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Role of Cover Crop, Irrigation Systems and Different Tillage on Soil Physical Properties

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Abstract: The central and southern regions of Iraq are located within the arid and semi-arid regions. The deterioration of the physical properties of the soil due to the low content of organic matter that is less than 1%. The high temperatures, low rainfall and the absence of vegetation cover, as well as the poor use of land and the absence of proper management of irrigation and tillage operations have negative effects on the physical, chemical and biological properties of the soil, which in turn will negatively affect the growth and production of agricultural crops. The experiment was conducted in the Nile district, located within the Babil Governorate, 86 km south of the capital, Baghdad, in a silty clay loam in the fall season 2020, aimed to examine the role of cover crop, irrigation systems and different tillage systems in some physical properties of soil (bulk density, porosity, mean weight diameter, soil resistance to penetration, and saturated soil hydraulic conductivity). The experiment was designed according to the strip-split plot arrangement according to a complete randomized block design. The experiment included three factors, the first that occupied the main plots is the cover crop (C) and included on two levels: without cover crop (C_0), and the presence of cover crop (C_1), and the second factor was the tillage systems (T) and included on four levels: Zero tillage (T_0), minimum tillage (T_1), medium tillage (T_2) and deep tillage (T_3), and the third factor is irrigation systems (I) with three levels: surface drip irrigation (I_1), subsurface drip irrigation (I_2) and surface irrigation in basins. (I_3) The results showed the superiority of treatment $C_1T_1I_2$ in obtaining the lowest value of bulk density, soil resistance to penetration, highest porosity, mean weight diameter rate, and soil hydraulic conductivity saturated while treatment $C_0T_3I_3$ gave the highest bulk density, soil resistance to penetration, less porosity, mean weight diameter and soil hydraulic conductivity saturated.

***Keywords*:** Drip irrigation, Bulk density, Soil hydraulic conductivity, Weighted drip rate, Penetration resistance

The physical properties of the soil play an important role in determining the suitability of the soil for agricultural, environmental and engineering uses. The supporting capacity for water and nutrients readiness, ease of root penetration, air flow and heat, as well as their impact and influence on the chemical and biological properties of soil (Sanchez 2019). One of the most important challenges of the twenty-first century is how humanity can cope with climate change and water scarcity to continue producing food at the levels necessary to feed a growing world population while preserving soil and water resources from degradation (Din et al 2019). Cover crops are a major tool that can contribute to increasing yields, maintaining surface and groundwater quality, reducing erosion potential, and improving soil properties and health in arid and semi-arid areas. Cover crops have a very high potential to reduce erosion and soil erosion. Cover crops appear to be good practice for coping with and mitigating climate change (Kocira et al 2020). Practicing a cover crop system can enhance soil construction by increasing the porosity, increasing the water tip rate as well as decreasing bulk density and decreasing soil resistance to penetration (Çerçioğlu et al 2019). Cover crops are generally considered to improve the properties of the soil in general and the physical properties in particular. The optimal management of tillage and crop residue plays an important role in the physical and chemical properties of the soil and ultimately affects the on crop productivity. A compatible combination of tillage and crop residue management improved soil properties and provided a suitable environment for crop growth (Wasaya et al 2019). Conservative tillage practices such as no-till, minimal tillage and reduced tillage while retaining crop residues on the soil surface have a significant advantage over conventional tillage by adding organic matter and carbon to the soil which is a prerequisite for better physical, biological and chemical properties (Vizioli et al 2021). Leaving crop residues on the soil surface reduces compaction, reducing bulk density, as well as increasing tip rate, Saturated Soil hydraulic conductivity and regulating soil temperature in the case of no-till compared to plowed soil due to better plant growth and increased microbial activity (Singh et al 2018). Salem et al (2015) observed effect different tillage systems such as zero tillage, short tillage and conventional tillage on some physical soil characteristics and maize yield The zero and short tillage outperformed the conventional tillage in terms of productivity, low bulk density and soil resistance to penetration. Ren et al (2018) observed the superiority of the short tillage system at a depth of 0.10 m over the traditional tillage system at a depth of 0.25 m, as the values of the bulk density and soil resistance to penetration decreased by 6.16 and 7.69%. Exploiting, distributing and rationalizing water consumption in an appropriate and efficient manner is one of the soil and water management programs, and choosing the appropriate irrigation method achieves the highest water use efficiency and maintains the good physical properties of the soil as well as providing suitable conditions for plant growth (FAO 2018). To achieve this, unconventional irrigation techniques must be resorted to, such as surface and sub-surface drip irrigation. These technologies have begun to spread widely in dry and semi-arid areas due to their high efficiency of use and their role in maintaining soil construction. As for irrigation, it is one of the common, easy, and low-cost methods, and it is preferable to use for soils that have a good ability to store and soils with high salinity that work to wash the accumulated salts and keep them away from the root zone (Wambua 2020). Al-Hadi and Aodeh (2014) observed that use of drip irrigation contributed to the preservation of the soil structure, which resulted in a significant increase in the values of the average weighted diameter, porosity, saturated Soil hydraulic conductivity, soil water drop rate, and a significant decrease in the apparent density of soil in comparison with flooded irrigation. Rodríguez et al (2016) also observed that the flooded soil recorded the highest bulk density of 1.14 mcg m^{-3} and the lowest porosity ratio of 56.32%, while the non-flooded soil recorded the lowest bulk density value of 1.00 mcg m-3 and the highest porosity. 61.58%. Abd AL- Gabbar and Al-Abaied (2016) observed the performance of center pivot and turbulent irrigation in some physical properties of soil. The adoption of center pivot irrigation method led to a decrease in the average values of the soil bulk density, which amounted to 1.38 mcg m^{-3} compared to 1.44 Mg m^{-3} for the irrigation treatment, and the total porosity of the soil increased to 0.45 compared to 0.42 for the two irrigation treatments on sedimentation. The irrigation method had a role in increasing the saturated soil hydraulic conductivity values, as adopting the center pivot irrigation method led to a significant increase with 9.18 cm h^{-1} compared to 8.51 cm h^{-1} for flooded irrigation . The pivot irrigation method had an important role in increasing the base tip rate as it reached 9.4 cm h^{-1} compared to 8.6 cm h-1 for flooded irrigation treatments This experiment was conducted with the aim of assessment of the physical properties of the soil and the changes that occur under the influence of the presence of cover crop, different plowing and irrigation systems.

