Impact of Tillage Systems and Organic Manure Application on Some Soil Physical Properties and Grain Yield of Oats *(Avena sativa* L.) Under Semi-Arid Climate Conditions

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Abstract

A field study was carried out at the Agricultural research station of the College of Agriculture - University of Basrah, located at Karama Ali, south of Iraq in silty clay loam soil at the semi-arid climate to study the impacts of tillage systems (i.e., conventional tillage CT, deep tillage DT, reduced tillage RT, and no-tillage NT) and organic manure contented with 10% maize straw, 20% chicken manure, and 70% cow manure at a rate of zero (M0), 20 (M1), 40 (M2), 60, and 80 Mg ha^{-1} (M4) on some soil's physical properties and oat grain yield. The experiment was carried out in a split-block design with three replications. Bulk density (BD), aggregate mean weight diameter (MWD), penetration resistance (PR), water content (MC), and saturated hydraulic conductivity (Ks) were measured in two periods at the beginning and end of the growing season. The results showed that DT achieved lower BD and PR, as well as higher Ks and grain yield, than CT, RT, and NT at both periods of the growing season. The highest MWD and MC values were achieved by NT, followed by RT in both periods. However, the addition of manure M1, M2, M3, and M4 resulted in a significantly increased in MWD, MC, and Ks, while decreasing BD and PR in both periods as well as increasing grain yield by 37.50, 74.34, 82.89, and 97.37 respectively, compared to M0. The interaction between the tillage system and the addition of manure had a highly significant effect ($p < 0.01$) on BD, PR, and Ks in both periods. According to the t-test, the results showed that there was a significant effect of the sampling period on the soil properties studied. BD, MWD, PR, and MC increased at the end of the season by 9.68, 10.13, 15.18, and 55.32% compared to the beginning of the season, while Ks decreased by 14.58% at the end of the season. The highest and lowest grain yields of oat achieved by (DT * M4) and (NT * M0), were 6.70 and 2.75 Mg ha^{-1}, respectively.

Keywords: Tillage system, organic manure, soil physical properties, oat grain yield.

Introduction

Tillage systems and adding organic fertilization are two significant factors that affect soil characteristics and crop production. Tillage is the mechanical manipulation of the soil to prepare an appropriate seedbed and weed control. Organic matter availability is the nutrients necessary for the growth of the plant and improves soil structure (4, 14 and 24). Tillage can assist in the incorporation of organic matter, such as manure or crop residues, into the soil. This incorporation increases the decomposition of organic matter and nutrient release, resulting in essential nutrients being considerably more available to crops. It can also enhance nutrient cycling in the soil, thereby increasing soil fertility. Soil tillage also improves water infiltration by breaking down compacted soil layers. Tillage also improves the soil's ability to hold water, thereby decreasing waterlogging and improving plant root growth (20). Sustainable agriculture emphasizes the utilization of farming techniques that are environmentally proper and economical. This includes decreasing the utilization of chemical fertilizers and pesticides, boosting crop variety and rotation, and conserving water and soil. Conservation tillage systems are one important of the most important applications of sustainable agriculture (25).

Conservation tillage systems such as no-till or minimum tillage can result in an improved soil organic matter content because of the reduced loosening of the soil, which allows plant residues to aggregate on the soil surface and then slowly decompose, consequently improving the soil organic matter content (22). Conservation tillage systems also encourage the formation of stable soil aggregates and decrease the compaction of soil, resulting in improved soil structure and increasing the ability of soil to water storage, which can benefit plant growth and increase crop yield. Zhu *et al.* (40) reported that the conservation tillage system increments soil organic carbon content by an average of 0.6% per year. They also reported that conservation tillage improved soil stable aggregate, which led to good water infiltration and decreased soil erosion. Conservation tillage systems are a sustainable agriculture technique that goals to decrease or eradicate the negative effects of traditional tillage while conserving or improving crop production. Conservation tillage can improve soil health by rising soil organic matter, decreasing erosion of soil, improving soil water storage, and enhancing soil structure. These advantages can result from rising crop production and decreased input costs, while also assisting to mitigate climate change by imprisoning carbon in the soil (12). Conservation tillage systems had a positive impact on soil bulk density, reduced tillage systems have been found to reduce soil bulk density because of the existence of plant residues on the soil surface, which work as a physical obstacle against soil compaction (36).

Organic manure also plays a vital role in controlling soil bulk density. Studies have shown that adding organic manure helps decrease soil bulk density. This is due to organic manure improving the structure and stability of the soil, leading to increased soil porosity and decreased compaction (35).

Several investigations studied the interaction influence between conservation tillage systems and adding organic matter on soil bulk density. In a study conducted by (3), they reported that reduced tillage combined with adding cow manure led to a considerable reduction in soil bulk density compared to conventional tillage systems. Page *et al.* (32) revealed that the impact of conservation tillage systems on soil bulk density was based on the level of organic matter available in the soil. The soils containing low levels of organic matter under the conservation tillage system had a limited impact on soil bulk density, while soils with high levels of organic matter content under the conservation tillage system decreased soil bulk density significantly.

The soil in central and southern Iraq suffers from many problems, such as salinity, erosion, waterlogging, compaction, and degradation (15, 17 and 19). In order to reduce soil degradation, organic matter should be added to the soil and using suitable tillage systems (12). Therefore, the study aimed to determine the effects of four tillage systems and four levels of adding organic manure on some soil properties and oat yield in southern Iraq under semi-arid climate conditions.

