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Evaluation the performance of a locally developed system for irrigation, planting, and fertigation and its effect on some soil properties and sunflower yield

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ABSTRACT

Sunflower production efficiency can be limited by suboptimal irrigation, planting, and fertilization practices, which may lead to uneven water distribution, poor nutrient availability, and reduced yields. Therefore, the present study aimed to evaluate the performance of a locally developed integrated irrigation–planting–fertilization system and its effects on some soil properties and sunflower yield. The study employed two factors: the first was the irrigation–planting–fertilization system with three levels, namely subsurface drip irrigation with a continuous seed-and-fertilizer strip (F), subsurface drip irrigation with an intermittent seed-and-fertilizer strip (S), and the traditional planting and fertilization system (C). The second factor was the type of subsurface drip irrigation tube at three levels, which were the Gr tube, the T-Tape tube, and the porous tube. Soil moisture content, moisture uniformity coefficient, soil penetration resistance, and sunflower yield were measured in this experiment. A nested design under a randomized complete block design (RCBD) was used, and the least significant difference (LSD = 0.05) at a probability level of 0.05 was applied to compare the treatment means. The results showed the following: The subsurface drip irrigation system with a continuous seed-and-fertilizer strip (F) outperformed the other treatments by achieving the highest plant height of 176.8 cm and the highest yield of 6.60 t/ha. There were no significant differences in the effects of this system on the moisture uniformity coefficient, soil penetration resistance, and soil moisture content compared with the intermittent-strip system and the traditional planting system. Regarding the irrigation tube treatments, the GR tube gave the highest soil moisture content of 28.76%, the highest moisture uniformity coefficient of 83.29%, the lowest soil penetration resistance of 1100 kg/cm^2, the highest plant height of 179.1 cm, and the highest yield of 6.90 t/ha compared with the treatments that used the T-Tape and porous tubes. As for the interaction between the irrigation–planting–fertilization systems and the irrigation tube treatments, the combination of the F system with the Gr tube outperformed the others by giving the highest soil moisture content of 29.21%, the highest plant height of 190.0 cm, and the highest yield of 8.30 t/ha, with no significant differences for this interaction in the moisture uniformity coefficient and soil penetration resistance.

Keywords: crop yield, emitters, irrigation systems, soil moisture content, uniformity coefficient.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops worldwide, widely cultivated for its seeds, which are rich in unsaturated fatty acids, antioxidants, and other bioactive compounds that provide numerous health benefits, including improving cardiovascular health and reducing oxidative stress. Successful cultivation of sunflowers requires adequate and balanced water supply along with proper fertilizer application, as the crop depends on soil moisture within the root zone to support growth and maximize productivity (Hernandez et al., 2021; Singh et al., 2023).

Irrigation is considered one of the fundamental pillars of agricultural production, as it aims to provide crops with the required amounts of water at the right time and place to ensure continuous growth and achieve high productivity

