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EFFECT OF TILLAGE SYSTEMS COMBINED WITH PLASTIC FILM MULCHES AND FERTILIZERS ON SOIL PHYSICAL PROPERTIES IN A WHEAT-AGRICULTURAL SITE IN SOUTHERN IRAQ

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ABSTRACT. This study researches the influence of the three tillage systems (conventional, economical and mulch tillage) when combined with different soil plastic mulching and fertilizer applications on key selected soil physical properties (SPP) at 0-20 cm soil depth in a wheat agricultural site, during summer (from 1st June to 31st July 2015). SPP include soil porosity (Φ), volumetric soil water content 60 days after irrigation to field capacity (θ_{60}), and mean weight diameter of aggregates (MWD). The term mulch tillage refers here to a soil conservation practice where the soil surface is disturbed by tillage whereby crop residues are mixed with the soil and a certain amount of residues remain on the soil surface, while mulching refers to the placement of inorganic material over the top of a soil surface to protect it. Soil treatments included tillage system: conventional tillage using a combination of a mouldboard plough and a disc harrow (MP+DH), economical tillage using a rotary cultivator (RC), and mulch tillage using a chisel plough (MT+CP); soil plastic mulching: transparent mulching (TM), black mulching (BM) of 200 cm wide with 0.05 cm thick, and without mulching (WM); and fertilisers: composed organic fertiliser (CoF), no-composed organic fertiliser (NoF), and chemical fertiliser (ChF). The split–split-plot design under the randomized complete block design (RCBD) was established in 27 treatments with 3 replicated, to map Φ, θ_{60}, and MWD based on 81 soil samples from all treatments. Results showed that the different soil treatments have diverse impacts on SPP. MP+DH resulted in the higher θ_{60} (0.22 cm^3 cm^{-3}), MWD (0.85 mm), and Φ (56.87%). Our findings showed that MT+CP obtained a higher MWD of 0.98 mm and lower Φ of 49% compared to other tillage systems. Soil mulching had significantly modified SPP, with BM resulting in the highest Φ (55.65%), θ_{60} (0.35 cm^3 cm^{-3}), and MWD (1.06 mm). Results indicated no significant differences between fertiliser types on SPP. The CoF had a significant effect on MWD and related soil characteristics studied. These findings can help us to understand the individual and combined effects of the tillage system, mulching, and fertilization application on some soil characteristics in wheat agriculture. A further study with more focus on the influence of tillage depths and mulching types (plastic vs organic mulch for different crops) under a variety of soils and climatic conditions, as well as on soil thermal properties needs further investigation.

Efecto de la combinación de sistemas de cultivo, cubiertas plásticas y fertilizantes sobre las propiedades físicas del suelo de un trigal del sur de Iraq

RESUMEN. Este estudio investiga la influencia de tres sistemas de labranza (convencional, económico y con mantillo) cuando se combinan con diferentes aplicaciones de fertilizantes y cobertura plástica del suelo en propiedades físicas del suelo (SPP), a 0-20 cm de profundidad, en un área agrícola de trigo, durante el verano (del

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1 de junio al 31 de julio de 2015). Los SPP incluyen la porosidad del suelo (Φ), el contenido volumétrico de agua del suelo 60 días después del riego a capacidad de campo (θ_{60}) y el diámetro medio ponderado de los agregados (MWD). El término cultivo con mantillo se refiere aquí a una práctica de conservación en la que la superficie del suelo es alterada por la labranza, de modo que los residuos del cultivo se mezclan con el suelo y una cierta cantidad de estos residuos permanece en la superficie del suelo. El *mulching* se refiere a la colocación de material inorgánico sobre la superficie del suelo para protegerlo. Los tratamientos del suelo incluyeron el sistema de labranza convencional que utiliza una combinación de arado de vertedera y grada de discos (MP+DH), labranza económica que usa un cultivador rotativo (RC) y labranza de cobertura que utiliza un arado de cincel (MT+CP); *mulching* plástico del suelo: *mulching* transparente (TM), *mulching* negro (BM) de 200 cm de ancho con 0,05 cm de espesor, y sin *mulching* (WM); y fertilizantes: fertilizante orgánico compuesto (CoF), fertilizante orgánico no compuesto (NoF) y fertilizante químico (ChF). El diseño de parcelas subdivididas bajo el diseño de bloques completos al azar (RCBD) se estableció en 27 tratamientos con 3 repeticiones, para cartografiar Φ, θ_{60} y MWD en base a 81 muestras de suelo con todos los tratamientos. Los resultados mostraron que los diferentes tratamientos del suelo tienen diversos impactos en SPP. MP+DH alcanzó el mayor θ_{60} (0,22 $cm^3\ cm^{-3}$), MWD (0,85 mm) y Φ (56,87%). Por otro lado, MT+CP obtuvo un MWD mayor de 0,98 mm y un Φ menor de 49% en comparación con otros sistemas de labranza. El mantillo del suelo modificó significativamente el SPP, con BM alcanzando el mayor Φ (55,65%), θ_{60} (0,35 $cm^3\ cm^{-3}$) y MWD (1,06 mm). Los resultados no indicaron diferencias significativas entre los tipos de fertilizantes en SPP. El CoF tuvo un efecto significativo en MWD y se relacionó con las características del suelo estudiadas. Estos hallazgos pueden ayudarnos a comprender los efectos individuales y combinados del sistema de labranza, el *mulching* y la aplicación de fertilizantes en algunas características del suelo en el cultivo del trigo. Un estudio más centrado en la influencia de las profundidades de labranza y los tipos de *mulchings* (*mulching* de plástico versus *mulching* orgánico para diferentes cultivos) en una variedad de suelos y condiciones climáticas, así como en las propiedades térmicas del suelo, necesitaría una investigación más profunda.

