sustainability

MDPI

Article

Effect of Planting Geometry on Growth, Water Productivity, and Fruit Quality of Tomatoes under Different Soil Moisture Regimes

Mir Moazzam Ali Talpur [1,†], Hiba Shaghaleh [2,†], Amar Ali Adam Hamad [2], Tingting Chang [1], Muhammad Zia-ur-Rehman [3], Muhammad Usman [2] and Yousef Alhaj Hamoud [4,*]

1 College of Agricultural Science and Engineering, Hohai University, Nanjing 210098, China; changtt@hhu.edu.cn (T.C.)
2 College of Environment, Hohai University, Nanjing 210098, China; lx20210505010@hhu.edu.cn (M.U.)
3 Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad 38000, Pakistan
4 College of Hydrology and Water Resources, Hohai University, Nanjing 210098, China
* Correspondence: yousef-hamoud11@hhu.edu.cn
† These authors contributed equally to this work.

Abstract: The present study investigated the impact of planting spacing on tomato crop growth, water productivity, and fruit quality under different water regimes. Thus, a field experiment was conducted using a randomized complete block design in a factorial arrangement of treatments. The tomato plants were grown at three planting spacing patterns: 30 cm row-to-row planting spacing, 60 cm row-to-row planting spacing, and 90 cm row-to-row planting spacing, which were marked as (G_1), (G_2), and (G_3), respectively. For each planting spacing pattern, irrigation regimes, namely (I_1), (I_2), and (I_3), were established by setting the soil moisture content to 50%, 100%, and 150% of the reference evapotranspiration. The $I_3 \times G_2$ combination resulted in the maximum values of plant height (68.2 cm), stem diameter (12.1 mm), and yield (41,269.9 kg/hm^2), providing the highest contents of protein (1.93 mg/kg), fat (0.81%), fiber (3.94%), and lycopene (4.00 mg/kg) of the fresh fruit. Conversely, the $I_1 \times G_1$ led to the minimum values of plant height (37.3 cm), stem diameter (5.65 mm), and yield (7814.7 kg/hm^2), providing the lowest contents of protein (1.15 mg/kg), fat (0.50%), fiber (2.39%), and lycopene (2.15 mg/kg) of the fresh fruit. The $I_1 \times G_1$ had the highest water productivity (25.06 kg/m^3) value, while the lowest WP (10.23 kg/m^3) value was achieved by $I_3 \times G_3$. While the $I_1 \times G_3$ treatment minimized the uniformity coefficient and distribution uniformity, the $I_3 \times G_3$ treatment maximized their values, indicating more uniform water distribution. Our findings indicate that the $I_3 \times G_2$ combination can increase tomato productivity, growth, and fruit quality. However, the $I_1 \times G_1$ performed better in terms of water productivity. The results of this study can positively contribute to improving tomato production systems' sustainability, productivity, and quality under the increasing problem of climate change.

Keywords: water regime; planting spacing; water use efficiency; fruit quality; *Solanum lycopersicum*

Citation: Talpur, M.M.A.; Shaghaleh, H.; Ali Adam Hamad, A.; Chang, T.; Zia-ur-Rehman, M.; Usman, M.; Alhaj Hamoud, Y. Effect of Planting Geometry on Growth, Water Productivity, and Fruit Quality of Tomatoes under Different Soil Moisture Regimes. *Sustainability* **2023**, *15*, 9526. https://doi.org/10.3390/su15129526

Academic Editor: Teodor Rusu

Received: 13 May 2023
Revised: 7 June 2023
Accepted: 13 June 2023
Published: 14 June 2023

1. Introduction

Climate change is an increasing problem in the changing world and is associated with water scarcity, food anxiety, environmental pollution, and the rapid growth of the world's population [1]. Therefore, the rapidly growing population has put much strain on agricultural resources to meet the rising demands for food. Thus, there is an urgent need to increase food production under changing climate conditions to cope with the increasing demand for food [2]. Hence, agriculture is now facing the challenge of increasing the crop yield per unit area.

Irrigation is the leading freshwater user and is the primary component in improving crop production [3]. However, irrigation management, which regulates water use efficiency

(WUE), is the primary component in enhancing the amount and timing of water application. Numerous variables, such as crop water demands, plant development stage, variety of crops and variations, weather conditions, and physiochemical soil characteristics, determine an irrigation system's water-holding capacity [4]. Moreover, the evapotranspiration rate of a crop is comparable to its requirement for water, which is the quantity of water the crop requires to replace the loss of water through evapotranspiration [5]. Therefore, irrigation water management is of the utmost importance [6] since water application is the most important factor determining the sustainability of agricultural cropping systems. Due to environmental degradation and climate change, freshwater is becoming increasingly scarce [7]. In addition, limited freshwater resources are available, while urban areas and industrial plants are overgrowing [8]. Furthermore, global warming is anticipated to exacerbate water scarcity by raising evapotranspiration and drought severity from 1% to 30% by 2100 [9]. At the same time, water scarcity has been a serious problem for sustainable development worldwide. Thus, water shortage and food security challenges must be minimized by improving water productivity and increasing the crop yield per unit cultivated area.

Drip irrigation (DI), as a water-saving method, is a very good water management option for locally grown produce as it uses minimal freshwater and can be applied easily. DI is also an inexpensive and risk-free irrigation method [10]. Additionally, DI is an efficient technique for delivering water and plant nutrients to the root area, and it helps to conserve water while increasing crop yield [11]. Therefore, DI is widely implemented as the most water-efficient way to irrigate crops [12]. However, the amount of irrigation water supplied and planting spacing play a significant role in determining the best performance of a DI system [13]. Consequently, crop response to variations in soil water content and planting spacing is of utmost interest in modern cropping systems.

Crop geometry is key to maximizing harvests [14]. By doing so, it is feasible to maximize the uptake of solar energy and use underground resources, enhancing photosynthetic formation. The term "efficiency" refers to a means by which a goal is attained while expending the fewest possible resources (time, money, and resources) [15]. Particularly, it has been demonstrated that irrigation water is a major factor in agricultural yields, and DI is superior to other approaches [16]. However, to maximize crop yield and quality and minimize water waste, it is important to consider plant spacing and irrigation scheduling when designing DI systems [17]. Therefore, DI and planting spacing offer the prospect of lowering evaporation and, consequently, enhancing crop water productivity as they do not moisten the entire surface of the soil [18].

The second most often consumed vegetable is the tomato (*Solanum lycopersicum* L.), which is widely cultivated and the most recommended fruit in the world [19]. However, with the world's population growing alarmingly, there is an urgent need to boost agricultural output to warrant food security [20]. According to Chanthini et al. [21], 2020, global tomato production was 186,821 million metric tons. This substantial yield was achieved across an area of 5,051,983 hectares, resulting in an average productivity of 37.1 metric tons per hectare. Furthermore, depending on the climate, the overall water requirements of tomato crops cultivated in the field for 90–120 days after transplanting are 400–600 mm, relying on the weather [22]. Accordingly, due to water scarcity, it is critical to find the ideal DI and plant spacing strategies for optimal tomato growth, water productivity, production, and quality.

Tomato crops require a regulated water supply during expansion for optimal yield quality. However, the ontology of tomatoes is extremely sensitive to water stress, which negatively impacts growth, yield, fruit quality, and shelf life, particularly when the organism has reached its physiological maturity. Subsequently, severe water stress causes substantial reductions in overall plant growth, leaf proportionate water content, the conductance of stomatal pores, and yield, and other physiological traits of plants are involved [23].

Fresh tomatoes are important because their nutritional value contributes substantially to the human diet. Fresh tomato contains vitamins A and C, protein, ascorbic acid, sugars, fibers, and fats [24]. It has been identified that the timely discovery of water stress symptoms in tomatoes is vital to maintaining the good fruit quality of tomatoes. For instance, tomato under timely water stress conditions inhibits vegetative plant growth but boosts fruit quality. However, plants may reduce fruit quality when subjected to severe abiotic stress [25]. Therefore, examining the effect of DI and plant spacing practices on tomato fruit quality and shelf-life is essential. Thus, analytical calculations detailing the efficiency of various planting geometries and irrigation schedules are required. However, there have only been a few prior attempts to analyze the benefits and drawbacks of different DI regimes and planting geometries. Hence, the main aims of the present study were to determine how the growth, water productivity, and fruit quality of tomatoes are influenced by varied planting geometries under varied irrigation regimes in a field trial.