Materials and Methods

Study site, experimental design and treatment

The study was carried out during the 2020–2021 agriculture season at the agriculture research station in Qurmat Ali in Basrah province, Iraq (N 47 ° 45 ‘08’ E’ 06' 34°30), to study the effect of four tillage systems and different levels of organic manure addition. The experiment arranged utilized a split plot in a randomized complete block design with three replications. The main plots consisted of CT (conventional tillage with a chisel plow and disk harrow with depths of 25 and 15 cm, respectively), DT (deep tillage with a subsoiler and disk plow at operating depths of 45 and 20 cm, respectively), RT (reduced tillage with a disk harrow with a depth of 15 cm), and NT (no-tillage) as a control treatment. The subplots consisted of four organic manure levels involved without manure fertilizer (control) and 20, 40, 60, and 80 Mg ha^{-1}, (M0, M1, M2, M3, and M4, respectively). Organic manure consists of 10% green manure (maize straw), 20% chicken manure, and 70% cow manure. Organic manure was manually added to the soil before tillage treatment. Organic manure was mixed with soil during tillage practices and then watered 21 days before sowing (28). Cow and chicken manure and maize straw were the sources of organic manure, which was obtained from the nearby farmers (Table 1).

The oat cereals were sown in the autumn on October 20 at a rate of 170 kg ha^{-1}. Sprinkler irrigation was used to irrigate the oat field. Irrigation water was added to the oat field based on the amount of evaporation from the class A evaporation pan. Phosphorus fertilizer was added before sowing at a rate of 65 kg P2O5 ha^{-1} as superphosphate (15.5% P2O5). Potassium sulfate (48% K2O) was supplied at a rate of 55 kg K2O ha^{-1} before sowing. Urea (46%, N) as a source of nitrogen, was added as a stimulation dose at 40 kg ha^{-1} (5). The experimental seasons' climate data were collected from the nearest meteorological stations (Table 2).

Table 1. Chemical properties of the organic manure used

Properties	Unit	Cow manure	Chicken manure	Maize straw
pH		7.9	9.82	10.24
N	g kg^{-1}	18.27	13.89	0.22
P	g kg^{-1}	4.37	16.13	2.1
K	g kg^{-1}	11.33	23.35	3.25
Na	g kg^{-1}	6.76	4.55	3.44
Ca	g kg^{-1}	15.51	60.73	6.25
Mg	g kg^{-1}	8	7.49	1.7
References		Muhsin *et al.* (29)	Celik and Kunene (11)	Hossain *et al.*(16)

Table 2. Mean precipitation, air temperature, and humidity during oat growing season.

	Temperature (C °)			
	Min	**Max**	**Humidity (%)**	**Precipitation (mm)**
November	11	23	18.92	0.05
December	10	19	20.14	0.51
January	10	20	20.02	1.8
February	10	22	16.03	1.2
March	17	31	9.11	0.8
April	20	40	8.49	0.41
May	26	44	7.92	0

Tillage machines

The technical specifications of the tillage machines used in the study are shown in Table 3. As the figure shows, the tillage machines of the study.

Table 3. Specifications of tillage machines used in the study

Tillage machines	Width (cm)	Shanks type	Shanks number	Mass of plow (kg)	Maximum depth (cm)
Subsoiler	100	Straight	1	301.75	90
Chisel plow	175	Curved	7	426.25	35
Disk harrow	280	Disk	28	487.55	22

Table (5) shows the chemical and physical characteristics of the soil at the location of the study. Prior to cultivation, random composite soil samples were collected from 0 to 60 cm depth to determine the

Figure 1. a- Subsoiler b- Moldboard plow c- Chisel plow d- Disk harrow

Tractor used

A Massey - Ferguson 440 Xtra tractor was used in the study. The specifications are illustrated in Table 4.

Table 4. Specifications of Massey- Ferguson 440 xtra tractor

Parameters	**Value**
Max Hp (kW) power	82 (61.1)
Engine speed (rpm)	2200
Engine type	Perkins (diesel)
Engine capacity (litter)	4.40
No. of cylinder	4
Compression ratio	18.5:1
Engine torque (Nm)	288
Cooling system	Liquid
P.T.O speed (rpm)	5400 (single speed)
3-Point linkage control	Mechanical
Lift capacity (kgf)	2500
Thrust generation	MFWD
Tractor weight kg (kN)	3430 (33.64)
Fuel tank capacity (litter)	100
Engine oil capacity (litter)	8
Transmission oil capacity (litter)	42
Factory	Canoas, Brazil

Soil properties measure

were collected. With 1:2.5 soil/water suspension, the pH was determined using a pH meter with a glass electrode. Utilizable phosphorus was computed utilizing the method of Olsen *et al.* (31). Calcium and magnesium were estimated using atomic absorption photometers, while potassium was determined using flame photometry. The soil texture was determined utilizing the Boycous hydrometric system (8). To determine the effects of tillage and organic manure on some soil properties, soil samples were collected twice during the growing season, once after four weeks, and again two weeks before harvesting. In order to determine soil bulk density and water content.

The undisturbed soil samples were collected at different depths (0–20 cm, 20–40 cm, and 40–60 cm) using metal cylinders with a volume of 100 cm3. Each depth range was sampled three times. Subsequently, the soil samples underwent a desiccation process in an electrical oven set at 105 ° C until a consistent mass was achieved. The dry mass (ms) was measured using a precision balance scale and then divided by the volume (v) of the corresponding soil. The equation 1 used in the calculation of soil bulk density was as follows:

$$\rho b = \frac{ms}{v} \qquad (1)$$

where ρb is the bulk density of the soil, Mg m^{-3}, ms is the dry weight of the soil, Mg and v is the sample volume, m^3.

On a wet weight basis, the moisture content of the soil was determined by collecting soil samples from specific soil depths with three replicates per plot, then drying the samples in an oven at 105 °C for 24 hours. The soil's moisture content was calculated by equation 2. Black (8).

$$M.C = \frac{W_{wet} - W_{dry}}{W_{dry}} * 100 \qquad (2)$$

$M.C$ is moisture content (%), W_{wet} is the weight of the wet soil sample (g), W_{dry} is the weight of the dried soil sample (g).

Soil penetration resistance In this investigation, a penetrologger (Eijkelkamp - Model 06.15.SC) (Fig.2) was utilized. The cross-sectional area of the cone is 2 cm^2, the angle of the upper cone is 60 degrees, the length of the penetrating rod is 80 cm, and the velocities of soil penetration reach 2 cm sec^{-1}. When the machine's handle is depressed, the cone penetrates the soil to the required depth, the device recorded soil penetration data each centimeter up to 80 cm. The data is displayed numerically or graphically on the digital device's screen. Each measurement was replicated three times per plot, and all data pertaining to soil penetration were stored in the machine's memory once the samples were taken. All recorded data was transmitted to the computer after the machine was connected to the computer.