Keywords: Conventional tillage, soil porosity, soil water content, soil aggregate stability, land management.

Palabras clave: labranza convencional, porosidad del suelo, contenido de agua del suelo, estabilidad de agregados del suelo, gestión del suelo.

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1. Introduction

The implementations of appropriate tillage systems, mulching, and fertilizers play a key role in improving soil properties as well as increasing crop productivity (Li *et al.,* 2022; Naveen *et al.,* 2021; Rodrigo-Comino *et al.,* 2020). Tillage is the mechanical manipulation of soil for managing crop production. It also has a substantial impact on soil properties such as porosity, water content conservation, and stability of aggregates (Al-Shammary and Al-Sadoon, 2014; Liebhard *et al.,* 2022; Ndzelu *et al.,* 2021; Silva *et al.,* 2021). It is based on the utilization of mechanical applications to overturn soil layers with its crop and weed residues, leading to an increase in soil organic content due to the mixture. There is a wide range of tillage systems: conventional tillage (Mirzaei *et al.,* 2023; Torppa and Taylor, 2022), reduced tillage (Deng *et al.,* 2022), shallow tillage (Arvidsson *et al.,* 2014), optimum tillage (Gorucu *et al.,* 2006), minimum tillage (Githongo *et al.,* 2021), economical tillage (Chen *et al.,* 2020), conservational tillage (Zheng *et al.,* 2022), mulch tillage (Jiang *et al.,* 2022), no/zero tillage (Mirzaei *et al.,* 2022; Zhao *et al.,* 2022), or tillage-plant systems (Li *et al.,* 2019).

Soil mulching is one of the most soil management applications used as the addition of any organic or inorganic material over the top of the soil surface to protect it (Al-Shammary *et al.,* 2020).

Some of the benefits include reduced soil erosion (Parlak *et al.,* 2022; Wang *et al.,* 2021), less compaction (Adekalu *et al.,* 2006), water conservation (Yang *et al.,* 2023), increased control of soil temperature (Yin *et al.,* 2023), and a reduction in weed growth (Agarwal *et al.,* 2022). Soil mulching is also a practical way of increasing soil temperature to levels that are lethal to microorganisms that cause disease in agricultural production (Bu *et al.,* 2013; Rodrigo-Comino, 2018; Steinmetz *et al.,* 2016; Zhao *et al.*, 2023). It is developed and used in different geographical areas with different purposes, for example, in the Middle East and Israel, to reduce soil heating. Still nowadays a great amount of soil mulching investigations is still being undertaken worldwide (Kahlon *et al.,* 2013; Nzeyimana *et al.,* 2017). However, the effect of mulching combined with mechanical and chemical treatments on soil properties has received less attention. Even less in arid and semi-arid areas where water scarcity and land degradation processes are a consequence of human impacts (Rodrigo-Comino *et al.,* 2022) and the imminent climate change such as Iraq (Qader *et al.,* 2023).

Soil porosity (Φ), volumetric soil water content conservation 60 days after irrigation to field capacity (θ_{60}), and mean weight diameter of aggregates (MWD) are some significant soil physical properties (SPP) affecting crop growth and development (Mondal and Chakraborty, 2022). They influence plant growth directly but are also affected by mulching, tillage, and fertilizer application (Zhao *et al.,* 2012). A considerable amount of literature has been published on determining the performance of soil mulching under different conditions. The use of plastic mulches in agricultural fields can influence soil's physical, chemical, and biological properties (Braunack *et al.,* 2015; Jiang *et al.,* 2017; Maul *et al.,* 2014; Rodrigo-Comino *et al.,* 2018; Scarascia-Mugnozza *et al.,* 2012). Furthermore, the plastic cover can reduce the consumption of water use in irrigation, and lead to conserving water (Anikwe *et al.,* 2007; Bhardwaj and Sarolia, 2013; Jiang *et al.,* 2017), decrease soil compaction (Mahadeen, 2014), and improve the heating conditions in the soil (Li *et al.,* 2016). The recent scientific literature is full of examples of countries where the use of these types of mulches are used. For example, Nzeyimana *et al.* (2017) investigated the effect of mulching type on SPP conditions in Rwanda, concluding that soil mulching has a significant influence on bulk density (ρb). Furthermore, the results revealed that improving SPP depends on the study location and the type of mulching used. Kahlon *et al.* (2013) and Figueiredo *et al.* (2017) also showed that the soil tillage system had a strong influence on SPP in Central Ohio. In addition, Crittenden and de Goede (2016) showed that a tillage system, directly and indirectly, influenced soil water content regimes. Zhang *et al.* (2017) investigated the effect of organic and chemical fertilizers on SPP, showing that organic fertilizer strongly led to a decrease in ρb. Xin (2016) argued that organic and mineral fertilizers can influence SPP in North China, showing a significant decrease in ρb. Although several studies have reported on individual influences of tillage practices, mulching and fertiliser application on SPP, the integrated effect has rarely been studied, particularly under dry soil conditions. Therefore, the main objective of this work is to study the influence of the individual and combined effects of a different combination of tillage, mulching, and fertilizers on SPP.

