MANAGEMENT OF USING SALINE IRRIGATION WATER AND TILLAGE SYSTEMS ON THE SOIL MECHANICAL AND HYDRAULIC

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ABSTRACT

A field experiment was carried out within the Shanafiyah - Nasiriyah project / Iraq during the autumn season 2022-2023 to evaluate the performance of the different tillage systems in some soil physical and hydraulic properties when irrigated with salt water and 25% Leaching factor throughout the growing season. In addition to evaluating its performance in mechanical technical properties before sowing. The experiment included three systems: A. minimum tillage with a disc harrow b. Tillage with Chisel Plow and Spring Tooth Harrows c. Tillage with Mold Plow and Spring Tooth Harrows. The study results showed that the Mini Tillage with (Disk Harrow) treatment was superior in giving the best values for the mechanical and technical properties and the soil's physical and hydraulic properties compared to other systems.

Keywords: minimum tillage, hydraulic conductivity, water infiltration, slippage percentage, and fuel consumption

إدارة أستخدام مياه الري المالحة ونظم الحراثة في الصفات المكنية والهيدروليكية للتربة

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المستخلص

نفذت تجربة حقلية ضمن مشروع شنافية – ناصرية / العراق خلال الموسم الخريفي 2022–2023، لتقييم إداء نظم الحراثة المختلفة في بعض الصفات الفيزيائية والهيدروليكية للتربة عند الري بمياه مالحة + 25% معامل غسل طيلة موسم النمو، فضلا عن تقييم اداءها في الصفات الفنية المكنية قبل الزراعة. وتضمنت التجربة ثلاث نظم هي أ. الحراثة الدنيا بألة التنعيم القرصية ب. الحراثة بألة عازقة نابضية القوائم والمحراث الحفار ج. الحراثة بآلة عازقة نابضية القوائم والمحراث المطرحي. وتوصلت نتائج الدراسة الى تفوق معاملة الحراثة الدنيا بألة التنعيم القرصية في اعطاء افضل قيم للصفات المكنية والفنية وصفات التربة الفيزيائية والهيدروليكية مقارنة بالنظم الاخرى.

الكلمات المفتاحية: الحراثة الدنيا، الايصالية المائية، غيض الماء، النسبة المئوية للانزلاق واستهلاك الوقود

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INTRODUCTION

Tillage is an essential process in agriculture because it helps to turn the soil layer, break it up, and prepare the soil surface to be a good bed for seeds, in addition to removing weeds and burying plant remains and organic fertilizers. Soil preparation equipment is making the physical soil conditions suitable for plant growth. Using equipment correctly helps maintain the qualitative characteristics of the soil. However, if this equipment is misused, it leads to the deterioration of many of the soil's physical characteristics, such as the structure and compaction of the soil, the closing of pores, the exposure of the surface to erosion, and the reduction of the soil's organic matter content, making it unsuitable for plant growth (6, 7, 24). The method of applying minimum tillage with a disc harrow reduced initial production costs, improved soil conditions, and reduced the types of broad-leaf weeds, and it can be considered an alternative and advanced tillage system to conventional tillage systems. Reduce tillage has been described as a sustainable agricultural practice that enhances land productivity and there is a growing interest in its application in developing countries (1, 18, 26, 27, 29). Choosing the appropriate type of plow is of great importance in determining the quality of plowing and improving soil properties thus increasing productivity. However, a mistake in choosing the appropriate machine and operating it in less-than-ideal conditions leads to negative results (16). Therefore, the current study aimed to:

1. Evaluating the performance of minimum and conventional tillage in some mechanical technical indicators.
2. The effect of minimum and conventional tillage on some physical properties of the soil when irrigated with salt water.

MATERIALS AND METHODS

A field experiment was carried out within the Shinafiya-Nasiriyah project during the fall season of 2022-2023. The study area is characterized by a flat to almost flat topography with a slope of less than 2%. The field's soil was classified as sedimentary with a sandy loam texture. Soil samples were taken from the field from a depth of 0-0.30 m to represent the physical and chemical properties of the field soil. The soil samples were air-dried in the laboratory, then ground and sieved with a sieve of 2 mm diameter. Table (1) shows some physical and chemical properties of field soil before planting according to (11). Water samples were also taken during different periods to determine the chemical properties of this water (Table 2) (25).

