Table 4 revealed that 2DH achieved the maximum ratio of seed emergence reaching 85.78% compared with CPDH, MPDH, and RP, which were 78.56, 76.89, and 72.33% respectively, and the reason could be returned to improving the soil properties considerably when using 2DH, thereby increasing the seed emergence ratio. Similar results were observed by [20,26].

3.3.2. Plant Height

The impact of tillage methods on plant height is shown in Table 4, which indicated that 2DH surpassed CPDH, MPDH, and RP significantly ($p<0.05$) in registering the

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highest value of plant height was 102.30 cm while the CPDH, MPDH, and RP recorded plant height values of 95.92, 87.91, and 71.26 cm respectively. This was due to improving soil properties and increasing the germination rate leading to increases in plant density, thereby increasing plant competition for light, which encourages the plant to produce Gibberellins which are responsible for the elongation of the plant stem to get enough light to grow and produce chlorophyll. These results are similar to that of [22, 24].

3.3.3. Leaf Area

Table 4 shows the influence of tillage methods on leaf area. The leaf area increased significantly under the 2DH treatment, which gave the highest leaf area of 24.10 m^2 in compared to the other tillage treatments. The CPDH gave the second highest leaf area of 22.78 m2, followed closely by the MDH, which gave a leaf area of 21.90 m^2, while the RP produced the lowest leaf area index of 20.06 m^2. These results may be due to the improvement of physical soil properties, thereby increasing the spread of roots and absorption of nutrients and resulting in the formation of high food stocks, which provided a suitable opportunity for the growth and expansion of cells and the construction of new cells and thus increased the leaf area. This trend accords with [15] where they found that DH had a greater leaf area value of 600 cm^2 compared to MDH, which gave a leaf area value of 566 cm2 after eight weeks from planting maize.

3.3.4. Number of Spikes Per Square Meter

Table 4 shows the impacts of tillage methods. The results reveal that the tillage technique significantly (p 0.05) affected the number of spikes per square meter. The highest and lowest values of the number of spikes per square meter were noted by 2DH and RP. The spike m^{-2} values were 256 and 225, respectively. CPDH and MDH had a number of spikes per square meter higher than RP and lower than. It was 248 and 234 spike m^{-2} respectively, these results were because of the improvement of the soil's physical properties when using 2DH, which led to an increase in germination rate and thus increased the number of square meters due to increasing plant density (number per square meter). These results agree with the findings reported by [20,26].

3.3.5. Thousand Kernel Weight

The effect of tillage method on 1000 kernel weight is illustrated in Table 4. The results demonstrated that the tillage method had significant ($p<0.05$) effects on 1000 kernel weight, except for MDH and RP, there were no significant ($p<0.05$) differences between them. 2DH obtained the highest value of 19.03 g while CPDH obtained the next highest value of 16.75 g. followed by MDH and RP. It was 15.83 and 15.70 g, respectively. This was because of the increasing in the leaf area and the increase in the competencies of photosynthesis, breathing, and plant activity in the absorption of water and nutrients, which is reflected in the fullness of grain because DH and CPDH methods worked on improving the soil's physical properties. The same trend was reported by [4].

3.3.6. Grain Yield of Oat

Data in Table 4 indicated the grain yield of oat was affected significantly ($p <0.05$) by tillage method. The grain yield of oats increased significantly under 2DH treatment. It achieved the highest value of 2.99 Mg ha^{-1}, followed by CPDH and MPDH. It recorded an oat grain yield of 2.86 and 2.52 Mg.ha^{-1}. while the RP treatment recorded the lowest value of 1.89 Mg.ha^{-1}. These results are due to various tillage methods, which have different effects on the soil's physical properties. The improvement in the characteristics of soil was decreased when the use of RP with increased density (high soil penetration resistance) and reduced soil porosity resulted in difficulty spreading the roots of the plant in the soil layer, lowering the absorption of nutrients and water needed for growth, which has a negative

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impact on grain output. This is consistent with the findings of [5, 6,17].

Table 4. Effect of tillage methods on plant growth parameters.