2. Materials and methods

2.1. Experimental site, soil sampling and measurements

This study was carried out during the summer season of 2015 at Al Qataniyah village experiment, Aziziyah city, Wasit, Iraq (32.9° N, 44.9° E at 36 m a.s.l.). The soil site was categorized under the Typic Torrifluvent group texture (Soil Survey Staff, 2014), it is located within arid and semi-arid areas, where the annual average temperature is 45 °C. The rainfall is mostly during the Dec to Feb with rainfall 145 mm, with site slope from (northeast to southwest and eastern outlines to the centre). Soil physical and chemical properties were measured using laboratory standard methods. This was done by collecting soil samples, 7 cm height and 5 cm diameter soil cylinders, at three depths (0-10, 10-20, and 20-30 cm) at randomly selected spots. Disturbed soil samples at each depth were mixed to obtain a representative sample of the corresponding depth. Samples were placed in plastic bags and transfer to the laboratory for drying under ambient conditions and grinding, then samples were passed through a 2 mm sieve. The physical and chemical analyses of the general soil characteristics are shown in Table 1. Soil bulk density (ρb) was measured by the ring method (with a volume of 125 cm^3) for undisturbed cores (Zheng *et al.,* 2021).Particle density (D_p) was measured by the pycnometer method (Ruehlmann and Körschens, 2020). Porosity was calculated from measured values of ρb and D_p. Particle size distribution was measured according to (Soil Survey Staff, 2014). Soil pH and electric conductivity (EC) were measured using an electrical conductivity meter, while soil organic matter (SOM) was determined by the loss on ignition method according to (Jackson, 2005), CO_3^{2-}, HCO_3^{1-}, CI^{1-} SO_4, Ca^{2+}, Mg^{2+}, Na^+, K+ were detected by saturated paste extract, according to (Rhoades, 1983).

The MWD was measured by several steps. Soil samples were taken from each soil treatment and transported to the laboratory to maintain soil structure from distortion or damage and then manually disaggregated at a certain water content suitable to maintain the natural order of the assemblies. Briefly, soil samples were sieved using two sieves: first with a mesh size of 9 mm, and then with a mesh size of 4 mm. Then, the soil aggregates between 4-9 mm were left to dry under laboratory conditions, 50 g from aggregates for each soil treatment was taken and placed on over a group of sieves with mesh sizes 4.75, 2.36, 1.00, 0.50, and 0.25 mm from top to bottom. Then, samples were moistened from the bottom by capillary using distilled water for 6 min and sieved again for 6 min. The contents of each sieve were separated and dried at 105 °C for 24 h. The MWD was computed as $MWD = \sum_{i=1}^{N} \bar{x}\ \omega_i$ (Besalatpour *et al.,* 2013), where: $\bar{x}$ is the average diameters of each mesh size (mm), ω_i is the rate of dry-weight aggregate to total dry-weight of soil expressed as a percentage.

Before tillage practices, the soil at the experimental site has a clay loam surface texture (Soil Survey Staff, 2014) with an average of 35% clay, 41 silt, and 24 sand. D_p at 0–30 cm depth has an average of 2.63 Mg m^{-3}. Soil EC decreased with increased soil depths. SOM was high with values of 6.0 g kg^{-1} at 0-10 cm soil depth and 4.0 g kg^{-1} at 20-30 cm depth. Main chemicals measured at the three depths include CO_3^{-2}, HCO_3^{-1} ,Cl^{-1}, SO_4^{-2}, Ca^{+2}, Mg^{+2}, Na^+, and K^+, are reported in Table 1.

Table 1. Main characteristics of the studied soil.