2. Materials and Methods

2.1. Experimental Site Description

This open-field experiment was carried out from September to December 2021 at the agriculture farm of Chukhi (25°30′ N. 68°58′ E), Hyderabad, Pakistan. The region's climate is semi-arid, with an annual average temperature of 32 °C. The absolute highest temperature reaches 41 °C, while the absolute lowest temperature falls to 8 °C. The yearly average rainfall in the region is 36 mm. The average monthly precipitation and temperature for the experimental year (2021) are displayed in Table 1.

Table 1. Average monthly climate records.

Month	September	October	November	December
Min. temp °C	22	17	12	8
Max. temp °C	40	41	40	33
Max. relative humidity%	90	49	8	1
Min. relative humidity%	51	8	1	0
Solar Rad. MJ m^{-2} day^{-1}	32.9	27.1	21.9	19.51
Sunshine (h)	12	11	11	10

Note: The climatological information came from the Hyderabad, Pakistan using the weather station (Onset, RX3000, InTemp, Houston, TX, USA).

2.2. Soil Analysis

The soil is categorized as loam clay textured soil based on USAD. The main physiochemical properties of the experimental soil are presented in Table 2. The soil texture was measured by the Bouyoucos hydrometer (ASTM 152H, Humboldt Mfg. Co., Elgin, IL, USA) [26]. Soil pH was measured using the pH meter [27] in a soil and water extract (1:5). Soil total organic carbon content was measured by the oxidation method [28] using a test tube heater, and a 2 g soil sample was decomposed in a mixture of selenium sulfate and salicylic acid (Hanna HI839800, Woonsocket, RI, USA). The temperature for processing was 100 °C for 30 min and then 380 °C for 3 h [29]. A spectrophotometer was used to measure the level of available nitrogen in the digest obtained (UV-1800, Shanghai, China) [30]. A flame photometer was used to find out how much potassium was in the soil (FB640N, Hunan Firstrate Sensor Co., Ltd., Changsha, China) [31]. The spectrophotometric method was used to measure available soil phosphorus [32].

Table 2. Basic properties of soil in the study area and irrigation water use.

Property	Soil	Irrigation Water
Clay%	47.1	
Silt%	9.3	
Sand%	43	
Field capacity%	36.2	
Porosity%	47.8	
Plant extractable water%	12	
Permanent wilting point%	24.2	
Bulk density g/m^3	1.15	
Organic matter%	0.70	
CEC cmol/kg	0.64	1.1
pH value	8.2	8.3
Total nitrogen%	0.019	
Phosphorus g/kg	2.50	
Potassium g k/g	246	0.03

Note: Average values for three replicates of each measured property; CEC donates cation exchange capacity of the soil.

2.3. Experimental Design, Cultural Practices, and Irrigation System

The current trial was conducted in a completely randomized block design with three repetitions. Planting geometry was the main treatment with three different management practices: 30 cm row-to-row planting spacing (G_1), 60 cm row-to-row planting spacing (G_2), and 90 cm row-to-row planting spacing (G_3) (Figure 1).

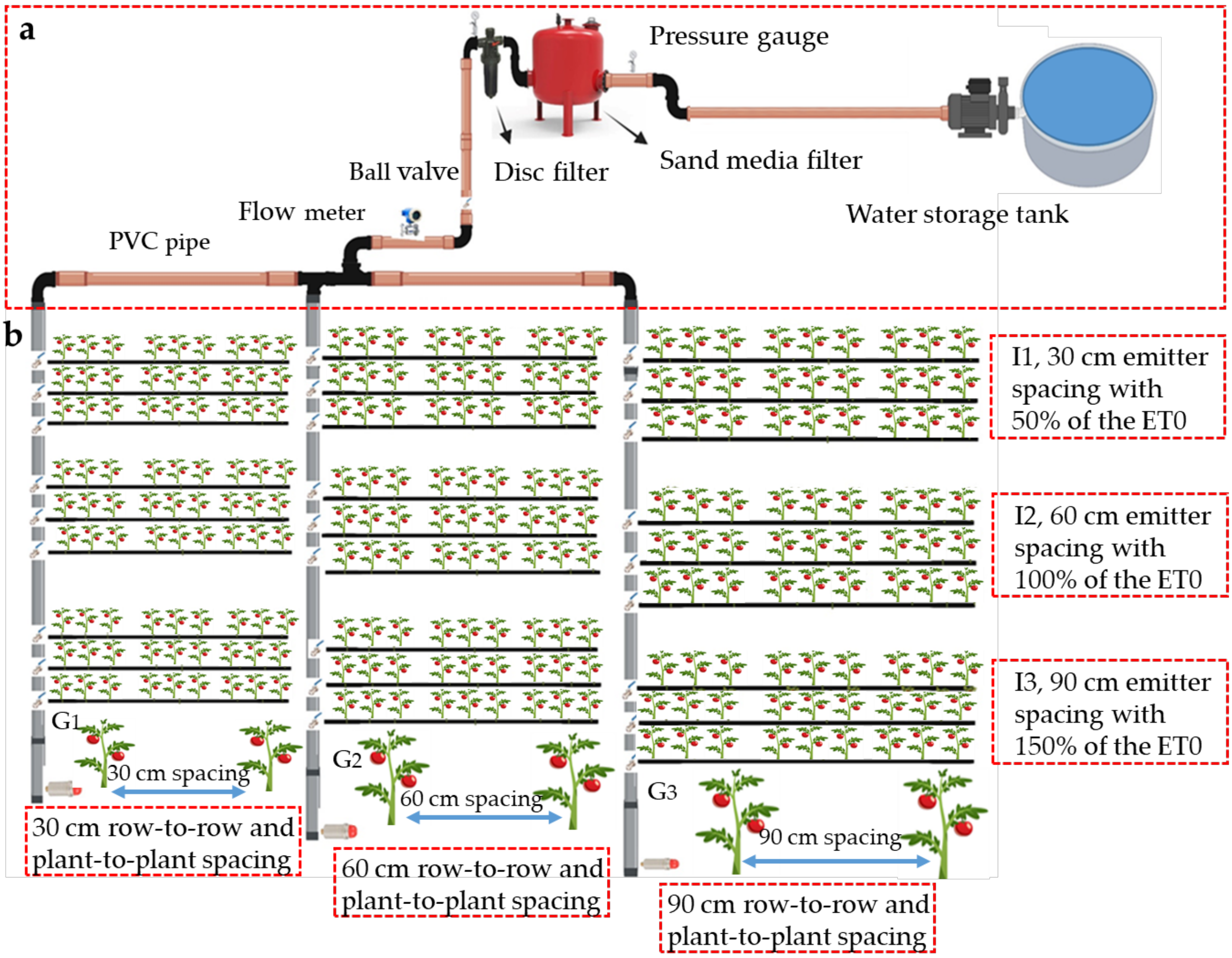

Figure 1. (**a**,**b**) The experimental design and plant transplantation.

The sub-treatment was the water regime with three distinct DI strategies termed I_1, I_2, and I_3. The three irrigation plots were implemented, including varying emitter spacing as the following: I_1 treatment received 50% of the reference evapotranspiration with emitters placed at a 30 cm distance, I_2 treatment received 100% of the reference evapotranspiration with emitters placed at a 60 cm distance, and I_3 treatment received 150% of the reference evapotranspiration with emitters placed at a 90 cm distance.

The plant's irrigation water demands were calculated as follows: With 3-day intervals during the growing season, volumetric moisture content (W_V, %) was detected using a Mini Trace System-Soil Moisture Equipment Corp time-domain reflectometer (Santa Barbara, CA, USA). At the beginning and end of the process of growth, irrigation was maintained while the soil dried completely throughout the maturation phase. The soil moisture deficit was determined analytically using the equation:

$$W_D = \frac{W_v t1 - W_v t2}{100} \times D_Z \times 10 \quad (1)$$

where W_D is the soil moisture deficit (mm), W_V t1 and W_V t2 are the root zone volumetric moisture contents (%) by time t1 and t2, respectively; D_Z denotes root zone depth (cm).

The following equation was used to calculate water quantities for treatments:

$$I = W_D \times R_n \quad (2)$$

where I is the irrigation water (mm), W_D is the soil water deficit prior to irrigation (mm), and R_n is the rate of water deficit (0.5 for I_{50}, 1.5 for $I_{150,}$ and 1.0 for I_{100}).