Experimental treatments and statistical design

Tillage systems:

a- Minimum tillage with Disk Harrow

b- Tillage with Chisel Plow+ Spring Tooth Harrows

c- Tillage with Mold Plow+ Spring Tooth Harrows

The experiment used a randomized complete block design (RCBD), with four replicates. The experiment data was analyzed statistically using the Genstat Discovery Edition 4 (2012) (28).

Table 1. Some physical and chemical properties of field soil before planting

Characteristic	Unit	Value
Sand		532
Silt	g kg^{-1}soil	380
Clay		88
Texture		Sandy loam
Bulk density	μg m^{-3}	1.46
Volumetric moisture content at 33 kPa		0.211
Volumetric moisture content at 1500 kPa	cm^3 cm^{-3}	0.154
Electrical conductivity $EC_{1:1}$	dS m^{-1}	3.20
pH		7.63
Organic matter	g kg^{-1}soil	9.14
Carbonate minerals		321
Available Nitrogen		29.00
Available Phosphorus	mg kg^{-1}soil	13.98
Available Potassium		220

Table 2. Chemical properties of irrigation water

Property	Unit	Before planting	December	March	April
EC	$dS\ m^{-1}$	5.75	4.01	4.11	4.66
pH	---	7.80	7.67	7.71	7.60
TDS	ppm	4365	2925	1940	3485

Agricultural Operations: Tillage was carried out using the minimum plowing method using a harrowing machine (Disc Harrows), the specifications of which are shown in Table (3) and Figure (1) as for conventional tillage: 1. tillage with (Chisel Plow and Spring Tooth Harrows) 2. tillage with (Mold Plow and Spring Tooth Harrows), whose specifications are shown in Tables 4, 5, and 6 and Figures 1. The practical speed of the tractor for all machines applied in the study is equal to 3.69 km/hour at a depth of 0.20 m. The tractor used in the study was Massey Ferguson. Wheat grains, variety Ibaa 99 were planted in the field on 20/11/2022, with a 160 kg/ha rate seeding. The process of controlling the weeds was carried out by spraying a Pallas herbicide, in addition to manual weeding whenever necessary. The plants were harvested on May 1, 2023. The experimental land was fertilized with triple superphosphate 200 kg/ha + potassium sulfate fertilizers at a rate of 240 kg/ha + 200 kg/ha urea. A diesel-powered pump was installed that draws water directly from the aqueduct using a spiral rubber tube with an inner diameter of 0.07 m. The pump pushes water through a linen tube with a diameter of 0.07 m and a length of 100 m. The process of evaluating the soil moisture content took place continuously throughout the experiment, and when the soil moisture content indicates that depleting 50% of available water. Then irrigation is performed by adding the depth of water necessary to reach the moisture content at the field capacity of the field soil using the moisture tension curve of the soil and for a period calculated based on drainage and the amount of water that the plant needs per irrigation (m^3/hour), this is in all field irrigation treatments with the addition of a 25% leaching requirement as in (Equation 2) according to the surface irrigation method used in the experiment. The equation mentioned in (8) was used to calculate the depth of water that must be added.

$$d = \left(\theta_{fc} - \theta_w\right) \times D \qquad (1)$$

Since:

d= depth of water added (mm)

θ_{fc} = Volumetric moisture at field capacity ($cm^3\ cm^{-3}$)

θ_w = Volumetric moisture before irrigation ($cm^3\ cm^{-3}$)

D = soil depth, which is equal to the depth of the effective root (m)

Leaching requirements were calculated according to the equations contained in the Irrigation Water Quality Guide issued by the Food and Agriculture Organization of the United Nations (1986).

$$LR = \frac{EC_{iw}}{(5(EC_e) - EC_{iw})} \qquad (2)$$

Since:

