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Evaluation of Nano-subsurface Drip Irrigation System Before and After the End of the Growing Season

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ABSTRACT

Background: Water scarcity and climatic challenges in Iraq necessitate the adoption of efficient irrigation systems such as drip and subsurface drip irrigation to improve water use efficiency and reduce soil degradation. This study evaluates the effectiveness of the subsurface nano-drip irrigation system.

Methods: A field experiment was conducted in 2025, which included measuring the uniformity of the emission and calculating the coefficient uniformity values, in addition to the percentage of variation in the drip discharge before planting under three levels of operating pressures 50, 100 and 150 kPa. A discharge rate of 2.26 L h^{-1} was adopted at 150 kPa.

Result: The operating pressure of 150 kPa gave moral values for the distribution homogeneity coefficient, emission uniformity and discharge variance ratio, reaching 98.13%, 96.57% and 6.44% respectively, with an actual dripper discharge of 2.26 L h^{-1}. At the end of the growing season, the operating pressure of 150 kPa resulted in a discharge rate of 2.19 L h^{-1}, while the values of distribution uniformity (DU), emission uniformity (EU) and coefficient of variation (CV) were 97.83%, 96.39% and 9.74%, respectively. Operating at 150 kPa provides optimal discharge characteristics, with minimal degradation observed after seasonal operation. These findings confirm the suitability of nano-drippers for subsurface irrigation applications, supporting their efficiency and sustainability in agricultural water management.

Key words: Coefficient of variation in discharge, Drip irrigation, Emission uniformity, Operating pressures, Uniformity coefficient.

INTRODUCTION

The modern irrigation system in Iraq holds particular importance due to the prevailing conditions and challenges faced by the country, namely water scarcity, low rainfall and prolonged drought periods. Therefore, it is essential to expand the adoption of modern irrigation technologies, such as surface drip irrigation, as an effective method for rationalizing water use in agriculture (Kumar *et al*., 2026). Furthermore, it plays a role in protecting soil from waterlogging and salinization, that contributing to substantial losses of soil moisture by evaporation into atmosphere from wetted-soil surface particularly around the dripper area. Efforts have been directed toward supplying water directly without saturating upper layers to minimizing percolation and deep seepage. The use of such techniques has pushed the evolution of subsurface drip irrigation (Ahmad *et al*., 2020).

The performance evaluation criteria of the drip irrigation system were on the basis of dripper discharge and the coefficient of variation. As the operating pressure of the system increases, so does dripper discharge rates along laterals and *vice versa*. Water is supplied through the supply laterals to the drippers which pass it onto the soil. Consequently, the dripper is regarded as a critical part of the drip irrigation system as it supplies small amounts of water at low discharge rates of between 2 to 10 L h^{-1} under a minimum operating pressure of 1.0 bar or about one atmosphere or 100 kPa (Al-Obaidi, 2003). Hisham (2014) experimented with T-Tape, GR and Turbo drippers at different working pressures of 20, 30, 40, 50 and 60 kPa. The average dripper discharge was also found to increase markedly with increasing operating pressure for all drippers. The maximum mean discharge of 5.7 L h^{-1} was observed for the T-Tape dripper, at an operating pressure of 60 kPa. In addition, the emission uniformity values were stepped up with operational pressures up to 40 kPa and then a decrease was observed in the T-Tape and GR drippers.

CV values can be classified as: preferred when CV is ≤10%, acceptable within >10 and ≤20, unacceptable if over 20% (Wu and Gitlin, 1979). Al-Najm (2013) observed an increase in dripper discharge with the increment of operating pressures, exhibiting values of 0.93, 2.94, 3.25 and 3.7 L h^{-1} for operating pressures of 20, 30, 40 and 50 kPa, respectively. Likewise, (DU) values increased to 80.3%, 90%, 93% and 97.2%, although, (CV) were decreased with increasing

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operating pressure, reaching 48.46%, 32.7%, 23.78% and 9.58% at the same pressures were mentioned.

