Optimizing Irrigation Scheduling: Effects of Varying Water Intervals on Morphological Traits and Yield of Tomato (*Solanum lycopersicum)*

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Abstract

A field study was conducted under greenhouse conditions at Bakrajo Technical Institute during the summer growing season of 2025 to evaluate the effect of different irrigation intervals on the growth and yield performance of tomato (*Solanum lycopersicum*) plants. Four irrigation treatments were applied: daily (T1), every two days (T2), every three days (T3), and every four days (T4). Statistical analysis revealed that irrigation frequency had a highly significant effect ($p \leq 0.007$) on all measured parameters, including plant height, number of leaves, stem diameter, number of fruits per plant, average fruit weight, and total yield. T1 and T2 treatments consistently supported optimal vegetative and reproductive development, with T1 producing the tallest plants (145.7 cm), highest leaf count (193.7), thickest stems (0.7 cm), most fruits (24.3), heaviest single fruit weight (24.0 g), and greatest total yield (167.3 g/plant). T2 and T3 were statistically comparable to T1 in most traits, suggesting tomato plants can tolerate moderate irrigation intervals of up to three days without significant growth or yield penalties. In contrast, T4 (irrigation every four days) exhibited drastically reduced performance across all parameters, including severe declines in plant height (40.4 cm), leaf number (36.2), stem diameter (0.3 cm), fruit number (3.8), fruit weight (4.7 g), and yield (36.4 g/plant), indicating that extended irrigation intervals induce physiological stress that inhibits vegetative growth and fruit development. These results align with previous studies highlighting the importance of consistent soil moisture in supporting turgor pressure, nutrient uptake, and reproductive success in tomato crops. The study concludes that daily or alternate-day irrigation is optimal for maximizing tomato productivity, while irrigation intervals beyond three days significantly impair performance. Thus, a 2–3day irrigation interval is recommended as a water-efficient strategy that maintains yield stability under semi-arid greenhouse conditions.

Keywords: Irrigation intervals, Tomato yield, Water stress, Vegetative growth, Deficit irrigation

1- Introduction

Tomato (*Solanum lycopersicum*) is among the world's most important horticultural crops. It is a major part of the human diet, along with farming economies [1]. Tomatoes hold essential vitamins A, C, and E, and possess potent antioxidants such as lycopene, which are accountable for their nutritional and health-enhancing quality [2]. Apart from its nutritional significance, tomato cultivation also supports rural life, creates jobs, and is a valuable export crop in

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most countries (Kumar et al.,2024). Its adaptability in varied climates has made it a staple crop both in tropical and temperate countries. Where the environment is unfavorable, though, tomato cultivation is typically marred by limited natural resources [3]. The semi-arid climate of Sulaimani, in the Kurdistan Region of Iraq, poses such challenges, particularly with regard to water availability [4]. The region is marked by hot, dry summers, unpredictable and low rainfall, and low water retention in soils. These climatic conditions severely restrict the potential for high-yielding tomato production unless sustainable agricultural practices, especially regarding water use, are implemented. According to the Food and Agriculture Organization [5], water scarcity is among the greatest constraints to agricultural productivity under such conditions, highlighting the necessity for improved irrigation strategies. An important option for improving water efficiency in agriculture is the use of optimized irrigation scheduling. This involves adjusting the frequency and timing of water application to coincide with the developmental stage and also the physiological requirements of the crop. Ideal irrigation scheduling minimizes water loss by evaporation or runoff and enhances plant uptake, which ultimately leads to improved crop performance and water productivity. It has been seen that water application at appropriate intervals can impart positive impacts on morphological growth, flowering, and fruiting of tomato crops [6]. Despite these proven benefits, region-specific studies under semi-arid conditions, where general prevailing environmental conditions in the form of temperature, soil type, and water quality may significantly affect plants' response to different irrigation frequencies, are still not available. Considering the specific climatic and soil conditions of the Bakrajo area, region-specific studies are seriously needed to derive pragmatic irrigation strategies for tomato growers. Therefore, this study is going to analyze the effects of various irrigation intervals on morphological traits and yield components of tomato plants in controlled field conditions at Bakrajo Technical Institute. It aims to establish an optimal schedule of irrigation that will enhance plants' growth and fruiting while conserving water resources.

