The Effect of Different Nano-irrigation Systems on Some Hydraulic Parameters for Evaluating Drip Irrigation Systems

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Abstract. A field experiment was conducted in Al-Habbaniyah district / Al-Khalidiya district / Al-Anbar governorate, western Iraq, in Silty loam soil during the fall season 2020, to study the effect of surface and subsurface drip irrigation and perfusion irrigation with nanotechnology on some international standards to evaluate the performance of the work of irrigation systems after using them in plowed and uncultivated soils. Perfusion was done when 50% of the prepared water was depleted, the treatments were distributed according to the Nested-Factorial Experiments Design (NFED) with three replications. The yellow corn, cultivar Euphrates, was planted on 15/7/2020. The American evaporation basin, class A, was used in the timing of irrigation. According to the rate of water consumption in terms of the equivalent depth of the added water, the total yield and the efficiency of water use. The results showed giving the best discharge rate, homogeneity coefficient and percentage variation in the system drainage before planting at pressure of 100 kPa, which amounted to 2.27 L hr⁻¹, 98.91 and 7.69%, respectively, while these parameters decreased after planting and reached the best in the perfusion irrigation system, which amounted to 2.25 L hr⁻¹, 98.11 and 16.31% at the same operating pressure sequentially, while the lowest amount of these parameters after planting was 1.90 L hr⁻¹, 90.95 and 41.66% respectively in the surface drip irrigation system under an operating pressure of 50 K Pas.

1. Introduction

Water plays a fundamental role in the field of agricultural and economic development all over the world, as well as the case in Iraq, where the first Sumerian, Babylonian and Assyrian civilizations arose on the banks of the Tigris and Euphrates rivers thousands of years ago. Those civilizations were accompanied by the establishment of the first hydraulic installations, dams, and irrigation channels and the enactment of laws regulating the use of river water. Water has been and still is important in the history and development of Iraq. In order to understand the future of Iraq, we must look at the water basics in Iraq and the challenges it faces in investing water resources [1]. The Iraqi water problem can be seen as having three dimensions; The first is related to global climatic changes and the lack of rainfall and drought, the second is local due to poor planning and management of water resources, and the third dimension is regional due to the location of Iraqi water sources outside its international borders and the neighboring countries of Iraq have confiscated its right of its water shares [2], [3]. Mentioned that increasing the operating pressure of the system improves its work performance by increasing the coefficient of homogeneity of distribution, consistency of emission and a decrease in the percentage of variance in the actual discharge of the droplet. [4] obtained an increase in the
homogeneity coefficient of the surface drip irrigation system before planting with an increase in operating pressure, which amounted to 86.30 and 97.50% at pressures 30 and 70 kPa, respectively, while the values decreased after planting to 81.59 and 96.94% at the aforementioned operating pressures sequentially.

This study was conducted with the aim of
1. Calculating the actual discharge rate and its variance under the study conditions.
2. The effect of irrigation methods and their management on the consistency of emission and the coefficient of uniformity of the distribution of droplets.

2. Materials and methods

A field experiment was conducted during the fall season 2020, in Abu Fils area - Habaniyah district - Anbar governorate, western Iraq. The field soil was morphologically classified as silty mixed texture, categorized under the group Typic Torrifluvent, Fine loamy mixed, Calcareous, hyperthermic according to what was stated in [5]. Representative samples of field soil were taken from different regions, randomly, with a depth of (0-0.30 m), and some physical and chemical analyzes were conducted on them (Table 1) according to the standard methods mentioned in [6].

| Sand (g Kg⁻¹) | Silt (g Kg⁻¹) | Clay (g Kg⁻¹) | Bulk density (g Kg⁻¹) | Tarared hydraulic conductivity (cm hr⁻¹) | pH | EC (ds. m⁻³) |
|---------------|---------------|---------------|-----------------------|-----------------------------------------|----|-------------|
| 222           | 541           | 237           | 1.29                  | 9.28                                    |    | 7.5         |
| Cl⁻ (mmol. L⁻¹) | CO₂⁻ (mmol. L⁻¹) | HCO₃⁻ (mmol. L⁻¹) | SO₄²⁻ (mmol. L⁻¹) | Ca²⁺ (mmol. L⁻¹) | Na⁺ (mmol. L⁻¹) | Mg²⁺ (mmol. L⁻¹) |
| 6.50         | Nill           | 2.50           | 1.10                  | 5.0                                     | 0.35| 1.5         |