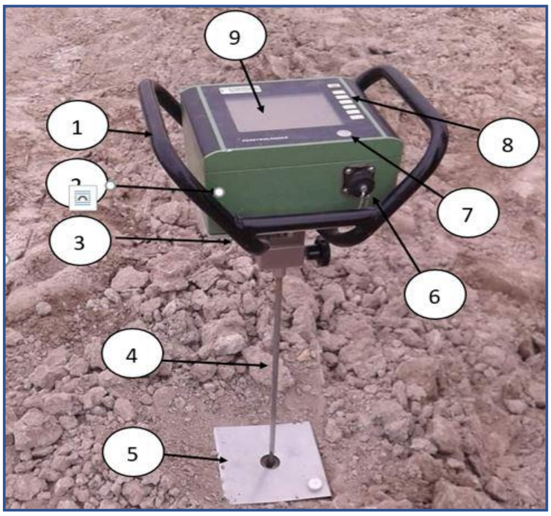

Figure 2. Digital soil penetrator

1 - Electrically insulated handles 2 - Digital penetration device 3 - Installing the piercing column 4 - Piling column 5 - A metal piece that contains a bubble to adjust the vertical balance between the device and the soil surface 6 -Point of contact 7 - Bubble for adjusting the vertical balance 8 - Control panel 9 - Screen Display data

Table 5. The initial physical and chemical properties of the test field soil

		Soil depths (cm)		
Soil properties	Unit	0-20	20-40	40-60
Sand	g kg^{-1}	37.27	13.5	9.56
Silt	g kg^{-1}	671.3	691.2	665.36
Clay	g kg^{-1}	291.43	295.3	325.08
Texture	g kg^{-1}	Silty clay loam	Silty clay loam	Silty clay loam
Real density Bulk	Mg m^{-3}	2.62	2.7	2.69
Bulk density	Mg m^{-3}	1.54	1.42	1.54
Moisture content	%	18.71	21.48	27.55
Soil penetration	kN m^{-2}	2209	3574	4786
MWD	mm	0.31	0.27	0.25
EC	dS m^{-1}	8.79	12.11	18.74
Available N	mg kg^{-1} soil	39.21	25.11	14.22
Available P	mg kg^{-1} soil	15.03	10.41	4.48
Available K	mg kg^{-1} soil	185.52	160.82	100.83
Soluble K+	mmoI L^{-1}	3.17	2.12	1.62
Soluble Na+	mmoI L^{-1}	28.63	22.61	10.37
Soluble Ca+2	mmoI L^{-1}	13.01	9.35	5.34
Soluble Mg2	mmoI L^{-1}	9.34	7.55	6.05
Cl- (mEq L-1)	mmoI L^{-1}	25.05	20.69	12.11
HCO3	mmoI L^{-1}	4.41	3.27	1.02
O.M. (%)	g kg-1 soil	9.03	6.36	1.30

Mean weight diameter (MWD)

The wet-sieved method was used to determine the mean weight diameter (MWD) (26). 100 g air-dried soil with a diameter of less than 4.75 mm was taken and saturated by capillary rise for six minutes. The saturated soil was put on top of a sieve series with mesh sizes of (0.25, 0.5, 1, and 2 mm). The sieving process was conducted by the wet sieving method for a period of 10 minutes, utilizing the wet sieving device (retsch as200, 2009) at a shaking speed of 60 rpm^{-1}. After the sieving procedure was complete, the sieves were separated, and the retained soil in each sieve was transferred to a glass beaker for drying in an oven at 105 °c for 24 hours to determine its dry weight. Then the values of the mean weight diameter (MWD) were calculated using the equation given by Kemper and Chepil (23).

$$MWD = \sum_{i=1}^{n} X_i \, W_i \tag{3}$$

Where: MWD is mean weight diameter (mm); X_i is mean diameter of each size fraction (mm) and W_i is proportion of the total sample mass in the corresponding size fraction.

Saturated hydraulic conductivity

Undisturbed soil samples were collected at different depths (0–20 cm, 20–40 cm, and 40–60 cm) using several metal cylinders with a volume of 100 cm3 with three replicating for each depth of the soil. The permeameter is cleaned and set up, and air bubbles are removed from the system to ensure accurate results. The soil sample is collected, prepared, and compacted to the desired density in the permeameter column. The soil should be representative of natural conditions. The soil specimen is saturated by allowing water to flow through it from the bottom until it flows out from the top. This ensures that all air is displaced and the soil is fully saturated. The water reservoir is filled, and the water level in the reservoir is adjusted to the desired constant head level. The flow control valve is adjusted to control the flow rate of water into the permeameter. The flow rate of water through the soil sample is measured over a certain period of time. The time interval could be minutes or hours, depending on the expected flow rate and permeability of the soil. Using Darcy's law as in Equation 4.

$$Ks = \frac{V}{A * t} \cdot \frac{L}{h} \qquad (4)$$

Where: *Ks* is saturated hydraulic conductivity of soil (cm h^{-1}); *V* is the volume of water passing through the soil column (cm3); L is the length of the soil column (cm); *A* is the surface area of the soil cross-section (cm2); *t* is time (hours); h is length of the soil column + height of the water column above the soil column (cm).

Grain yield

Grain yield of oats yield was determined by hand-harvesting for each plot. The harvested grains were weighed by the sensitive scale of moisture (15%). The yields of grain for each plot were converted to Mg per hectare.

Statistical analyses

IBM SPSS. Version 21 was used to conduct statistical analyzes. The data were statistically analyzed using analysis of variance (ANOVA), at a significance level of 1%, the mean of measured soil properties and oat yield were compared using the least significant difference (LSD) test. Data were analyzed using a split plot arrangement within a completely randomized block design. The means of the coefficients at the beginning and end of the planting season were compared using a t-test with a significance level of 0.01. Only effects of significance were discussed.