Using the water balance method, crop evapotranspiration was calculated:

$$ET_C = I + \Delta_{ms} - R - D \quad (3)$$

where ET_C (mm) represents crop evapotranspiration, I (mm) represents irrigation water, Δ_{ms} (mm) represents soil moisture storage change, and R and D (mm) represent losses resulting from runoff and percolation, respectively. R and D have no bearing on the DI method. As a result, Formula (3) can be shortened:

$$ET_C = I + \Delta_{ms} \quad (4)$$

After plowing and laddering, the soil plots were ready for planting. Each plot (6 m × 9 m) was prepared by 9 rows with row lengths ranging from 3 m to 9 m, divided by ridges to minimize water movement between treatments. A local tomato variety T-1057, a commonly planted cultivar and one of the most regularly used varieties in Hyderabad, Pakistan's planting zones, was used in this trial. The seeds were cultivated in a nursery, and after 10 days of emergence, seedlings were transplanted from the nursery plots to the experimental plots. On 12 September 2021, tomato seedlings were planted in the plots at the crop density (81 plants/m^2).

As base doses, the fertilizers applied were urea (46% N), superphosphate (12%, P_2O_5), and potassium chloride (60% K_2O) as N, P, and K fertilizers, respectively, which were applied at the rates of 80 kg ha^{-1} (N), 80 kg ha^{-1} (P), and 90 kg ha^{-1} (K), respectively. Two months after planting, a side-dressing of 25 kg ha^{-1} (N) was supplied. Then, a DI system was installed and supplied irrigation water to the experimental plots via pipelines, with a 2.24 kW electrical monoblock pump extracting water from a storage reservoir (45 m^3) located at the high point of the blocks and turning in the contributing system and operating at a pressure of 2 MPa. The sub-main pipe was attached with main pipe lengths of 15, 30, and 40 m, each having 32 mm diameters. Each emitter was discharged at a rate of 12 L/h. In the center of each treatment plot (Figure 1), a separate drip tube was installed. The irrigation water utilized in the experiment was pure and nutrient-free. The water for irrigation used in the experiment was pure and nutrient-free. According to regional agricultural practices, the plots were intensively managed, i.e., frequently weeded by hand, and insect attacks and crop diseases were properly managed to save yield loss. The crop was harvested on 4 December 2021. The total growth period was 117 days across all regimens.

2.4. Collection of the Data

2.4.1. Measurements of Plant's Morphological Traits

The plant height (cm) was detailed manually using a steel scale. A high-precision digital caliper was used to measure the stem diameter (SD, cm) at the plant's base, middle, and top at maturity.

2.4.2. Fresh Fruit Yield, Yield Components, and Water Productivity

At maturity, each treatment's fresh fruit had been collected by hand. The fresh fruit weight (FFW, kg) was determined by preparing, labeling, and weighing the samples.

For each treatment, yield (t/ha) was also estimated by adding the entire fruit weight for each treatment. The following factors determined the water productivity:

$$WP = \frac{Y}{TWU} \quad (5)$$

where WP (kg/m^3) is WUE, Y (kg) is the fruit yield, and TWU (m^3) is the total water consumption.

2.4.3. Determination of Fruit Quality

The Kjeldahl apparatus determined the crude protein amount (%). By using concentrated H_2SO_4 and Cu as a catalyst, acid digestion was used to turn the nitrogen in protein molecules into ammonium sulfate. By distilling a solution of H_3BO_3, NH_3 was caught. A 0.01 N H_2SO_4 was used to test this solution. The following formulas were used to get the crude protein:

$$\begin{gathered} N(\%) = \frac{\text{Volume of acid(mL)} \times \text{acid(N)} \times 0.014}{\text{weight of sample(g)}} \times 100 \\ \text{Crude protein}(\%) = N \times 6.25 \end{gathered} \quad (6)$$

Crude fat (%) was calculated with a Soxtec 2055 extraction unit (Tecator, Höganäs, Skåne, Sweden). Fruit samples were taken in an aluminum thimble installed under the extracting machine's condenser. Afterward, 40 mL of ether was filled in the beaker and put on the condenser. After turning on the water extraction system, it was operated for 16 h. The ether was used to clean the tube after the sample was taken. After that, we oven-dried the ether extract and placed it in a desiccator.

$$\text{Crude fat}(\%) = \frac{\text{Weight of ether extract}}{\text{weight of sample(g)}} \times 100 \quad (7)$$

For crude fiber (%), a 1 g pulverized fruit sample was placed in a flask with 200 mL H_2SO_4 for acid digestion for 30 min, then rinsed with water and lactic acid. Following acid digestion, 200 mL of NaOH was added to the sample for 30 min of base digestion. Then, the sample was washed again with water and acetone. After that, the leftover fiber remnant was placed in a crucible, weighed, and placed at 70 °C. After drying, it went through ashing in a furnace at 600 °C. A second time, the sample was weighed and we applied the Formula (8).

At 503 nm, a spectrophotometer determined the lycopene content (mg/kg). To make their juice pulp, samples of fresh tomato fruits were taken for this. Then, 3 mL of tomato pulp juice was added to 8 mL of the extraction mixture [33]. Then, the test tube was shaken well by an automatic shaker, and the white deposit was skimmed. This layer was put into the small glass cuvette, and an atomic spectrophotometer was used to measure lycopene content at a wavelength of 553 nm. Then, the absorbance (A503) was logged and applied the following equation.

$$\text{Lycopene}(\text{mg/kg}) = \frac{A503}{137.5} \quad (8)$$

2.4.4. Uniformity Coefficient (UC) and Distribution Uniformity (DU) of Exiting Drip System for Tomato Plants

The efficiency of irrigation systems must be assessed on paper as a design and management criterion and in the field as an operational criterion. For more than four decades, the present system's uniformity coefficient and distribution uniformity have been measured in treatment plots with different planting geometries and irrigation schedule treatments [34]. As recommended by [35], the water depth in the formula [36] was replaced with the drip discharge rate to determine the uniformity coefficient in DI. The volumetric discharge of the emitter was measured at the head, middle, and tail ends of the laterals. The measurements were conducted for 15 min. Using an equation, the uniformity coefficient was derived.

$$\mathrm{CU}(\%) = 100 \times \left(1 - \frac{\mathrm{D}}{\mathrm{M}}\right) \tag{9}$$

where D denotes the average absolute deviation from the mean discharge rate, and M symbolizes the average discharge rate.

The following relationship was used to determine distribution uniformity, representing the degree of uniformly water application across the area [37].

$$\mathrm{DU}(\%) = \frac{\text{Average low quarter depth of water caught}}{\text{The average depth of water caught}} \tag{10}$$

where acceptable values for DU are more than 0.7.

The coefficient of variation (CV) was calculated as the percentage of the standard deviation of the emitter discharge to the average flow rate. The CV was detailed by the following formula [38]:

$$\mathrm{CV} = \frac{Sq}{qa} \times 100 \tag{11}$$

where CV is the emitter flow coefficient of variation, Sq is the standard deviation of emitter flow in L/h, and qa is the average emitter flow rate in L/h.

2.5. Statistical Analysis

Statistical software IBM-SPSS, version 28.0.1.1 (19, USA) was employed for analyzing the data. The two-way analysis of variance (ANOVA) was performed utilizing the general linear model procedure. While p values were statistically significant ($p \leq 0.05$), mean values were compared using Duncan's multiple range test at a significance level 0.05.

3. Results

3.1. Effect of Irrigation Regime and Planting Geometry on the Growth of Tomato

The irrigation regimens significantly improved the morphological characteristics of plant shoots across all planting geometry treatments (Figure 2). This positive impact grew from the 60 cm planting spacing (G_2), was intermediate in the 30 cm planting spacing (G_1) treatment, and the lowest plant height and stem diameter were measured in the 90 cm planting spacing (G_3) treatment. Under the same planting spacing treatment, the irrigation treatments displayed a different response in terms of plant height and stem diameter, where their values decreased due to a reduction in water application during I_3 (water applied at 150% water applied at), I_2 (water applied at 100% of the evapotranspiration) treatment, and I_1 (water applied at 50% of the evapotranspiration). Additionally, the combined treatment $I_3 \times G_2$ showed the greatest plant height values (68.2 cm) and stem diameter (12.1 mm), respectively. In contrast, the lowest plant height and stem diameter values were observed for the combined treatment $I_1 \times G_2$, which corresponded to (37.3 cm) and (5.65 mm), respectively (Figure 2a,b).