The irrigation water characteristics were estimated on the basis of the methods suggested by the American Lab of Salinity. The Euphrates water has been used to irrigate yellow corn crop which chemical characteristics are stated in (Table 2).

| Cl₄S₁ | SAR | NO₃⁻ Ppm | CO₃²⁻ | HCO₃⁻ | SO₄²⁻ | Cl⁻ | K⁺ | Na⁺ | Mg⁺ | Ca⁺ | pH | EC (ds.m⁻¹) |
|-------|-----|----------|-------|-------|-------|-----|----|-----|-----|-----|----|-------------|
| 1.15  | 2.10| 0.0      | 2.0   | 3.5   | 4.0   | 0.14| 2  | 2.89| 4.1 | 7.4 | 0.98|

The experiment included a study of the effect of three different irrigation systems, with nano-droppers, which included subsurface drip irrigation, sub-surface drip irrigation, and perfusion irrigation with nano-technology. When 50% of the available water for the plant was drained, it was actually measured by the gravimetric method in the field, and the irrigation water was added in the irrigation system by nanotechnology in a continuous perfusion throughout the season, taking into account the increase and decrease in the added quantity according to the stage of growth, depending on the water consumption rate of the maize plant for the loop autumn, he placed in each system two plowing patterns; zero tillage and conventional tillage.

A plot of land 52.2 m long, 21.5 m wide, was chosen, and then divided into three equal sites, With dimensions of 14.5 m x 17.5 m separated by a distance of 2.5 m between the sites as a guard area, each of the three irrigation methods was placed in a site and perpendicular to the direction of the prevailing winds to represent the main panels, and each irrigation method included three replicates and two plowing treatments were placed in each repeater, which included plowing A platform with a length of 1.5 m and a width of 1.5 m by a moldboard plow, then the soil was softened, while a distance of 1.5 m was left from the plowed treatment and the non-plowed treatment was placed (this was done as a precautionary measure to prevent the overlapping of wet sides, as well as to facilitate the movement of the tractor when plowing the treatment Under study, and the treatment was not aroused without
plowing), three drip lines were extended in each experimental unit, separated by a distance of 0.5 m, thus we have six experimental units in each irrigation method, with 18 experimental units in each experiment, leaving 2 m in the vicinity of the experiment to separate them. About the guard panels planted on both sides of the experiment (from the side of the wind blowing) to ensure reducing the damage of dry winds and creating homogeneous conditions for all treatments. Figure (2) shows the field scheme of the irrigation systems distributed among the study parameters.

Yellow corn seeds were planted for the autumn season, Furat variety, on 15/7/2020, by placing 3-4 seeds in each hole. The hole was reduced to one plant two weeks after planting. The distance between one line and another is 0.5 m, and between one line and another is 0.25 m, with 58 plants in each planting line, so the number of plants per system is 1044 plants, the whole experiment has a capacity of 3132 plants.

Nitrogen was added from urea fertilizer in an amount of 400 kg ha$^{-1}$ in two batches: the first batch included 200 kg ha$^{-1}$ with 260 kg ha$^{-1}$ of triple superphosphate before planting. While the second batch was added five weeks after planting. Crop service operations were conducted from the weeding process periodically and for all transactions. While the Yellow Corn Crop borer Sesamia Cretica L. was controlled with the use of the insecticide (granular diazinon 10% active substance), with an amount of 6 kg ha$^{-1}$ by placing a feed in the heart of the plant 20 days after the date of sowing, for three times with an interval of 10 days.