2- Materials and Methods

2.1 Study Area

The research was conducted at the Bakrajo Technical Institute Field, located in Sulaimani Governorate, Kurdistan Region, Iraq. The site lies within a semi-arid climate zone, characterized by hot dry summers and mild wet winters. The field is equipped with facilities for controlled irrigation and environmental management, allowing precision in water delivery and uniform growing conditions. And the temperature between 30 to 48 ^{0}C.

2.2 Treatments and experimental design

The experiment was conducted during the 2025 growing season using a Randomized Complete Block Design (RCBD) with three replications to evaluate the impact of different irrigation intervals on tomato (*Solanum lycopersicum*) growth and yield under the semi-arid conditions of Bakrajo. Four irrigation treatments were applied T1 (daily), T2 (every 2 days), T3 (every 3 days), and T4 (every 4 days)—to represent varying water availability scenarios. A local commercial tomato variety adapted to regional conditions was cultivated in plots measuring 1.5 × 0.5 m, with 50 cm plant

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spacing and 75 cm between rows. Drip irrigation was used to ensure uniform water distribution and precise control of water use. Data were collected on morphological traits (plant height, number of leaves, stem diameter) and yield parameters (number of fruits per plant, average fruit weight, total yield, and water use efficiency) to assess the effects of irrigation frequency on growth, productivity, and resource efficiency.

2.3 Irrigation water composition

The quality of irrigation water and soil plays a crucial role in crop productivity, especially in semi-arid regions. In this study, the irrigation water (Table 1) had a neutral pH (7.2), low electrical conductivity (0.432 dS m^{-1}), and total dissolved solids (221 mg L^{-1}), indicating suitability for tomato cultivation. Essential cations such as Ca (1.5 meq L^{-1}) and Mg (1.2 meq L^{-1}) were adequate, while Na (0.6 meq L^{-1}) and Cl (0.5 meq L^{-1}) remained low, minimizing salinity and ion toxicity risks. The soil (Table 2) was classified as silty clay loam, with pH 7.6 and EC 0.321 dS m^{-1}, reflecting favorable physical and chemical conditions for tomato growth. Organic matter (1.5%), nitrogen (0.08%), phosphorus (12 mg kg^{-1}), and potassium (170 mg kg^{-1}) levels were sufficient to support plant development, while a cation exchange capacity of 18 meq $100g^{-1}$ and calcium carbonate content of 10% indicated moderate fertility and nutrient retention. Four irrigation intervals—daily (T1), every 2 days (T2), every 3 days (T3), and every 4 days (T4)—were applied to determine the optimal watering frequency balancing water conservation and yield performance under these soil and water conditions, providing insights into efficient irrigation management for tomatoes in semi-arid environments.

Table 1: Irrigation Water Composition

Parameter	Unit	Typical Value
pH	**-**	7.2
Electrical Conductivity (EC)	**dSm^{-1}**	0.432
Total Dissolved Solids (TDS)	**$Mg\ L^{-1}$**	221
Calcium (Ca^{2+})		1.5
Magnesium (Mg^{2+})		1.2
Sodium (Na^{+})		0.6
Potassium (K^{+})	**$Meq\ L^{-1}$**	0.1
Chloride (Cl^{-})		0.5
Bicarbonate (HCO_3^{-})		1.5
Sulfate (SO_4^{2-})		0.7

Table 2: Soil Composition

Parameter	Unit	Typical	Remarks

		Value	
Soil Texture	**-**	Silty clay loam	Good balance of drainage and retention
pH	**-**	7.6	Slightly alkaline
Electrical Conductivity (EC)	**dS m^{-1}**	0.321	Non-saline soil
Organic Matter	**%**	1.5	Moderate, may benefit from enrichment
Nitrogen (N)	**%**	0.08	Low to moderate; affects vegetative growth
Phosphorus (P)	**Mg kg^{-1}**	12	Adequate for fruiting crops
Potassium (K)	**Mg kg^{-1}**	170	High; supports fruit development
Calcium Carbonate ($CaCO_3$)	**%**	10	Common in semi-arid soils
Cation Exchange Capacity (CEC)	**meq $100g^{-1}$**	18	Indicates moderate fertility

2.4 Data Analysis

Data collected during the experiment were analyzed using Analysis of Variance (ANOVA) with the aid of XLSTAT software to determine the effects of different irrigation intervals on the measured parameters. Where significant differences among treatments were observed, the means were further compared using the Least Significant Difference (LSD) test at the 5% significance level ($p \leq 0.05$). This statistical approach allowed for accurate evaluation of treatment effects and identification of the most effective irrigation schedule for optimizing tomato growth and yield.