Solomon and Keller (1978) emphasized the significant importance of both dripper discharge rate and distribution uniformity when designing drip irrigation networks. They indicated that an appropriate uniformity coefficient for designing a drip irrigation system should be equal to or greater than 94% (Ramachandran *et al*., 2019).

Al-Saadoun (2006) also found that the distribution uniformity of the drippers decreased at the end relative to early in the growing season when using three types of drippers (Turbo, Spiral and GR), with values of 2.8%, 3.9% and 11.8% respectively. Al-Janabi (2012) found that the percentage of dripper distribution uniformity improved as the operating pressure increased to a maximum value of 98.6% at an operating pressure of 150 kPa. It was due to the fact that uniformity of water discharge in drip irrigation system depends on many factors, such as operating pressure, frictional losses, length of lateral lines and land slope (Kapupara *et al*., 2020). To achieve the best emission consistency (EU) on uneven terrain, pressure regulators and pressure compensation drippers are used for a long time. But, compensating drippers are usually more expensive and complicated devices than non-compensating drippers. To reduce the emission heterogeneity in drip irrigation and to mitigate the inconveniences associated with clogging of emitters, microtubes (of small diameter approximately 2-4 mm) have been employed. Microtube has many cost-effectiveness and practicability compared to as-built types of drippers, because its material is flexible enough to change the shape and length at any energy level and also keep uniform amounts of water seeping. These microtubes act as the emission sources on a sideways line (Steele, 2015).

Al-Shaabani (2017) concluded that that the distribution CU increased significantly with operating pressure before planting, as it ranged between the lowest and highest values of 86.30 and 97.50% at operating pressures of 30 and 70 kPa, respectively. He also found a significant increase in the homogeneity coefficient values after planting with increasing operating pressure, as it ranged between the lowest and highest values of 81.59 and 96.94% at operating pressures of 30 and 70 kPa, respectively. Likewise, the emission consistency values before planting increased significantly with increasing operating pressure and ranged between the lowest and highest values of 78.55 and 96.29% with operating pressures of 30 and 70 kPa, respectively. He also found that the emission consistency values after planting increased significantly with increasing operating pressure, as the lowest and highest values were 72.22 and 95.31% at operating pressures of 30 and 70 kPa. In sequence. Al-Dulaimi *et al*. (2018) in their study evaluated the performance of drip irrigation pipes on some soil water parameters and water consumption of cucumbers indicated that the homogeneity coefficient for drip irrigation reached 97% and the percentage of variation in drip discharge reached 8.33%.

Al-Ani (2023) pointed out the impact of operating pressure on the pre-planting dripper discharge rate. It is clear from this that the dripper discharge rate increases with increasing operating pressures, as the highest discharge rate reached 5.56 L h^{-1} at 150 kPa, compared to 4.19 and 2.86 L h^{-1} at operating pressures of 100 and 50 kPa, respectively. The discharge rate reached 3.85 L h^{-1} after planting at an operating pressure of 100 kPa. The operating pressure of 100 kPa was adopted to give an actual discharge closer to the manufacturing design, the best consistency factor, the lowest percentage of variation in discharge between drippers and the highest EU.

Al-Mansi *et al.* (2024) assessed the hydraulic performance of low-pressure drip irrigation systems applicable to smallholder farms. The objective of this study was to evaluate the hydraulic performance of LPDI in respect to dripper discharge, coefficient of variation (CV), water distribution uniformity and emission uniformity. Hydraulic performance of three kinds of driplines (T-Tape (10 L h^{-1}/ m), Flat Tapes (2 L h^{-1}/ 30 cm) and GR (4 L h^{-1}/30 cm) was performed in laboratory and field experiments. Discharge was recorded at four pressure levels (0.4, 0.6, 0.8 and 1 bar). The discharge increased with increasing pressure and it decreased with increasing lateral line length. 4 in every case and emission uniformity was also high (90-97%) at all operating pressure.

The aim of this study was to determine the influence of operating pressure on dripper discharge, CU, EU and coefficient of variation of discharge during both beginning and end of growing season.

