



## The Role of Moisture Depletion of The Two Tillage Depths and The Type of Emitters on Some Physical Properties of The Soil and Water Productivity of The Yellow Maize Crop

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### ABSTRACT

A field experiment was conducted to determine the role of moisture depletion percentages, two tillage depths, and two types of emitters and their interactions on some soil physical properties and water productivity of yellow maize crop during the fall season of 2024 at the Agricultural Research and Experiment Station - University of Kirkuk. The experiment included three main factors: moisture depletion percentage 45% and moisture depletion 65%, the second factor was two tillage depths (20 and 30) cm, and the third factor was two types of emitters (GR and T-Tape). A split-split plot design with a randomized complete block arrangement (RCBD) was used. The results of the experiment showed that the 45% moisture depletion led to an improvement in the physical properties and showed significant differences in both the total porosity and the weighted average diameter, as the total porosity values reached 48.74% for the 45% moisture depletion, while they reached 38.99% for the 65% moisture depletion. The weighted average diameter values were 1.63 mm for the 45% moisture depletion and 0.85 mm for the 65% moisture depletion. Significant differences were found when using 30cm tillage depth in growth characteristics, crop yield and water productivity. It was found that depth 30 gave the highest values for (leaf area, biological yield and crop water use efficiency) which reached (5088.57cm<sup>2</sup>, 28.863Mg ha<sup>-1</sup> and 3.16kg m<sup>-3</sup>) respectively, compared to depth 20cm which reached (5930.62cm<sup>2</sup>, 24.530Mg ha<sup>-1</sup> and 2.65kg m<sup>-3</sup>) respectively. It was also found from the evaluation of the drip irrigation system before and after planting that the values of hydraulic characteristics which include two characteristics, namely the difference in discharge qvar% and the absolute field emission uniformity FEUa% were significantly better before planting compared to the values after planting.

**Keywords:** moisture depletion, crop water use efficiency, biological yield, tillage depths, emitters GR and T-Ta.

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### INTRODUCTION

Moisture depletion is an essential factor, as it directly affects the Crop yield and quality by providing adequate water and indirectly by improving the physical properties of the soil. This is evident in the growth and productivity of maize. Lower moisture depletion helps provide the soil and plant with adequate moisture before the plant reaches water stress due to a lack of necessary moisture. A study showed that soil physical properties, such as porosity, increased at lower moisture depletion rates, reaching 51.71% compared to higher moisture depletion percentage, reaching 49.24%. Increased porosity means more spaces between soil particles, which improves soil aepercentage and water permeability and promotes root growth, thus increasing leaf area and biological yield of maize. This is consistent with [1, 2].

When measuring the weighted diameter percentage (WDR) at two depletion rates (50 and 75%), the WDR values increased significantly. This is noticeable at lower moisture depletion (50%) compared to higher moisture depletion (75%), leading to increased aggregate stability and improved soil structure, thus enhancing plant growth and productivity. This is consistent with [3, 4].

Phenological observations of maize plant growth and grain quality were studied, statistical analysis results showed

that tilling the soil to a depth of 30 cm resulted in the highest maize yield, reaching 91.6 megagrams ha<sup>-1</sup>, while tilling to a depth of 15 cm produced the lowest yield, reaching 80.6 megagrams ha<sup>-1</sup>. The study confirmed that tillage method affects grain quality indicators, particularly the content of crude fiber, starch, protein, and crude fat. When tilling to a depth of 30 cm, the starch content of the grain was 70.9%, and the crude fiber was 2.12%. Protein: 10.2%, and crude fat: 4.225% [5].

Emitter types (such as GR and T-Tape) and their hydraulic properties play an important role in determining soil physical properties and water productivity efficiency of maize crops when using drip irrigation. Choosing the appropriate emitter type directly affects moisture distribution, bulk density, total porosity, soil structural stability, and water use efficiency. This is consistent with [6]. In a study on emitter types, the GR emitter outperformed the Turbo emitter in terms of manufacturing coefficient of variation (Cv%), water application efficiency (Eu%), field emission uniformity (F.EU%), and absolute field emission uniformity (F.EUa%), at water stress levels of 100% and 75%. This increases water use efficiency and thus enhances plant height and overall yield [7].

Yellow Maize is an important crop in providing many nutrients, essential minerals, proteins, carbohydrates, and fats. It is also used in many industries. Maize is also used as an animal feed crop, such as raw feed rich in nutrients and vitamins [8, 9]. Based on the above, this study aims to investigate the effect of moisture depletion rate and plowing depth on some soil physical properties, growth, and water productivity of yellow maize using two types of emitters.

### Materials And Methods

A field experiment was conducted to determine the role of moisture depletion rates, two tillage depths, and two types of emitters and their impact on the productivity of yellow maize during the fall season of 2024 at the Agricultural Research and Experiment Station, University of Kirkuk. The experiment was implemented according to a split-plot design with a randomized complete block arrangement (RCBD) and three replicates, as shown in Figure (1). The experiment included the following factors as studied treatments, as shown in Table (1):

**1- The first factor: Moisture depletion percentage (M), which includes two percentages:**

- a) Depletion of 45% of the available water (M1)
- b) Depletion of 65% of the available water (M2)

**2- The second factor: Plowing depth (D), which includes two depths:**

- a) Plowing to a depth of 20 cm (D1)
- b) Plowing to a depth of 30 cm (D2)

**3- The third factor: Drip irrigation emitter type (T), which includes two types:**

- c) T-type drip irrigation emitter (T1)
- d) GR-type drip irrigation emitter (T2)