MATERIAL AND METHODS

Field experiment was conducted in Nile sub-district of Babil Governorate, 86 km south of Baghdad, during the fall season of 2020, (latitude 35” 32º 31' north, longitude 21” 36' 44º east, at a height of 31 m above sea level. The study area is characterized by a flat to semi-flat topography with a slope of less than 2%, and the soil of the field was classified as sedimentary with a texture of silty clay loam and classified under the Typic torrifluvent group according to the classification of the soil (Survey 2019). The field was planted with wheat and left residues to cover the soil surface by 30% .Soil samples were taken randomly from the site of the experiment before planting from layers 0-0.30 and 0.30-0.60 m in order to estimate some physical and chemical properties of soil (Table 1). The pocket penetrometer model CL700 with a cylindrical stem and a flat end with a diameter of 0.672 cm and a penetration depth of 1 cm from the surface was used to measure the resistance of the soil to penetration. Undisturbed samples were manually broken and air dried, then the samples were sieved to obtain aggregates with a volume range of 4-9 mm. Soil aggregates were sieved by wet sieving method according to the method mentioned by Aoda and Mahdi (2017) and the weighted diameter ratio was calculated from the following equation:

$$MWD = \sum_i^n = 1\, \acute{X}_i\, W_i$$

Table 1. Physical and chemical properties of the experimental site

Property	Soil layer (m)	
	0.30-0	60-30
Sand (gm Kg^{-1})	181	230
Silt (gm Kg^{-1})	471	453
Clay (gm Kg^{-1})	348	317
Soil Texture	SiCL	SiC
Bulk density Mg m^{-3}	1.32	1.38
Particle density Mg m^{-3}	2.65	2.65
Porosity %	50.18	47.92
Void ratio	1.007	0.920
Volumetric water content at 33 kpa (cm^3 cm^{-3})	0.32	0.34
Volumetric water content at 1500 kpa (cm^3 cm^{-3})	0.13	0.14
Available water (cm^3 cm^{-3})	0.19	0.20
Saturated Soil hydraulic conductivity	3.20	2.91
basic infiltration rate (Double ring method) cm h^{-1}	2.86	——
Soil resistance of penetration Mpa	2.54	——
MWD mm	0.87	0.58
EC_e ds m^{-1}	1.70	1.75
pH	7.6	7.6
Organic matter (%)	1.8	1.7
CEC (Cmolc Kg^{-1} soil)	16.83	16.05

MWD = Mean weight diameter (mm).

Wi = Mass of the aggregates as relative to the total weight of the sample (without units).

Xi = average diameter of those aggregates (mm.)

The saturated soil hydraulic conductivity was measured by constant head method. Soil samples were, dried, crushed, and sieved with a sieve with a diameter of 2 mm. The soil was filled with a glass cylinder with a diameter of 0.038 m and a height of 0.12 m. The soil was saturated from the bottom for 24 hours. A fixed water column of 2 cm was determined above the soil column. The quantities of percolating water were collected over time until reaching the stability state and calculated. The saturated soil hydraulic conductivity was estimated according to the equation of Aoda and Mahdi (2017).

$$K = \frac{V \times L}{At\,(h+L)}$$

The quality of water was determined, which was C_1S_3, according to the Irrigation Water Use Manual (Boyd, 2019) (Table 2).