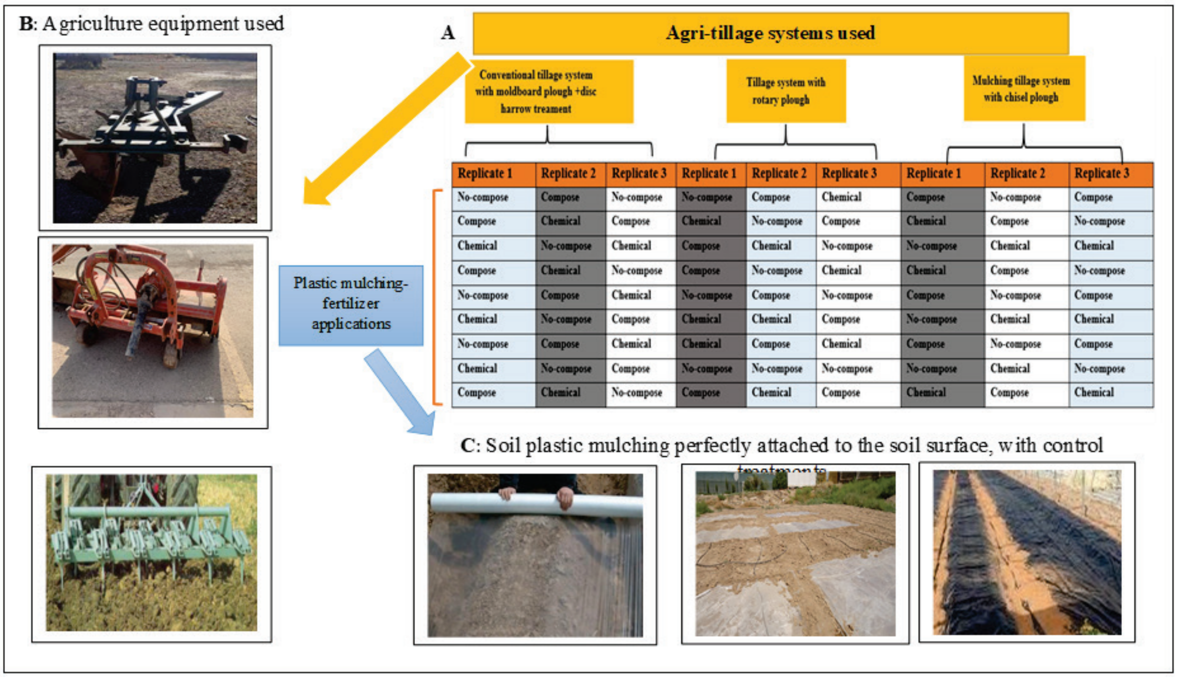
Soil depth (cm)	EC dsm^{-1}	pH	SOM g kg^{-1}	C mole c/L in saturated paste extract								ρb Mg m^{-3}	D_p Mg m^{-3}	MWD mm	Particle size distribution %			Texture
				CO_3^2	Hco_3^1	CI^{1-}	So_4	Ca^{2+}	Mg^{2+}	Na+	K+				Clay	Silt	Sand	
0-10	2.06	7.0	6.0	0	7	13	1.4	14.4	4	3.8	0.717	1.21	2.61	0.60	39	40	21	Clay loam
10-20	1.70	7.3	4.8	0	9	8	1.1	7.2	8	2.9	0.651	1.24	2.64	0.56	33	44	23	
20-30	1.34	7.3	4.0	0	10	3	1.0	8.3	2	2.6	0.648	1.29	2.65	0.48	34	40	26	

2.2. Experimental design

The field site includes the following experimental design:

- Tillage systems: 1) Conventional tillage: a combination of mouldboard plough followed by a disk harrow (MP+DH), plough to 25 cm depth; 2) Economical tillage: rotary cultivator (RC); and 3) Mulch tillage: chisel plough (CP) to a depth of 30 cm and leaving the remains of the straw crop to cover the soil surface after ploughing.
- Mulching: transparent mulch (TM), black mulch (BM), and without mulch (WM).
- Fertilisers: composted organic fertiliser (CoF), no-composted organic fertiliser (NoF) at an amount of 0.40 kg m^{-2} of cattle dune, and chemical fertiliser (ChF) of diammonium phosphate (DAP) at an amount 0.06 kg m^{-2}. The CoF was prepared by aerobic decomposition before being used by leaving it for a period of 10 weeks until an appropriate degree of decomposition was reached and, then, mixed with the soil surface manually.

These three individual treatments combined resulted in 27 treatments (3 tillage systems * 3 mulching * 3 fertilizers). Each combined treatment was implemented in 4 m^2 plots, leaving 1 m between each of the experimental units, 1 m between ploughing treatments, and 1 m between replicates to prevent interferences among experimental units. Each of the 27 combined treatments was replicated three times, making a total of 81 experimental plots over the entire area of 585 m^2, as shown in Figure 1.



Conventional tillage system with moldboard plough +disc harrow treament			Tillage system with rotary plough			Mulching tillage system with chisel plough		
Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 3
No-compose	Compose	No-compose	No-compose	Compose	Chemical	Compose	No-compose	Compose
Compose	Chemical	Compose	Chemical	No-compose	Compose	Chemical	Compose	No-compose
Chemical	No-compose	Chemical	Compose	Chemical	No-compose	No-compose	Chemical	Chemical
Compose	Chemical	No-compose	Compose	No-compose	Chemical	Chemical	Compose	No-compose
No-compose	Compose	Chemical	No-compose	Compose	No-compose	Compose	No-compose	Compose
Chemical	No-compose	Compose	Chemical	Chemical	Compose	No-compose	Chemical	Chemical
No-compose	Compose	Chemical	Chemical	Compose	Chemical	Compose	No-compose	Compose
Chemical	No-compose	Compose	No-compose	No-compose	No-compose	No-compose	Chemical	No-compose
Compose	Chemical	No-compose	Compose	Chemical	Compose	Chemical	Compose	Chemical

Figure 1. Schematic diagram of the experimental field.