LR= Minimum Leaching requirements for salinity control expressed as a decimal

ECiw= added irrigation water salinity dSm^{-1}

ECe = soil salinity dSm^{-1}

Table 3. Disc harrow machine specifications

Origin	Number of discs	Diameter of discs	Distance between discs	Type of combs	Weight of discs	Length	Working width	Number of batteries
Iraq	14 discs	48 cm	18 cm	Double	170 kg	110 cm	105 cm	2

Table 4. Some characteristics of the chisel plows

Origin	Type	Tine numbers	Working width	Height	Weight
Iraq	Mounted	11 tine	216 cm	122 cm	305 kg

Table 5. Some characteristics of the mold-board plows

Origin	Type	Tine numbers	Working width	Height	Weight
Iraq	Mounted	3	105 cm	220 cm	293 kg

Table 6. Some characteristics of the Spring Tooth Harrows

Origin	Type	Tine numbers	Working width	Height	Weight
Iraq	Mounted	11	270 cm	105 cm	295 kg

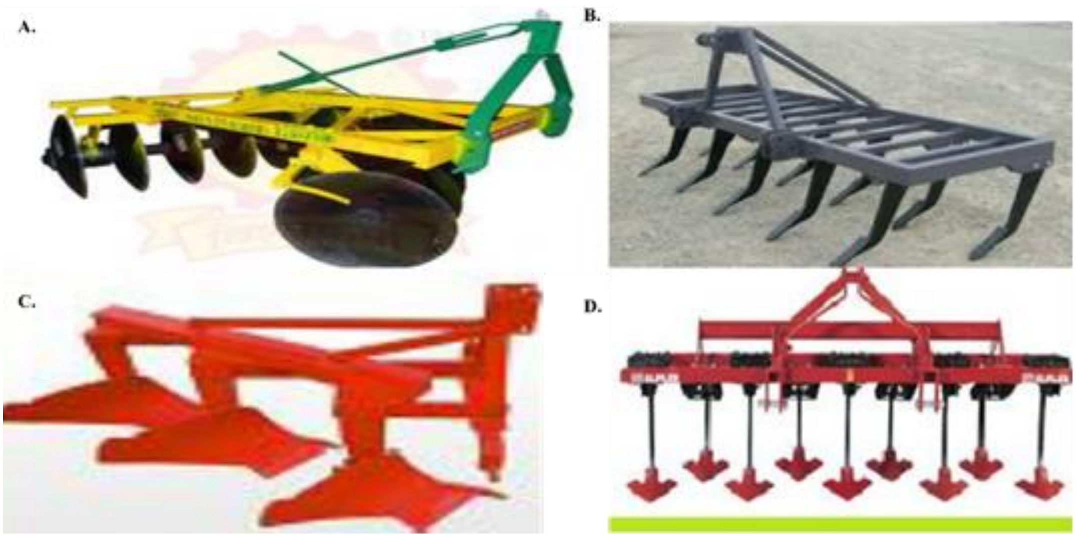

Figure 1. Tillage machines: Disc harrow (A), chisel plow (B), mold-board plows (C), spring spike harrows (D).

Mechanical Technical Properties

The slippage percentage was measured according to the method of (30) (Equation 3).

$$S_p = \frac{V_T - V_P}{V_T} * 100 \qquad (3)$$

Since:-

SP: slippage percentage (%)

Vt: theoretical speed (km/hour)

Vp: practical speed (km/hour)

Field efficiency according to the method of (19) (Equation 4)

$$Fe = \left(\frac{EFC}{TFC}\right) \times 100 \qquad (4)$$

EFC: Practical productivity of composite machinery (ha.hour^{-1})

TFC: Theoretical productivity of composite machinery (ha.hour^{-1}).

Fuel consumption was measured according to (5) (Equation 5)

$$Q_F = \frac{Q_d \times 10000}{W_p \times D \times 1000} \qquad (5)$$

Field tests: The bulk soil density and hydraulic conductivity were measured from the area where the effective roots of the plant spread and according to the following wheat growth stages:

1- End of the tillering stage

2. The period between the elongation and flowering stages

3.End of maturity

The soil bulk density was estimated according to (20). The saturated hydraulic conductivity was measured according to (21). However, the accumulative infiltration measurements were made before plowing and at the end of the growing season using a measurement of a Double Ring Infiltrometer according to (12).