The experiment was designed according to the strip-split plot arrangement according to a complete randomized block design (RCBD) with three replications. The experiment included three factors. The first factor is the cover crop (the remnants of the wheat crop of the previous agricultural season and occupied the main plot) and included two levels: without cover crop C_0 and the presence of cover crop C_1. The second factor was the occupation of the secondary plot and included four levels: no-till T_0, minimum tillage T_1(tillage depth 0.10 m by spike harrows pin), medium tillage T_2 (tillage depth 0.20 m by chesil plow), and deep tillage T_3 (Tillage depth 0.30 m by chisel plow). The third factor is the irrigation systems occupy the sub-sub plot) was at three levels: surface drip irrigation I_1, subsurface drip irrigation I_2, and surface irrigation in basins I_3 (Table 3).

After plowing, the land was divided into slabs with dimensions of 5 x 6 m. A separation distance between the experimental units from all directions was left by about 2 m for the purpose of controlling the irrigation treatments, as well as leaving a separation distance of 3 m between the replicates. A drip irrigation system was used with pipes dedicated to surface and subsurface irrigation, with a diameter of 0.016 m. It contains emitters with a discharge of 4.00 liters per hour^{-1} of the emitter. The experimental units for surface and subsurface drip irrigation treatments were equipped with seven drip lines, the distance between one drip line and another 0.75 m, and the distance between one emitter and another 0.20 m. Subsurface drip lines are installed at a depth of 0.20 m. Irrigation water was added for surface irrigation treatments through field pipes that branched off from the

Table 3. Details of experiment treatments

Symbol	Treatments
$C_0T_0I_1$	Remove cover crop + No tillage + Surface drip irrigation
$C_0T_0I_2$	Remove cover crop + No tillage + Sub-Surface drip irrigation
$C_0T_0I_3$	Remove cover crop + No tillage + Surface irrigation
$C_0T_1I_1$	Remove cover crop + Tillage at depth 0.10 m + Surface drip irrigation
$C_0T_1I_2$	Remove cover crop + Tillage at depth 0.10 m + Sub-Surface drip irrigation
$C_0T_1I_3$	Remove cover crop + Tillage at depth 0.10 m + Surface irrigation
$C_0T_2I_1$	Remove cover crop + Tillage at depth 0.20 m + Surface drip irrigation
$C_0T_2I_2$	Remove cover crop + Tillage at depth 0.20 m + Sub-Surface drip irrigation
$C_0T_2I_3$	Remove cover crop + Tillage at depth 0.20 m + Surface irrigation
$C_0T_3I_1$	Remove cover crop + Tillage at depth 0.30 m + Surface drip irrigation
$C_0T_3I_2$	Remove cover crop + Tillage at depth 0.30 m + Sub-Surface drip irrigation
$C_0T_3I_3$	Remove cover crop + Tillage at depth 0.30 m + Surface irrigation
$C_1T_0I_1$	Cover crop + No tillage + Surface drip irrigation
$C_1T_0I_2$	Cover crop + No tillage + Sub-Surface drip irrigation
$C_1T_0I_3$	Cover crop + No tillage + Surface irrigation
$C_1T_1I_1$	Cover crop + Tillage at depth 0.10 m + Surface drip irrigation
$C_1T_1I_2$	Cover crop + Tillage at depth 0.10 m + Sub-Surface drip irrigation
$C_1T_1I_3$	Cover crop + Tillage at depth 0.10 m + Surface irrigation
$C_1T_2I_1$	Cover crop + Tillage at depth 0.20 m + Surface drip irrigation
$C_1T_2I_2$	Cover crop + Tillage at depth 0.20 m + Sub-Surface drip irrigation
$C_1T_2I_3$	Cover crop + Tillage at depth 0.20 m + Surface irrigation
$C_1T_3I_1$	Cover crop + Tillage at depth 0.30 m + Surface drip irrigation
$C_1T_3I_2$	Cover crop + Tillage at depth 0.30 m + Sub-Surface drip irrigation
$C_1T_3I_3$	Cover crop + Tillage at depth 0.30 m + Surface irrigation