The study used a tractor (New Holland T8.320), mouldboard plough (MP) with four boards, rotary plough (RC; mini-1200), chisel plough (CP), and disk harrow (DH). The specifications for the tractor and equipment used are shown in Appendices 1-2. The DH was used to mix fertilisers with the soil. In addition, irrigation to field capacity was made by surface irrigation. After the implementation of the three different tillage systems and the incorporation of the three different fertiliser types, the experimental plots were covered with plastic sheets (mulching) 200 cm wide and 0.05 cm thick for the transparent mulching (TM) and the black mulching (BM). Polyethylene film was used for soil mulching perfectly attached to the soil surface, which is essential to reduce water losses. Finally, the polyethylene sheets from all plots were removed after 60 days and the soil samples were collected to measure Φ, θ_{60}, and MWD for each soil treatment.

2.3. Statistical analysis

The split–split-plot design under the randomized complete block design (RCBD) was used to design and analyze the experimental data. Φ, θ_{60}, and MWD were calculated for each soil treatment at 0-20 cm soil depth, and the influence of tillage, mulching, and fertilizer on Φ, θ_{60}, and MWD was tested by the two-way ANOVA analysis using SAS 9.4v (SAS, 2013). The results were statistically tested by the least significant difference (LSD) method at the 0.05 probability level.

3. Results and discussion

3.1. Soil Porosity

The effect of tillage, mulching, and fertilizer on Φ are presented in Figure 2. A significant variation between tillage on Φ was found, where the CP gave the lowest Φ at 49.00%, while the MP+DH gave the highest Φ at 56.87% (Fig. 2a). The reason for this result is the rise of ρ_b in CP treatment compared with RC and MP+DH treatments, as shown in Figure 2a. Mulching shows significant differences in Φ between BM treatment (55.65%) and WM (52.98%). However, the differences between BM and TM treatment and between TM and WM, were non-significant (Fig. 2b). These results are due to decreasing soil ρ_b with BM compared with TM and WM. The findings show no significant differences between fertiliser applications on Φ (Fig. 2c). The interaction between tillage and mulching showed significant differences in Φ, with the highest value for MP+DH and BM (58.34%) and the lowest Φ for CP+WM (51.29%) (Fig. 2d). Also, Φ values were higher for MP+DH than for CP, RC as a result of decreasing SD values in plots ploughed by MP+DH compared with RC ploughing. The general trend in Φ values with the three types of tillage from highest to lowest was BM > TM > WM for the majority of soil treatments.

A significant positive correlation was indicated between tillage and fertilizers in Φ values (Fig. 2d), with the highest Φ value showing for MP+DH and CF (58.60%) and the lowest Φ value at CP and CF (49.40%). The interaction between mulching and fertilizer found significant differences in Φ, with the highest value for BM and CF (56.77%), and the lowest value for WM (52.14%) (Fig. 2e).