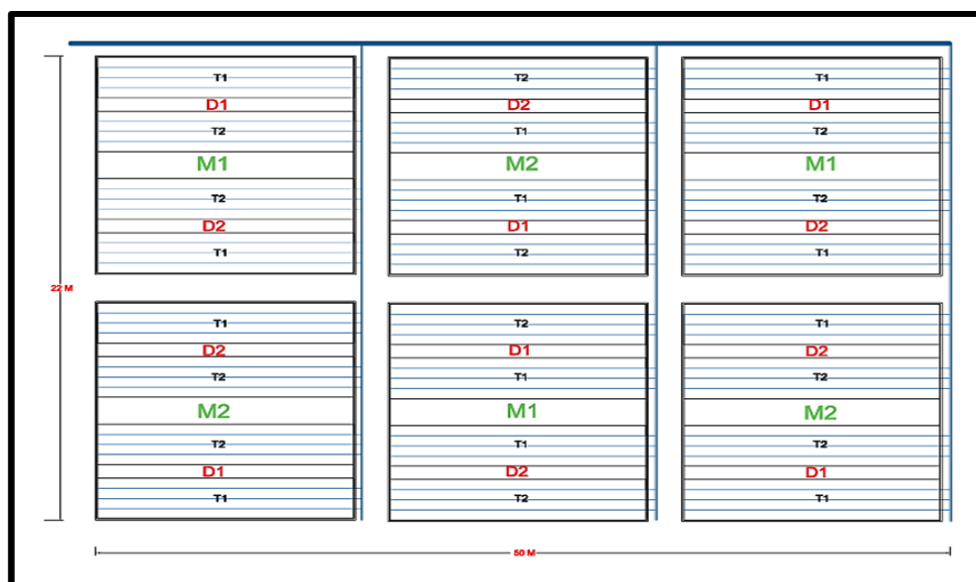


Figure (1) shows a diagram of the distribution of experimental parameters across three replicates.

\*M: Moisture depletion

\*D: Plowing depth

\*T: Emitter type

Table (1) Experimental transaction codes and details

Treatment	The symbol	the details
T1	M1D1T1	moisture depletion to a plowing depth of %45 Irrigation at cm with a 20T -tape emitter.
T2	M1D1T2	moisture depletion to a plowing depth of %45 Irrigation at cm with a 20GR emitter.
T3	M1D2T1	30cm tillage moisture depletion to a %45 Irrigation at depth with aT -tape emitter.
T4	M1D2T2	moisture depletion to a ploughing depth %45 Irrigation at cm with a 30 ofGR emitter.
T5	M2D1T1	moisture depletion to a plowing depth of %65 Irrigation at cm with a 20T -tape emitter.
T6	M2D1T2	20cm tillage moisture depletion to a %65 Irrigation at depth with aGR emitter.
T7	M2D2T1	30cm tillage moisture depletion to a %65 Irrigation at depth with aT -tape emitter.
T8	M2D2T2	30cm tillage moisture depletion to a %65 Irrigation at depth with aGR emitter.

A soil auger was used to randomly collect soil samples in the experimental field at a depth ranging between 0 and 0.3 meters. The samples were then mixed together and air-dried, then passed through a sieve with 2 mm diameter holes, and the necessary analyses and measurements were carried out. Table (2) shows some of the physical and chemical properties of the study soil before planting.

Table 2. Some physical and chemical properties of the study soil before planting at a depth of 0-0.30 m.

The adjective	value	Unity
EC	1.02	ds m <sup>-1</sup>
PH	7.71	
Organic matter	4.7	
CaCO <sub>3</sub>	13.5	g kg <sup>-1</sup>
CaSo4	0	
Sand	371	
Silt	240	g kg <sup>-1</sup>
Clay	389	
Soil Texture	<i>clay loam</i>	
Bulk density	1.7	
Particle density	2.65	Mg.m <sup>-3</sup>
Porosity	35.84	%
Saturated water conductivity	0.17	cm.hr <sup>-1</sup>
Mean weighted diameter	0.80	mm

For any experiment that uses a drip irrigation system, it is crucial to assess the system's performance prior to starting cultivation in order to guarantee its effectiveness. An essential part of evaluating the system is figuring out the average discharge rates under various operating pressures. It is especially important to measure the emitters' actual discharge because this information is used to calculate how long irrigation should run for best results. Before cultivation began, a thorough assessment of the drip irrigation system was conducted in order to determine the ideal operating pressure to use during the growing season. Numerous hydraulic parameters of the two drip irrigation systems were measured and examined throughout this procedure. [10].

**1. Measurement of some hydraulic properties:**

1.1 Variation of emitter flow (qvar)

A calculation was performed to measure the variability of emitter flow along the irrigation line using the author's equation [11].

$$qvar(\%) = \left( \frac{q_{max.} - q_{min}}{q_{max.}} \right) \times 100 \dots \dots \dots (1)$$

Where:

- qvar = emitter discharge variance (%)
- qmax = maximum emitter discharge (liters per hour)
- qmin = minimum emitter discharge (liters per hour)

1.2 Absolute Field Emission Uniformity

The absolute field emission uniformity value was calculated based on the equation mentioned in [12].

$$F. EUa\% = \left( \frac{q_n}{q_m} \right) + \left( \frac{q_m}{q_x} \right) \times 50 \dots \dots \dots (2)$$

Where:

- F. EUa = absolute field emission uniformity (%)
- qx = average emitter discharge for the upper eighth of the emitters (liters per hour)
- qn = average emitter discharge for the lower quarter (liters per hour).