Results and Discussion

Mean weight diameter (MWD)

The soil mean weight of the soil is a crucial factor in improving the soil structure. Different tillage systems had a significant effect ($P < 0.01$) on MWD at both periods of the growing season (Table 6). NT treatment gave the highest MWD values of 0.91 and 1.00 mm at the beginning and end of the season, respectively. The RT treatment recorded the second highest MWD values of 0.84 and 0.94 mm at the beginning and end of the season, respectively, while the DT treatment gave the lowest MWD values of 0.65 and 0.72 mm at the beginning and end of the season, while the MWD increased in this order, DT > CT > RT > NT. This may be attributed to the fact that intensive tillage can destroy soil aggregate stability, resulting in smaller aggregates or even their complete destruction, and this results in a reduction in MWD. On the other hand, no-tillage systems facilitate the formation and conservation of greater soil aggregates. The absence of intensive mechanical disturbance allows for increased microbial activity, which contributes to the formation of stable soil aggregates. As a result, MWD values tend to increase, showing improved soil aggregation and stability. These results are consistent with the findings reported by Karami *et al.* (21), who found that MWD increases for no-tillage treatment compared to the conventional tillage system by 7.25%.

Table 6. Effect of tillage systems and organic manure on soil properties and their interactions at the beginning and end of the season

	Soil properties									
	Beginning					End				
Tillage systems	MWD Mm	BD Mg m^{-3}	MC %	PR MPa	Ks cm h^{-1}	MWD mm	BD Mg m^{-3}	MC %	PR MPa	Ks cm h^{-1}
CT	0.77	1.20	16.60	1.05	3.55	0.85	1.32	26.76	1.21	3.01
DT	0.65	1.14	19.40	0.72	6.31	0.72	1.25	29.93	0.83	5.04
RT	0.84	1.25	20.20	1.27	2.33	0.92	1.38	31.82	1.46	1.93
NT	0.91	1.36	22.77	1.42	1.28	1.00	1.50	34.13	1.64	1.15
LSD	0.033	0.016	1.54	0.02	0.1	0.036	0.018	1.749	0.023	0.08
M0	0.67	1.35	14.66	1.26	2.45	0.73	1.48	24.57	1.43	2.03
M1	0.76	1.28	17.18	1.19	3.01	0.81	1.41	27.41	1.37	2.49
M2	0.85	1.24	20.81	1.11	3.47	0.91	1.36	31.51	1.28	2.87
M3	0.79	1.19	21.15	1.06	3.73	0.84	1.31	33.65	1.22	3.09
M4	0.89	1.12	24.93	0.96	4.16	0.95	1.24	36.17	1.11	3.44
LSD	0.037	0.018	1.73	0.023	0.146	0.04	0.02	1.955	0.024	0.12
CT * M0	0.67	1.32	12.33	1.24	2.11	0.83	1.45	21.94	1.42	1.74
CT * M1	0.74	1.22	14.57	1.19	2.83	0.9	1.35	24.46	1.37	2.43
CT * M2	0.82	1.19	15.95	1.11	3.6	0.95	1.31	26.02	1.28	3.06
CT * M3	0.76	1.15	19.32	0.95	4.13	0.93	1.27	29.83	1.09	3.51
CT * M4	0.86	1.12	20.83	0.76	5.03	1.00	1.23	31.54	0.88	4.28
DT * M0	0.54	1.27	15.25	0.84	4.57	0.59	1.40	25.23	0.97	3.66
DT * M1	0.62	1.23	17.70	0.75	5.673	0.68	1.35	28.00	0.87	4.54
DT * M2	0.71	1.18	19.33	0.68	6.617	0.78	1.30	29.85	0.78	5.29
DT * M3	0.65	1.08	21.55	0.72	6.997	0.71	1.19	32.35	0.83	5.60
DT * M4	0.76	0.92	23.18	0.63	7.67	0.83	1.01	34.20	0.72	6.12
RT * M0	0.76	1.39	14.53	1.40	2.03	0.83	1.53	24.42	1.61	1.73
RT * M1	0.82	1.29	17.22	1.36	2.28	0.90	1.42	27.45	1.56	1.90
RT * M2	0.87	1.23	23.47	1.24	2.36	0.95	1.35	34.52	1.43	1.96
RT * M3	0.84	1.19	19.76	1.21	2.42	0.93	1.31	35.33	1.39	2.01
RT * M4	0.91	1.16	26.01	1.15	2.49	1.00	1.28	37.39	1.32	2.07
NT * M0	0.73	1.42	16.53	1.55	1.03	0.8	1.56	26.68	1.78	0.93
NT * M1	0.86	1.39	19.22	1.47	1.28	0.95	1.53	29.71	1.69	1.11
NT * M2	1.01	1.36	24.47	1.41	1.31	1.11	1.50	35.65	1.62	1.18
NT * M3	0.89	1.34	23.97	1.37	1.37	0.98	1.47	37.08	1.57	1.23
NT * M4	1.05	1.30	29.68	1.32	1.44	1.15	1.43	41.54	1.51	1.30
LSD	Ns	0.036	ns	0.045	0.27	ns	0.04	ns	0.026	0.22

Table 7. Analysis of variance (ANOVA) of two periods, the beginning and end of the growing season, for soil properties and grain yield of oats