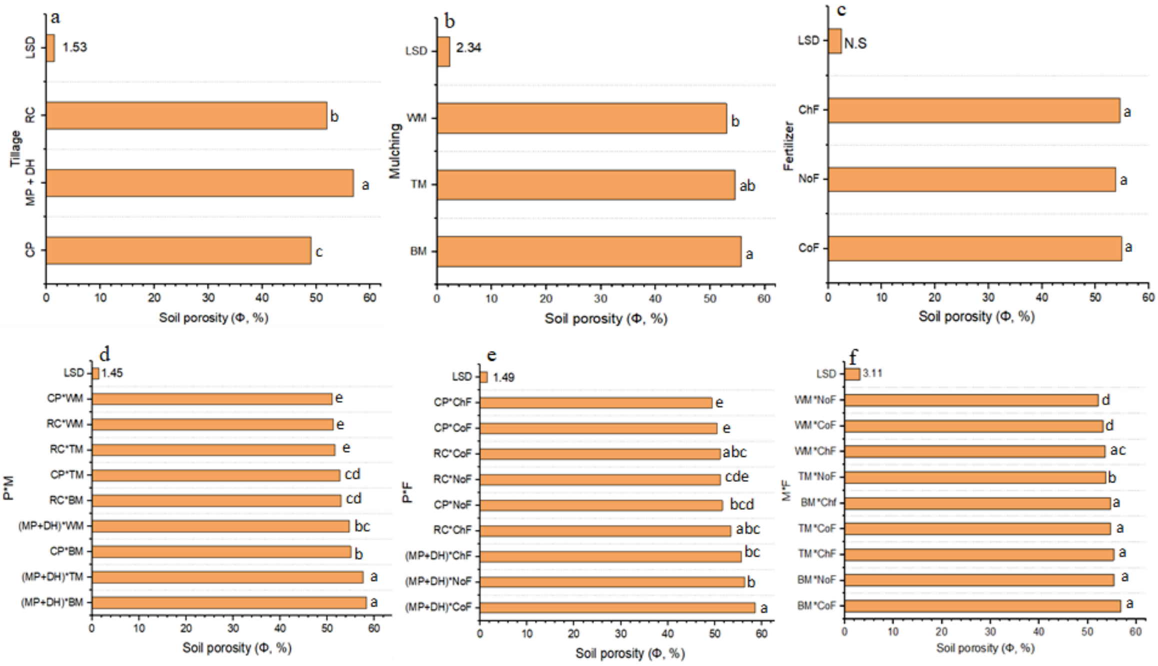


*Figure 2. Individual and combined effects of tillage, mulching, and fertilization practices on soil porosity (Φ). LSD: least significant difference (method at the 0.05 probability level, RC: Rotary cultivator, MP+DH: Ploughing mouldboard plough followed by a disk harrow, CP: Chisel plough, TM: Transparent mulch, BM: black mulch, WM: without mulch, CoF: composed organic fertilizer, NoF: no-composed organic fertilizer, ChF: chemical fertilizer, *: Interaction effect of the treatments.*

3.2. Soil water conservation

Results in Figure 3 represent the effect of tillage, mulching, and fertilizers on soil water conservation measured as the volumetric soil water content 60 days after irrigation to field capacity (θ_{60}). Results show a significant difference between the tillage system on θ_{60} values. The RC gave the highest average θ_{60} with 0.30 cm^3 cm-^{3}, whereas the CP gave the lowest average θ_{60} with 0.15 cm^3 cm^{-3} (Fig. 3a). This is expected due to the increase of ρ_b with CP treatments. Soil mulching also provides significant differences in θ_{60}, with the highest value of θ_{60} using BM, 0.35 cm^3 cm^{-3}, and the lowest value using WM, 0.17 cm^3 cm^{-3}. The general trend in θ_{60} from highest to lowest, is BM > TM > WM, caused by the fact that BM has a stronger effect on reducing evaporation (Anikwe *et al.*, 2007; Bhardwaj and Sarolia, 2013; Jiang *et al.,* 2017; Mahadeen, 2014). On the other hand, no significant differences between fertilizers on θ_{60} values were found. The interaction between tillage and mulching in θ_{60} (significance at the p level of 0.05) had the highest value for RC+TM (0.33 cm^3 cm^{-3}), whereas the lowest θ_{60} (0.13 cm^3 cm^{-3}) was obtained for CP * WM (Figure 3d). Also, θ_{60} values were higher in BM plots for the three tillage systems compared with TM and WM. Plots ploughed by RC using BM had significantly higher θ_{60} values than plots using TM and WM, with values 37% and 43% higher respectively, while θ_{60} values in the RC and BM plots were significantly higher than in TM and WM plots with values 30% and 180%, respectively. Furthermore, the interaction between the tillage system and fertilizer type showed non-significant differences between most treatments except for RC and CoF, NCF, and ChF with MP+DH and CoF. The highest θ_{60} value was obtained for RC and CoF (0.32 cm^3 cm^{-3}), and the lowest value for MP+DH and CoF (0.18 cm^3 cm^{-3}). The interaction between soil mulching and fertilizer type showed significant differences between most treatments, presenting the highest θ_{60} value (0.388 cm^3 cm^{-3}) for BM and ChF, while the lowest value (0.09 cm^3 cm^{-3}) appeared for WM and CoF (Figure 3f). The general trend in θ_{60} values considering interactions between mulching and fertilizer type, from highest to lowest, was BM and all fertiliser types > TM and all fertiliser types > WM and all fertiliser types. The reason for this is the influence of soil mulching on soil water consumption by controlling evaporation from the soil surface, which leads to water conservation (Jiang *et al.,* 2017; Mamkagh, 2009; Testa *et al.,* 2015; Wang *et al.,* 2009).