(Al-Sammarraie and Kaplan, 2025). Irrigation efficiency is influenced by various factors related to soil properties, plant characteristics, climatic conditions, and the irrigation method applied. These factors have made the development of irrigation technologies and the adoption of modern practices an urgent necessity to achieve optimal use of water resources, particularly in arid and semi-arid regions that suffer from water scarcity (Al-sammarraie and Ilbas, 2024). Advances in irrigation systems-such as surface irrigation, sprinkler irrigation, and drip irrigation – have contributed to improving field-scale water management, reducing losses due to evaporation and surface runoff, and increasing crop water-use efficiency, which is clearly reflected in agricultural productivity and resource sustainability (Barker et al., 2024; Batisha, 2024). The agriculture sector in Iraq faces significant difficulties owing to water scarcity, land salinization, and increased production costs. So, adopting innovative and advanced irrigation technologies that play important roles in water conservation and efficient production with reduced production costs is necessary. The adoption and use of subsurface drip irrigation and smart irrigation technologies showed significant efficiency and potential for water management and improvement of land properties. Research studies indicate that the shift from traditional irrigation methods, such as flood irrigation, to modern systems like drip irrigation leads to a significant improvement in water use efficiency in agriculture. Field evidence has shown that drip irrigation increases water use efficiency and reduces losses due to evaporation and surface runoff compared to traditional methods, while also contributing to higher crop yields, making these technologies an effective option for water conservation under limited water resources (Al-Sammarraie and Kaplan, 2025; Santini et al., 2025).The process is marked by the minimum loss of water due to evaporation and deep percolation that leaves the root zone unsuitable and provides a stable and continuous amount of water within the root zone with significant effects on crop growth and overall productivity (Sinobas and Rodríguez, 2012). Production cost saving and innovation and invention of new and innovative methods in the field of planting and fertilizer application such as adopting innovative irrigation methods such as surface drip irrigation and sprinkler irrigation and adopting untraditional methods for planting and application of nutrients represent one of the prime goals and priorities cited and emphasized within agriculture today. Seeding and complete/fertilizer application within irrigation represent one of the most significant factors in the establishment and nourishment processes for crops. Nutrients and seeds can be applied within the root zone with equal seeding and decreased loss and improved efficiency with subsurface drip irrigation and complete seeding (Coates, 1986).

GR irrigation tubes and T-Tape irrigation tubes along with seepage irrigation tubes represent one of the significant and important technologies used for efficient irrigation water management and crop productivity along with irrigation productivity. The process is marked by homogeneous seeding and irrigation water distribution with reduced differences between seeds and crops with significant growth and overall production (Al-Janabi et al., 2021; Mašán et al., 2025). T-Tape irrigation tubes represent one of the significant irrigation methods marked by flexible tubes with minimum difficulties and sufficient irrigation water furnished with the release and distribution by evenly distributed amounts for balanced and precise amounts with significant efficiency for irrigation water and significant improvements within crop production and growth with significant water productivity (Mohammed and Abbas, 2020). Research revealed that GR tubes with evenly distributed emitters throughout the tube offer superior uniformity, soil moisture content, and reduced resistance to soil penetration compared to T-Tape and porous tubes (Ali et al., 2019; Elmaloglou and Diamantopoulos, 2020; Abdrabou et al., 2023). As for the porous/seepage tubes with water release from tiny pores evenly distributed on the surface of the tubes, they offer a near-uniform distribution of water (Al-Hadidi et al., 2018; Al-Janabi et al., 2021). Therefore, sunflower production efficiency is negatively affected by suboptimal irrigation, planting, and fertilization practices, leading to irregular water distribution, nutrient deficiencies, and consequently, reduced productivity. In response to the challenges of water scarcity and increasing environmental pressures globally, this research aims to develop and test a locally designed and manufactured precision system that integrates irrigation, planting, and fertilization into a single system. The aim is to improve the efficiency and accuracy of these processes, reduce agricultural production costs, and decrease reliance on multiple machines.

MATERIALS AND METHODS

The experiment was conducted in one of the fields of the College of Agricultural Engineering Sciences / University of Baghdad / Al-Jadriya, latitude 33°16′12″N and longitude 44°22′54″E. The objective was to investigate the efficiency of the locally made system for irrigation and planting as well as fertilization, and its impact on select properties of the soil and the sunflower productivity. Specifically at the beginning stage, the experimental field was tillage with a moldboard plow with a depth of 25 cm to loosen the soil and prepare for planting. This is trailed by pulverizing the soil with a depth of tillage at 12 cm with a Rotary Tiller to obtain a similar structure for all portions and to remove any big lumps, and finally leveled with a land leveler to smooth out the surface uniformly.