Source of variation	df	BD	MWD	PR	MC	Ks	Yield
		The mean squares of the beginning of the growing season					
Source of variation	df	BD	MWD	PR	MC	Ks	
Block	2.0	1.09E-03	1.29E-02	1.48E-03	27.291	1.28E-02	
Tillage system	3.0	1.37E-01**	1.76E-01**	1.38E+00 **	96.91 **	7.05E+01**	
Organic matter	4.0	8.80E-02**	8.78E-02 **	1.58E-01 **	187.126 **	1.30E-02**	
T * M	12	6.26E-03**	2.97E-03 ns	1.15E-02 **	6.71 ns	5.21E+00**	
Error	38	4.83E-04	1.97E-03	7.62E-04	4.382	1.05E+00	
Total	59						
		The mean squares of the end of the growing season and yield					
Source of variation	df	BD	MWD	PR	MC	Ks	Yield
Block	2.0	1.31E-03	1.56E-02	1.96E-03	34.847	9.12E-03	2.56E-01
Tillage system	3.0	1.66E-01 **	2.13E-01 **	1.82E+00 **	123.744 **	4.28E+01	1.42E+01**
Organic matter	4.0	1.06E-01 **	1.06E-01 **	2.09E-01 **	238.941 **	9.11E-03	1.81E+01 **
T * M	12	7.58E-03 **	3.59E-03 ns	1.53E-02 **	8.567 ns	3.58E+00	7.87E-01 **
Error	38	5.85E-04	2.38E-03	1.01E-03	5.596	6.99E-01	7.51E-02
Total	59						

** Significantly different at 0.01 probability levels, ns: not significant

The data presented in Table (6) showed that the level of organic manure had a significant effect ($p < 0.01$) on soil mean weight diameter. The M4 treatment recorded the highest soil mean weight diameter values of 0.89 and 0.95 mm at the beginning and end of the season, respectively, with significant differences between it and other treatments. In contrast, the control treatment (M0) recorded the lowest soil mean weight diameter values of 0.67 and 0.73 mm. This may be attributed to the organic manure being rich in organic matter, which assists to form larger soil aggregates. Organic matter acts as a binding agent and encourages the aggregation of soil particles into larger groups. This results in an increase in MWD, which indicates a better soil structure. As well as organic fertilizers provide a source of organic carbon, resulting in improved stability of the soil aggregates. Carbon compounds are the nutrition source for soil microorganisms and, in turn, promote the production of polysaccharides and glues that combine soil particles. This increased aggregation and stability of soil aggregates contribute to higher MWD. These results were in agreement with the findings of Ramadhan (34), who reported that soil MWD of soil increased by 64.98% with the application of manure compared to the control treatment (no organic manure added). This was confirmed by the findings of Biswas *et al.* (9), they reported a positive correlation coefficient ($r = 0.85$) between the organic carbon in the soil and the mean weight diameter of the soil. Hasan *et al.* (14) revealed that the increase in mean weight diameter with the application of organic manure was attributed to the release of some organic acids by microbial activity, which assists in improving the soil aggregate stability, as well as raising the concentration of some organic compounds such as fulvic acid and polysaccharides, which play a vital role in increasing the soil aggregate stability, thereby increasing the MWD of soil.

Based on ANOVA and data presented in Table (7), it is evident that no significant interactions exist between the tillage system and organic manure level on MWD.

Bulk density of soil (BD)

The data in Table (6) showed a highly significant effect ($p<0.01$) of the tillage system on the bulk density of the soil for both periods, the beginning and the end of the growing season. DT treatment was significantly superior in achieving the lowest soil bulk density values of 1.14 and 1.25 Mg m^{-3} at the beginning and end of the growing season, respectively. The CT treatment achieved the second lowest soil bulk density values of 1.20 and 1.32 Mg m^{-3} at the beginning and end of the season, respectively, followed by the RT treatment, which was given soil bulk density values of 1.25 and 1.38 Mg m^{-3} at the beginning and end of the season, respectively. While the NT treatment recorded the highest soil bulk density values of 1.36 and 1.50 Mg m^{-3} at the beginning and end of the season, respectively. The lower bulk density of soil when using the deep tillage system (DT) may be due to the increased volume of disturbed soil. The higher bulk density with the application of the no-tillage system could be the result of the pressure of the upper soil layers exerted on the lower layers, consequently increasing soil compaction and the convergence of soil particles with each other. The decrease in the bulk density across the profile after tillage compared to the bulk density of the soil under no tillage was due to the increased volume of loosening soil and, consequently, the increase in the pores between the soil particles. These results are also in agreement with Ramadhan (34), who reported that the deep tillage system had the lowest soil bulk density value of 1.38 Mg m^{-3}, followed by the conventional tillage system, which was 1.44 Mg m-3, while the no-tillage had the highest soil bulk density value of 1.48 Mg m^{-3}.

The statistical analysis data in Table (7) showed that the addition of organic manure had a highly significant effect on the bulk density of the soil for both periods of the growing season. The results presented in Table (6) showed that the addition of manure treatment (M4) was significantly superior in recording the lowest bulk density values of 1.12 and 1.24 Mg m^{-3} at the beginning and end of the season, respectively, while the control treatment (M0) recorded the highest soil bulk density values of 1.35 and 1.48 Mg m^{-3} at the beginning and end of the season, respectively. The results also showed that the increase in manure level led to a decrease in soil bulk density of 5.19, 8.15, 11.85, and 17.04% for M1, M2, M3 and M4, respectively, compared to the control treatment (M0) at the beginning of the season, while soil bulk density decreased by 4.73, 8.11, 11.49, and 16.22% respectively, at the end of the season. This was because organic fertilizers are rich in organic matter and contribute to stable soil aggregates by incorporating them into the soil. These aggregates improve soil structure and create pore spaces, reducing soil compaction and thus decreasing the bulk density of the soil. Organic fertilizers are food sources for soil microorganisms. Microorganisms decompose organic matter. This microorganism activity contributes to the formation of soil aggregates and stabilization of the soil structure, thus reducing the bulk density of the soil. These results agreed with the findings of Muhsin *et al.* (29) who reported that adding manure of 30 and 60 Mg ha^{-1} led to a decrease in the bulk density of soil compared to the control treatment by 6.01 and 11.85%, respectively. Das *et al.* (13), confirmed this, as they obtained a decrease in bulk density of 10.73% when adding organic manure by 4%. They attributed this to the role of added manure in improving soil structure and its reflection in a decrease in the bulk density of the soil.