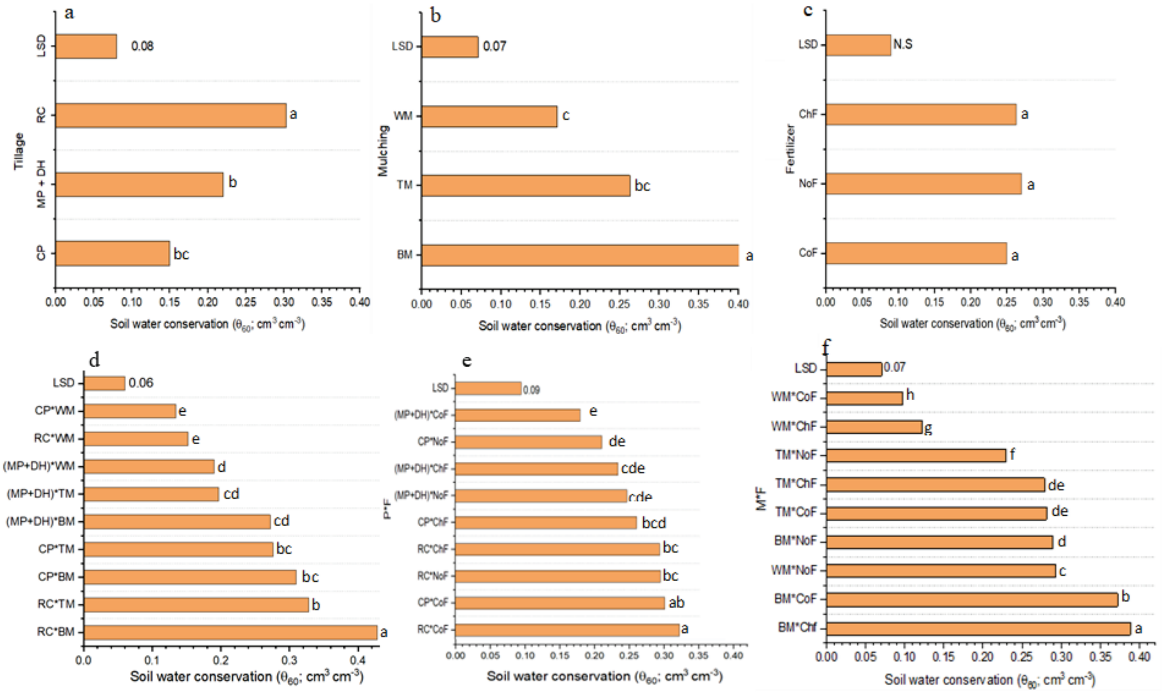


*Figure 3. Individual and combined effects of tillage, mulching, and fertilizer practices on soil water conservation (θ_{60}). LSD: least significant difference method at the 0.05 probability level, RC: Rotary cultivator, MP+DH: Ploughing mouldboard plough followed by a disk harrow, CP: Chisel plough, TM: Transparent mulch, BM: black mulch, WM: without mulch, CoF: composed organic fertilizer, NoF: no-composed organic fertilizer, ChF: chemical fertilizer, *: Interaction effect of the treatments.*

3.3. Mean weight diameter of aggregates

The effect of tillage, mulching, and fertilizers, as well as their interactions on the mean weight diameter of aggregates (MWD) is shown in Figure 4. Significant differences were found between the tillage system on MWD. The CP showed the highest MWD value of 0.98 mm, whereas the RC showed the lowest MWD of 0.73 mm (Fig. 4a). This is because ploughing with CP leads to the destruction of soil structure as a result of turning the subsoil to the top by CP, as well as with MP+DH. The mulching type also had a significant effect on MWD, showing higher MWD for BM and TM (1.06 and 0.84 mm, respectively) compared to WM with MWD of 0.66 mm. MWD increased using mulching (Fig. 4b), which could be explained by the increased soil water content with mulching leading to higher stability of the soil aggregates (Ma *et al.,* 2014). As expected, fertilizer type significantly affects MWD. The highest MWD occurred for CoF with 1.02 mm, and lowest for ChF with 0.75 mm (Fig. 4c). Soil structural stability increase with rising the decomposition of organic content (Ye *et al.,* 2017).