Yellow maize seeds (*Zea mays* L., American variety DKC6777) were planted on July 26, 2020. The planting was done in rows, each row 10 m long, with a distance of 0.2 m between plants and a distance of 0.75 m between rows. Two seeds were placed in each hole at a depth of 0.04-0.05 m. The thinning was done after one week, then thinned to one plant two weeks after germination to obtain 50 plants in each row, equivalent to 66.665 plants/ha-1. Crop maintenance, including weeding and manual weed removal, continued throughout the experiment. The plants were harvested on November 20, 2020 (growing season 120 days). Based on the initial moisture content, all study treatments received their first irrigation. After 50% of the water supply had been used, germination was complete, and three to four leaves appeared on each plant, the second and third irrigations were carried out. Treatments for moisture utilisation (45 and 65 percent) of the available water were used. Utilising the evapopercentage basin as a preliminary indicator to guide the collection of soil samples from the field and the actual estimation of the remaining soil moisture using the weight method, irrigation scheduling was implemented in accordance with the crop growth stages. Until half of the plant's water supply was depleted, the procedure was repeated. When irrigating, the soil's moisture content was then measured. The depth of water that should be added to the soil (d) was calculated by applying the mathematical equation mentioned by [13].

$$d = (\theta_{fc} - \theta_{pw}) D \dots \dots \dots (3)$$

- d = depth of water to be applied (cm), equivalent to actual water consumption (ETa).
- $\theta_{fc}$  = soil moisture at field capacity ( $cm^3/cm^3$ ).
- $\theta_{pw}$  = soil moisture before irrigation ( $cm^3/cm^3$ ).
- D = root zone depth (mm).

The total irrigation depth was calculated according to the following equation:

$$GDI = (d) / (E_a) \dots \dots \dots (4)$$

Where:

- GDI = Total Irrigation Depth (mm)
- E<sub>a</sub> = Drip Irrigation Efficiency

Irrigation time was calculated based on the equation mentioned in (Al-Hadith et al., 2010) [14] and the following:-

$$V = Q \times N \times T \dots \dots \dots (5)$$

Where:

- V: Volume of water to be added, in liters.
- T: Irrigation time, in hours.
- Q: Emitter discharge, in liters per hour.
- N: Number of emitters operating simultaneously for a total of 72 lines.

## 2 Measurement of Some Physical Properties

### 2.1 Mean Weight Diameter:

The soil was sifted through two 4- and 9-mm sieves after samples were collected from a depth of 0 to 0.3 m. 50 g of the leftover dirt from the 4-mm sieve was spread out on filter paper, put in a Petri dish, and physically moistened for six minutes. According to the procedure, the sieves were set up on a Yoder apparatus with opening diameters of 0.3, 0.6, 1, 2, and 4 mm [16]. The proposed equation [17] was used to calculate the mean weight diameter (M.W.D.).

$$M.W.D. = \sum_{i=1}^n \bar{X}_i \times W_i \dots \dots \dots (6)$$

Where:

MWD = Mean weighted diameter (mm)

$\bar{X}_i$  = Average volume range of separated soil aggregates (mm)

$W_i$  = Percentage of soil aggregate mass at any volume range to total dry soil mass (%)

### 2.2 Porosity:

The soil porosity was calculated based on its apparent and true densities, using the following equation:

$$f = 1 - \frac{P_b}{P_s} \times 100 \dots \dots \dots (7)$$

### 2.3 Measuring some growth and yield characteristics:

Growth characteristics were measured at the onset of male inflorescence emergence by randomly selecting five plants from the midribs of each experimental unit at the flowering stage. The following measurements were then taken

#### 2.4 Leaf area (cm<sup>2</sup>):

The leaf area of the leaf under the main ear was measured for all treatments at the end of the growing season, by randomly selecting five plants from each replicate according to the following equation ([18]:

$$LSA = 0.75 LW \dots \dots \dots (8)$$

Where:

LS = leaf area (cm<sup>2</sup>)

L = leaf length (cm)

W = maximum leaf width (cm)

#### 2.5 Biological yield (megagrams/ha<sup>-1</sup>):

After full maturity, five plants were randomly selected and then oven-dried for 72 hours at 75°C. Each plant and ear were then weighed, and the average was calculated for each experimental unit. Crop water use efficiency (WUEc). The crop water use efficiency was calculated according to the following equation [19].

$$WUE_c = \frac{Yield}{ET_a} \dots \dots \dots (9)$$

Where:

WUEc = crop water use efficiency (kg m<sup>-3</sup>).

ET<sub>a</sub> = seasonal actual evapotranspiration per unit area (m<sup>3</sup> ha<sup>-1</sup>).

Actual water consumption of maize was estimated using the following water balance equation [20]:

$$ET_a = I + P \pm \Delta S \dots \dots \dots (10)$$

Where:

ET<sub>a</sub> = Actual evapotranspiration (mm).

I = Depth of applied irrigation water (mm).

P = Depth of rainwater (mm).

C = 0 Capillary water height (mm). Based on groundwater monitoring, it was found to be deep.

ΔS = Change in soil moisture storage over a specified period of time (mm).

R = 0, assuming the ground is flat and there is no surface runoff.

**Results And Discussions**

**1. Hydraulic characteristics of the drip irrigation system:**

in the comparison between the GR and T-Tape emitters when evaluating the system before planting, in the characteristic of difference in discharge  $q_{var}$ , that there are significant differences before planting, and the values for the GR emitter were lower than the T-Tape emitter Table (3). In general, the values before planting were lower than the values after planting for both systems. The values for the two emitters (GR and T-Tape) were (0.0463, 0.0616)%, respectively. This was observed when evaluating the system after planting, as both systems were affected by environmental conditions and saline and organic sediments. The values for both emitters (GR and T-Tape) increased, reaching (0.1314 and 0.1333), respectively. This is consistent with [21]. Table (3) also shows the absolute field emission regularity characteristic when evaluating the two systems, comparing the GR and T-Tape emitters. There were significant differences in this characteristic before planting, in favor of the GR emitter. However, the values fell within the excellent range for the GR and T-Tape emitters, reaching (97.675 and 96.874), respectively, according to Table (4).