2.1. Calibration of the perfusion irrigation system

An initial field experiment was carried out in order to calibrate the subsurface drip irrigation system to ensure that the actual expenditures correspond to the daily water consumption rate of the maize plant. With a branch line length of 14.5 m and an internal diameter of 0.016 m, with a distance between the two adjacent points of 0.33 m, as in Scheme No. 5, after several attempts, the required operational pressures were obtained, which are shown in Table (3).

| No | growing stages | Water column height (meters) | System theoretical discharge (l day$^{-1}$) |
|----|----------------|----------------------------|------------------------------------------|
| 1  | germination    | 0.18                       | 736                                      |
| 2  | vegetative growth | 0.29                     | 724                                      |
| 3  | Flowers        | 0.35                       | 747.5                                    |
| 4  | Maturity       | 0.12                       | 314.5                                    |

2.2. Evaluation of the performance of the field work of irrigation systems

The field work performance of the drip irrigation system was evaluated twice during the experiment, before and after planting; The evaluation was carried out before planting to choose the most appropriate pressure to operate the surface and subsurface drip irrigation system, to be approved during the season.

2.3. Dripper discharge and emission consistency

Three operating pressures, 50, 75 and 100 kPa, were selected during the evaluation process to measure the discharge of the XF nano-droppers type (1) before and after planting, by reading the pressure meter. Connecting at the beginning of the main line after the disc filter stage by controlling a switch connected to the excess water return tube. , Nine field lines were selected, including lines 1, 3, 5, 7, 9, 11, 13, 15 and 17 from each system, for the purpose of measuring at each operating pressure Figure 5, the discharge of drips was measured by the volumetric method by calculating the volume of water received within 15 minutes, 16 readings were taken from Each field line separately, using two-liter cube-shaped cans, placed under the drippers to collect water, the measurement process was repeated three times at each pressure, then the discharge rate was calculated according to the equation mentioned by [7] as follows:-
Whereas: -

\[ Q = \frac{V}{t} \]  

(1)

Whereas:-

\( Q \): Dripper drainage, (L hr\(^{-1}\)).
\( t \): Operating time, (hr\(^{-1}\)).
\( V \): The volume of water coming into the can, (L).

The emission consistency of blobs was calculated using equation (2), and the emission consistency is a parallel criterion for the homogeneity of blobs distribution, and it expresses the ratio between the average of the least quarter to the general discharge rate of blobs, [8] and is calculated according to the following equation;

\[ EU = \frac{q_{25\%}}{q} * 100 \]  

(2)

Whereas:-

\( EU \) = Emission consistency (%).
\( q_{25\%} \) = Discharge rate for the least quarter (L hr\(^{-1}\)).
\( q \) = Emetars discharge rate (L hr\(^{-1}\)).

2.4. Uniformity coefficient and variance ratio

The Uniformity Coefficient (U.C) was calculated based on the rates of drippers' expenditures and at the same operating pressures, using equation (3) The variance ratio in the variance ratio discharge was also calculated by equation (4) The actual discharge was 2.27 liters per hour-1 at the operating pressure of 100 kPa to give it a quantity of water closer to the industrial discharge, the best Uniformity coefficient, and the lowest variance ratio between the drippers.

\[ U_c = \left( 1 - \frac{\sum |x_i|}{M n} \right) * 100 \]  

(3)

Whereas:-

\( U_c \) = Uniformity coefficient (%).
\( \sum |x_i| \) = The sum of the deviations of the discharge from the rate of discharge (L hr\(^{-1}\)).
\( M \) = Average droplet discharge (L hr\(^{-1}\)).
\( n \) = the number of emetars.

As for the covariance of the discharge along the lateral line, it is calculated according to the equation proposed by [10], which is:-

\[ q_{var} = \frac{q_{max} - q_{min}}{q_{max}} * 100 \]  

(4)
Whereas:

$q_{var}$ = Droplet discharging variance ratio (L hr$^{-1}$).
$q_{max}$ = Maximum dripping drainage (L hr$^{-1}$)
$q_{min}$ = Minimum drip drain (L hr$^{-1}$).

The results were analyzed using Genstat v.12.1 software and the averages were compared according to the least significant difference (LSD) test at the 0.05 probability level.

Figure 2. Field diagram and irrigation system.
3. Results and discussion

Evaluation of the performance of the work of drip and perfusion irrigation systems before and after planting.