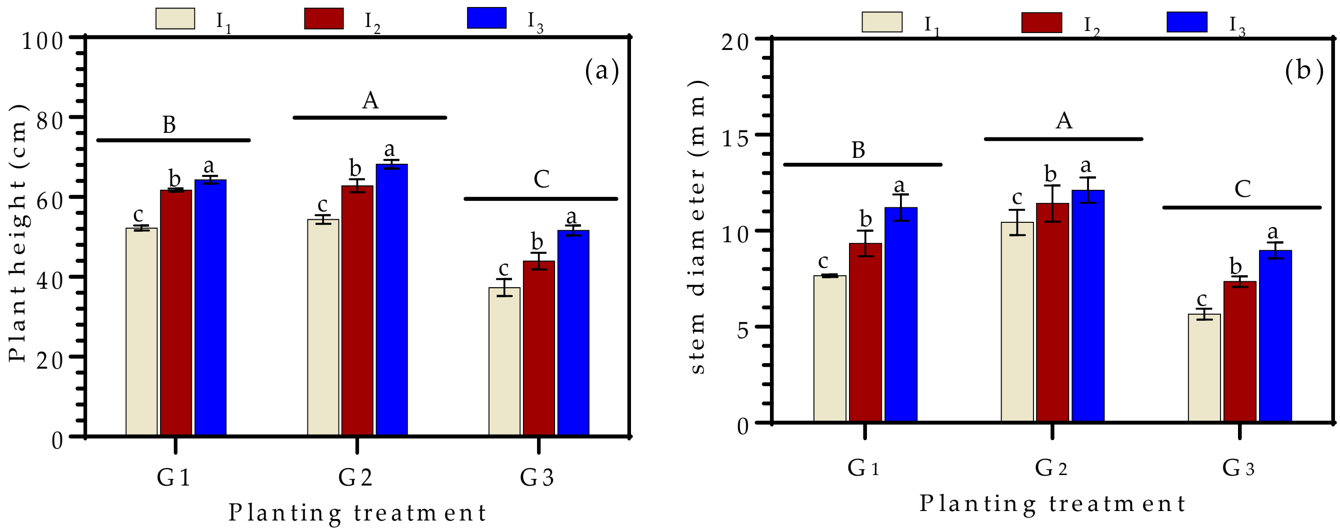

Figure 2. Effect of planting geometry and watering regime on the plant height (**a**) and stem length (**b**) of tomato under different treatments. G_1, $G_{2,}$ and G_3 denote 30, 60, and 90 cm planting space and I_1, $I_{2,}$ and I_3 irrigation regimes, with 50%, 100%, and 150% of the evapotranspiration, respectively. The significant differences on the base of Duncan's multiple range test at a significance level of 0.05 are denoted by uppercase and lowercase letters above the grouped column and error bars.

3.2. Impact of Different Water Regimes and Planting Geometries on Fresh Yield and Tomato Yield Components

The ANOVA analysis of tomato production differed depending on the planting geometry, water regime, and their interaction (Figure 3). The average fruits per plant, yield index, and tomato yield boosted with rises in water amount under the same planting geometry treatment, where their values increased during I_1, I_2, and I_3, respectively. Moreover, for the same irrigation regime, the lowest fruits per plant, yield index, and fruit yield were in G_3, followed by G_1, while the highest was in G_2. In a continuous context, the fruits per plant, yield index, and fruit yield elevated significantly ($p \leq 0.05$), with increases in water supply, and reached their maximum values ((33.6 fruit/plant), (942.4 kg), and (41,269.9 kg/hm^2)) at the combination $I_3 \times G_2$. In contrast, the minimum values ((12.6 fruit/plant), (439.3 kg), and (7814.7 kg/hm^2) were obtained by the combination $I_1 \times G_3$ (Figure 3a–c).

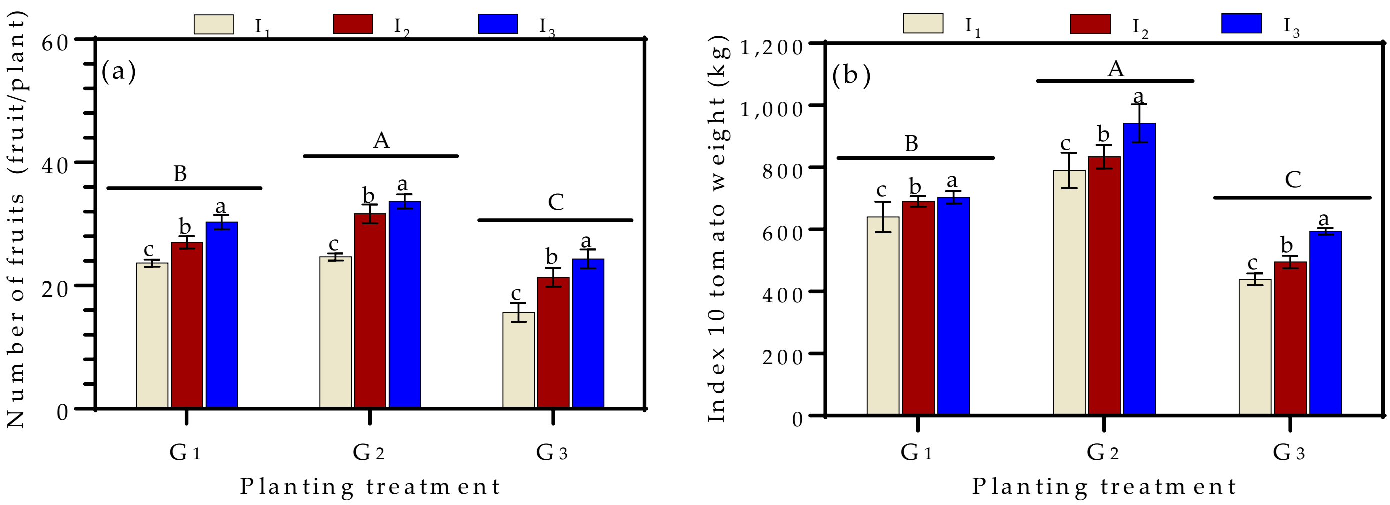

Figure 3. *Cont.*

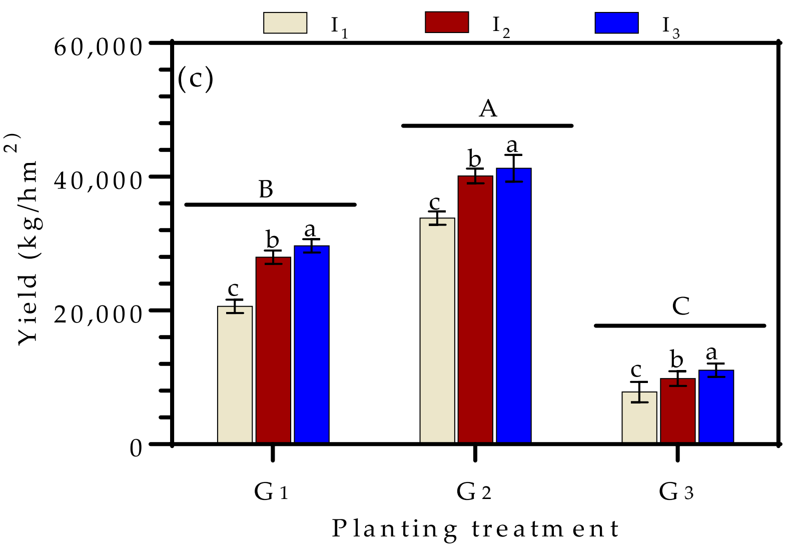

Figure 3. Impact of planting geometry and watering regime on tomato fruits per plant (**a**), yield index (**b**), and fresh yield (**c**) under DI treatments. G_1, G_2, and G_3 denote 30, 60, and 90 cm planting space and I_1, I_2, and I_3 irrigation regimes, with 50%, 100%, and 150% of the evapotranspiration, respectively. The significant differences are shown by uppercase and lowercase letters above the grouped column and error bars. This is based on Duncan's multiple range test at the 0.05 significance level.

3.3. Effect of Different Watering Regimes and Planting Geometries on Water Use (WU) and Water Productivity (WP)

Significant variations ($p \leq 0.05$) among planting geometry and water regimes were noticed for the WU of tomatoes. For the planting spacing treatments, the maximum value of WU was detected in the G_3 treatment, followed by the G_2 treatment, while the minimum value of WU was detected in the G_1 treatment. For the water treatments, the WU increased during the I_1, I_2, and I_3 regimes, respectively. The results specified that the $I_3 \times G_3$ treatment reflected the maximum WU (433.5 mm) compared to other treatments. Compared to other treatments, the minimum value of 159.4 mm was realized by the $I_1 \times G_1$ combined treatment (Figure 4a).