Table (3) also showed that there was no significant difference in the absolute field emission regularity characteristic after planting, but the values of the GR and T-Tape emitters decreased after planting to what they were before planting for both GR and T-Tape emitters, reaching (93.232, 93.121) respectively. However, the values fall within the excellent range for the emitters according to Table (4). The reason may be due to the environmental conditions and the salt and organic sediments to which the emitters were exposed throughout the planting period.

Comparison between two types )3( Table of GR emitter s T- Tape in some characteristics related to the drip irrigation system before and after planting

T	Measurable attributes	Before planting			After planting		T value The calculated
		Type of emitter		value he calculated	Type of emitter		
		GR	T-Tape		GR	T-Tape	
2	Difference in inflection (%) $q_{var}$	0.0463	0.0616	26.43 *	0.1314	0.1333	0.33
6	Absolute field emission uniformity (%) FEU <sub>a</sub>	97,675	96,874	13.88 *	93,232	93,121	1.93

\* indicates the presence of significant differences between the two means.

Tabled value of the t-test corresponding to a degree of freedom of 4 and a probability of 0.05 = 2.77

P Significant differences in the t-test analysis at a probability of 0.05

Table (4) Estimates of broadcast regularity values F.Eua & F.EU (Standard) according to the standard recommendations according to the American Society (1996), ASAE EP405.1 FEB03 for Agricultural Engineers

Appreciation	F.EU values	F.Eua values
excellent	%90 greater than	94-100%
very good	80-90%	81-87%
good	70-80%	68-75%
acceptable	%70 Less than	56-62%

**2. Some physical properties of the studied soil**

**2.1 Average weighted diameter (mm):**

The effect of the study parameters on the average weighted diameter values is shown in Table (5). The data show that moisture depletion has a significant impact on these values. The highest value of 1.63mm was recorded at 45% moisture depletion, while the lowest value of 0.85 mm obtained at 65% moisture depletion. This may be attributed to the fact that the 45% moisture depletion leads to a higher moisture content that helps reduce the forces of expansion and contraction within the soil, which maintains the cohesion of the aggregates and reduces their disintegration.

thus increasing the values of the weighted diameter rate. At the highest depletion, i.e. 65%, it leads to a decrease in soil moisture, which increases the forces of expansion and contraction within the soil, which increases the fragility of the aggregates and makes them more susceptible to disintegration due to external factors such as rain or irrigation, as indicated by both [22, 23].

As shown in Table (5), there was no significant effect of tillage depth on the weighted diameter values, with depths of 20 cm and 30 cm yielding weighted diameter values of 1.27 mm and 1.21 mm, respectively. Table (5) also shows significant differences in the emitter type in the weighted diameter values, with the GR drip irrigation emitter achieving the highest value of 1.54 mm, compared to the T-tape drip irrigation emitter, which had a lower weighted diameter value of 0.94 mm. The reason may be due to the coefficient of variation (CV), as Table (3) shows the presence of significant differences in the coefficient of variation of the manufacturing between the GR and T-tape emitters, as the T-tape emitter recorded a higher value for the coefficient of variation (CV), and this leads to a difference in the moisture content in the soil between the emitter locations or between the depths and their imbalance, which leads to a variation, difference, or disturbance in the stability of the aggregates, as moisture affects the cohesion of the particles and thus the average weighted diameter, and this is what was indicated by [24, 25].

Table (5) Effect of the moisture depletion percentage of the two plowing depths and the type of emitter on the weighted diameter rate (mm)

Moisture depletion % (M)	Plowing depth (D)	Type of emitters (T)		Exhaustion * Plowing depth
		T1	T2	
M1	D1	1.32 b	1.96 a	1.64 a
	D2	1.29 bc	1.95 a	1.62 a
M2	D1	0.61 d	1.21 bc	0.91 b
	D2	0.57 d	1.03 c	0.80 b
M * T		Average drip type (T)		Average moisture depletion (M)
		T1	T2	
Exhaustion rate	M1	1.30 b	1.95 a	1.63 a
	M2	0.59 c	1.12 b	0.85 b
Average driptype (T)		0.94 b	1.54 a	
Plowing Depth * Dripper Type		Type of emitter		Average tillage depth (D)
		T1	T2	
Plowing depth	D1	0.96 b	1.59 a	1.27 a
	D2	0.93 b	1.49 a	1.21 a

The results showed that there is a significant effect of the two-way interaction between moisture depletion and tillage depth on the weighted diameter values, as the highest value of the weighted diameter reached 1.64 mm for the two-way interaction between (45% depletion and 20 cm depth), while the lowest value of the weighted diameter reached 0.80 mm for the two-way interaction between (65% depletion and 30 cm depth). The results of the same table showed a significant effect of the two-way interaction between moisture depletion and emitter type on the weighted diameter values. The highest weighted diameter value was 1.95 mm for the two-way interaction between (45% depletion and a GR emitter), while the lowest weighted diameter value was 0.59 mm for the two-way interaction between (65% depletion and a T-tape emitter).

The results of the same table showed that the two-way interaction between plowing depth and emitter type had a significant effect on the weighted diameter values. The highest weighted diameter value was 1.59 mm for the two-way interaction between (20 cm depth and a GR emitter), while the lowest weighted diameter value was 0.93 mm for the two-way interaction between (30 cm depth and a T-tape emitter).

Also indicated significant differences in the three-way interaction between depletion and Moisture, tillage depth and emitter type affected the weighted diameter values. The highest weighted diameter value was 1.96 mm for the triple overlap treatment (45% depletion, 20 cm depth and GR emitter). While the lowest weighted diameter value was 0.57 mm for the triple overlap treatment (65% depletion, 30 cm depth and T-tape emitter).