The study employed two factors: the first was the irrigation–planting–fertilization system with three levels, namely subsurface drip irrigation with a continuous seed-and-fertilizer strip (F), subsurface drip irrigation with an intermittent seed-and-fertilizer strip (S), and the traditional planting and fertilization system (C). The second factor was the type of subsurface drip irrigation tube at three levels, which were the Gr tube, the T-Tape tube, and the porous tube. Various measurements were elicited, including the soil moisture content, uniformity coefficient, penetration resistance, plant growth, and plant productivity. Random sampling was utilized for obtaining dirt from the experimental field prior to beginning the project. The dirt was found to be Silty Clay Loam. The experiment was implemented using a nested design within a randomized complete block design (RCBD) framework (Jasim et al., 2023). Each treatment was randomly assigned within the blocks, and all measurements were conducted according to the experimental layout to ensure reliability and statistical validity. The least significant differences (LSD at a depth of probability at the α =0.05 significance were utilized for the research. The irrigation system utilized for this research was made from pipes with a diameter of 1.5 inches for the basic pipes, and then sub mains with a diameter of one-inch inches and then field laterals with a diameter of 0.5 inches, and then drip irrigation and emitters. It is accompanied by a water storage tank and then with a pumping unit, and then with a fertilizer storage tank. Planting was carried out using the conventional method at a depth of 6 cm, where both seeds and fertilizers were placed at the same depth, with the use of a subsurface drip irrigation system. In addition, the continuous and intermittent drip tapes were installed at the same depth (6 cm) to ensure uniformity of planting and irrigation conditions among all treatments. Further components included within the system were the main controlling switch, filters, a water flow meter, and a pressure gauge. The main unit for the irrigation system consisted of several components that function together as a system for efficient water supply to the irrigation network. A 2 m^3 water tank was used to store the water prior to pumping, from which water was drawn using an electric pump connected to a main control switch used to operate and shut down the system. Figure 1 illustrates the layout of the system.

Design of the irrigation, planting, and fertilization system

Two main factors were used for distributing seeds and fertilizers in relation to the subsurface drip irrigation pipes: the continuous system, the drip tape system. Water is delivered directly to the seeds and fertilizers, resulting in improved and accelerated germination and plant growth. In contrast, in the intermittent drip tape system, the seeds and fertilizers are spaced apart, which may affect the rate and efficiency of germination and growth compared with the continuous system. the intermittent system, and the traditional method, which serves as a substitute when using seeding and fertilizing equipment, as follows: the strip is made of a lightweight fabric material (tulle or gauze) with mesh fibers that allow the passage of air and water and dissolve upon contact with water. Seeds and fertilizers are fixed onto it in appropriate and predetermined amounts using a sewing machine, ensuring that they are distributed uniformly to guarantee good plant growth. Figure 2 shows the gauze on which the seeds are fixed

The subsurface drip irrigation system with a continuous seed-and-fertilizer strip (F) was prepared by placing the continuous planting and fertilization strip along the entire length of the tube, running parallel to the pipeline throughout its full length. This strip was fixed to the tube using adhesive tape to ensure stability during system operation and to prevent displacement (Figure 3).

In the subsurface drip irrigation system with an intermittent seed-and-fertilizer strip (S), the intermittent planting and fertilization strip was