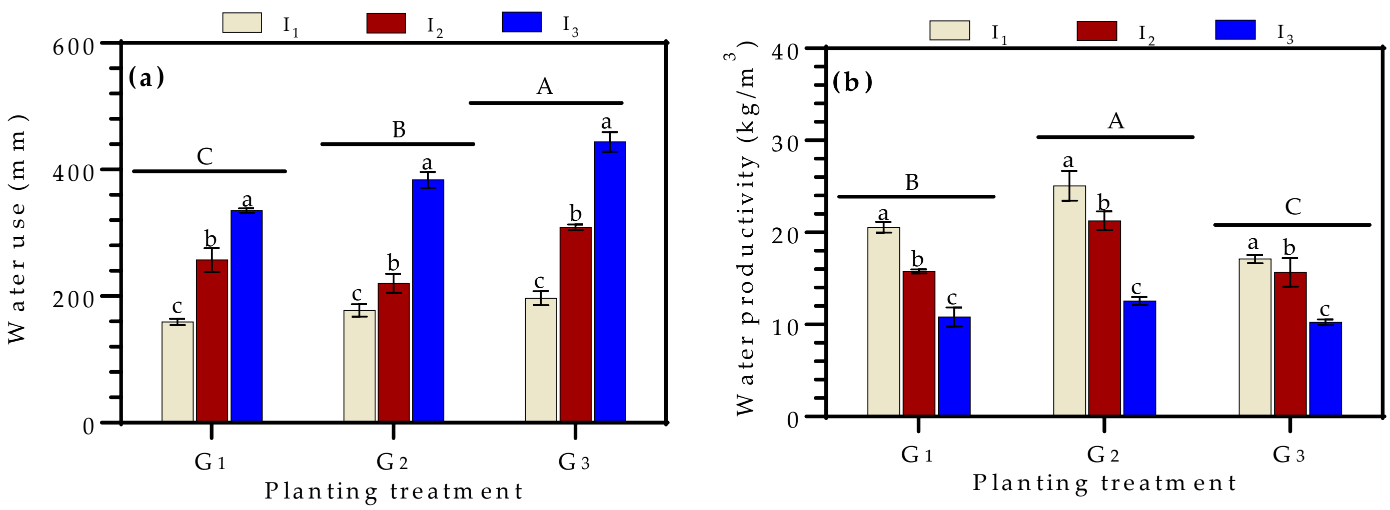

Figure 4. Effect of planting geometry and irrigation water regimes on water use (**a**), and water productivity (**b**) under varied watering regimes. G_1, G_2, and G_3 denote 30, 60, and 90 cm planting space and I_1, I_2, and I_3 irrigation regimes, with 50%, 100%, and 150% of the evapotranspiration, respectively. The significant differences are shown by uppercase and lowercase letters above the grouped column and error bars, on the base of Duncan's multiple range test at the 0.05 significance level.

Significant variances ($p \leq 0.05$) among planting geometry and irrigation regimes were identified for the WP of tomatoes. For the planting spacing treatments, the WP seemed to improve with the increase in fruit yield, despite the reduction in water use. The greatest value of WP was achieved by the G_2 treatment, followed by the G_1 treatment and the G_3 treatment, respectively (Figure 4a,b). The irrigation treatments presented similar trends, where the WU increased with fruit yield, although water use was reduced during the I_1, I_2, and I_3 regimes, respectively.

The results specified that the $I_1 \times G_2$ combined treatment reflected the maximum WP (25.06 kg/m^3) compared to other treatments. However, the minimum value of 10.23 kg/m^3 was achieved by the $I_3 \times G_3$ treatment compared to other treatments (Figure 4b).

3.4. Effect of Different Watering Regimes and Planting Geometries on Tomato Fruit Quality

The tomato's fruit quality was considerably affected by planting geometry and water regimes (Figure 5a–d). The most advantageous characteristic of tomato fruits is their high protein content, and ANOVA analysis revealed that the tomato protein content decreased consistently as water stress increased during I_3, I_2, and I_1 regimes, respectively. Across the planting spacing treatments, the highest protein of tomato fruit was found under the G_2 treatment, followed by the G_1 treatment, while the lowest protein content was found in the G_3 treatment (Figure 5a). The method through which the tomato plants were planted and how they were watered obviously affected the tomato protein content. The $I_3 \times G_2$ treatment reflected the maximum protein content (1.93 mg/kg) compared to other treatments. However, the minimum value of protein content (1.15 mg/kg) was realized by the $I_1 \times G_3$ combined treatment compared to other treatments (Figure 4a).

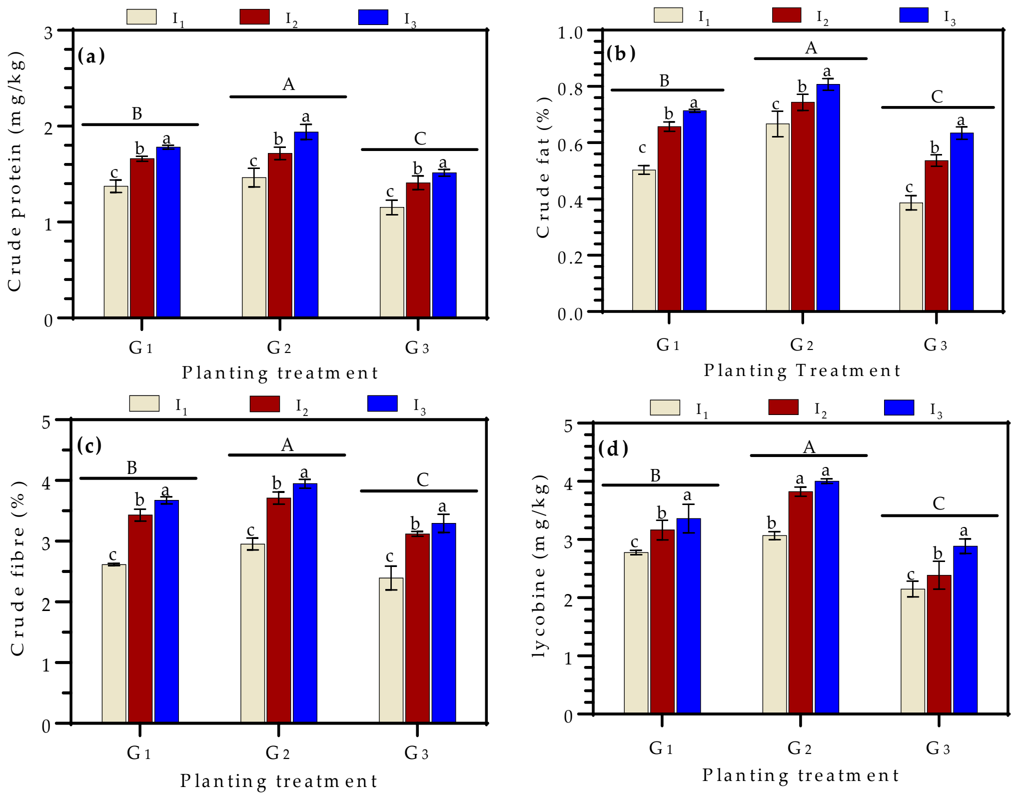

Figure 5. Impact of planting geometry and watering regimes on crude protein (**a**), crude fat (**b**), crude fibre (**c**), and lycopene (**d**) of tomato plants under DI treatments. G_1, G_2, and G_3 denote 30, 60, and 90 cm planting space and I_1, I_2, and I_3 irrigation regimes, with 50%, 100%, and 150% of the evapotranspiration, respectively. The significant differences on the base of Duncan's multiple range test at a significance level of 0.05 are denoted by uppercase and lowercase letters above the grouped column and error bars.

The best thing about tomato fruits is that they have more crude fat than others. ANOVA analysis showed that tomatoes' crude fat content steadily decreased as water stress increased during I_3, I_2, and I_1 irrigation regimes, respectively (Figure 5b). The tomato plants had the greatest crude fat in the G_2 treatment, followed by the G_1 treatment, while the lowest crude fat was found in the G_3 treatment (Figure 5b). Due to interaction, the $I_3 \times G_2$ treatment exhibited the greatest value of fat content (0.81%) compared to other treatments. However, the minimum value of fat content (0.50%) was realized by the $I_1 \times G_3$ combined treatment compared to other treatments (Figure 4a).