**2.2 Total porosity (%):**

Table (6) illustrates the effect of the study parameters on the total porosity of the soil. It shows a significant effect of moisture depletion on the total porosity values, the highest value was recorded at 45% moisture depletion, reaching 48.74%. In contrast, the lowest total porosity value was 38.99% at 65% moisture depletion. This may be due to the fact that a low depletion level positively affects the maintenance of soil porosity and structure. When using low depletion levels, such as 45%, the soil bulk density remains low and the weighted diameter percentage values are higher, i.e. good stability, which helps maintain a high level of total porosity. This contributes to maintaining good soil structure and the continuity of pore distribution within it. In contrast, when the depletion level rises to 65%, the bulk density increases due to soil compaction and lower values of weighted diameter percentage are obtained, which leads to a decrease in the total porosity due to the loss of a portion of the air pores [26].

As shown in Table (6), there was non significant effect of plowing depth on total porosity values. Depths of 20 cm and 30 cm that achieved values of 45.25 and 42.48%, respectively.

Table (6) also shows significant differences in total porosity based on the type of emitter. The GR drip irrigation emitter achieved the highest value of 45.37%, compared to the T-tape irrigation emitter, where the total porosity value decreased to 42.35%. This may be due to the GR emitter's ability to produce a homogeneous wettability front due to its stable hydraulic properties over time, such as a lower coefficient of variation, higher water uniformity efficiency, and higher field emission uniformity, as shown in Table (3). This contributes to maintaining soil structure and stability in aggregates and a lower apparent density. This leads to higher soil porosity, as indicated by [27].

Table (6) Effect of the moisture depletion percentage for the two plowing depths and the type of emitter on the total porosity (%)

Moisture depletion percentage ( M )	Plowing depth ( D )	Type of emitter ( T )		Exhaustion * Plowing depth
		T1	T2	
M1	D1	49.18 ab	51.70 a	50.44 a
	D2	46.29 b	47.79 b	47.04 b
M2	D1	39.12 c	41.00 c	40.06 c
	D2	34.84 d	41.00 c	37.92 c
M *T		( Average drip typeT )		Average moisture depletion (M)
		T1	T2	
Exhaustion rate	M1	47.73 a	49.74 a	48.74 a
	M2	36.98 c	41.00 b	38.99 b
( Average drip typeT )		42.35 b	45.37 a	
Plowing Depth * Dripper Type		Type of emitter		( Average tillage depthD )
		T1	T2	
Plowing depth	D1	44.15 a	46.35 a	45.25 a
	D2	40.56 b	44.40 a	42.48 a

The results extracted from the same table showed a significant effect of the two-way interaction between moisture depletion and tillage depth on total porosity values. The highest value, 50.44%, was recorded in the two-way interaction treatment (45% depletion and 20 cm depth), while the lowest porosity value, 37.92%, was recorded in the two-way interaction treatment (65% depletion and 30 cm depth). The results of the same table showed a significant effect of the two-way interaction between moisture depletion and emitter type on total porosity values. The highest total porosity value was 49.74% for the dual interlocking treatment (45% depletion and GR-type emitter), while the lowest total porosity value was 36.98% for the dual interlocking treatment (65% depletion and T-tape emitter). The results in the same table also showed that there was a significant effect of the dual interlocking between tillage depth and emitter type. The highest porosity value was 46.35% for the dual interlocking treatment (20 cm depth and GR-type emitter), while the lowest porosity value was 40.56% for the dual interlocking treatment (30 cm depth and T-tape emitter). The results in the same table also indicate significant differences for the triple interlocking treatment between

moisture depletion, tillage depth, and emitter type. The highest total porosity value was 51.70% for the triple interlocking treatment (45% depletion and 20 cm depth). The emitter was of the GR type. While the lowest value of total porosity was 34.84% for the triple overlap treatment (65% depletion, 30 cm depth and T-tape emitter).

### 3. Some plant growth characteristics

#### 3.1 Leaf area (cm<sup>2</sup>/plant<sup>-1</sup>):

Table (7) shows the effect of the study treatments on the leaf area values of the yellow maize crop. It is noted that there is a significant effect of moisture depletion on leaf area values. The highest value was at 45% moisture depletion, which was 6310.25 cm<sup>2</sup> plant<sup>-1</sup>, while the lowest value was 4708.94 cm<sup>2</sup>/plant<sup>-1</sup> at 65% moisture depletion. The reason for the decrease in leaf area per plant when 65% of the available water is depleted may be attributed to the effect of the plant's biological activity, as the amount of water absorbed decreases, negatively impacting the ability of photosynthesis. Although complex physiological and chemical changes occur to adapt to harsh environmental conditions, such as long-term evolutionary adaptations such as changing leaf orientation, or short-term acclimatization mechanisms such as vasoconstriction, growth is affected, leading to a decrease in the leaf area values of the plant, as indicated by [28]. The reason for the increase in leaf area for the 45% moisture depletion treatments may be attributed to the fact that providing moisture in the root zone of the plant increased leaf elongation and expansion as a result of the increased turgor pressure on the cell walls, which resulted in increased leaf cell growth and elongation and increased leaf area of the crop, as indicated by [29].

As shown in Table (7), there is a significant effect of the tillage depth coefficients on the leaf area values, as the depth of 30 cm gave the highest value of leaf area, which amounted to 5930.62 cm<sup>2</sup> plant<sup>-1</sup>, compared to the depth of 20 cm, which gave a lower value of leaf area, which amounted to 5088.57 cm<sup>2</sup> plant<sup>-1</sup>. The reason may be attributed to the fact that tillage at a depth of 30 cm enhances the growth of roots in the deep layers, which increases the plant's ability to absorb water and nutrients, which leads to better plant growth and thus a larger leaf area, and leads to an increase in the total length and density of the roots compared to less deep tillage [30]. Table (7) shows significant differences in the leaf area values for the emitter type, as the GR drip irrigation emitter gave the highest value of 5717.14 cm<sup>2</sup> plant<sup>-1</sup> compared to the T-tape drip irrigation emitter, in which the leaf area value decreased, reaching 5302.05 cm<sup>2</sup> plant<sup>-1</sup>. The reason may be that the GR emitters are characterized by better water addition efficiency (EU), which helps in better distribution of water in the soil in general and around the root zone, which helps in providing adequate water to the plant and thus a larger leaf area for the plant. Also, improving water distribution around the roots contributes to the continuous availability of water to the plant, which supports root growth and leaf area, and this is consistent with [31].