Tillage System	Plant parameters					
	Seedling emergence %	Plant height Cm	Leaf area cm^2	No. panicles per m^2	1000 seed weight gm	Seed yield Mg ha^{-1}
MPDH	76.89	87.91	21.09	234.56	15.83	2.52
CPDH	78.56	95.92	22.78	248.78	16.75	2.86
2DH	85.78	102.30	24.15	256.44	19.03	2.99
RP	72.33	71.26	20.06	225.11	15.70	1.98
LSD $_{0.05}$	1.366	1.596	0.986	3.140	0.241	0.081

3.4. Effect of Tillage Depth on Plant Growth Parameters

From Table 5, the results demonstrated a significant effect of tillage methods on plant growth parameters. The tillage depth of 10 achieved the lowest values of percentage of emerged seedlings, plant height, leaf area, spikes per square meter number, 1000 kernel weight, and grain yield of oats. The values were 73.58%, 82.15 cm, 20.61 cm2, 230 spikes m-2, 15.59 g, and 2.29 Mg ha-1, in that order. While the tillage depth of 20 was achieved, the highest values of the above parameters were 82.83%, 95.05 cm, 23.12 cm2, 251.33 spike m-2, 17.87 g, and 2.98 Mg ha-1 respectively. This is because increasing the depth has a positive effect on soil characteristics, as shown in Table 3. The low soil bulk density of the soil and the increased fragmentation of the soil clouds with increased tillage depth assisted in increasing the proportion of germination. The improvement of soil properties created conditions more suitable for growth as a result of the increasing spread of plant roots in the soil layer, which increased the plant root's absorption of water and nutrients, thereby increasing plant growth and grain filling and thus increasing the grain yield. These factors positively increased plant growth and yield [15, 19, 20, 22].

Table 5. Effect of tillage depth on plant growth parameters.

Tillage depth (cm)	Plant parameters					
	Seedling emergence %	Plant height Cm	Leaf area cm^2	No. panicles per m^2	1000 seed weight gm	Seed yield Mg ha^{-1}
10	73.58	82.15	20.61	230.00	15.59	2.29
15	78.75	90.81	22.33	242.33	17.00	2.49
20	82.83	95.08	23.12	251.33	17.87	2.98
LSD $_{0.05}$	1.183	1.382	0.854	2.719	0.209	0.070

Conclusions

This study indicates the improvement of soil physical properties with increased tillage depth and the use of the different tillage methods 2DH, CPDH, and MPDH, led to a positive effect on the parameters and growth of oats, but the RT had limited influence in improving the soil properties, thus reducing the growth parameters and yield of oats. The soil physical properties were improved under a plowing depth of 15-20 cm. The tillage depth of 15-20 cm achieved a high grain yield of oats compared to the tillage depths of 0-10 and 10-15 cm by 30.13 and 19.68% respectively.

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References

[1] Food and Agriculture Organization (FAO) 2004. Socio-economic Analysis and Policy Implication of the Roles of Agriculture in Developing Countries. Summary Report, Roles of Agriculture Project FAO Rome Italy.

[2] Ordoñez-Morales, K. D., Cadena-Zapata, M., Zermeño-González, A., & Campos-Magaña, S. 2019. Effect of tillage systems on physical properties of a clay loam soil under oats. Agriculture, 9(3), 62. https://doi.org/10.3390/agriculture9030062

[3] Korczak, R., Kocher, M., & Swanson, K. S. 2020. Effects of oats on gastrointestinal health as assessed by in vitro, animal, and human studies. Nutrition reviews, 78(5), 343-363. https://doi.org/10.1093/nutrit/nuz064

[4] Kumar, S., Jain M., Rani,V Kumar, V., Kumar, A & Naresh, A. 2018 Plant Growth and Yield Response of Tillage in Wheat Crop with Rotavator and Subsoiler Combination and No Tillage, International Journal of Current Microbiology and Applied Sciences. 7(3): 1597-1600. https://doi.org/10.20546/ijcmas.2018.703.192

[5] Khorami, S. S., Kazemeini, S. A., Afzalinia, S., & Gathala, M. K. 2018. Changes in soil properties and productivity under different tillage practices and wheat genotypes: A short-term study in Iran. Sustainability, 10(9), 3273. https://doi.org/10.3390/su10093273

[6] Buchi, L., Wendling, M., Amossé, C., Jeangros, B., Sinaj, S., & Charles, R. 2017. Long and short term changes in crop yield and soil properties induced by the reduction of soil tillage in a long term experiment in Switzerland. Soil and Tillage Research, 174, 120-129. https://doi.org/10.1016/j.still.2017.07.002

[7] Jabro, J. D., Iversen, W. M., Stevens, W. B., Evans, R. G., Mikha, M. M., & Allen, B. L. 2016 Physical and hydraulic properties of a sandy loam soil under zero, shallow and deep tillage practices. Soil and Tillage Research, 159, 67-72. https://doi.org/10.1016/j.still.2016.02.002

[8] Jabro, J. D., Stevens, W. B., Iversen, W. M., Sainju, U. M., & Allen, B. L. 2021 . Soil cone index and bulk density of a sandy loam under no-till and conventional tillage in a corn-soybean rotation. Soil and Tillage Research, 206, 104842. https://doi.org/10.1016/j.still.2020.104842