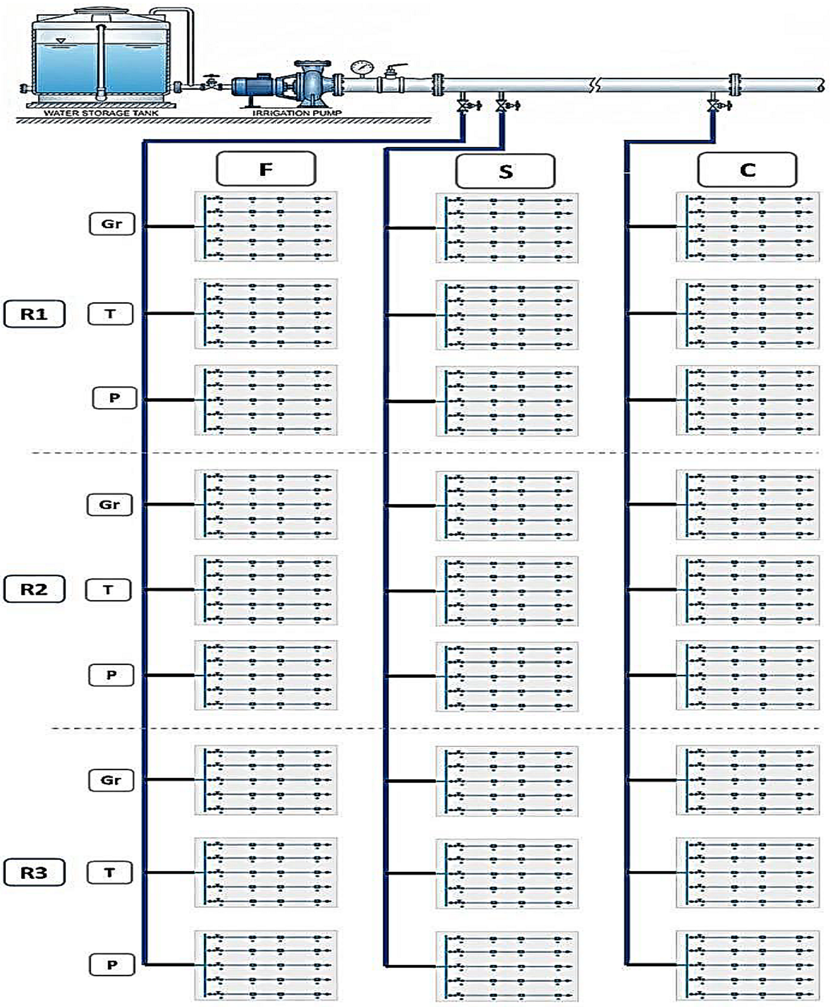

Figure 1. Schematic diagram of the irrigation system

Figure 2. The gauze on which the seeds are fixed

designed so that seeds and fertilizers are placed close to the emitters on the tube. This strip was also fixed to the tube using adhesive tape to ensure proper alignment of the seeds and fertilizers with the irrigation points (Figure 4).

In the traditional planting and fertilization system (C), seeds were sown, and fertilizers were applied directly into the soil above the emitter locations, without using any fixing strip. Seeds and fertilizers were manually placed in their designated positions along the drip line, representing the conventional planting system.

Studied traits

Soil moisture content

Soil moisture content was determined using the gravimetric method by collecting soil samples from the specified depth of the experimental field for each experimental unit using a soil core sampler. The samples were weighed before and after

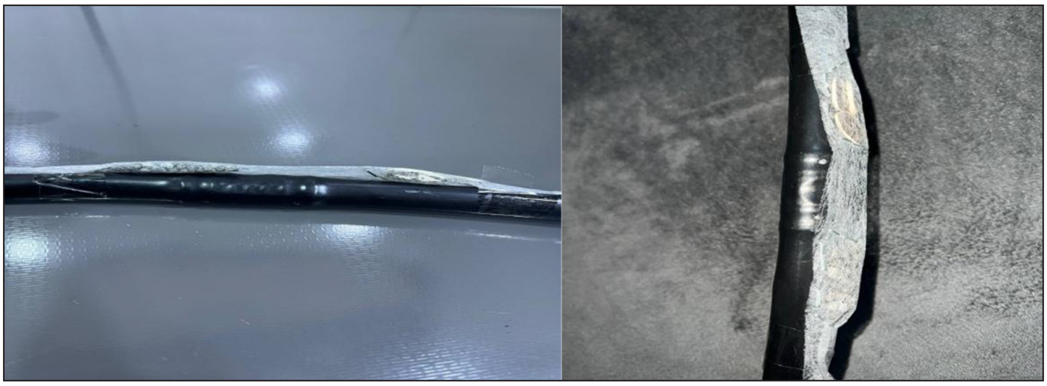

Figure 3. The continuous planting and fertilization strip along the tube

Figure 4. An intermittent seed and fertilizer strip is designed so that seeds and fertilizers are placed near the emitters on the tube

oven drying at 105 °C for 24 hours, and the moisture content was then calculated according to the standard equation (Dowad and Jasim, 2023).

$$pw = \left(\frac{Msw - Ms}{Ms}\right) \times 100\% \tag{1}$$

where: *pw* – gravimetric soil moisture content (%); *Msw* – wet soil mass in grams (g); *Ms* – dry soil mass in grams (g).