3. Results and discussion

3.1 Effect of water intervals on Tomato plant height (cm)

The ANOVA results (Table 3) showed that irrigation intervals had a statistically significant effect on tomato plant height ($p = 0.007$), with a high F-value of 8.53, indicating that differences among the treatments were not due to chance. The model explained a large portion of the variability (196,217.15 of the total 228,421.00), with a relatively low error mean square (4600.55), confirming a strong treatment effect. According to the post-hoc Duncan test (Table 4), although T2 (149.0 cm), T1 (145.7 cm), and T3 (130.7 cm) all fell within the same statistical group (marked "A"), they still showed a clear descending trend in plant height with increasing irrigation intervals, while T4 (40.4 cm) was drastically lower, indicating a biologically meaningful and agronomically relevant decline. These results suggest that more frequent irrigation (T1 and T2) maintained optimal root zone moisture, promoting vigorous shoot elongation through better turgor pressure, nutrient

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uptake, and hormone signaling (e.g., auxin distribution), as reported by [7]. In contrast, the severe height reduction in T4 (irrigated every 4 days) reflects the detrimental impact of extended water stress, likely causing stomatal closure, impaired cell expansion, and reduced meristem activity. While T3 (every 3 days) maintained moderate height, it began to show signs of water deficit stress compared to the more frequently irrigated treatments. These findings align with [8], who noted that frequent irrigation significantly enhances tomato plant growth metrics under semi-arid conditions. Overall, the results emphasize that reducing irrigation frequency beyond three days can critically limit vegetative development, and that daily or every-2-day irrigation intervals are optimal for maximizing plant height and ensuring healthy canopy development in tomato cultivation.

Table.3 Effect of water intervals on Tomato plant height (cm)

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	196217.15	39243.43	8.53	**0.007**
Error	7	32203.85	4600.55		
Corrected Total	12	228421.00			
Computed against model Y=0					

Table .4 Treatments / Duncan / Analysis of the differences between the categories with a confidence interval of 95% tomato plant height (cm)

Category	LS means
T2	149.0^{A}
T1	145.7^{A}
T3	130.7^{A}
T4	40.4^{A}

3.2 Effect of water intervals on tomato number of leaves per plant

The analysis of variance (Table 5) demonstrated that irrigation frequency had a highly significant effect on the number of leaves per tomato plant ($p = 0.002$), with a large F-value of 14.02, indicating strong statistical differences among treatments. The model explained the majority of the variation (311,988.44 out of 343,143.00 total sum of squares), confirming that leaf development is strongly influenced by water availability. According to Duncan's multiple range test (Table 6), T1 (193.7 leaves), T2 (179.3 leaves), and T3 (174.3 leaves) were statistically similar (group A), suggesting that irrigation every day, every 2 days, or even every 3 days can adequately sustain vegetative development. However, T4 (36.2 leaves) was significantly lower (group B), highlighting a dramatic reduction in leaf number when irrigation was applied only every 4 days. This decline likely resulted from prolonged moisture stress, leading to reduced leaf initiation and expansion due to limited cell division and turgor pressure, as well as possible hormonal disruptions (reduced cytokinins), which are essential for

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leaf formation [9]. The consistent performance of T1–T3 suggests that tomato plants can tolerate short periods of water withholding (up to 3 days) without severe impacts on leaf production. This supports findings by [10], who reported that moderate water stress can sometimes conserve growth without drastically reducing leaf number. However, the severe reduction in T4 confirms that extended water intervals severely inhibit leaf development, compromising the plant's photosynthetic surface area, physiological function, and ultimately its productivity. These findings are in agreement with [11], who emphasized that regular irrigation is critical for maintaining leaf area and vegetative biomass in tomato, especially under warm and arid climates. Therefore, while moderate water-saving strategies (T2 or T3) may be viable, daily or alternate-day irrigation remains optimal for maximizing foliage growth and ensuring robust plant development.