The greatest benefit of tomato fruit is its high crude fiber content. Planting geometry and water regimes substantially affect tomatoes' crude fiber content (Figure 5c). It was determined through this study that when water stress increased during the I_3, I_2, and I_1 regimes, the crude fiber content of tomatoes decreased. Tomato plants' crude fiber was highest in the G_1 treatment, followed by the G_2 treatment, while the lowest was found in the G_3 treatment (Figure 5a–c). According to interaction, the $I_3 \times G_2$ treatment exhibited the maximum value of fiber content (3.94%) compared to other treatments. Conversely, the minimum value of fiber content (2.39%) was realized by the $I_1 \times G_3$ treatment compared to other treatments (Figure 4a).

The most attractive characteristic of tomato fruits is the higher lycopene concentration. Both planting geometry and water treatments substantially impact the lycopene content of tomatoes (Figure 5d). The treatment G_2 showed the greatest levels of lycopene, followed by those under the G_1 treatment, which were intermediate, and those under the G_3 treatment, which were the lowest. The $I_3 \times G_2$ combined treatment reflected the maximum lycopene content (4.00 mg/kg) compared to other combined treatments. However, the minimum value of lycopene content (2.15 mg/kg) was realized by the $I_1 \times G_3$ combined treatment compared to other treatments (Figures 4a and 5d).

3.5. Uniformity Coefficient of Exiting Drip System for the Tomato Crop

According to the findings of this research, DI systems for tomato crops had a uniformity coefficient of 95% under various planting geometries and irrigation regimes. A high CU demonstrates that sufficient water is delivered to each plant, allowing for optimum growth and production (Table 3).

Table 3. Drippers discharge under different planting geometry and irrigation regime treatments.

Lateral Sections	**The Emitter's Flow Rate of Different Lateral Lines**								
	L1	**L2**	**L3**	**L1**	**L2**	**L3**	**L1**	**L2**	**L3**
Head	12	12	12	11.97	11.99	12	11.92	11.90	11.91
Middle	11.95	11.96	11.95	11.94	11.93	11.92	11.91	11.89	11.9
Tail	11.92	11.94	11.91	11.92	11.90	11.91	11.88	11.89	11.91
Sub-average	11.96	11.97	11.95	11.94	11.94	11.94	11.90	11.89	11.91
Average		11.96			11.94			11.90	

Note: L1, L2, and L3 denote laterals, respectively.

3.6. Distribution Uniformity of Exiting Drip System for Tomato Crop

Analysis showed that DI systems' distribution uniformity (DU) for the tomato crop was more than 95% under different planting geometries and irrigation regimes as shown in Table 4. As the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture recommends, high DU is required for row crops, with at least 85% for DI systems used in row crop agriculture.

Table 4. Distribution uniformity of the existing system.

Water Regime	Lateral Lines	q_m (L/h)	q_{avg}	$\Sigma (q - q_{av})^2$	σ	CV	CU	DU
I_1	L1	11.39	11.957	0.321	0.444	0.024	95.26	0.96
	L2	11.41	11.967	0.31	0.434	0.024	95.35	0.95
	L3	11.47	11.953	0.233	0.358	0.021	95.96	0.96
	Overall	11.42	11.959	0.288	0.412	0.023	95.52	0.96
I_3	L1	11.43	11.943	0.263	0.388	0.022	95.70	0.95
	L2	11.35	11.940	0.388	0.469	0.025	95.06	0.95
	L3	11.32	11.943	0.386	0.506	0.027	94.78	0.95
	Overall	11.37	11.942	0.346	0.454	0.025	95.18	0.95
I_2	L1	11.41	11.903	0.243	0.3680	0.021	95.86	0.95
	L2	11.29	11.893	0.363	0.3015	0.026	94.93	0.95
	L3	11.31	11.907	0.356	0.2985	0.026	94.99	0.95
	Overall	11.34	11.901	0.321	0.3227	0.024	95.26	0.95

Note: L1, L2, and L3 denote laterals, respectively, I_1, I_2, and I_3 water regimes, with 50%, 100%, and 150% evapotranspiration, Minimum discharge (q_m, L/h), average discharge (q_{avg}), standard deviation (σ), coefficient of variation (CV), uniformity coefficient (CU), respectively.

4. Discussion

The current study proves that the yield, growth, water productivity, and fruit quality of tomatoes were influenced by planting geometry under different irrigation regimes. The increase in stem diameter and plant height under the I_3 regime compared to other regimes reflects the strength of the tomato plants, which is directly proportional to the greatest availability of moisture in the soils due to the reason that maintaining soil water content at 100% of ET helped soils to hold more moisture content as well as more nutrients for plants to be fully matured. On the contrary, reducing the soil moisture content to 50% of ET resulted in a deficiency of moisture and nutrients. Plant growth was greatly hampered regarding the drop in plant tallness and stem thickness. Ref. [39] consistently reported the best results of plant height and stem diameter of tomato plants under well-watered conditions compared to water-stressed conditions. The results of plant height and stem diameter under different planting geometries were in harmony with the increase in planting area as the increase in area from 30 to 60 cm increased the area of soil in which plant roots grew. Correspondingly, Narolia et al. [40] evaluated the impact of distinct watering levels and planting geometries on the development of cucumber plants under the DI system. They found that the planting geometry of 60 cm resulted in improved stem diameter, plant height, and leaf area index under well-watered conditions.

The amount of water applied and planting geometry could play a major role in determining the best performance of the DI system, thereby improving the yield components and fruit yield of tomatoes [41]. In this study, the enhancement in fruit yield of tomatoes under $I_3 \times G_2$ is ascribed to better development conditions with more available water and nutrients due to less water stress with enough soil area, encouraging more emergence of fruits and overall plant growth resulting in high fruit biomass. Reducing the soil moisture content to 50% of ET and increasing the planting spacing of tomatoes reduced the growth and decreased fruit yield. Similarly, the effects of DI on tomatoes' fruit yield and yield components were investigated by Paterl et al. [42], who indicated that well-watered irrigation with a planting spacing of 60 cm resulted in significantly high yield and yield components compared to water-stressed irrigation and other planting densities. Additionally, Attia et al. [43] studied the effect of different watering regimes and planting densities on tomato crop water productivity using a DI system. They discovered that applying 60 cm planting spacing with well-watered conditions resulted in the maximum fruit yield of tomatoes compared to 90 cm planting spacing with water-stressed conditions.

Under the DI system, planting spacing of 60 cm with applying water of 100% ET could enhance WUE by increasing fresh fruit production. Similarly, Parameshwarareddy et al. [44] considered the impact of different watering regimes and planting densities on tomato crop water productivity under the DI system. They reported that applying 60 cm of planting spacing can enhance water utilization efficiency under well-watered conditions by increasing yield components and fruit yield of tomatoes. Additionally, Lei et al. [45] also discovered that applying water at 100% ET considerably boosted WUE in tomatoes under a planting spacing of 60 cm compared to other irrigation and planting spacing treatments.

Applying water stress significantly influences plant physiology, plant water relations, and fruit quality. However, plant receiving low drought stress preserve higher crop water status and fruit quality [46,47]. Therefore, in this study, plants showed a variation in protein, fat, fiber, and lycopene contents when exposed to varying water scarcity and planting geometries. The fruit quality results under $I_3 \times G_2$ prove that tomato plants received enough water and growing area for optimal growth, yield, and, thus, fruit quality. This study verified the findings of Zuazo et al. [48], who stated that the fruit quality decreased under high water stress levels compared to well-watered conditions due to a decreased transpiration rate and stomatal conductance as water stress increases.

To achieve the goal of an optimal irrigation system, uniformity coefficient (UC) and distribution uniformity (DU) are key factors in assessing the efficiency of the DI technique. Higher UC is desirable in arid regions with limited water resources or areas with high evapotranspiration rates [49]. In this study, the great value of UC of DI systems for the different planting geometries and irrigation regimes proves that each plant receives enough water for optimal growth, yield, and fruit quality of tomato. The 95% rate of UC is a typical efficiency for row crops according to the recommendation of the NRCS, which should be at least 85% for DI systems used in row crop agriculture [50].