Table (6) shows that there was a highly significant effect (p<0.01) of the interaction between tillage systems and organic manure level on the bulk density of the soil for both periods of the growing season. The results showed that (DT * M4) treatment was superior in recording the lowest soil bulk density values of 0.92 and 1.01 Mg m^{-3}, at the beginning and end of the season respectively, followed by (CT * M4) treatment, which was recorded soil bulk density values of 1.12 and 1.23 Mg m^{-3} at the beginning and end of the season respectively. While (NT * M0) recorded the highest soil bulk density values of 1.42 and 1.56 Mg m^{-3} at the beginning and end of the season, respectively. This was in agreement with the results reported by Busari (10) who found that there was a significant interaction effect between the tillage system, organic manure, and NPK fertilizer on soil bulk density. In plots treated with a mix of 20 Mg ha^{-1} organic manure and 150 kg N ha^{-1}, the soil bulk density was significantly lower for conventional tillage (CT) and for minimum tillage (MT) compared to the control plots by 11.25 and 7.89% respectively.

Soil water content (MC)

The tillage system significantly (P < 0.01) affected the soil water content at both periods of the growing season (Table 6). NT treatment achieved the highest soil water content values of 22.77 and 34.13% at the beginning and end of the season, respectively. In comparison, DT obtained the lowest soil water content values of 16.60 and 26.76% at the beginning and end of the season, respectively. Whereas CT and RT treatments gave a middle value of soil water content, which was 19.40 and 29.93% for CT and 20.20 and 31.82% for RT at the beginning and end of the season, respectively. However, the soil water content increased with this order, DT > CT > RT > NT. This may be attributed to that deep tillage can increase evaporation and water loss, particularly if surface residues are removed. Deep tillage can increase soil surface area and promote water evaporation, thereby reducing soil water content. No-tillage practices assist in the preservation of soil protecting surface residues, such as crop residue. These residues reduce soil surface evaporation by providing shade and minimizing direct exposure to wind and sunlight. This can aid in soil water retention and increase soil water content. The preservation of soil structure and organic matter by no-till techniques increases the soil's capacity to retain water. The presence of undisturbed soil aggregates and organic matter results in an increase in the water content. This agrees with the findings of Ramadhan (34) he reported that the NT had 4.4% more soil water stored than strategic tillage (ST) and 15.7% more than reduced tillage (RT) for soils and mentioned that these results attributed to soil aggregation improved and increased water storage in soil under NT treatment. Similarly, Sokolowski *et al.* (38)

they found that the no-tillage system leads to increased soil water content compared to conventional tillage systems. The presence of surface residues and undisturbed soil structure aids to decrease evaporation and increase water retention within the soil profile.

The statistical analysis of the data showed that the soil water content was significantly ($P < 0.01$) affected by the treatment with organic manure in both periods of the growing season (Tables 6, 7). In general, soil water content increased with increasing organic manure levels. The highest soil water content was recorded for M4 treatment, which achieved 24.93 and 36.17% at the beginning and end of the season, respectively, closely followed by M3, which gave soil water content values of 21.15 and 33.65% at the beginning and end of the season, respectively. While the M0 (control) treatment recorded the lowest soil water content of 14.66 and 24.57% at the beginning and end of the season, respectively. Organic manure levels (M1, M2, M3, and M4) treatments achieved a soil water content higher than that of the control treatment (M0) by 17.19, 41.95, 44.27, and 70.05%, respectively, at the beginning of the season; however, the soil water content increased by 12.,94, 29.83, 38.65, and 49.03%, respectively, at the end of the season. This may be because organic fertilizer helps to improve the soil structure making it more porous, and thus water easily enters the soil, resulting in decreased runoff and increased water storage in subsoil layers, which contributes to a higher soil water content. In addition, the existing organic manure in the upper soil layer helps to block out the soil and decrease direct exposure to sunlight and wind, thus reducing water loss due to evaporation. This helps to maintain the water content over time. Many studies have reported that adding manure increases soil water content (21). Liu *et al.* (26) reported that adding organic manure led to an increased soil capacity to store water in the 0–100 cm layer, especially at 20–40 cm, compared to treatment without manure by 47.68%.

There were no significant effects of interaction between the tillage system and organic manure on soil water content (Tables 6, 7).

Penetration resistance of soil (PR)

The effects of tillage systems on soil penetration resistance are presented in Table 6. The results showed that the tillage systems have significant ($p<0.01$) effects on soil penetration resistance. The NT treatment obtained the highest soil penetration resistance values of 1.42 and 1.64 MPa at the beginning and end of the season, respectively. In comparison, DT gave the lowest soil penetration resistance values of 0.72 and 0.83 MPa at the beginning and end of the season, respectively. However, CT and RT treatments gave a middle value of soil penetration resistance, which was 1.05 and 1.21 MPa for CT and 1.27 and 1.46 MPa for RT at the beginning and end of the season, respectively. This may be attributed to the fact that deep tillage can assist in loosening compacted layers or hardpans of the soil, which decreases soil compaction and improves its structure. Although a no-tillage system leads to higher soil penetration resistance compared to deep tillage. By evading mechanical disturbance, where the soil rests relatively undisturbed, this could result in the occurrence of a compacted layer near the surface. This compacted layer can increase soil penetration resistance. This was in agreement with Ji *et al.* (20), they reported that deep tillage resulted in a lower soil penetration resistance than conventional tillage. Similarly, Abidela *et al.* (1) they found that the application of deep tillage (DT) had the lowest soil penetration resistance of 0.90 MPa compared to the conventional tillage system (CT) and no-tillage (NT), which recorded higher soil penetration resistance of 1.51 and 1.75 MPa, respectively. The lower soil penetration resistance obtained with DT is due to the deep loosening of the soil profile, which breaks down the hardpan of the soil and increases the pore space.