RESULTS AND DISCUSSION

In light of the statistical analysis results obtained in Table 7, it was observed that there is an effect of tillage systems on the slippage percentage. The results observed a significant increase in the slippage percentage from 6.76 to 7.16 and then to 9.01%. The reason is that the disc harrows during the harrowing process do not go deep into the soil compared to Mold Plow and Spring Tooth Harrows, which go deeper into the soil, which leads to an increase in the load imposed on the mold-board plow, as a result of increasing the soil facing the plow tine, this increases the towing resistance of the machine and thus increases the slippage percentage (10). The results in Table 8 showed a significant effect of tillage systems on field efficiency. The lowest value of field efficiency was 67.300% at the treatment of mini tillage, then field efficiency increased at the treatment of Chisel Plow and Spring Tooth Harrows, reaching 77%, then it decreased to 75.96% at the treatment of Mold Plow and Spring Tooth Harrows. The reason for this is due to the lack of practical productivity and field efficiency for disc harrows, which leads to a decrease in field efficiency (4). Table (9) shows the effect of tillage systems on the fuel the tractor consumes. In light of the results, it was shown that there was a significant increase in fuel consumption amounting to 18.78, 22.50, and 25.64 L.ha^{-1} in the treatment of Mini Tillage (Disk Harrow), Chisel Plow and Spring Tooth Harrows, and Mold Plow and Spring Tooth Harrows, respectively. The reason for this is that the increased load on the plow as a result of its deepening in the soil leads to greater resistance and tension and an increase in fuel consumed by the tractor because the Mold Plow and Spring Tooth Harrows work deeper than when using mini tillage (Disk Harrow) (2).

Table 7. Effect of tillage systems on the slippage percentage (%)

Tillage systems	Slippage percentage
Mini Tillage (Disk Harrow)	6.76%
Chisel Plow+ Spring Tooth Harrows	7.16%
Mold Plow+ Spring Tooth Harrows	9.01%
L.S.D	0.54

Table 8. Effect of tillage systems on field efficiency (%)

Tillage systems	Field efficiency
Mini Tillage (Disk Harrow)	67.300
Chisel Plow+ Spring Tooth Harrows	77.00
Mold Plow+ Spring Tooth Harrows	75.96
L.S.D	1.12

Table 9. Effect of tillage systems on the amount of fuel consumption (L ha^{-1})

Tillage systems	Amount of fuel consumption
Mini Tillage (Disk Harrow)	18.78
Chisel Plow+ Spring Tooth Harrows	22.50
Mold Plow+ Spring Tooth Harrows	25.64
L.S.D	1.67

Figure 2 shows the effect of tillage treatments on soil bulk density at the beginning, middle, and end of the growing season under the surface irrigation system. The results at the beginning of the growing season show a decrease in average soil bulk density values of 1.37, 1.34, and 1.31 µg m^{-3}, with a decrease of 6.16, 8.21, and 10.27% for the treatments Mini Tillage (Disk Harrow), Chisel Plow and Spring Tooth Harrows, and Mold Plow and Spring Tooth Harrows respectively compared to their values before sowing. It was also noted that the treatment (Mold Plow and Spring Tooth Harrows) gave the lowest average soil bulk density, amounting to 1.31 µg m^{-3}, with a decrease of 4.37 and 2.23% compared to the mini tillage treatment and plowing with a (Chisel Plow and Spring Tooth Harrows), respectively. Figure 2 also shows the effect of tillage treatments on soil bulk density at the middle of the growing season. There were significant differences between the average bulk density values under the effect of different tillage treatments, as the mini-tillage gave the highest decrease in the bulk density values, amounting to 1.38 µg m^{-3}, with a decrease of 4.17%, compared to the lowest decrease of 1.44 Mg.m^{-3} at the treatment of Mold Plow and Spring Tooth Harrows. It also significantly exceeded by a decrease of 0.72% compared to the treatments of Chisel Plow and Spring Tooth Harrows, which amounted to 1.39 µg m^{-3}. Figure 2 also shows the average soil bulk density for the experimental treatments at the end of the growing season. The statistical analysis results showed that there were significant differences in the average bulk density as a result of the effect of the difference in the tillage type, as it gave average soil bulk density of 1.41, 1.43, and 1.50 µg m^{-3} in the Mini Tillage (Disk Harrow), Chisel Plow and Spring Tooth Harrows, and Mold treatment. Plow+ Spring Tooth Harrows respectively.