Table 2. Chemical analysis of irrigation water

Property unit	Ec ds m^{-1}	pH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	SO_4^{-2}	HCO_3^{-1}	Classify the water according to (USDA)
Value	0.79	7.55	3.55	3.19	2.76	0.11	2.08	4.55	2.17	C_1S_3

secondary pipe at the middle of the edge of the plate. Seeds of maize (*Zea mays* L.), a hybrid Euphrates cultivar from the Dutch company Monarch, were planted on July 23, 2020 and each plot included 7 lines. The maize was harvested on November 20, 2020. (growing season 120 days). The irrigation process was conducted after depletion 50% of the soil water available for the plant. In calculating the amount of irrigation water added to each irrigation system in the surface irrigation system and was based on measuring the water content in the soil by the gravimetric method, according to the equation of Waller and Yitayew (2016):

$$d = (\theta_{fc} - \theta_{I}) \times D$$

where, d: is the depth of water added (mm). and θ_{fc}: the volumetric water content at field capacity ($cm^3\ cm^{-3}$). θ_I: the volumetric water content before the irrigation procedure and after depletion 50% of the available water ($cm^3\ cm^{-3}$). and D: depth of the soil layer (mm).

According to the depth of water added (mm) in each irrigation for the drip irrigation system by applying the following equations (Omran and Negm, 2020)

Wet area (%) was calculated as:

$$Pw = \frac{SW}{SR} \times 100$$

where: Pw = is the wet area (%). And Sw = the diameter of the wetted area (m) and it was 0.30 m for the surface dripping and 0.27 m for the subsurface drip. SR = the distance between the drip lines (m), which was 0.75 m. According to the depth of water added in each irrigation system for the drip irrigation system.

$$dn = AW \times Ds \times Pw \times dep$$

where: dn = maximum net depth irrigation for one irrigation (mm). and AW = water storage capacity of the soil (%) = $(\theta_{fc} - \theta_{wpw})$. and Ds = depth of the root zone (m). and Pw = wet area percentage (%). and dep = depletion rate of available water (%). According to the time required for irrigation (T) minutes from the following equation:

$$A = \frac{Ae \times d}{Q}$$

where Ae = The area of wetness for the single emitter, was calculated from the following equation:

$$Ae = 0.8\ (Sw)^2$$

d = depth of water added (cm), which represents the net depth of irrigation (NDI). Q = the given discharge, which was 4 liters per $hour^{-1}$ per emitter.

RESULTS AND DISCUSSION

Bulk density ($Mg\ m^{-3}$): The influence of cover crop, irrigation systems and different tillage systems on bulk density values, was highest (1.480 mg m^{-3}) in $C_0T_3I_3$ and the lowest of 1,200 mg m^{-3} was $C_1T_1I_2$ with a decrease of 23.33%. There were no significant differences in the bulk density of the triple interaction and the interaction between cover crop and tillage, as the highest value of bulk density was 1.453 mg m^{-3} in C_0T_3 and the lowest in C_1T_1 (1.237 mg m^{-3}) with a decrease of 17.88% . The interaction between cover crop and irrigation, indicated the highest bulk density was 1,400 mg m^{-3} in C_0I_3 and the lowest was 1.288 mg m^{-3} in C_1I_2, with a decrease of 8.69%.

There were significant differences in the average bulk density of tillage and irrigation treatments and the interaction between them. Irrigation treatments affected the average bulk density, as the traditional irrigation treatment I_3 gave the highest average bulk density of 1.371 mg m^{-3} and the subsurface drip irrigation I_2 the lowest average of 1.313 mg m^{-3} This may be due to the effect of the traditional irrigation treatment In the basins, the movement of fine soil particles during irrigation and their deposition in the large pores and also due to the succession of the cycles of hydration and drying and the confinement of air in the pores of the soil and the occurrence of air explosions leading to the destruction of soil aggregates, which increases the values of the bulk density. This may also be attributed to the different irrigation method used in the transactions. The adoption of the subsurface drip irrigation system led to an improvement in soil construction, while the adoption of the subsurface irrigation system led to the collapse of the building and the redistribution of soil particles within the interspaces, which led to an increase in the values of the bulk density due to the sudden immersion of the tourist irrigation compared to the slow wetting of the drip irrigation and the movement of some fine soil particles. This leads to an increase in compaction and a decrease in porosity when using the irrigation method, and this came in agreement with the results of Cerdà et al (2021). The tillage treatments had a significant effect on the values of the average bulk density, highest average bulk density in T_3 (1.427 mg m^{-3}) and T_1 gave the lowest bulk density of 1.262 mg m^{-3}. Perhaps the reason for the increase in the average bulk density is due to the deterioration of the soil structure, including the formation of the deaf layer, as well as the increase in soil cohesion with depth, as well as the compaction of the underlying soil layers as a result of the pressure imposed on it from the surface layers as well as through the passage of agricultural machinery and equipment. These results are in agreement with Pranagal and Woźniak (2021). The largest value of the bulk density was 1.450 mg m^{-3} in T_3I_3 and the lowest was 1.225 mg m^{-3} in treatment T_1I_2. The bulk density varied within the interactions of the other treatments, as the bulk density decreased in the surface and subsurface drip irrigation T_0I_1 and T_0I_2 compared to the traditional irrigation T_0I_3, with a decrease of 3.90 and