MATERIALS AND METHODS

Experimental design

The experiment was conducted to evaluate the drip irrigation system 2025 at the first research station of the College of Agriculture, University of Anbar. The system consisted of secondary lines (lateral pipes carrying the drippers) made of polyethylene with an internal diameter of 0.017 m and a length of 10 m, with a dripper spacing of 0.33 m. The drippers were nano-type, manufactured in the USA (Rain Bird® XFS), with a discharge rate of 2.3 L h^{-1}, an external diameter of 0.017 m, an internal diameter of 0.016 m, a wall thickness of 0.0012 m and a spacing of 0.33 m. These small-sized drippers help minimize pressure losses by providing a consistent flow along the entire lateral line, ensuring uniform pressure ranging from 0.85 to 4.14 bar. They operate using Copper Shield™ technology to protect the drippers from root intrusion and their design prevents clogging through a reinforced flow path with self-cleaning capacity, as shown in Fig 1.

Evaluation of the drip irrigation system

The quarter technique was applied by Al-Amoud (1997). Dripper discharge was recorded at three operating pressures (50, 100 and 150 kPa) using a control valve installed after the PRV, taking readings of pressure from a liquid manometer. Volumetric dripper discharge for each of the lateral lines was deter-mined separately as the volume of water collected in 10 min. cylindrical forms 0.10 m high and 0.08 m in diameter were employed. Three measurements were taken to each pressure on each lateral line. The flow was estimated using the formula of Hajim and Yassin (1992) as:

$$Q = \frac{V}{t} \quad ...(1)$$

Where,

Q= Dripper discharge (L h^{-1}).

T= Operating time (h).

V= Volume of water collected in the container (L).

The uniformity coefficient (UC) was calculated based on the dripper discharge rates at operating pressures of 50, 100 and 150 kPa using the equation proposed by Christiansen (1942), expressed as follows:

$$UC = \left(1 - \frac{\Sigma|xi|}{Mn}\right) *100 \quad ...(2)$$

Where,

UC= Uniformity coefficient (%).

Σ|xi|= Sum of absolute deviations from the mean discharge (L h^{-1}).

M= Mean dripper discharge (L h^{-1}).

n= Number of drippers.

The emission uniformity (EU) is the percentage of the rate of water delivery by the lowest quarter flow of emitters compared to that by all emitters. This parameter is complemented to the DU and may be estimated by (Ortega *et al*., 2002).

$$EU = \frac{\bar{q}25\%}{\bar{q}} *100 \quad ...(3)$$

Where,

EU= Emission uniformity (%).

$\bar{q}$25%= Discharge rate of the lowest quartile (L h^{-1}).

$\bar{q}$: Drippers' discharge rate (L h^{-1}).

Coefficient of variation of dripper discharge (q_{var}) was calculated based on the highest dripper discharge (q_{max}) and the lowest dripper discharge (q_{min}) according to Camp *et al*. (1997) to determine the percentage variation of discharge along the lateral line, as follows:

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} *(100) \quad ...(4)$$

Where,

q_{var}= Coefficient of variation of dripper discharge (L h^{-1}).

q_{max}= Maximum dripper discharge (L h^{-1}).

q_{min}= Minimum dripper discharge (L h^{-1}).

A discharge rate of 2.26 L h^{-1} at 150 kPa was adopted, as it provided the best UC, highest EU and the lowest coefficient of variation between the drippers.

RESULTS AND DISCUSSION

Fig 2 shows the effect of operating pressure on dripper discharge before planting. It is clearly found that the dripper discharge increased appreciably with increase of operating pressure, to a maximum of 2.257 L h^{-1} at 150 kPa compared to values of 2.12 and 2.05 L h^{-1} for the other two pressures (100 and 50 kPa). At the end of the growing season, the flow rate at 150 kPa was 2.18 L h^{-1} (3.1% less).

Fig 3 shows the lowest coefficient of variation (6.44%) was observed at 150 kPa and increased to 9.82% and 14.48% at 100 and 50 kPa respectively. The figure also indicates that the best operating pressure was 150 kPa, corresponding to the minimal variation in dripper discharge (6.44%) in the pre-planting period. In general, the coefficient of variation increased at the end of the growing season compared to its pre-planting value, reaching 9.74%, an increase of 5.12% at the aforementioned operating pressure.