The results in Table (6) showed that the soil penetration resistance significantly decreased ($p<0.01$) with increasing organic manure level addition. The M4 treatment achieved the lowest soil penetration resistance of 0.96 and 1.11 MPa at the beginning and end of the season, respectively, while the M0 (control) treatment recorded the highest soil penetration resistance values of 1.26 and 1.43 MPa at the beginning and end of the season respectively. The results also showed that the M1, M2, M3, and M4 soil penetration resistance for M1, M2, M3, and M4 treatments significantly decreased compared to M0 treatment by 5.88, 13.51, 18.87, and 31.25% at the beginning of the season respectively, and decreased at end of the season by 4.38, 11.72, 17.21, and 28.83 respectively. This is due to the fact that organic manure improves soil structure and aggregation. When organic matter decomposes, it releases substances such as humus and polysaccharides that promote the formation of stable soil aggregates by acting as binding agents. This improved soil structure may reduce soil penetration resistance. This result was consistent with the findings of many previous investigations (Stock and Downes (39) and Bandyopadhyay *et al.* (7)), they showed that the addition of organic manure can reduce soil resistance to penetration. According to Page *et al.* (32), organic manure can directly increase organic carbon, and this may lead to improved soil structure and aggregation, thereby reducing the soil's resistance to penetration.

The interaction between the tillage system and organic manure addition treatment had a significant effect ($p < 0.01$) on soil penetration resistance (Table 6). The highest value of soil penetration resistance was recorded in the control treatment (NT * M0), which was 1.55 and 1.78 MPa at the beginning and end of the season, respectively, while the treatment (DT * M4) treatment achieved the lowest values of soil penetration resistance value of 0.63 and 0.88 MPa at the beginning and end of the season respectively.

Saturated hydraulic conductivity (Ks)

The results of the statistical analysis shown in Table (7) showed that there was a highly significant effect ($p < 0.01$) of the tillage system on the Ks of the soil for both periods of the growing season. It was seen from Table (6) that the deep tillage treatment (DT) obtained the highest Ks at the beginning and end of the season, which amounted to 6.31 and 5.04 cm h^{-1}, respectively, followed by CT, which recorded Ks of 3.55 and 3.01 cm h^{-1} at the beginning and end of the season, respectively. While NT (control treatment) recorded the lowest Ks of 2.33 and 1.93 cm h^{-1} at the beginning and end of the season, respectively. The results showed that the Ks increased in order as follows: NT > RT > CT > DT. The reason may be attributed to increasing the volume distributed and breaking down the compact layer of soil by the subsoiler and its positive effect on reducing the bulk density and penetration resistance of the soil, thus, deep tillage results in increasing pore space and allowing water to penetrate easily in the soil body. These results are consistent with the findings of Jabro *et al.* (18), who reported that the Ks results were significantly higher in the deep tillage system (3.79 cm h^{-1}) than in the shallow tillage system (1.23 cm h^{-1}) and zero tillage system (1.20 cm h^{-1}). They attributed the reason to the increase in soil loosening and then the increase in soil permeability when DT was compared to ST and ZT.

The data demonstrated in Table (6) showed that the addition of organic manure had a highly significant effect on increasing the Ks for both periods of the growing season. The M4 achieved the highest Ks of 4.16 and 3.44 cm h^{-1} at the beginning and end of the season, respectively, followed by the treatments of M3, M2, and M1, where Ks were recorded at 3.73, 3.47, and 3.01 cm h^{-1} at the beginning of the season, respectively, However, by the end of the season, the Ks values decreased to 1.22, 1.28, and 1.37 cm h^{-1}, respectively, for the M3, M2, and M1 treatments. The control treatment (M0) recorded the lowest Ks of 2.45 and 2.03 cm h^{-1}, at the beginning and end of the season, respectively. The reason for the increase in Ks with the addition of organic manure, compared to the control treatment may be attributed to increased pore space and improved soil porosity, which facilitate water movement and improve Ks, as well as organic manure contributing to the increase in soil organic matter content. Higher levels of organic matter improve the soil's capacity to retain moisture, decreasing the hazard of waterlogging and promoting efficient drainage. The improved water-holding capacity allows for better soil moisture distribution and movement, positively affecting Ks. Many previous studies indicated that the addition of organic manure to soil caused an increase in Ks (36 and 38).

The data in Table (6) showed that there was a highly significant effect ($p < 0.01$) of the interaction between tillage systems and organic manure level on the Ks for both periods of the growing season. The results showed that (DT * M4) treatment was superior in recording the highest Ks values of 7.67 and 6.12 cm h^{-1}, at the beginning and end of the season, respectively, followed by (CT * M4) treatment, which recorded Ks values of 5.03 and 4.28 cm h^{-1} at the beginning and end of the season, respectively. While (NT * M0) recorded the highest Ks values of 1.03 and 0.93 cm h^{-1} at the beginning and end of the season, respectively. This was in accord with the results reported by Al-Wazzan and Muhammad (6).

Effect of soil sampling time on the soil properties

Based on the t-test (Table 8), the results showed that the sampling period significantly affected ($p < 0.01$) soil bulk density, MWD, soil penetration resistance, and soil water content. The results also, showed that the end of the growing season achieved the highest MWD of 0.79 mm, while the beginning of the season recorded the lowest MWD of 0.87 mm, i.e. an increase of 10.12%. This may be because of the wide spreading of oat crop roots during the growing season. Furthermore, the mechanical effect of root hairs plays a vital role in bringing soil particles closer and forming cohesive soil aggregates that are resistant to loosening apart. Therefore, this process improves soil stability. Additionally, the increased activity of microorganisms at the end of the season, which secrete adhesive resinous substances, further contributes to the deposition of these fine particles within the soil's pores. Consequently, this process binding of soil particles. These results agree with (3). The results also showed that the soil bulk density decreased at the end of the growing season by 9.17% compared to the beginning of the season, while soil penetration resistance increased by 15.25% at the end of the season. These results agree with the findings of Sokolowski *et al*. (38). They attributed the reason to the deposition of fine soil particles in the soil pores as a result of irrigation operations, which led to an increase in the bulk density of the soil and then an increase in the soil penetration resistance at the end of the season. However, the soil water content increased at the end of the season by 55.30%. Growth increased and the soil was covered more with oat crops. This reduced evaporation rates and therefore increased soil moisture retention, which increased soil moisture content. This result is consistent with Li *et al.* (25). It is seen from Table (8) that at the beginning of the season, Ks reached the highest value of 3.36 cm h^{-1}, while it decreased at the end of the season to reach 2.87 cm h^{-1}. The reason attributed to this is the movement of fine soil particles throughout the crop growing season. This movement occurs due to the crushing of soil mass during irrigation operations as well as wetting and drying cycles, further contributing to the deposition of these fine particles within the soil's pores. Consequently, this process results in the closure of most of the soil pores, leading to a decrease in total soil porosity and thus reducing Ks. These findings align with the research conducted by Seguel *et al.* (37), who also attributed reducing Ks at the end of the season to the increase of soil cohesion throughout the

Table 8. Results of the paired-sample t-test comparing the soil properties studied between the beginning and end periods of the season.