5.13%, respectively. In T_2I_1 and T_2I_2, the bulk density decreased by 1.09 and 2.58% compared to T_2I_3, respectively. T_3I_1 and T_3I_2, the values of bulk density decreased by 1.75 and 3.20% compared to T_3I_3, respectively. The cover crop treatments significantly affected the bulk density values, where the highest value of bulk density was 1.364 mg m^{-3} when treatment C_0 and treatment C_1 reached 1.313 mg m^{-3} with a decrease of 3.88%, and this result was in agreement with Chalise et al (2018).

Porosity %: The total porosity values, as it ranged between 44.15 and 54.71% (Table 5). $C_0T_3I_3$ achieved the lowest value of total porosity, while $C_1T_1I_2$ reached the highest total porosity. The results of the statistical analysis showed that there were no significant differences between the three experimental treatments in total porosity, as well as the interaction between the cover crop treatment and the irrigation treatment. The lowest porosity was in treatment C_0I_3 47.16%, while treatment C_1I_2 gave the highest porosity, which amounted to 51.39%, with a percentage decrease of 8.96%. Likewise, the interaction between cover crop and tillage, there were insignificant differences, and the highest porosity was in C_1T_1 with porosity of 53.33%, while for treatment C_0T_3 gave the lowest porosity of 45.15% with a decrease of 18.11% compared with C_1T_1. The interaction between tillage and irrigation, the results showed that there were significant differences in total porosity. The T_1I_2 recorded the highest value of the porosity (53.77%,) while T_3I_3 gave the lowest porosity(45.28%, 0 with a decrease of 18.75%. There were significant differences between the levels of each treatment, so that the cover crop had a significant effect compared to the absence of the cover crop. The average total porosity in C_1 was 50.45% and was higher than C_0, which recorded the average total porosity of 48.51%. This may be due to the role of the cover crop in creating A suitable environment for the activity of soil biology, especially earthworms, which have the ability to improve soil construction by increasing the stability

Table 4. Influence of cover crop, irrigation and tillage systems on bulk density (Mg m^{-3})

Cover crop	Tillage	Irrigation			Cover crop* tillage
		I_1	I_2	I_3	
C_0	T_0	1.300	1.290	1.360	1.317
	T_1	1.270	1.250	1.340	1.287
	T_2	1.400	1.380	1.420	1.400
	T_3	1.450	1.430	1.480	1.453
C_1	T_0	1.260	1.240	1.300	1.267
	T_1	1.220	1.200	1.290	1.237
	T_2	1.350	1.330	1.360	1.347
	T_3	1.400	1.380	1.420	1.400
LSD			N. S		N. S
Cover crop * Irrigation					
Cover crop		I_1	I_2	I_3	Average of cover crop
C_0		1.355	1.338	1.400	1.364
C_1		1.308	1.288	1.343	1.313
LSD			N. S		0.020
Tillage * Irrigation					
Tillage		I_1	I_2	I_3	Average of tillage
T_0		1.280	1.265	1.330	1.292
T_1		1.245	1.225	1.315	1.262
T_2		1.375	1.355	1.390	1.373
T_3		1.425	1.405	1.450	1.427
LSD			0.028		0.021
Average of irrigation		1.331	1.313	1.371	
LSD			0.013		

of soil aggregates, as well as affecting the cover crop in the volume distribution of pores and that the decomposition of the components of the cover crop will lead to an increase in the percentage of organic matter in the soil and thus reduce its apparent density and increase its porosity These results were in agreement with the findings of Frazão et al. (2019). Likewise in the plowing treatments, there were significant differences, as the minimum tillage T_1 was superior by with highest average total porosity of 52.38%, while the deep tillage T_3 gave the lowest mean total porosity and reached 46.16, with a decrease of 13.47%. The reason is that deep plowing destroys the soil structure and forms layers of compacted soils that increase its apparent density and reduce soil erosion. Porous, the other irrigation treatments significantly affected the average total porosity. It was the best result was by using the sub-surface drip irrigation method because it gave the highest average porosity of 50.47%, while the lowest average porosity was when treating the traditional irrigation in basins, with the average porosity reaching 48.25%, with a decrease of 4.60% and perhaps The reason for the increase in the total porosity of the soil when following the subsurface drip irrigation system compared to the traditional irrigation system in basins is due to the growth and penetration of plant roots with the progression of the growing season, which works to bind soil particles, as well as the presence of microorganisms and the substances they secrete that improve soil construction as a result of increased its activities. The tourist irrigation led to the confinement of the air inside the pores and the occurrence of localized explosions that destroyed the soil structure and broke the gatherings, as well as the difference in the expansion of the different parts of the soil assemblies as a result of the rapid wetting. The effect of the succession of wetting and drying played a role in creating a tight compaction of soil particles, which resulted in an increase in the apparent density of the soil and a decrease in its porosity. These results were similar with what was found. Abd AL-Gabbar and Al-Abaied (2016).