[9] Muhsin, S. J. 2017. Performance study of moldboard plow with two types of disc harrows and their effect on some soil properties under different operating conditions. Basrah Journal of Agricultural Sciences, 2, 1-15. https://bjas.bajas.edu.iq/index.php/bjas/article/view/19

[10] Shen, Q., Wu, M., & Zhang, M. 2022. Accumulation and relationship of metals in different soil aggregate fractions along soil profiles. Journal of Environmental Sciences, 115, 47-54. https://doi.org/10.1016/j.jes.2021.07.007

[11] Nassir, A. J., Ramadhan M. N., &. Muhsin, S. D. 2016. Studying draft requirements and plowing specifications for chisel plow in silty clay soil. Muthanna Journal of Agricultural Sciences, 4, 100-119. (In Arabic). https://muthjas.mu.edu.iq/?p=613

[12] Nassir, A. J. 2017. The effect of tillage methods on energy pulverization requirements under various operating conditions in silty loamy soil. Thi-Qar University Journal for Agricultural Researches, 6(2), 55-73.

[13] Ozpinar, S., & Cay, A. 2006. Effect of different tillage systems on the quality and crop productivity of a clay–loam soil in semi-arid north-western Turkey. Soil and Tillage Research, 88(1-2), 95-106. https://doi.org/10.1016/j.still.2005.04.009

[14] Rashidi, M., & Keshavarzpour, F. 2007. Effect of different tillage methods on grain yield and yield components of maize (Zea mays L.). Intnational Jonrnal of Agriculture. Biology, 9(2), 274-277.

[15] Aikins, S. H. M., & Afuakwa, J. J. 2010. Effect of four different tillage practices on

ISSN 2072-3857

cowpea performance. World Journal of Agricultural Sciences, 6(6), 644-651.
[16] Akbarnia, A., Alimardani, R., & Baharloeyan, S.2010. Performance comparison of three tillage systems in wheat farms. Australian Journal of crop science, 4(8), 586-589.
[17] Solodovnikov, A. P., Denisov, E. P., Denisov, K. E., & Shagiev, B. Z. 2017. Spring crops yield dynamics using energy-efficient methods of primary tillage of southern black soil in the Volga Region. Journal of Pharmaceutical Sciences and Research, 9(9), 1583. https://www.proquest.com/openview/5b3eee996e500c83ec044438194d1f66/1?pq-origsite=gscholar&cbl=54977
[18] Masek, J., & Novak, P. 2018. Influence of soil tillage on oats yield in Central Bohemia Region. Agronomy Research 16(3), 838845. https://doi.org/10.15159/AR.18.110
[19] Malecka, I., Blecharczyk, A., Sawinska, Z., & Dobrzeniecki, T. 2012. The effect of various long-term tillage systems on soil properties and spring barley yield. Turkish Journal of Agriculture and Forestry, 36(2), 217-226. doi:10.3906/tar-1104-20
[20] Ramadhan, M. N. 2013. Tillage systems and seeding rates effect on yield components, seed yield and biological yield of barley cultivars. J. Basra. Res. Sci, 39(1A), 33-46.
[21] Morris, N. L., Miller, P. C. H., Orson, J. H., & Froud-Williams, R. J. 2010. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment—A review. Soil and Tillage Research, 108(1-2), 1-15. https://doi.org/10.1016/j.still.2010.03.004
[22] Ali, M. A., & Khalid, L. 2015. Comparative performance of wheat in response to different phosphatic fertilizers. International Journal of Research, 1, 2394-5907.
[23] Bayhan, Y., Kayisoglu, B., & Gonulol, E. (2002). Effect of soil compaction on sunflower growth. Soil and Tillage Research, 68(1), 31-38. https://doi.org/10.1016/S0167-1987(02)00078-8
[24] Black, C.A.; Evans, D.D., White, J.L., Ensminger, L.E. and Clarck, F.E. 1965. Methods of soil analysis. Part 1. Physical properties. American Society of Agronomy. Madison, Wisconsin, 770pp.
[25] Nassir, A. J. 2018. Effect of moldboard plow types on soil physical properties under different soil moisture content and tractor speed. Basrah Journal of Agricultural Sciences, 31, 48-58. https://doi.org/10.37077/25200860.2018.75
[26] Muhsin, S. J., Ramadhan, M. N., & Nassir, A. J. 2021, April. Effect of organic manure and tillage depths on sunflower (Helianthus annuus L.) production. In IOP Conference Series: Earth and Environmental Science (Vol. 735, No. 1, p. 012070). IOP Publishing. doi:10.1088/1755-1315/735/1/012070.

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