Uniformity coefficient

The Christiansen (1942) equation was used to calculate the water distribution uniformity coefficient.

$$CU = \left\{1 - \frac{\sum IXI}{m \times n}\right\} \times 100 \tag{2}$$

where: *CU* – uniformity coefficient (%); *X* – sum of absolute deviations from the average emitter discharge (L/h), *m* – mean emitter discharge (L/h), *n* – number of emitters.

Soil penetration resistance

The soil penetration resistance was measured and recorded using the electronic Cone Penetrating Meter 300 (CP300), manufactured by RIMIK Workshop, Queensland, Australia (Dowad and Jasim, 2023).

Plant height

Plant height was measured from the soil surface to the base of the disc for ten randomly selected plants from the middle rows (non-border rows) when the crop reached maturity and before harvest (Jasim and Abbas, 2023).

Plant yield

Sunflower yield was calculated based on the average yield of ten randomly selected plants from the middle rows of each experimental unit and multiplied by plant density (Jasim and Abbas, 2023).

RESULT

Soil moisture content

Figure 5 illustrates the effect of the irrigation–planting–fertilization system and the type of irrigation tubes on soil moisture content. The results showed no significant differences among the three irrigation systems in soil moisture content. However, there were important differences noticed among the types of tubes used, and the GR tube registered the highest content of soil moisture at 28.76% compared with the porous (dripper) tube, which registered the lowest at 27.81%. This can be explained by the fact that GR tubes normally possess equal rates of drainage and emitters that are not under the influence of the pressure exerted by the soil underneath, thus creating equal amounts of water distribution within the soil and improving the stability of the moisture within the root environment (Singh et al., 2023). On the other hand, differences in water drainage amounts within the porous dripper irrigation tube might occur depending on the quality and design of the emitters, thus creating differences in the amounts of soil moisture and finally reducing the content (Kandelous et al., 2012). About the interaction between the irrigation systems and types of irrigation tubes, there were important differences noticed among all combinations, and the combination between the GR and F irrigation system registered the highest content of soil moisture at 29.21% compared with the combination between the porous dripper and the C irrigation system at 27.81% among all other combinations.

Uniformity coefficient

A diagram showing the impact of the irrigation-planting-fertilization system and type of irrigation tubes on the uniformity coefficient is shown in Figure 6. The analysis showed that there were no significant differences among the three irrigation systems concerning the uniformity coefficient. On the other hand, significant differences were found among the treatments involving the tubes, and the GR tube showed the highest uniformity coefficient with a percentage value of 83.29% compared to the other tubes. On the other hand, the dripper porous tube showed the lowest uniformity coefficient with a percentage value of 77.50%. This might be due to the small holes found on the dripper tube compared to the other tubes that release water from emitters installed on them. In addition to this, the pressure required is higher on the dripper compared to the other tubes. With respect to the irrigation system and tubes interaction effect on the uniformity coefficient, there were no significant differences.

Soil penetration resistance

Figure 7 represents the effect of the irrigation-planting-fertigation process and irrigation pipes on the penetration resistance of the soil. It was observed that the three irrigation methods were similar with respect to the penetration resistance of the soil.