Impact of operating pressure on the pre-planting UC is shown in Fig 4. The significant enhancement in distribution uniformity with the increase of operating pressure is clear, as it was 98.13% at 150 kPa, against 97.50% and 97.46% at 100 and 50 kPa, respectively. The uniformity coefficient was slightly reduced after growing season ended (97.88%) with a decrease of only 0.25% in comparison to its pre-planting value at 150 kPa.

The influence of operating pressure on SDI, Dew and EU before planting was presented in Fig 5. There were significant differences in emission uniformity as a result of the different operating pressures. At a pressure of 150 kPa, the maximum emission uniformity was 96.57%, which is higher than 96.5% and 95.25% at pressures of 100 and 50 kPa, respectively. Emitters uniformity slightly reduced after the end of the growing season to 96.397%, corresponding to a reduction of only 0.19% at this pressure level.

The rise of discharge with increase in operating pressure from 50 to 150 kPa is due to the high speed of water molecules between the pipe, causing less resistance by the water molecules against the wall of pipelike as that mentioned by Al-Mohammedi *et al*. (2018). This decrease is a result of the deposition of salts, solids and algae at the outlets of the dripper that block the flow water during autumn after prolonged accumulation over olive growing season. These results are consistent with Al-Shaabani and Al-Obeid (2021).

The coefficient of variation increased at the end of the growing season compared to its pre-planting value due to the fact that higher operating pressures generate less friction between water molecules and the pipe walls and between them and each other (because of the higher flow velocity), which reduces the variability of drip discharge. These results are consistent with those of Al-Mohammedi (2011).

With the elevation of operating pressure, the uniformity coefficient increased; it is suggested that the stability per square meter of system and pipe cross-sectional area

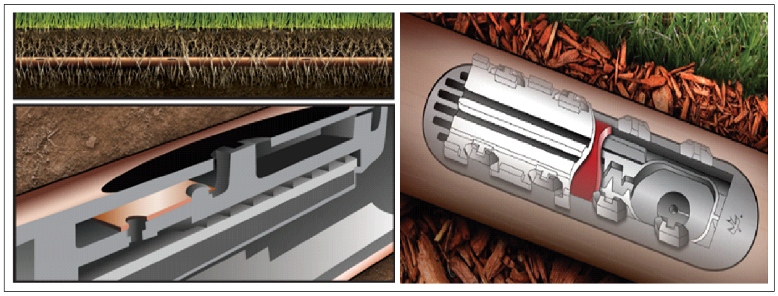

Fig 1: Design of small-sized nano-dripper.

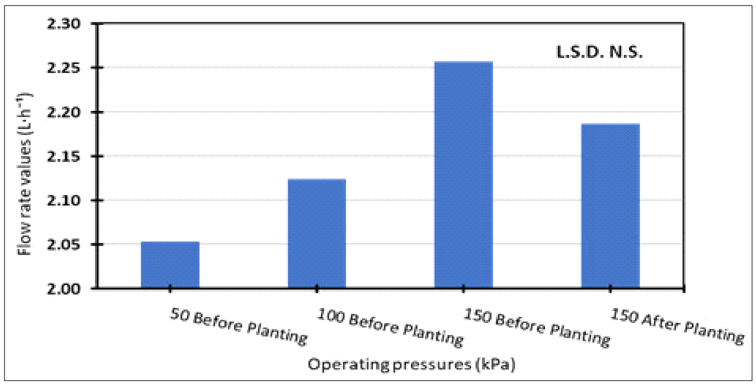

Fig 2: Effect of operating pressure variation in discharge (%) before and after cultivation.