Table (7) Effect of the moisture depletion rate of the two plowing depths and the type of emitter on the average leaf area (cm<sup>2</sup> plant<sup>-1</sup>)

Moisture depletion percentage ( M )	Plowing depth ( D )	Type of emitter ( T )		Exhaustion * Plowing depth
		T1	T2	
M1	D1	5734.48 d	6052.06 c	5893.27 b
	D2	6492.37 b	6962.08 a	6727.23 a
M2	D1	4058.70 h	4509.03 g	4283.87 d
	D2	4922.63 f	5345.39 e	5134.01 c
M * T		(Average drip type T)		Average moisture depletion ( M )
Exhaustion rate	M1	6113.43 b	6507.07 a	6310.25 a
	M2	4490.67 d	4927.21 c	4708.94 b
) Average drip type T (		5302.05 b	5717.14 a	
Plowing Depth * Dripper Type		Type of emitter		) Average tillage depth D (
Plowing depth	D1	4896.59 d	5280.55 c	5088.57 b
	D2	5707.50 b	6153.74 a	5930.62 a

The data from the table(7) demonstrated a notable impact of the interaction between moisture depletion and tillage depth on leaf area measurements. The largest leaf area recorded was 6727.23 cm<sup>2</sup> per plant under the combined conditions of 45% moisture depletion and a tillage depth of 30 cm. Conversely, the smallest leaf area measured was 4283.87 cm<sup>2</sup> per plant, observed under the conditions of 65% moisture depletion and a tillage depth of 20 cm. Furthermore, the table highlighted a significant effect of the interaction between moisture depletion and emitter type on leaf area values. The highest leaf area under these conditions was 6507.07 cm<sup>2</sup> per plant for the treatment involving 45% moisture depletion paired with a GR emitter, while the lowest was 4490.67 cm<sup>2</sup> per plant for the interaction between 65% moisture depletion and a T-tape emitter.

The results showed that the two-way interaction between tillage depth and emitter type had a significant effect, as the highest value of leaf area was recorded at 6153.74 cm<sup>2</sup> plant<sup>-1</sup> for the two-way interaction treatment (30 cm depth and GR emitter), while the lowest value of leaf area was recorded at 4896.59 cm<sup>2</sup> plant<sup>-1</sup> for the two-way interaction treatment (20 cm depth and T-tape emitter). and also indicates the presence of significant differences in the triple interaction between moisture depletion, tillage depth and emitter type in the leaf area values. The highest value of leaf area reached 6962.08 cm<sup>2</sup> plant<sup>-1</sup> for the triple interaction treatment (45% depletion, 30 cm depth and GR emitter type). While the lowest value of leaf area reached 4058.70 cm<sup>2</sup> plant<sup>-1</sup> for the triple interaction treatment (65% depletion, 20 cm depth and T-tape emitter type).

### 3.2 Biological Yield (megagrams ha<sup>-1</sup>):

Table (8) shows the effect of the study treatments on the biological yield values of maize. A significant effect of moisture depletion was observed, with the highest biological yield value recorded at 45% moisture depletion, reaching 31.269 megagrams ha<sup>-1</sup>, while the lowest value was recorded at 65% moisture depletion, reaching 22.125 megagrams ha<sup>-1</sup>Table (8) . This may be due to the low soil moisture at 65% depletion, which led to a significant decline in grain production and biomass of maize. This decrease reduces leaf area and chlorophyll content, leading to a decrease in photosynthetic efficiency and a decrease in grain number and weight. Low moisture also accelerates leaf aging and reduces the plant's ability to produce the nutrients necessary for grain growth. Water stress during the flowering and pollination periods leads to a decrease in yield, which negatively impacts overall production. Maize is highly sensitive to water shortages, especially during critical growth stages. Maintaining soil moisture at appropriate levels is essential to achieve high productivity and good photosynthetic efficiency [32,33].

Table (8) also shows a significant effect of the tillage depth coefficients on the biological yield values, as the depth of 30 cm gave the highest value of 28.863 megagrams ha<sup>-1</sup>, compared to the depth of 20 cm, which recorded a lower value of 24.530 megagrams ha<sup>-1</sup>. The reason may be attributed to the fact that tilling the soil at a depth of 30 cm led to an increase in the soil's ability to retain moisture, and also improved the movement of water and nutrients in the root zone, and reduced the presence of impediment layers that hinder root growth, which allows for better root spread in the lower layers of the soil, which supports plant growth and increases the biological yield. This is consistent with [34].

Table (8) shows that the type of emitter led to significant differences in the biological yield, as the GR drip irrigation emitter recorded the highest value of 27.753 megagrams ha<sup>-1</sup>, compared to the lowest value of 25.640 megagrams ha<sup>-1</sup> when using a T-tape emitter. The reason may be attributed to the difference in the hydraulic properties of the drip irrigation system, as the GR emitter recorded better values in the coefficient of variation (CV) of 0.065, water addition efficiency of 98.02, and field emission regularity of 95.73,Table (3). This led to the availability of equal water distribution along the emitter lines, which ensures that water reaches all plants in a balanced manner, reduces areas of drought or over-saturation, reduces clogging problems, and ensures the continuity of water flow, which maintains regular irrigation throughout the season. It also leads to an improvement in soil structure, increases the values of the weighted diameter rate and total porosity, and reduces the apparent density (Table 3), which facilitates root growth and absorption of nutrients, which improves It increases the growth of yellow maize and significantly increases the biological yield, which is what was reached by [36,35].