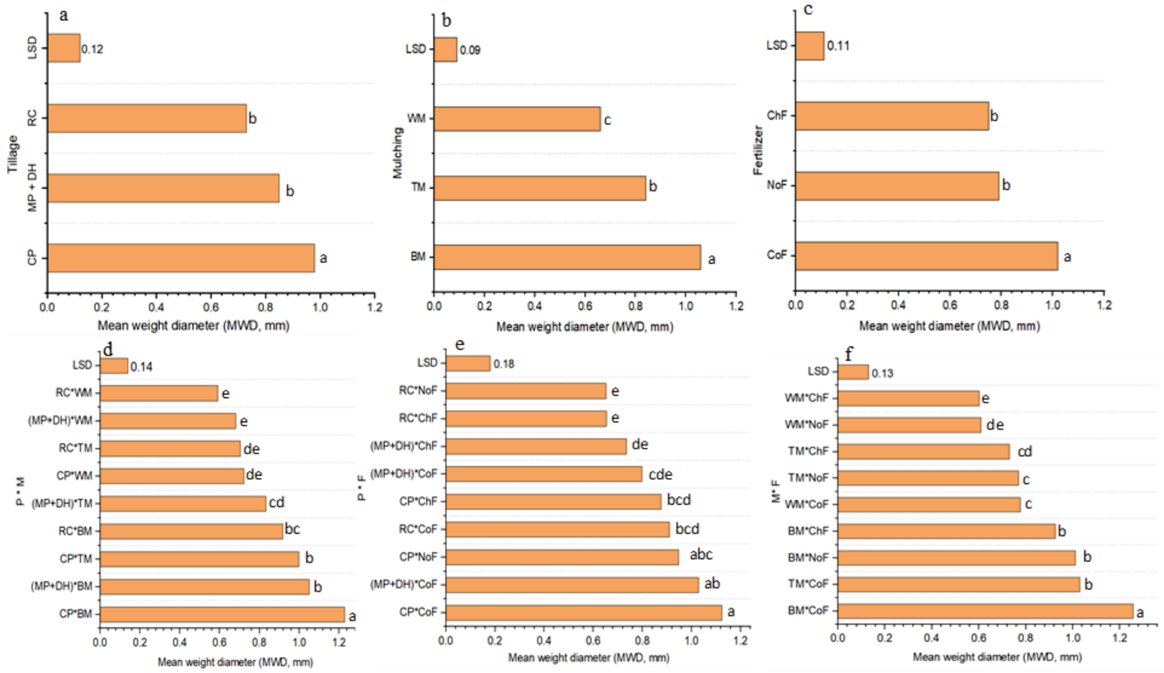


*Figure 4. Individual and combined effects of tillage, mulching, and fertilizer practices on mean weight diameter of aggregates (MWD). LSD: least significant difference method at the 0.05 probability level, RC: Rotary cultivator, MP+DH: Ploughing mouldboard plough followed by a disk harrow, CP: Chisel plough, TM: Transparent mulch, BM: black mulch, WM: without mulch, CoF: composed organic fertilizer, NoF: no-composed organic fertilizer, ChF: chemical fertilizer, *: Interaction effect of the treatments.*

The combination of the tillage system and mulching showed significant differences in MWD (Fig. 4d), with the highest MWD value for CP+BM (1.22 mm) and the lowest MWD for RC+WM (0.59 mm). Moreover, the results showed that the interaction between MP+DH and BM had a higher MWD value (1.05 mm) compared to MP+DH, and WM showed a lower value (0.68 mm). A likely explanation is that the lower destruction of soil aggregated by CP compared to turning ploughs, and mulching reduces evaporation allowing the soil to maintain high water content.

Figure 4e shows a significant effect of the combined tillage system and fertilizer type on MWD. The highest value was 1.12 mm for CP+CoF, while the lowest value was 0.65 mm, for RC+NoF and RC+ChF. The stability of soil aggregates is increased by CP, which breaks up and loosens the soil without turning it. As expected, MWD increased as soil organic content increased. Another important finding was that mulching + fertilizer application had a significant influence on MWD, obtaining the highest value (1.25 mm) at BM * CoF, whereas the lowest (0.60 mm) at WM * ChF. Thus, the MWD is indirectly influenced by tillage, mulching, and fertilizer treatments.

4. Challenges of the current study

The soil physical properties (SPP) were studied with the impact of the individual and combined effects of soil management practices within arid and semi-arid areas in southern Iraq. The conventional, economical, and mulch tillage system; transparent, black plastic mulch; organic and chemical fertilizers were effect on the SPP in clay loam texture for the wheat-agricultural sites. These results might be applicable to clay loam and clay texture properties. On the other hand, despite these recent limitations, Further investigation about long-term studies based on the influence of tillage and mulching under a variety of soils and climatic conditions of Iraq, as well as on soil thermal properties are strongly recommended. Furthermore, the Long-term no-tillage system effect on soil thermal-physical attributes in wheat /barley cultivation needs to be further studied.

5. Conclusions

The present study was designed to study the individual and combined effects of tillage, mulching, and fertilizer on Φ, θ_{60}, and MWD in agricultural land. The main results indicate that tillage systems were significantly positively correlated with Φ, and MWD ($p<0.05$). MP+DH showed higher Φ, whereas CH showed higher MWD (0.98 mm) compared to MP+DH, RC (0.85 and 0.73 mm, respectively). The highest values of Φ, θ_{60}, and MWD were obtained when BM was used. This was attributed to the influence of BM on reducing water losses, thus, allowing the soil to retain more water. On the other hand, no significant differences between fertilizer types on Φ and θ_{60} were found. However, fertilizer type was significantly correlated to MWD, with the highest MWD for CoF and the lowest for ChF due to the increasing decomposition of organic content in the CoF. The interaction between MP+DH and BM showed the highest Φ, while CP+BM showed the highest MWD.

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Appendices. Specifications for the tractor and equipment used

Appendix 1. Characteristics of the tractor used.

Specification	New Holland T8.320
Years of production	2007
Engine model / type	6.75T
Engine displacement (cm^3)	7474
Number of cylinders	6 T
Engine rated power (hp)	125
Type of drive transmission	Mech
Front wheel size	23.1R26
Rear wheel size	13/65-18
Weight	11200 kg

Appendix 2. Specification for the agriculture equipment used.

Specification	Mouldboard plough with four mould-board	Rotary plough, mini 1200 with 7 discs loaded blade	Chisel plough with 7 Blade	Disk harrow/ Double unit /8 Disc of each unit
Working width (cm)	105	128	170	155
Maximum soil tillage depths (cm)	33	20	40	20
Length (cm)	220	-	-	-
Weight (Kg)	300	232	390	-