High UC and DU indicate that the system delivers water uniformly to all parts of the field. In contrast, a low UC and DU indicate non-uniform water distribution, which can lead to reduced crop yields and increased water use. A study by Attia et al. [43] evaluated the performance of a DI technique in the tomato crop using UC and DU parameters. The study found that applying 100% of ET and using a planting spacing of 60 cm resulted in a higher UC and DU than other irrigation regimes and planting densities. This indicates that the DI system delivers water more uniformly to all parts of the field when using these parameters. Additionally, Selvaperumal et al. [51] assessed the uniformity of a DI method in a tomato crop using UC and DU. The study found that using a planting spacing of 60 cm resulted in a higher UC and DU than other planting densities. In our study, UC and DU suggest that the planting geometry of 60 cm planting can improve the uniformity of water distribution in a DI method for the tomato crop. Thus, the yield components, water utilization efficiency, fruit yield, and quality of tomatoes can benefit from using DI systems with 100% ET.

5. Conclusions

Planting geometry significantly affects tomato growth, water productivity, and fresh fruit quality under different irrigation regimes. Specifically, a row-to-row planting spacing of 60 cm combined with applying water at 100% of ET resulted in the greatest plant height and stem diameter. Furthermore, this planting pattern substantially impacted the nutritional composition of fresh fruits, leading to increased levels of protein, fat, fiber, and lycopene. Additionally, the 60 cm planting pattern exhibited a higher UC and DU within the DI system, resulting in improved water productivity and reduced water usage. Employing a 90 cm plant spacing with 50% ET was an inappropriate management option for tomatoes as it negatively affected plant height, stem diameter, and the nutritional content of fresh fruits. Moreover, this configuration compromised irrigation uniformity. Our findings enhance the sustainability, productivity, and quality of tomato production systems, particularly in the context of climate change. It is recommended that farmers and growers adopt the row-to-row planting spacing of 60 cm along with optimal irrigation practices to maximize plant growth, yield, and fruit quality. Future studies should explore further innovative strategies for tomato cultivation practices to meet the increasing demand for high-quality tomatoes while effectively addressing the challenges posed by climate change.

Author Contributions: Conceptualization, Y.A.H.; Data curation, A.A.A.H., T.C. and M.Z.-u.-R.; Formal analysis, M.M.A.T., H.S., M.U. and Y.A.H.; Investigation, M.U. and M.Z.-u.-R.; Methodology, H.S., A.A.A.H., T.C., M.U. and Y.A.H.; Resources, M.Z.-u.-R.; Software, M.M.A.T. and A.A.A.H.; Supervision, Y.A.H.; Validation, T.C.; Writing—original draft, M.M.A.T., H.S. and Y.A.H.; Writing—review and editing, M.M.A.T., H.S. and Y.A.H. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the China Postdoctoral Science Foundation, the Jiangsu Funding Program for Excellent Postdoctoral Talent, Hohai University Scientific Research Project (B200203004), the National Natural Science Foundation of China (51879067), and the Fundamental Research Funds for the Central Universities of China (B220204014).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Naheed, S. An overview of the influence of climate change on food security and human health. *Life* **2023**, *3*, 15.
2. Hamoud, Y.A.; Guo, X.; Wang, Z.; Shaghaleh, H.; Chen, S.; Hassan, A.; Bakour, A. Effects of irrigation regime and soil clay content and their interaction on the biological yield, nitrogen uptake and nitrogen-use efficiency of rice grown in southern China. *Agric. Water Manag.* **2019**, *213*, 934–946. [CrossRef]
3. Attri, M.; Bharti, V.; Ahmad Nesar, N.; Mehta, S.; Bochalya, R.S.; Kumar Bansal, K.; Sandhu, R. Improved irrigation practices for higher agricultural productivity: A review. *Int. J. Environ. Clim. Chang.* **2022**, *12*, 51–61. [CrossRef]
4. Ignaciuk, A.; D'Croz, D.; Islam, S. Better drip than flood: Reaping the benefits of efficient irrigation. *EuroChoices* **2015**, *14*, 26–32. [CrossRef]
5. Payero, O.; Tarkalson, D.; Irmak, S.; Davison, D.; Petersen, L. Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate. *Agric. Water Manag.* **2008**, *95*, 895–908. [CrossRef]
6. Patra, S.K.; Poddar, R.; Pramanik, S.; Gaber, A.; Hossain, A. Crop and water productivity and profitability of broccoli (*Brassica oleracea* L. var. *italica*) under gravity drip irrigation with mulching condition in a humid sub-tropical climate. *PLoS ONE* **2022**, *17*, e0265439. [CrossRef]
7. Hamoud, Y.A.; Shaghaleh, H.; Sheteiwy, M.; Guo, X.; Elshaikh, N.A.; Khan, N.U.; Oumarou, A.; Rahim, S.F. Impact of alternative wetting and soil drying and soil clay content on the morphological and physiological traits of rice roots and their relationships to yield and nutrient use-efficiency. *Agric. Water Manag.* **2019**, *223*, 105706. [CrossRef]
8. Cao, T.; Wang, S.; Chen, B. Water shortage risk transferred through interprovincial trade in Northeast China. *Energy Procedia* **2019**, *158*, 3865–3871. [CrossRef]
9. Misra, A.K. Climate change and challenges of water and food security. *Int. J. Sustain. Built Environ.* **2014**, *3*, 153–165. [CrossRef]
10. Murad, K.F.I.; Hossain, A.; Fakir, O.A.; Biswas, S.K.; Sarker, K.K.; Rannu, R.P.; Timsina, J. Conjunctive use of saline and fresh water increases the productivity of maize in saline coastal region of Bangladesh. *Agric. Water Manag.* **2018**, *204*, 262–270. [CrossRef]
11. Çetin, Ö.; Uygan, D. The effect of drip line spacing, irrigation regimes and planting geometries of tomato on yield, irrigation water use efficiency and net return. *Agric. Water Manag.* **2008**, *95*, 949–958. [CrossRef]
12. Gerçek, S.; Demirkaya, M.; Işik, D. Water pillow irrigation versus drip irrigation with regard to growth and yield of tomato grown under greenhouse conditions in a semi-arid region. *Agric. Water Manag.* **2017**, *180*, 172–177. [CrossRef]
13. Sinha, B. Hydraulic performance evaluation of drip irrigation system under field condition in Chhattisgarh plain. *J. Pharmacogn. Phytochem.* **2021**, *10*, 79–83.
14. Dutta, D.; Mudi, D.D.; Thentu, T. Effect of irrigation levels and planting geometry on growth, cob yield and water use efficiency of baby corn (*Zea mays* L.). *J. Crop Weed* **2015**, *11*, 105–110.
15. Jensen, M.E. Beyond irrigation efficiency. *Irrig. Sci.* **2007**, *25*, 233–245. [CrossRef]
16. Zhai, Y.; Shao, X.; Xing, W.; Wang, Y.; Hung, T.; Xu, H. Effects of drip irrigation regimes on tomato fruit yield and water use efficiency. *J. Food Agric. Environ.* **2010**, *8*, 709–713.
17. Li, J.; Gao, Y.; Zhang, X.; Tian, P.; Li, J.; Tian, Y. Comprehensive comparison of different saline water irrigation strategies for tomato production: Soil properties, plant growth, fruit yield and fruit quality. *Agric. Water Manag.* **2019**, *213*, 521–533. [CrossRef]
18. Badr, M.; Abou-Hussein, S.; El-Tohamy, W. Tomato yield, nitrogen uptake and water use efficiency as affected by planting geometry and level of nitrogen in an arid region. *Agric. Water Manag.* **2016**, *169*, 90–97. [CrossRef]
19. Padayachee, A.; Day, L.; Howell, K.; Gidley, M. Complexity and health functionality of plant cell wall fibers from fruits and vegetables. *Crit. Rev. Food Sci. Nutr.* **2017**, *57*, 59–81. [CrossRef] [PubMed]