Table (8) Effect of the moisture depletion rate of the two plowing depths and the type of emitter on the biological yield rate (megagram ha<sup>-1</sup>)

Moisture depletion percentage ) M (	Plowing depth )D (	Type of emitter ) T (		Exhaustion * Plowing depth
		T1	T2	
M1	D1	28.163 d	30.156 c	29.160 b
	D2	32.083 b	34.673 a	33.378 a

M2	D1	19.176 h	20.626 g	19.901 d
	D2	23.140 f	25.556 e	24.348 c
M *T		) Average drip typeT (		Average moisture depletion
		T1	T2	)M (
Exhaustion rate	M1	30.123 b	32.415 a	31.269 a
	M2	21.158 d	23.091 c	22.125 b
) Average drip typeT (		25.640 b	27.753 a	
Plowing depth * Dripper type		Type of emitter		) Average tillage depthD (
		T1	T2	
Plowing depth	D1	23.670 d	25.391 c	24.530 b
	D2	27.611 b	30.115 a	28.863 a

The data in the same table indicate a significant effect of the two-way interaction between moisture depletion and tillage depth on the biological yield values. The highest biological yield value was 33.378 megagrams ha<sup>-1</sup> for the two-way interaction treatment (45% depletion and 30 cm depth), while the lowest value was 19.901 megagrams ha<sup>-1</sup> for the two-way interaction treatment (65% depletion and 20 cm depth). The results of the same table showed a significant effect of the two-way interaction between moisture depletion and emitter type on the biological yield values. The highest value, 32.415 mg ha<sup>-1</sup>, was recorded for the two-way interaction treatment (45% depletion and GR emitter), compared to the lowest value, 21.158 mg ha<sup>-1</sup>, for the two-way interaction treatment (65% depletion and T-tape emitter). The results of the table also showed that the two-way interaction between tillage depth and emitter type also had a significant effect. The highest value for biological yield was 30.115 mg ha<sup>-1</sup> for the two-way interaction treatment (30 cm depth and GR emitter), while the lowest value, 23.670 mg ha<sup>-1</sup>, was recorded for the two-way interaction treatment (20 cm depth and T-tape emitter). Finally, the results of the same table indicate significant differences as a result of the three-way interaction between Moisture depletion, tillage depth and emitter type, the highest value of biological yield was recorded at 34.673 Mg ha<sup>-1</sup> for the triple overlap treatment (45% depletion, 30 cm depth, and GR emitter), while the lowest value was 19.176 Mg ha<sup>-1</sup> for the triple overlap treatment (65% depletion, 20 cm depth, and T-tape emitter).

### 3.3 Crop Water Use Efficiency (kg m<sup>-3</sup>):

Table (9) shows a significant effect of the study parameters on crop water use efficiency values. It is noted that moisture depletion significantly affected crop water use efficiency values. The highest value was at 45% moisture depletion, reaching 3.43 kg m<sup>-3</sup>, while the lowest value was 2.38 kg m<sup>-3</sup> at 65% moisture depletion. The reason for the low crop water use efficiency values at 65% depletion may be attributed to the dryness of the soil around the roots, which causes water stress in the plant, leading to a decrease in crop water efficiency and consequently a reduction in growth and productivity. This is consistent with [37, 38].

As shown in Table (9), there is a significant effect of the tillage depth coefficients on the crop water use efficiency values, as the depth of 30 cm gave the highest value of crop water use efficiency, amounting to 3.16 kg m<sup>-3</sup>, compared to the depth of 20 cm, which gave the lowest value of crop water use efficiency, amounting to 2.65 kg m<sup>-3</sup>. The reason may be attributed to the choice of a 30 cm tillage depth, which leads to breaking and preparing the appropriate depth for vertical root growth, thus the roots benefit from moisture in depth and reduce water losses lost by evapotranspiration, which increases the efficiency of crop water use and increases productivity, as shown by [40, 39]. Table (9) shows significant differences in the crop water use efficiency values for the emitter type, as the GR emitter gave the highest value of 3.35 kg m<sup>-3</sup> compared to the T-tape emitter, in which the crop water use efficiency value decreased to 2.46 kg m<sup>-3</sup>. This may be due to the high coefficient of variation in the T-tape emitter, as shown in Table (3), as the increase in leakage from some emitters often leads to irregular distribution in the field, which results in disparities in irrigation between plants and consequently a decrease in crop water use efficiency. In contrast, the low coefficient of variation, as in the GR emitter, as shown in Table (3), ensures equal access to water to all plants, which reduces water stress and increases the efficiency of water and nutrient absorption. This is reflected in an increase in crop water use efficiency, which is consistent with [41, 42].

Table (9) Effect of the moisture depletion rate of the two plowing depths and the type of emitter on the crop water use efficiency rate ( $\text{kg m}^{-3}$ )

Moisture depletion percentage) M (	Plowing depth) D (	Type of emitter ( T )		Exhaustion * Plowing depth
		T1	T2	
M1	D1	2.64 e	3.57 b	3.10 b
	D2	3.17 c	4.35 a	3.76 a
M2	D1	1.90 g	2.50 e	2.20 d
	D2	2.15 f	2.98 d	2.56 c
M * T		) Average drip type T (		Average moisture depletion
		T1	T2	) M (
Exhaustion rate	M1	2.90 b	3.96 a	3.43 a
	M2	2.02 d	2.74 c	2.38 b
		) Average drip type T (		
		2.46 b	3.35 a	
Plowing depth * Drinker type		Type of emitter		) Average tillage depth D (
		T1	T2	
Plowing depth	D1	2.27 d	3.03 b	2.65 b
	D2	2.66 c	3.67 a	3.16 a