Mean weight diameter (MWD): The statistical analysis

Table 5. influence of cover crop, irrigation and tillage systems on porosity (%)

Cover crop	Tillage	Irrigation			Cover crop* tillage
		I_1	I_2	I_3	
C_0	T_0	50.94	51.32	48.67	50.31
	T_1	52.07	52.83	49.43	51.44
	T_2	47.16	47.92	46.41	47.16
	T_3	45.28	46.03	44.15	45.15
C_1	T_0	52.45	53.20	50.94	52.20
	T_1	53.96	54.71	51.32	53.33
	T_2	49.05	49.81	48.67	49.18
	T_3	47.16	47.92	46.41	47.16
LSD			N. S		N. S
Cover crop * Irrigation					
Cover crop		I_1	I_2	I_3	Average of cover crop
C_0		48.86	49.50	47.16	48.51
C_1		50.64	51.39	49.32	50.45
LSD			N. S		0.77
Tillage * Irrigation					
Tillage		I_1	I_2	I_3	Average of tillage
T_0		51.69	52.26	49.81	51.25
T_1		53.01	53.77	50.37	52.38
T_2		18.11	48.86	47.54	48.17
T_3		46.22	46.98	45.28	48.16
LSD			1.05		0.77
Average of irrigation		49.76	50.47	48.25	
LSD			0.50		

showed that there were no significant differences in the triple interaction between the experimental treatments and the mean weight diameter values (Table 6). The highest mean weight diameter was 3.93 mm in $C_1T_1I_2$ and the in $C_0T_3I_3$ (1.03 mm,) with a decrease of 281.55%. There were significant differences between the treatment of cover crop and different tillage, the highest value of weighted diameter was 1.26 mm in C_0T_3 treatment, while C_1T_0 excelled by giving the highest value of the average weighted diameter (3.72 mm) with an increase rate of 195.23%. The binary interaction of the cover crop and irrigation treatments gave significant differences in the average weighted diameter, and the lowest average weighted diameter was 2.32 mm for C_0I_3, while the highest was 3.11 mm in the C_1I_2 with an increase of 33.76%. The interaction between the tillage and irrigation systems did not differ significantly. The T_3I_3 gave the lowest value of the average weighted diameter (1.33 mm), while the highest average weighted diameter was in T_0I_2 (3.70 mm) with an increase of 173.43%. The treatment C_1 achieved the highest value in the MWD of 2.889 mm compared to 2.488 mm in C_0. Increasing the activity of soil microorganisms because it provides a fertile environment for the growth of these microorganisms that bind soil particles and thus increase the stability of soil assemblies. These results are in agreement with the findings of Jeghata and Muhawish (2021).

Tillage treatments showed significant differences in the values of the mean weight diameter T_0 achieved the highest average of the mean weight diameter of 3.517 mm, while treatment T_3 gave the lowest average of 1.565 mm, with an increase of 124.72%. This is due to the role of the no-till treatment in preserving the soil structure and its content of organic matter in the surface layer of the soil because it has a role in improving some soil characteristics through the cohesion and interconnection of soil aggregates to each other and increasing soil water holding through increasing soil porosity as well as decomposition of the organic matter produces viscous gels consisting of disaccharides, cellulose, proteins and glue that bind the soil particles with each other,

Table 6. influence of cover crop, irrigation and tillage systems on MWD (mm)

Cover crop	Tillage	Irrigation			Cover crop* tillage
		I_1	I_2	I_3	
C_0	T_0	3.350	3.440	3.150	3.313
	T_1	3.310	3.400	3.110	3.273
	T_2	2.120	2.190	2.010	2.107
	T_3	1.300	1.450	1.030	1.260
C_1	T_0	3.850	3.970	3.340	3.720
	T_1	3.810	3.930	3.280	3.673
	T_2	2.300	2.480	2.100	2.293
	T_3	1.870	2.060	1.680	1.870
LSD			N. S.		0.141
Cover crop * Irrigation					
Cover crop		I_1	I_2	I_3	Average of cover crop
C_0		2.520	2.620	2.325	2.488
C_1		2.958	3.110	2.600	2.889
LSD			0.105		0.135
Tillage * Irrigation					
Tillage		I_1	I_2	I_3	Average of tillage
T_0		3.600	3.705	3.245	3.517
T_1		3.560	3.665	3.195	3.473
T_2		2.210	2.335	2.055	2.200
T_3		1.585	1.755	1.355	1.565
LSD			N.S.		0.119
Average of irrigation		2.739	2.865	2.463	
LSD			0.059		