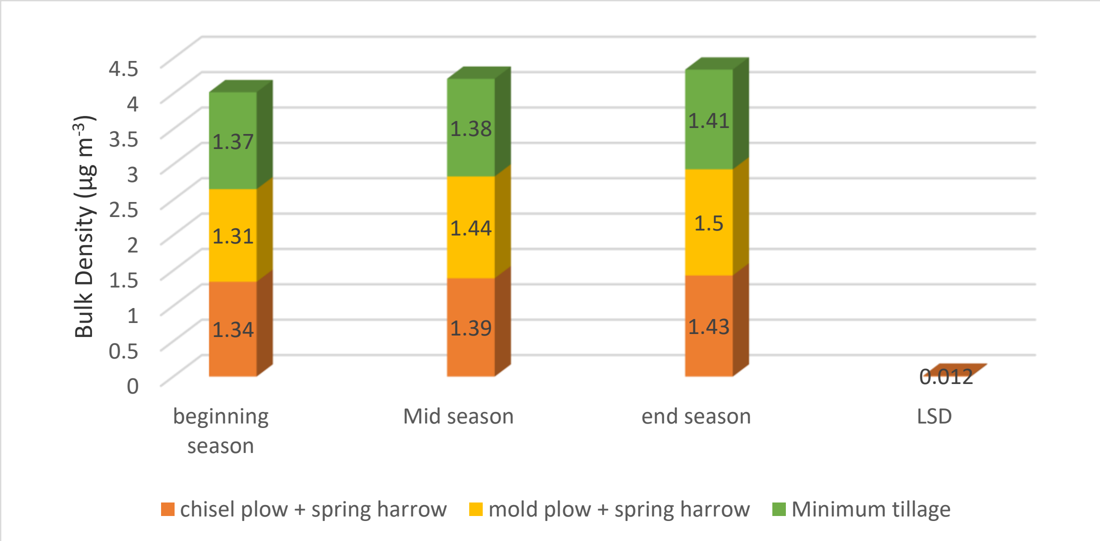

Figure 2. Effect of tillage systems on soil bulk density

Figure 3 shows the effect of the type of tillage treatments on saturated hydraulic conductivity at the beginning, middle, and end of the growing season. It was noted from the results that the saturated hydraulic conductivity values increased at the beginning of the growing season to reach 6.47, 7.40, and 7.21 cm h^{-1} in the Mini Tillage (Disk Harrow), Chisel Plow and Spring Tooth Harrows, and Mold Plow and Spring Tooth Harrows treatments, respectively, compared to their value before sowing 3.66 cm h^{-1}. While the Mini Tillage (Disk Harrow) treatment maintained the highest value of saturated hydraulic conductivity at the end of the season, reaching 5.18 cm h^{-1}. It was also noted that managing irrigation with saline water throughout the growing season, by applying a 25% leaching factor, has led to the absence of significant salt accumulation in the effective root zone and its removal to depths greater than the effective root zone. This has contributed to maintaining the values of soil bulk density and good and acceptable hydraulic conductivity and did not reach the signifient negative impact associated with using salty water in irrigation throughout the growing season, which lasted approximately 160 days. Using an appropriate management method for using saline irrigation water, with an appropriate leaching factor in a winter season accompanied by good rain depths that reached 240 mm in that season, contributed to the success of the correct management strategy.