The results obtained from the same table showed a significant effect of the two-way interaction between moisture depletion and tillage depth on the crop water use efficiency values, as the highest value of crop water use efficiency reached  $3.76 \text{ kg m}^{-3}$  for the two-way interaction treatment (45% depletion and 30 cm depth), while the lowest value of crop water use efficiency reached  $2.20 \text{ kg m}^{-3}$  for the two-way interaction treatment (65% depletion and 20 cm depth). The results of the same table showed a significant effect of the two-way interaction between moisture depletion and emitter type on crop water use efficiency values. The highest value of crop water use efficiency was  $3.96 \text{ kg m}^{-3}$  for the two-way interaction treatment (45% depletion and a GR emitter), while the lowest value of crop water use efficiency was  $2.02 \text{ kg m}^{-3}$  for the two-way interaction treatment (65% depletion and a T-tape emitter).

The results of the same table also showed that the two-way interaction between plowing depth and emitter type had a significant effect. The highest value of crop water use efficiency was recorded at  $3.67 \text{ kg m}^{-3}$  for the two-way interaction treatment (30 cm depth and a GR emitter), while the lowest value of crop water use efficiency was recorded at  $2.27 \text{ kg m}^{-3}$  for the two-way interaction treatment (20 cm depth and a T-tape emitter). The same table indicates significant differences in the three-way interaction between moisture depletion, tillage depth, and emitter type in crop water use efficiency values. The highest crop water use efficiency value reached  $4.35 \text{ kg m}^{-3}$  for the three-way interaction treatment (45% depletion, 30 cm depth, and a GR emitter). The lowest crop water use efficiency value reached  $1.90 \text{ kg m}^{-3}$  for the three-way interaction treatment (65% depletion, 20 cm depth, and a T-tape emitter).

### Conclusion

1. The values of the deviation in the discharge rate increased and the values of the absolute field emission uniformity decreased after planting compared to their pre-planting values for both types of emitters (GR and T-tape) used in the study.
2. The 45% moisture depletion rate yielded the best values for weighted diameter, total porosity, leaf area, biological yield, and crop water use efficiency compared to the values when applying a 65% moisture depletion rate.
3. The values of weighted diameter, total soil porosity, leaf area, biological yield, and water use efficiency increased when using GR emitters, compared to the lowest values when using T-tape emitters.
4. The 30 cm plowing depth yielded the best values for leaf area, biological yield, and crop water use efficiency compared to the values when applying a 20 cm plowing depth. While the ploughing depth of 20 cm improved the weighted diameter and total porosity of the soil compared to their values at a depth of 30 cm.
- 5- The triple interaction of treatments (45% moisture depletion, 30 cm plowing depth and GR emitter) gave the highest values for each leaf area, biological yield and crop water use efficiency compared to their values in the triple interaction treatments (65% moisture depletion, 20 cm plowing depth and T-tape emitters).

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## دور الاستنفاد الرطوبي لعمقي الحراثة ونوع المنقطات في بعض الخصائص الفيزيائية للتربة و انتاجية المياه لمحصول الذرة الصفراء

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### الخلاصة

نفذت تجربة حقلية لمعرفة دور نسبة الاستنفاد الرطوبي وعمقين من الحراثة ونوعين من المنقطات وتأثيرها في بعض الخصائص الفيزيائية للتربة و انتاجية المياه لمحصول الذرة الصفراء خلال الموسم الخريفي لعام 2024 في محطة البحوث والتجارب الزراعية – جامعة كركوك. تضمنت التجربة ثلاث العوامل الرئيسية وهي نسبة الاستنفاد الرطوبي 45% والاستنفاد الرطوبي 65% ، العامل الثاني عمقين من الحراثة (20 و 30) سم والعامل الثالث نوعين من المنقطات (*GR*) و (*T-Tape*) وتم استخدام تصميم القطع المنشقة – المنشقة بترتيب القطاعات العشوائية الكاملة . (*RCBD*) بينت نتائج التجربة ان الاستنفاد الرطوبي 45% ادى الى تحسن الخصائص الفيزيائية وظهرت فروق معنوية لكل من المسامية الكلية ومعدل قطر الموزون اذ بلغت قيم المسامية الكلية 48.74% للاستنفاد الرطوبي 45% بينما بلغت 38.99% للاستنفاد الرطوبي 65% وكانت قيم معدل قطر الموزون 1.63 مم للاستنفاد الرطوبي 45% وبلغت 0.85 مم للاستنفاد الرطوبي 65% . ظهرت فروق معنوية عند استخدام عمق حراثة 30 سم في صفات النمو وحاصل المحصول و انتاجية المياه اذ تبين ان العمق 30 اعطى اعلى قيم لكل من (المساحة الورقية، الحاصل البيولوجي و كفاءة استعمال الماء المحصولي ) اذ بلغت (5088.57 سم<sup>2</sup> ، 28.863 ميكاغرام هكتار-1 و 3.16 كغم م-3) بالتتابع ، مقارنة بالعمق 20 سم اذ بلغت (5930.62 سم<sup>2</sup> ، 24.530 ميكاغرام هكتار-1 و 2.65 كغم م-3) بالتتابع . كما تبين من تقييم منظومة الري بالتنقيط قبل وبعد الزراعة ان قيم الصفات الهيدروليكية التي تتضمن صفتين هما الاختلاف في التصريف % *q var* وانتظامية الانبعاث الحقلية المطلقة % *FEUa* قد كانت قبل الزراعة افضل بشكل ملحوظ مقارنة بالقيم بعد الزراعة.

الكلمات المفتاحية: عمق الحراثة ، الاستنفاد الرطوبي ، كفاءة استعمال الماء المحصولي ، الحاصل البيولوجي، منقطات *T-tape* و *GR*.