Table (4) shows the effect of the operating pressure on each of the droplet discharge rate, the homogeneity coefficient, the variance ratio and the emission consistency before planting, and it is clear that the droplet discharge rate, the distribution homogeneity rate, and the emission consistency increased by increasing the operating pressure, while the variance percentage decreased with the increase in the operating pressure. The lowest and highest discharge rate reached about 2.02 and 2.27 L hr⁻¹, at pressures 50 and 100 kPa, respectively, and the value of the Uniformity coefficient increased from 97.77% to 98.51%, compared to the aforementioned pressures, while the droplet discharge variation percentage decreased from 8.33% to 7.69% when the operating pressure is increased from 50 to 100 kPa. The reason for the increase in the discharge by increasing the operating pressure of the system is due to the stability of the cross-sectional area of the pipe, so the increase in the operating pressure reduces the friction between the inner wall of the pipes and water molecules, and then increases the movement of water inside the pipe, and this led to an increase in the rate of discharge, and this is consistent with what was mentioned by [11], which has a significant increase in the discharge rate with an increase in the operating pressure, and the reason for the increase in the homogeneity coefficient and the decrease in the variance ratio with an increase in the operating pressure is due to the stability of each m. The square of the system, the cross-sectional area of the pipe, and the diameter of the dripper opening made the pressure distribution along the pipe less variable at each unit, an increase in pressure and water velocity within the distribution network, [4].

Table 4. The effect of different operational pressures on the criteria for evaluating the irrigation system before planting.

| Evaluation Criteria          | 50  | 75  | 100 |
|------------------------------|-----|-----|-----|
| Discharge rate (L hr⁻¹)      | 2.02| 2.04| 2.27|
| Uniformity coefficient (%)   | 97.77| 98.36| 98.51|
| Variation (%)                | 8.33| 8.33| 7.69|
| Emission consistency (%)     | 97.77| 97.05| 97.35|

Table 5. shows the effect of operational pressure and irrigation method on the rate of dripping discharge after planting. There is no doubt that the increase in the rate of discharge by increasing the operational pressure and this effect was addressed and explained before planting, but it is worth mentioning and explaining that the decrease in the values of discharge rates after planting compared to their values before planting when the same operational pressures, as the values of the characteristic decreased to 2.02 and 2.27 L hr⁻¹, before planting to 2.00 and 2.19 L hr⁻¹, after cultivation at pressures 50 and 100 kPa respectively, and the reason for this effect is attributed to the deposition of salts, plankton and the growth of lichens and others at the nozzle of the dripper that causes an obstruction in the drainage of water through it [2], [12].

The results of the above-mentioned table also indicate the effect of the applied irrigation method on the value of the droplet discharge rate, as the highest discharge rate was 2.177 L hr⁻¹ as the average of the three pressures at the nano perfusion irrigation system, and it decreased significantly to 2.107 and 2.003 liters per hour⁻¹ with a decrease rate of 3.21% and 7.99% in the two methods of subsurface drip irrigation and surface drip irrigation sequentially, and the reason for the lag in the rate of discharge during surface drip irrigation is due to the deposition of salts and the growth of lichens at the nozzle of the dripper, which caused impeding the exit of water through it, while these deposits decrease during subsurface drip irrigation due to the lack of exposure of the drippers directly to the atmosphere, which reduced the evaporation of water by leaving the salts deposited at their openings, while the continuous drainage of water from irrigation pipes by exudation throughout the season had a role in reducing these deposits as a result of providing continuous moisture, which makes the salts in a state of
continuous melting as well as the continuation of drainage holes. The drippers prevent the deposition of silt and clay particles in front of it, as in the case of subsurface drip irrigation, in addition to the lack of water evaporation from the dripper area, leaving salts deposited as in the case of surface drip irrigation, and this is one of the technical advantages of using nano-droppers for irrigation purposes under the soil surface.