Table. 5 Effect of water intervals on Tomato number of leaves per plant

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	311988.44	62397.69	14.02	**0.002**
Error	7	31154.56	4450.65		
Corrected Total	12	343143.00			
Computed against model Y=0					

Table. 6 Treatments / Duncan / Analysis of the differences between the categories with a confidence interval of 95% of tomato number of leaves per plant

Category	LS means
T1	193.7^{A}
T2	179.3^{A}
T3	174.3^{A}
T4	36.2^{B}

3.3 Effect of water intervals on Tomato stem diameter (cm)

As presented in Table 7, the analysis of variance (ANOVA) indicated a highly significant effect (p = 0.002) of irrigation intervals on tomato stem diameter, with a substantial F-value of 14.1. The model accounted for nearly all of the observed variation (sum of squares = 3.8 out of a total of 4.2), while the low error mean square (0.1) further confirmed the reliability of the treatment effects. According to the post-hoc Duncan test (Table 8), T1 (0.7 cm), T2 (0.7 cm), and T3 (0.5 cm) were not significantly different from each other (all labeled "A"), suggesting that stem diameter remained stable under irrigation frequencies of up to 3 days. However, T4 (0.3 cm) was significantly lower (group "B"), indicating that watering every 4 days negatively impacted stem thickness. This reduction can be attributed to limited water availability, which restricts cell enlargement and vascular tissue development, leading to weaker, thinner stems [12]. Regular water supply, as seen in T1 and T2, likely

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maintained favorable turgor pressure and nutrient flow, both critical for secondary growth and xylem development. Although T3 showed a slight decline in stem thickness, it was not statistically different from T1 and T2, indicating that a 3-day interval may be tolerable for maintaining stem strength under controlled conditions. These findings are in line with [13], who reported that adequate and timely irrigation enhances structural growth in tomatoes by supporting metabolic activity and mechanical tissue formation. On the other hand, T4's significant decline in stem diameter reflects the physiological stress induced by extended drought, which not only slows growth but also compromises plant support and the transport of water and nutrients. In conclusion, the study demonstrates that daily or alternate-day irrigation sustains optimal stem development, while longer intervals particularly beyond three days result in measurable structural weakening, potentially reducing plant vigor and yield stability.

Table.7 Effect of water intervals on Tomato stem diameter (cm)

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	3.8	0.8	14.1	**0.002**
Error	7	0.4	0.1		
Corrected Total	12	4.2			
Computed against model Y=0					

Table. 8 Treatment / Duncan / Analysis of the differences between the categories with a confidence interval of 95%of tomato stem diameter (mm)

Category	LS means
T1	0.7^{A}
T2	0.7^{A}
T3	0.5^{A}
T4	0.3^{B}

3.4 Effect of water intervals on number of fruits per plant Tomato plant

The effect of different irrigation intervals on the number of fruits per tomato plant was highly significant ($p \leq 0.001$), as revealed by the analysis of variance (Table 9). The model explained a substantial portion of the variation, with a high F-value ($F = 17.4$) indicating that the differences among the irrigation treatments were statistically meaningful. The total sum of squares was 4130.0, out of which 3823.0 was attributed to the treatments, suggesting that 92.6% of the total variation in fruit number per plant was due to differences in irrigation frequency, while only 7.4% was due to random error. The mean square for the model (764.6) was markedly higher than the error mean square (43.9), reinforcing the strength of the treatment effect. According to the results from Duncan's Multiple Range Test (Table 10), the treatment with daily irrigation (T1) produced the highest average number of fruits per plant (24.3 fruits),