However, there were significant differences between the types of pipes. The GR pipe showed the lowest value for soil penetration resistance at

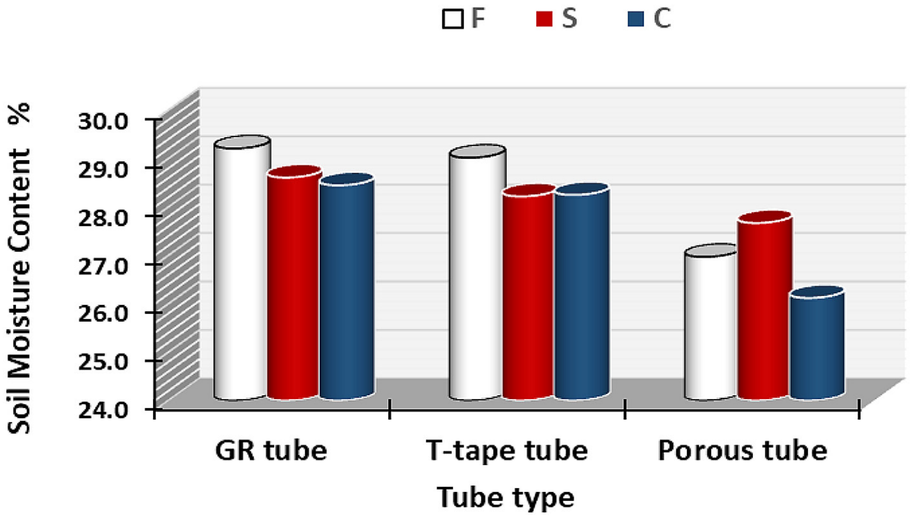

Figure 5. Effect of the irrigation–planting–fertigation system and pipe type on soil moisture content

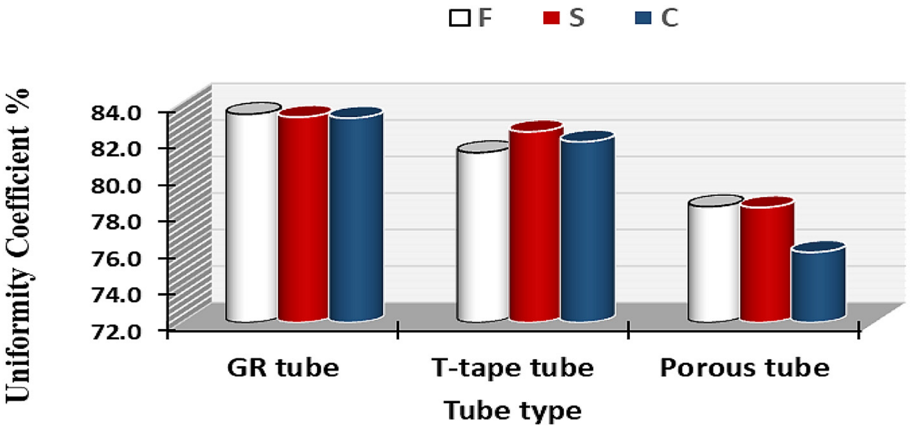

Figure 6. Effect of the irrigation–planting–fertigation system and pipe type on the uniformity coefficient (%)

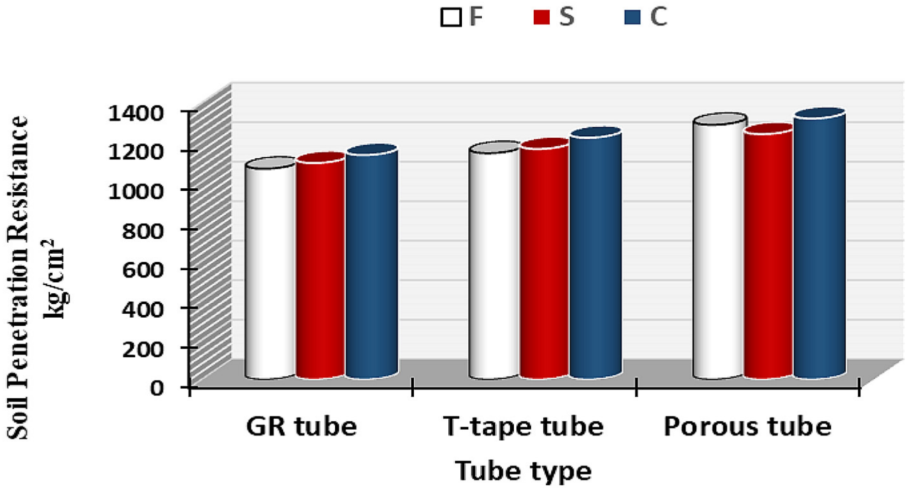

Figure 7. Effect of the irrigation–planting–fertigation system and pipe type on soil penetration resistance (kg/cm²)