Table 5. The effect of different operating pressures on the rate of discharge of the irrigation system after planting.

| irrigation systems | 50 pressure (kPa) | 100 average irrigation |
|-------------------|------------------|------------------------|
| I₁                | 1.900            | 2.120                  |
| I₂                | 2.000            | 2.227                  |
| I₃                | 2.100            | 2.250                  |

LSD 0.045

Table 6. The effect of different operating pressures on the homogeneity coefficient of the irrigation system after planting.

| irrigation systems | 50 pressure (kPa) | 100 average irrigation |
|-------------------|------------------|------------------------|
| I₁                | 90.95            | 95.46                  |
| I₂                | 93.31            | 96.62                  |
| I₃                | 94.02            | 98.11                  |

LSD 0.080

Table (6) shows the effect of the operating pressure and irrigation method on the values of the coefficient of homogeneity of the distribution of dots after planting, as the values of the trait decreased after planting compared to their values before planting at the same operating pressures, and the decline was the values of the trait from 97.77 and 98.51% before planting at pressures 50 And 100 kPa sequentially to 92.76 and 96.73% after planting with a decrease of 5.12 and 1.80% at the same operating pressures sequentially, %, which is greater than when using a pressure of 100 kPa, which was 1.80%, and this indicates that the possibility of operating at high pressures to remove some sediments from the nozzle of the drippers, which increases the expenses of those drippers in a manner close to the general drainage of them, as well as an increase in the speed of water movement inside the pipes with a fixed area. The flow section and the size of the system made the water pressure distributed more homogeneously than it is in the low pressures [4], in addition to the industrial recommendations for the nano-droppers to work at high pressures (not less than 100 kPa).

The results of the aforementioned table also indicate the effect of the irrigation method on the value of the coefficient of homogeneity of the distribution of the dots, as the highest mean values of the characteristic reached 96.21% for the three pressures (50, 75 and 100 kPa) at the nano-perfusion irrigation system, and it decreased significantly to 94.86 and 93.35% by percentage. A decrease of 1.40% and 2.97% for subsurface drip irrigation and surface drip irrigation sequentially, the reason was explained by discussing the discharge rate.

Table 6. The effect of different operating pressures on the homogeneity coefficient of the irrigation system after planting.

| irrigation systems | 50 pressure (kPa) | 100 average irrigation |
|-------------------|------------------|------------------------|
| I₁                | 92.76            | 96.73                  |

LSD 0.035

The results of Table (7) show the effect of the operational pressure and the irrigation method on the variance of the drips discharge after planting, as the trait values increased after planting compared to their values before planting at the same operating pressures, since this ratio is negatively related to both the coefficient of Uniformity and the operating pressure, and it was 8.33 and 7.69% before planting at pressures 50 and 100 kPa sequentially, it increased to 33.18 and 16.31% as an average of the characteristic values for the three irrigation systems after planting, with an increase of 298.3 and
112.0% at the same operating pressures sequentially, and the reason for this is due to the low values of each of the homogeneity factor and drainage due to sediment and salt accumulation, especially in the case of surface drip irrigation, which was the most irrigation method with these negative factors [13], [4].

The results of the above-mentioned table show the effect of the irrigation method on the variance of the droplet distribution, as the lowest average values of the trait reached 21.22% in the irrigation system with nanotechnology for the three pressures (50, 75 and 100 kPa), while it increased significantly to 27.63 and 32.98% with an increase rate of up to 30.20% and 55.41% for subsurface drip irrigation and surface drip irrigation sequentially, and the reason for this is due to the increase in water evaporation from the drips nozzle at the surface drip irrigation system, which left quantities of salts and sediments at the Muhammadi [14].

Table 7. Effect of different operating pressures on the rate of variance of drainage of the irrigation system after planting.

| irrigation systems | pressure (kPa) | pressure (kPa) | pressure (kPa) | average irrigation |
|--------------------|---------------|---------------|---------------|-------------------|
|                    | 50 | 75 | 100 |                  |
| I₁                 | 41.66 | 29.82 | 28.57 | 32.98 |
| I₂                 | 33.33 | 29.58 | 20.85 | 27.63 |
| I₃                 | 24.55 | 22.80 | 16.31 | 21.22 |
| LSD                | 2.977 |       |       | 2.977 |
| average pressure   | 21.91 | 27.40 | 33.18 |       |
| LSD                | 1.789 |       |       |       |

4. Conclusions
The nano-technology perfusion irrigation system gave the best values of criteria for evaluating the performance of irrigation systems. In general, the discharge rate, homogeneity coefficient and emission consistency increased with increasing operating pressure, while the percentage of variation in dripping discharge decreased.

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