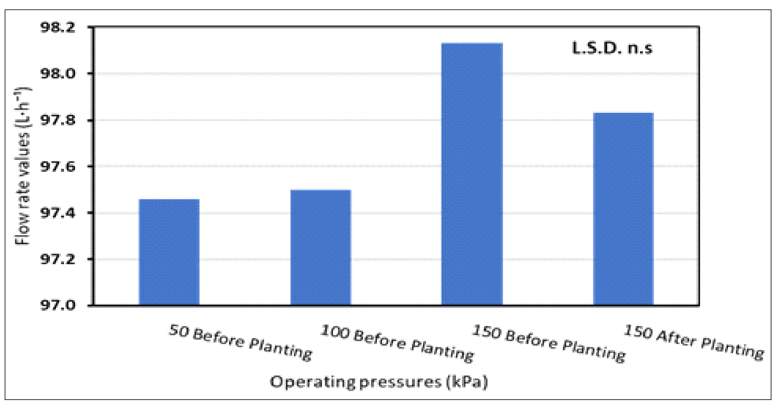

Fig 3: Effect of operating pressure variation in coefficient of variation in discharge (%) before and after cultivation.

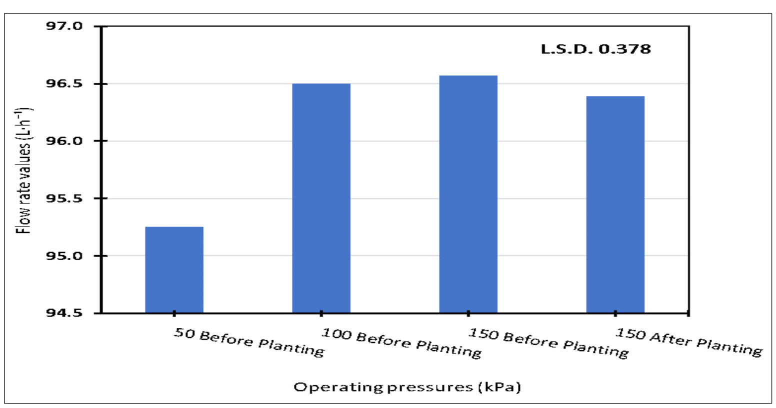

Fig 4: Effect of operating pressure variation in uniformity coefficient (%) before and after cultivation.

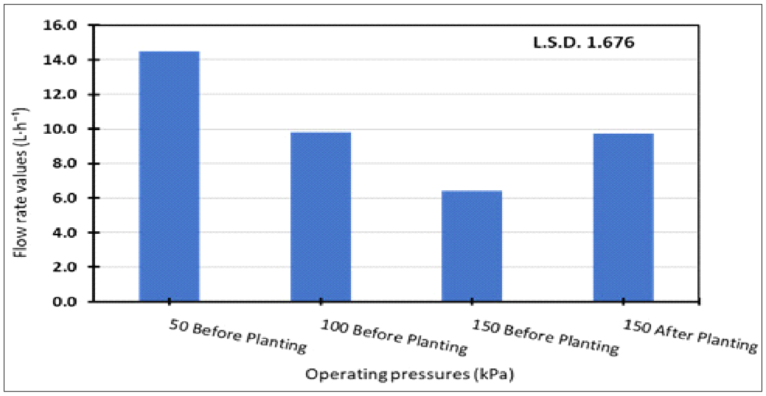

Fig 5: Effect of operating pressure variation in emission uniformity (%) before and after cultivation.

and dripper orifice diameter became better, produced more even pressure distribution along pipe with increasing water velocity in distribution.

This higher operating pressure in the drip system resulted in more uniform water discharge by the drips into the field. Higher emission uniformity (EU) values refer to a more uniform water distribution, which is closer to ideal situation of the field. Furthermore, the microtubes utilized are fabricated from flexible materials that can be easily shaped and lengthened to match the physical and energy requirements associated with uniform emission. These results are in line with Steele (2015).

CONCLUSION

The values of the performance evaluations at 150 kPa operating pressure and 2.26 L h^{-1} flow rate before planting are obtained as the best values using nano-drippers subsurface drip irrigation system. Under the same pressure, it discharged at a rate of 2.18 L h^{-1} following termination of the growing season.

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Disclaimers

This article was exclusively written by the authors. The opinions expressed are not necessarily those of their institutions.

Informed consent

There were no human or animal subjects in this study. All sampling and laboratory works were carried out according to environmental and lab safety rules.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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