which increases the stability of the aggregates in the soil. The traditional plowing destroy the soil structure. Irrigation treatments affected the values of the mean weight diameter, and the statistical analysis showed that there were significant differences in the values of the MWD. Treatment I_2 gave the highest average of the weighted diameter which was 2.865 mm, while treatment I_3 gave the lowest average of 2.463 mm. The reasons for the decrease in the values of the MWD of the traditional irrigation treatments in basins are due to the destruction that occurs to large gatherings during the irrigation process, which results in smaller gatherings and individual soil particles, as well as to the role of the traditional irrigation process and its negative effects in wetting the soil aggregates and weakening the bonding strength between them and thus the building collapse. As a result of the rapid and sudden immersion and the rapid escape of air trapped in the pores, which destroys large soil gatherings, as well as the succession of wetting and drying, which leads to a difference in the expansion of clay minerals, causing cracks and cracking of gatherings that further deteriorate soil structure (Al-Shamari et al 2020).

Soil resistance of penetration (Mpa): The highest value was 2.54 MPa for $C_0T_3I_3$ and the lowest value was for $C_1T_1I_2$ (0.91 MPa) (Table 7). There were no significant differences between the three treatments in the values of soil resistance to penetration, as well as the bilateral interaction between cover crop and tillage and also between cover crop and irrigation. However, significant differences were found between the treatments of the cover crop, as the percentage increase was 91%, and the highest average was in C_0, (1.91 MPa) and the lowest average was in C_1 (38 MPa). The decrease in soil resistance to penetration may be attributed to the role of the cover crop in holding the soil to water as a result of the improvement of soil construction, as the research indicated the role of the cover crop in improving the soil structure and improving the capacity of the soil to hold water as a result of increasing the porosity of the soil and the volume distribution of pores of small size (Gabriel et al 2021)

Table 7. influence of cover crop, irrigation and tillage systems on soil resistance of penetration ()Mpa

Cover crop	Tillage	Irrigation			Cover crop* tillage
		I_1	I_2	I_3	
C_0	T_0	1.69	1.66	1.75	1.70
	T_1	1.53	1.45	1.69	1.55
	T_2	2.04	2.04	2.11	2.06
	T_3	2.45	2.16	2.54	2.38
C_1	T_0	1.16	1.10	1.23	1.16
	T_1	0.98	0.91	1.17	1.02
	T_2	1.54	1.54	1.64	1.57
	T_3	1.86	1.68	1.90	1.81
LSD			N. S		N. S
Cover crop * Irrigation					
Cover crop		I_1	I_2	I_3	Average of cover crop
C_0		1.89	1.76	2.10	1.91
C_1		1.39	1.24	1.53	1.38
LSD			N. S		0.013
Tillage * Irrigation					
Tillage		I_1	I_2	I_3	Average of tillage
T_0		1.41	1.35	1.49	1.41
T_1		1.25	1.18	1.43	1.28
T_2		1.79	1.79	1.89	1.82
T_3		2.17	1.96	2.20	2.11
LSD			0.056		0.026
Average of irrigation		1.65	1.57	1.75	
LSD			0.032		

This improvement in soil structure and the increase in moisture preservation and the percentage of pores and their regularity made soil particles slip on each other, which facilitated penetration. Tillage treatments showed a significant difference in the average soil resistance to penetration, T_1 gave the lowest mean of soil resistance to penetration, (1.28 MPa) while treatment T_3 gave the highest mean of soil resistance to penetration (2.11 MPa) with an increase of 111%. This is due to the role of deep plowing in compacting the soil, increasing its apparent density and decreasing its porosity. The results are similar to Altalabani and Saad (2018). The irrigation treatments affected the average soil resistance to penetration, I2 gave the lowest mean of soil resistance to penetration (1.57 MPa) and treatment I_3 highest average soil resistance to penetration (1.75 MPa). This also led to a decrease in the total porosity and the values of the average weighted diameter, so this effect was also negatively reflected on the soil's resistance to penetration.