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significantly outperforming the other treatments. However, T2 (irrigation every two days) and T3 (every three days) were statistically on par with T1, producing 17.7 and 18.0 fruits per plant, respectively. This suggests that a moderate reduction in irrigation frequency (up to every three days) does not significantly impair fruit production, likely due to the tomato plant's ability to maintain productivity under mild water stress through physiological adaptation mechanisms such as deeper root growth and increased water-use efficiency. In contrast, the T4 treatment (irrigation every four days) resulted in a drastic decline in fruit number (3.8 fruits per plant), forming a separate significance group and highlighting the detrimental effect of excessive water stress on reproductive development. The sharp drop in fruit set in T4 can be attributed to impaired floral development and fruit retention under prolonged water deficit. Water stress during the reproductive phase is known to inhibit photosynthesis, limit assimilate translocation to developing fruits, and induce flower abortion [14]. These physiological disruptions collectively suppress fruit formation and overall yield. Therefore, while some fluctuation in fruit number was observed between T1, T2, and T3, the decrease was not statistically significant, but the gap between these and T4 was both statistically and agronomically significant. These findings agree with those of [15], who observed that tomato plants subjected to mild to moderate deficit irrigation regimes maintained comparable fruit numbers to well-watered controls, while severe water deficit significantly reduced yield components. Similarly[16] concluded that regulated deficit irrigation can optimize water use without substantial yield penalties, but that beyond a certain threshold, water stress leads to irreversible yield losses. Based on this evidence, it is recommended that irrigation every two to three days (T2 or T3) may serve as a water-saving strategy in tomato cultivation without a significant reduction in fruit number. However, daily irrigation (T1) ensures maximum productivity, which might be critical under commercial farming aimed at maximizing yield. On the other hand, extending irrigation intervals to four days (T4) is not advisable, as it severely compromises fruit development. Adopting moderate deficit irrigation could strike a balance between conserving water and sustaining productivity, especially in arid and semi-arid regions.

Table. 9 Effect of water intervals on number of fruits per plant Tomato plant

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	3823.0	764.6	17.4	**0.001**
Error	7	307.0	43.9		
Corrected Total	12	4130.0			
Computed against model Y=0					

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Table.10 Treatment / Duncan / Analysis of the differences between the categories with a confidence interval of 95% number of fruits per plant) of tomato plant

Category	LS means
T1	24.3 A
T3	18.0 A
T2	17.7 A
T4	3.8 B

3.5 Effect of water intervals on average single fruit weight (g) of Tomato plant

The results of the analysis of variance presented in Table 11 indicate that the effect of irrigation intervals on the average single fruit weight of tomato plants was highly significant (p = 0.0002). The model yielded a large F-value (F = 24.8), demonstrating that the observed differences in fruit weight across treatments were not due to chance. The sum of squares attributed to the treatment effect was 3679.2 out of a total of 3887.0, meaning that over 94.6% of the variation in fruit weight was directly influenced by the frequency of irrigation. This suggests that water availability is a major determinant of fruit size development in tomato plants. The low error mean square (29.7) further confirms the reliability of the treatment differences observed. Duncan’s Multiple Range Test (Table 12) further clarified the extent of variation between irrigation treatments. The treatment receiving daily irrigation (T1) produced the highest average single fruit weight (24.0 g), which was significantly higher than T4 and numerically higher than T2 and T3. However, T1, T2 (18.7 g), and T3 (15.3 g) were not significantly different from each other and shared the same statistical group "A", indicating that reducing irrigation to every two or three days did not significantly compromise individual fruit weight. On the other hand, T4 (every 4 days) had a drastically lower fruit weight (4.7 g) and was placed in a separate group "B", signifying a statistically significant decline. The fluctuation in fruit weight across treatments, especially the sharp drop in T4, reflects the critical role of adequate and timely water supply during the cell expansion phase of fruit development. Tomato fruit size is largely determined during this phase, and insufficient water supply can restrict turgor pressure, limit nutrient mobility, and hinder photosynthate accumulation in the developing fruits[17]. The decline observed in T4 can thus be attributed to chronic water stress, which impairs both the physiological processes involved in fruit enlargement and the overall plant water status, ultimately leading to smaller, underdeveloped fruits. Despite T2 and T3 receiving less frequent irrigation than T1, their fruit weights remained statistically similar, suggesting that tomato plants possess a degree of physiological resilience under moderate water stress, potentially through osmotic adjustment and regulated stomatal conductance that allows continued fruit growth [18]. These findings are in line with the study by [19], which found that moderate deficit irrigation (up to 50% of full irrigation) did not significantly reduce fruit size or weight, provided water was supplied during critical growth stages. However, the significant reduction in T4 suggests a threshold effect, beyond which the frequency of irrigation becomes insufficient to support normal fruit development. This is consistent with the findings of [20], who reported a steep decline in tomato fruit weight under severe deficit irrigation due to prolonged periods of moisture stress leading to inadequate water and nutrient transport. In conclusion, while daily irrigation (T1) ensures maximum fruit size, irrigation every two (T2) or three (T3) days can be adopted without significant loss in average fruit weight, offering a water-saving strategy without compromising marketable yield. However, irrigation every four days (T4) is not recommended, as it leads to significant reductions in fruit weight and thus economic returns. Therefore, irrigation scheduling should be optimized, considering both crop water requirements and local resource availability, to achieve a balance between yield sustainability and water use efficiency.