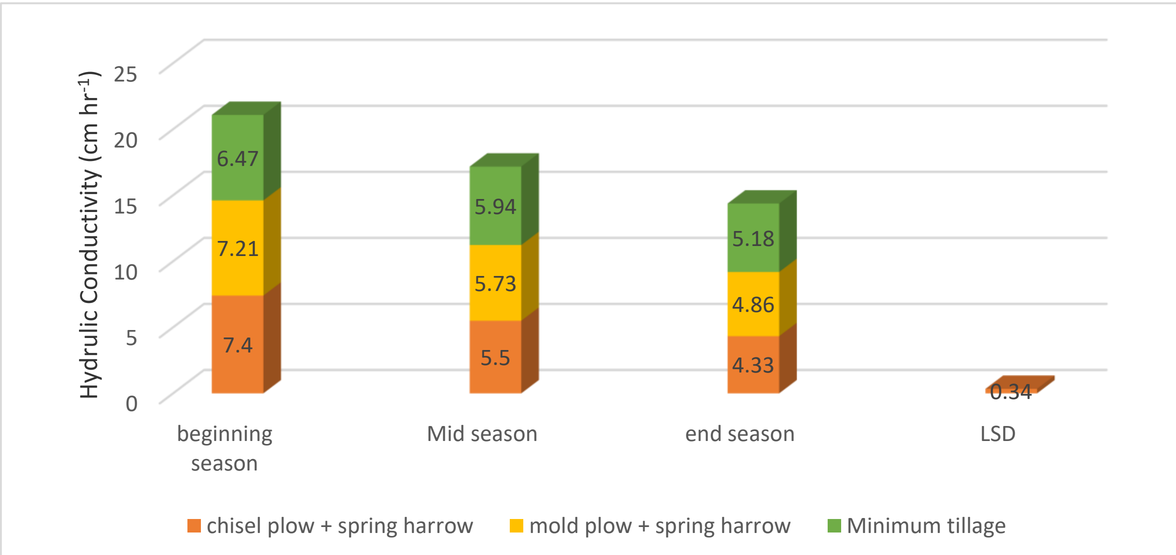

Figure 3. Effect of tillage systems on saturated hydraulic conductivity

The results of Figures 2 and 3 showed that at the beginning of the season, the Mold Plow and Spring Tooth Harrows treatment was superior compared to other tillage treatments in the average hydraulic conductivity of the soil, as it worked to disintegrate the soil which caused a decrease in the soil bulk density and saturated hydraulic conductivity increased at the beginning of the season compared to the Mini Tillage (Disk Harrow) and Chisel Plow and Spring Tooth Harrows treatments. However, this effect was temporary due to the soil disintegration, the destruction of its aggregates, and the movement of fine soil particles during irrigation, their sedimentation in the soil pores, and the closing of some of them. The Mold Plow and Spring Tooth treatment affected the soil's bulk density and reduced its saturated hydraulic conductivity in the middle and end of the season compared to its beginning. Whereas the Mini Tillage (Disk Harrow) treatment maintained the structure of the soil, the stability of its aggregates, and maintained a good pore distribution, so it worked to reduce the effect on the soil's bulk density and saturated hydraulic conductivity (9, 23). The results of the two figures show that the soil bulk density values increased and the saturated hydraulic conductivity decreased at the end of the season compared to its values at the middle and beginning of the season. The reason for this is attributed to the effect of the root mass on the aggregation of soil particles and aggregates the growth of roots in the interstitial pores, and the increase in the proportion of fine particles that led to fill the large spaces between soil particles and then close the waterways, which led to an increase in mass per unit volume and an increase in the soil bulk density. Figures 4, 5, and 6 show the cumulative water infiltration curves in the soil for the different tillage system treatments at the end of the experiment. The figures showed the relationship between the cumulative water infiltration depth I (cm) and time t (min). The points in the figures represent the values of the depth of the infiltration water (measured values), while the graphic line represents the curve of the best match for the values of the cumulative depth of the infiltration water (calculated values). It is evident from the graphs that the infiltration speed was fast at the beginning of the test for all experimental treatments. This is due to the large difference in the water potential at the top wet soil surface and the bottom of the surface. Because of this difference, the force of the water's movement will be downward, and this force will be added to the force of the earth's attraction, therefore, the water will move downward due to these two forces, so that the movement of the water is rapid. With time, the lower part of the soil becomes wet, and then the capillary water potential decreases continuously, which reduces the water infiltration as time continues. At the same time, the soil moisture content increases. It was observed that the minimum tillage treatment continued to excel in cumulative infiltration values until the end of the experiment. The reason for this is attributed to it providing good physical properties compared to other treatments due to its preservation of soil aggregates by slightly agitating the surface layer and not demolishing or dismantling it while keeping the residues of the previous crop and turning it into the organic matter led to the plant growth and its roots penetrated well, and as the growing season progressed, it worked to bind the soil particles, in addition to the microbial activity and the materials it secretes that work to improve the soil structure as a result of increasing its activities. The Mold Plow + Spring Tooth treatment led to the demolition and disintegration of the soil structure and the deposition of separated particles in the interstitial pores within the soil body, thus increasing the bulk density of the soil and decreasing its hydraulic conductivity (3, 13, 14, 15, 17, 22).