Saturated soil hydraulic conductivity (cm min^{-1}) : The highest value of the Saturated soil hydraulic conductivity was 3.81 cm min^{-1} in $C_1T_1I_2$ while treatment $C_0T_3I_3$ recorded the lowest of 0.91 cm min^{-1} (Table 8). There were significant differences in the values of the saturated soil hydraulic conductivity for the triple interaction between the treatments of the experiment and also for the bilateral interaction between the treatments of cover crop and tillage. The highest value of the saturated soil hydraulic conductivity was 3.49 cm min^{-1} for C_1T_1, while the lowest was 1.08 cm min^{-1} for C_0T_3 with an increase of 223.14%. The treatments of cover crop and irrigation and the interaction between them, had a significant effect on the saturated soil hydraulic conductivity as the highest value of the water conductivity was 2.93 cm min^{-1} and the lowest value was 1.64 cm min^{-1} for treatments C_1I_2 and C_0I_3 according to the sequence, with an increase of 192.5%. The binary interaction between the tillage and irrigation treatments gave values of the saturated soil hydraulic conductivity was significantly different among them. The

Table 8. Influence of cover crop, irrigation and tillage systems on saturated soil hydraulic conductivity (cm min^{-1})

Cover crop	Tillage	Irrigation			Cover crop* tillage
		I_1	I_2	I_3	
C_0	T_0	2.86	2.87	2.11	2.61
	T_1	2.93	2.94	2.16	2.67
	T_2	1.80	1.88	1.36	1.68
	T_3	1.12	1.21	0.91	1.08
C_1	T_0	3.75	3.75	2.81	3.43
	T_1	3.80	3.81	2.86	3.49
	T_2	2.17	2.23	1.91	2.10
	T_3	1.78	1.86	1.32	1.65
LSD			0.135		0.149
Cover crop * Irrigation					
Cover crop		I_1	I_2	I_3	Average of cover crop
C_0		2.16	2.24	1.63	2.01
C_1		2.86	2.92	2.23	2.67
LSD			0.150		0.178
Tillage * Irrigation					
Tillage		I_1	I_2	I_3	Average of tillage
T_0		3.31	3.31	2.46	3.02
T_1		3.36	3.38	2.51	3.08
T_2		1.98	2.05	1.63	1.89
T_3		1.45	1.53	1.11	1.36
LSD			0.053		0.02
Average of irrigation		2.52	2.56	1.93	
LSD			0.031		

minimum value of the water conductivity was in the T_3I_3 (1.12 cm min^{-1}), while the largest was in the T_1I_2 (3.38 cm min^{-1}) with an increase of 202.69%. The effect of cover crop on the soil saturated soil hydraulic conductivity was significant, and lowest value of the average water conductivity was 2.01 cm min^{-1} when treatment C_0 compared to treatment C_1, which gave the largest the average water conductivity of 2.67 cm min^{-1} with an increase of 32.68%. The reason for this is that the cover crop provided suitable environment and conditions that improve the physical properties of the soil. When the bulk density is low, the total porosity is high and the construction is good, This is logical that the saturated soil hydraulic conductivity are high. The values of saturated soil hydraulic conductivity were significantly affected by different plowing treatments, and treatment T_1 gave the largest of 3.08 cm min^{-1}, while the lowest was in T_3 (.37 cm min^{-1}). The minimal tillage treatment maintained a good soil structure and provided protection against the destruction of soil agglomerations, as evidenced by an increase in the weighted diameter of this treatment. Irrigation treatments affected the average saturated soil hydraulic conductivity significantly, as the I_2 irrigation treatment gave the highest mean of saturated soil hydraulic conductivity of 2.57 cm min^{-1}, and I_3 irrigation lowest of 1.93 cm min^{-1}, with a decrease of 33.83%. The reason for the low water conductivity of the soil for treatment I_3 is due to the lack of stability of the soil structure and the destruction of its aggregates as a result of immersion of the soil with irrigation water. The soil body then precipitates and closes some of its pores, thus changing the water conductivity value of the soil.

CONCLUSION

The irrigation management with the presence of cover crop with minimum tillage and subsurface drip irrigation ($C_1T_1I_2$) improved the physical properties of the soil as it preserved the soil structure from breakdown and deterioration in terms of the increase in the mean weight diameter of the soil aggregates. This improved the soil's ability to hold water and nutrients as a result of increase in the total porosity, as well as increasing the ability of the soil to conduct water. On the other hand, the soil became brittle and porous, so the values of its resistance to penetration decreased, and this would stimulate the growth and spread of plant roots. These results encourage the investment of a subsurface drip irrigation system to manage field irrigation for many years with the presence of the remnants of the previous crop and minimum tillage to create a good germination site for seeds and an appropriate growth environment for the plant while maintaining the construction, health and quality of the soil through the role of the cover crop in improving the physical, chemical and biological properties of the soil as well as for reducing the costs of preparing the land , plowing and fertilizers. Long-term investment requires periodic maintenance of the irrigation system to ensure its continued operation and high efficiency and to protect it from damage.

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