1100 kg/cm², and the highest was registered for the porous (seepage) pipe at 1284 kg/cm². This may be explained by the reason that GR pipes increase the moisture content of the soil and allow for balanced water infiltration around the root zones at moderate rates, thus resulting in a low soil penetration resistance. On the other hand, the higher variability of water release associated with the porous pipe increases the values for soil penetration resistance (Arbat et al., 2021). As for the interaction between irrigation system types and pipe types on the growth response measurements listed above, no significant differences were found.

Plant height

Figure 8 depicts the impact of the irrigation-planting-fertigation system and irrigation pipes on plant height. The analysis showed that there were significant differences between the three irrigation methods and plant height. The F method showed the tallest plants at 178.4 cm. This can be explained by the fact that this method enabled the efficient and even distribution of water and nutrients through the irrigation channel compared with the other two methods, and this promoted root water efficiency and vegetative growth (Elmaloglou and Diamantopoulos, 2009). On the other hand, the conventional method (C) showed the shortest plants at 163.9 cm. This is due to the unbalanced distribution of water around the root zone and variability in water content during the critical growth stages for limited stem growth. Significant differences were observed between the three types of pipes. The GR pipes showed the tallest plants at 179.1 cm. This is due to the pipes' uniform outlet and water output for a stable and optimal moisture content that supported vegetative growth and root water nutrients' efficiency (Arbat et al., 2021). Conversely, the porous (seepage) pipe showed the

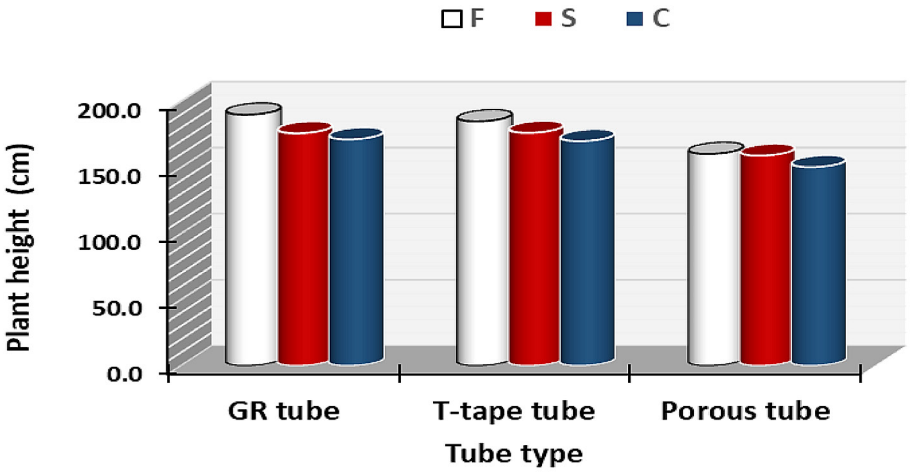

Figure 8. Effect of the irrigation–planting–fertigation system and pipe type on plant height (cm)

shortest plants at 156.6 cm. This can be clarified by the unbalanced water release and possible blockage by particles and debris leading to an unbalanced root zone and water content for limited stem growth (Ascough and Kiker, 2002). Regarding the interaction between irrigation methods and types of pipes, significant differences were observed. Together, the F method and GR pipe showed the tallest plants at 190.0 cm. This can be explained by the combination of the efficient water distribution produced by the F method and the optimal outlet of GR pipes for the best root zone environment with optimal moisture content for enhanced vegetative growth (Lamm and Ayars, 2023). Together, the C method and the porous pipe showed the shortest plants at 156.6 cm. This can be clarified by the combination of the unbalanced irrigation and the root zone conditions produced by the C method and the unbalanced root zone conditions from the porous pipes, leading to repeated water deficiencies for reduced growth (Camp, 1998).