20. Shabbir, A.; Mao, H.; Ullah, I.; Buttar, N.A.; Ajmal, M.; Lakhiar, I.A. Effects of drip irrigation emitter density with various irrigation levels on physiological parameters, root, yield, and quality of cherry tomato. *Agronomy* **2020**, *10*, 1685. [CrossRef]
21. Chanthini, K.M.-P.; Senthil-Nathan, S.; Pavithra, G.-S.; Asahel, A.-S.; Malarvizhi, P.; Murugan, P.; Deva-Andrews, A.; Sivanesh, H.; Stanley-Raja, V.; Ramasubramanian, R. The Macroalgal Biostimulant Improves the Functional Quality of Tomato Fruits Produced from Plants Grown under Salt Stress. *Agriculture* **2022**, *13*, 6. [CrossRef]
22. Chapagain, A.; Orr, S. An improved water footprint methodology linking global consumption to local water resources: A case of Spanish tomatoes. *J. Environ. Manag.* **2009**, *90*, 1219–1228. [CrossRef]
23. Hamoud, Y.A.; Shaghaleh, H.; Wang, R.; Gouertoumbo, W.F.; Hamad, A.A.A.; Sheteiwy, M.S.; Wang, Z.; Xiangping, G. Wheat Straw Burial Improves Physiological Traits, Yield and Grain Quality of Rice by Regulating Antioxidant System and Nitrogen Assimilation Enzymes under Alternate Wetting and Drying Irrigation. *Rice Sci.* **2022**, *29*, 473–488. [CrossRef]
24. Ali, M.Y.; Sina, A.A.I.; Khandker, S.S.; Neesa, L.; Tanvir, E.; Kabir, A.; Khalil, M.I.; Gan, S.H. Nutritional composition and bioactive compounds in tomatoes and their impact on human health and disease: A review. *Foods* **2020**, *10*, 45. [CrossRef] [PubMed]
25. Chen, S.; Wang, Z.; Guo, X.; Rasool, G.; Zhang, J.; Xie, Y.; Yousef, A.H.; Shao, G. Effects of vertically heterogeneous soil salinity on tomato photosynthesis and related physiological parameters. *Sci. Hortic.* **2019**, *249*, 120–130. [CrossRef]
26. Mwendwa, S. Revisiting soil texture analysis: Practices towards a more accurate Bouyoucos method. *Heliyon* **2022**, *8*, e09395. [CrossRef] [PubMed]
27. Libohova, Z.; Seybold, C.; Adhikari, K.; Wills, S.; Beaudette, D.; Peaslee, S.; Lindbo, D.; Owens, P. The anatomy of uncertainty for soil pH measurements and predictions: Implications for modellers and practitioners. *Eur. J. Soil Sci.* **2019**, *70*, 185–199. [CrossRef]
28. Roper, W.R.; Robarge, W.P.; Osmond, D.L.; Heitman, J.L. Comparing four methods of measuring soil organic matter in North Carolina soils. *Soil Sci. Soc. Am. J.* **2019**, *83*, 466–474. [CrossRef]
29. Beugre, E.Y.-M.; Gnagne, T. Vane geometry for measurement of influent rheological behaviour in dry anaerobic digestion. *Renew. Sustain. Energy Rev.* **2022**, *155*, 111928. [CrossRef]
30. Isaac, W.; Na, A. On-the-go soil nitrogen sensor based on near infrared spectroscopy. In Proceedings of the 2016 International Conference on Information Technology (InCITe)-The Next Generation IT Summit on the Theme-Internet of Things: Connect Your Worlds, Noida, India, 6–7 October 2016; pp. 312–315.
31. Kamble, D.; Chavan, P.; Jondhale, V. Study of potassium and sodium content of mahad-raigad tertiary soil by flame photometry. *Asian J. Res. Chem.* **2021**, *14*, 417–420. [CrossRef]
32. Lin, X.; Zhang, J.; Chen, H.; Han, L. Determination of available phosphorus in alkaline soil by molybdenum blue spectrophotometry. In Proceedings of the IOP Conference Series: Earth and Environmental Science, Surakarta, Indonesia, 24–25 August 2021; p. 052003.
33. Alda, L.M.; Gogoasa, I.; Bordean, D.-M.; Gergen, I.; Alda, S.; Moldovan, C.; Nita, L. Lycopene content of tomatoes and tomato products. *J. Agroaliment. Process. Technol.* **2009**, *15*, 540–542.
34. Sadeghi, S.H.; Peters, T. Analytical determination of distribution uniformity for microirrigation tapered laterals laid on uphill and horizontal slopes. *J. Irrig. Drain. Eng.* **2013**, *139*, 483–489. [CrossRef]
35. Kara, T.; Ekmekci, E.; Apan, M. Determining the uniformity coefficient and water distribution characteristics of some sprinklers. *Pak. J. Biol. Sci. PJBS* **2008**, *11*, 214–219. [CrossRef] [PubMed]
36. Ravikumar, V.; Ranganathan, C.; Bosu, S. Closure to "Analytical Equation for Variation of Discharge in Drip Irrigation Laterals," by V. Ravikumar, CR Ranganathan, and S. Santhana Bosu. *J. Irrig. Drain. Eng.* **2005**, *131*, 302–303. [CrossRef]
37. Jamrey, P.; Nigam, G. Performance evaluation of drip irrigation systems. *Pharma Innov. J.* **2018**, *7*, 346–348.
38. Mashandudze, W. A performance evaluation of a one hectare gravity fed drip irrigation system under varying vertical head. *Natl. Res. Database Zimb.* **2015**, *114*, 1825.
39. Hernandez-Espinoza, L.H.; Barrios-Masias, F.H. Physiological and anatomical changes in tomato roots in response to low water stress. *Sci. Hortic.* **2020**, *265*, 109208. [CrossRef]
40. Narolia, R.; Bhunia, S.; Yadav, P. Effect of Irrigation Levels and Plant Growth Regulators on Cucumber (*Cucumis sativus* L.) under Poly House. *Int. J. Plant Soil Sci.* **2021**, *33*, 36–41.
41. Wu, Y.; Yan, S.; Fan, J.; Zhang, F.; Xiang, Y.; Zheng, J.; Guo, J. Responses of growth, fruit yield, quality and water productivity of greenhouse tomato to deficit drip irrigation. *Sci. Hortic.* **2021**, *275*, 109710. [CrossRef]
42. Patel, A.; Gohel, T.; Davara, D.; Solanki, M. Effect of drip irrigation and mulching on growth, yield and water use efficiency of rabi pigeon pea (*Cajanus cajan* L.). *Trends Biosci.* **2015**, *8*, 4275–4279.
43. Attia, M.; Swelam, A.; Sallam, A.; Osman, A. Effect of Irrigation Regimes, Nitrogen, and Mulching Treatments on Water Productivity of Tomato under Drip Irrigation System. *Misr J. Agric. Eng.* **2019**, *36*, 861–878. [CrossRef]
44. Parameshwarareddy, R.; Angadi, S.; Biradar, M.; Patil, R. Water productivity of tomato as influenced by drip irrigation levels and substrates. *J. Pharmacogn. Phytochem.* **2018**, *7*, 1343–1346.
45. Lei, S.; Yunzhou, Q.; Fengchao, J.; Changhai, S.; Chao, Y.; Yuxin, L.; Mengyu, L.; Baodi, D. Physiological mechanism contributing to efficient use of water in field tomato under different irrigation. *Plant Soil Environ.* **2009**, *55*, 128. [CrossRef]
46. Nahar, K.; Ullah, S.M. Drought stress effects on plant water relations, growth, fruit quality and osmotic adjustment of tomato (*Solanum lycopersicum*) under subtropical condition. *Asian J. Agric. Hortic. Res* **2018**, *1*, 1–14. [CrossRef]

47. Chen, S.; Zhang, Z.; Wang, Z.; Guo, X.; Liu, M.; Hamoud, Y.A.; Zheng, J.; Qiu, R. Effects of uneven vertical distribution of soil salinity under a buried straw layer on the growth, fruit yield, and fruit quality of tomato plants. *Sci. Hortic.* **2016**, *203*, 131–142. [CrossRef]
48. Zuazo, V.H.D.; Tarifa, D.F.; Rodríguez, B.C.; Ruiz, B.G.; Sacristán, P.C.; Tavira, S.C.; García-Tejero, I.F. Mango fruit quality improvements in response to water stress: Implications for adaptation under environmental constraints. *Hortic. Sci.* **2021**, *48*, 1–11. [CrossRef]
49. Darko, R.O.; Yuan, S.; Liu, J.; Yan, H.; Zhu, X. Overview of advances in improving uniformity and water use efficiency of sprinkler irrigation. *Int. J. Agric. Biol. Eng.* **2017**, *10*, 1–15.
50. Wallace, D.C.; Young, F.J. Black walnut suitability index: A natural resources conservation service national soil information system based interpretive model. In Proceedings of the 16th Central Hardwood Forest Conference, West Lafayette, IN, USA, 8–9 April 2008; Gen. Tech. Rep. NRS-P-24. US Department of Agriculture, Forest Service, Northern Research Station: Newtown Square, PA, USA, 2008; pp. 589–595.
51. Selvaperumal, A.; Sujitha, E.; Muthuchamy, I. Evaluation of uniformity coefficient and soil moisture distribution under drip irrigation system. *Curr. J. Appl. Sci. Technol.* **2019**, *34*, 1–9. [CrossRef]