Soil properties	Beginning	End	df	t- value	Probability
BD (Mg m^{-3})	1.24	1.36	59	79.48	$p < 0.001$
MWD (mm)	0.79	0.87	59	46.78	$p < 0.001$
PR (MPa)	1.12	1.29	59	29.89	$p < 0.001$
MC (%)	19.74	30.66	59	32.08	$p < 0.001$
Ks (cm h^{-1})	3.36	2.87	59	10.08	$p < 0.001$

Table 9. Effect of tillage system, organic manure levels and their interactions on oat grain yield (Mg ha^{-1})

	Organic manure levels					Mean
Tillage systems	M0	M1	M2	M3	M4	
CT	3.00	4.77	5.80	6.31	6.76	5.33
DT	3.33	5.60	6.35	6.78	6.70	5.75
RT	3.08	3.21	5.16	5.23	6.31	4.60
NT	2.75	3.15	3.88	3.90	4.24	3.58
Mean	3.04	4.18	5.30	5.56	6.00	
LSD $_{(0.05)}$	Tillage systems (0.20) Organic manure levels (0.23) Interaction (0.45)					

growing season and the effect of irrigation operations on the clogging of certain soil pores by fine soil particles, thus reducing the soil's saturated water conductivity.

Grain yield of oat (Mg ha^{-1})

It was found from the ANOVA (Table 7) that grain yield was significantly ($p<0.01$) affected by tillage systems. It can be seen from Table (9) that DT, CT, and RT achieved higher grain yields compared to NT by 48.88, 60.61, and 28.49%, respectively. This is in accordance with the results reported by Obour *et al.* (30) and Nassir et al. (27). This may be due to increased soil disturbance, low bulk density, and increased porosity. In addition to the lower values of penetration resistance of DT, CT, and RT compared to NT (Table 4), this helped to increase root spread, which allowed the plant roots to uptake more essential nutrients such as nitrogen, phosphorus, and potassium, which are essential for plant growth and grain development. Adequate nutrient availability promotes healthier plants and can lead to increased grain yield.

Grain yield varied significantly ($P<0.01$) due to different organic manure treatments of oats. It was observed that grain yield increased gradually and significantly with increasing organic manure levels. The M4 achieved the maximum grain yield, reaching 6 Mg ha^{-1} followed closely by the M3, which achieved a grain yield of 5.56 Mg ha^{-1}. While the M0 (control treatment) recorded the minimum grain yield of 3.04 Mg ha^{-1}. The M1, M2, M3, and M4 treatments increased grain yield compared to M0 by 37.50, 74.34, 82.89, and 97.37%, respectively. The addition of organic manure could increase the nutrients available for intake by the plant within the root zone, thereby improving the soil's physical properties (table 6) and increasing the ability of the soil to retain moisture at the root zone, consequently improving the absorption of water and nutrients, This led to an increase in the effectiveness and efficiency of the food manufacturing process, which was reflected in an increase in yield. This result agrees with Adami *et al.* (2), they found a positive correlation coefficient (r = 0.94) between the organic manure and oat grain yield, which also showed that increasing the organic manure level to 14.95 mg ha^{-1} compared to the control treatment (without organic manure) led to an increase in the oat grain yield of 53.48%.

The interaction between the tillage system and organic manure treatments had a significant effect ($p < 0.05$) on oat grain yield (Table 7). The interaction treatment between deep tillage system (DT) and organic manure level (M4) gained the highest oat grain yield, reaching 6.70 Mg ha^{-1}, while the interaction between no-tillage treatment (NT) and control treatment (without organic manure) recorded the lowest values of Oat grain yield, amounted to 2.75 Mg ha^{-1}. The results agree with the results reported by Ramadhan (33).

Conclusion

Field tests were conducted to determine the effects of four different tillage systems and five levels of organic manure on soil properties and grain yield of oats in silty clay loam soil. It was concluded that The (NT) system resulted in a significant improvement in soil mean weight diameter (MWD), with values of 0.91 and 1.00 mm at the beginning and end of the growing season, respectively. On the other hand, the deep tillage (DT) system led to a substantial reduction in bulk density (BD), with values of 1.14 and 1.25 Mg m^{-3} at the beginning and end of the season. The application of organic manure, especially the treatment, led to significant increases in soil water content (MC), with values of 24.93% and 36.17% at the beginning and end of the season, respectively. The interaction treatment (DT * M4) led to significant decreases in soil penetration resistance (PR), with values of 0.63 and 0.88 MPa at the beginning and end of the season, respectively. Saturated hydraulic conductivity (Ks) increased in the deep tillage (DT) system, with values of 6.31 and 5.04 cm h^{-1} at the beginning and end of the season, respectively. While decreasing under the NT system, with values of 1.28 and 1.15 cm h^{-1} at the beginning and end of the season, respectively. The DT system achieved a high yield of 6 Mg ha^{-1}, surpassing the no-till (NT) system by 48.88%. The interaction treatment (DT * M4), which achieved the highest oat grain yield, achieved the highest oat grain yield value of 6.70 Mg ha^{-1} followed by the (RT * M4) treatment, which recorded 6.31 Mg ha^{-1} in contrast to the (NT * M0) treatment, which had the lowest oat grain yield value of 2.75 Mg ha^{-1}.

Conflict of interest

The authors declare no conflict of interest.

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