Plant yield

Figure 9 illustrates the effects of irrigation–planting–fertigation setup and type of irrigation piping on plant yield. From the data presented, there is distinct variation among the three irrigation systems; the highest yield produced by F was 6.60 t/ha, whereas C yielded a crop of 4.70 t/ha. Indeed, F had superior advantages due to the homogeneity in water distribution and proper supply of water and fertilizers in the root zone, which enhances absorption and motivates growth, increasing the yield accordingly (Arbat et al., 2021). The yields among the three pipe types also vary significantly. The yield from the GR pipe is the highest at 8.30 t/ha, while the porous (seepage) pipe has the lowest at 4.10 t/ha. From this, it is clear that the advantage of GR pipe is its evenly spaced internal emitters and steady discharge, which cut moisture variation around the root, provide water availability steadily, support root growth

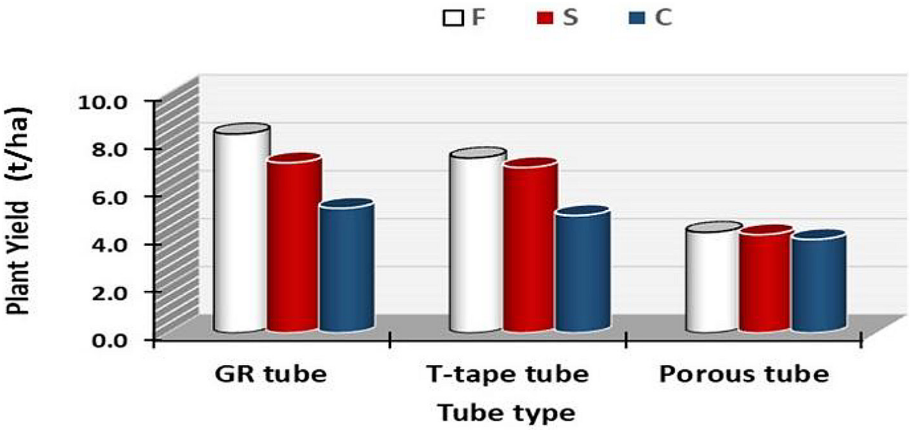

Figure 9. Effect of the irrigation–planting–fertigation system and pipe type on plant yield (t/ha)

continuously, and result in higher nutrient uptake efficiency, hence driving higher yield (Lamm and Ayars, 2023). When the interaction of irrigation systems and pipe types is considered, significant differences are evident. The most productive combination is that of the GR pipe with the F system, producing 8.30 t/ha, while the least productive is the porous pipe with the C system at 4.10 t/ha. This result is indicative of the fact that the F system's efficiency in water distribution is combined with the GR pipe's unique characteristics of constant discharge and homogeneous wetting pattern, leading to the most favorable moisture and nutrient regime in the root zone, thus stimulating growth and productivity. In other combinations, these benefits are not utilized, and the yield is considerably lower (Camp, 1998).

CONCLUSIONS

The results demonstrated the effectiveness of the integrated irrigation–planting–fertilization system in improving crop performance under the studied conditions. The subsurface drip irrigation system combined with a continuous seed-and-fertilizer strip (F) and the GR tube consistently produced superior outcomes compared with the other treatments, reflecting enhanced water distribution, improved nutrient availability, and better root–soil interaction. The interaction between the F system and the GR tube further strengthened these benefits, confirming their capability to enhance key agronomic traits and improve overall production efficiency. Based on these findings, it is recommended to adopt the locally developed irrigation–planting–fertilization system as a more efficient and productive alternative to traditional planting methods. Future research should expand the evaluation of this system across different crops, soil conditions, and climatic environments to further validate its applicability and optimize its performance.

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