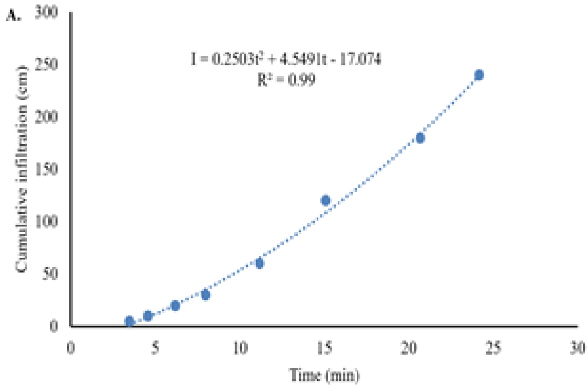

Figure 4. The cumulative water infiltration and time for the Mini Tillage (Disk Harrow) treatment

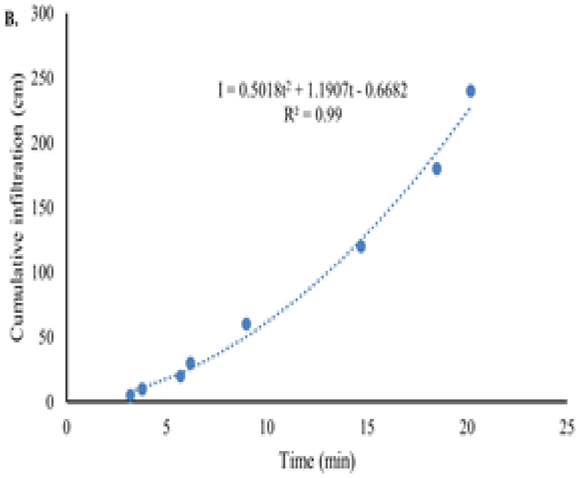

Figure 5. The cumulative water infiltration and time for the Chisel Plow and Spring Tooth Harrows treatment

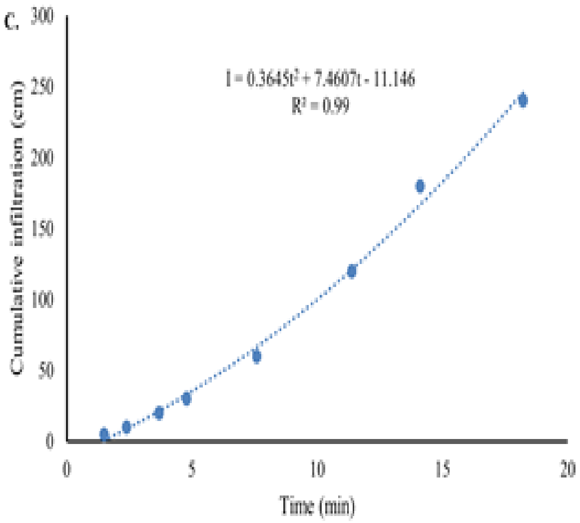

Figure 6. The cumulative water infiltration and time for the mold Plow and Spring Tooth Harrows treatment.

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