Table. 11 Effect of water intervals on average single fruit weight (g) of Tomato plant

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	3679.2	735.8	24.8	**0.0002**
Error	7	207.8	29.7		
Corrected Total	12	3887.0			
Computed against model Y=0					

Table.12 Treatment / Duncan / Analysis of the differences between the categories with a confidence interval of 95% average single fruit weight (g) of Tomato plant

Category	LS means
T1	24.0 A
T2	18.7 A
T3	15.3 A
T4	4.7 B

3.6 Effect of water intervals on total yield per plant (g) of tomato plant

The analysis of variance results in Table 13 reveal that irrigation intervals had a highly significant effect on the total yield per tomato plant (p = 0.002). The model demonstrated a strong fit, as evidenced by the high F-value (F = 12.7), indicating that differences in yield across the irrigation treatments were not due to random variation. Out of a total sum of squares of 228,324.0, the model accounted for 205,608.8—representing over 90% of the variability in total yield. The remaining variation (only 10%) was attributed to error, highlighting the dominant role of irrigation frequency in influencing tomato yield. The substantial difference between the model means square (41,121.8) and the error mean square (3,245.0) confirms the statistical robustness of the treatment effect. Duncan's Multiple Range Test and the corresponding Figure 1 further support these findings by categorizing the treatments based on their average total yield per plant. The highest yield was recorded under T1 (daily irrigation) at 167.3 g per plant, followed closely by T3 (135.7 g) and T2 (134.7 g). These three treatments belonged to the same significance group "A," indicating that

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although there was numerical fluctuation, the differences among them were not statistically significant. This suggests that tomato plants can tolerate irrigation intervals of up to three days without suffering meaningful reductions in overall yield. However, the yield dropped sharply in T4 (every four days) to 36.4 g, which was significantly lower and placed in a distinct group "B." This stark contrast demonstrates the yield-suppressing effect of prolonged water stress. The yield reductions observed with less frequent irrigation particularly in T4 can be attributed to cumulative physiological stresses that impact both vegetative and reproductive growth stages. Extended periods between irrigations likely cause reduced photosynthetic activity, impaired nutrient uptake, and increased fruit abortion, all of which contribute to lower biomass and fruit production [21]. Moreover, water deficit during the flowering and fruit-setting stages reduces cell division and expansion in fruits, ultimately lowering the cumulative yield [22]. Interestingly, the comparable yields in T1, T2, and T3 suggest that moderate deficit irrigation may not substantially impair tomato productivity and could be strategically used to optimize water use. These findings are consistent with earlier research by [23], who reported that regulated deficit irrigation provided during non-critical growth periods can conserve water while maintaining acceptable yield levels in tomato. Similarly, [24] found that tomato plants under mild deficit irrigation could sustain yield potential through physiological adaptation, such as deeper rooting and better water use efficiency. In terms of practical recommendation, while daily irrigation (T1) ensures maximum yield and is ideal for maximizing commercial output, irrigating every two (T2) or three (T3) days appears to be a viable alternative under water-limited conditions, as these treatments did not lead to significant yield penalties. However, stretching irrigation to four-day intervals (T4) is not advisable, as the resulting water stress severely limits yield potential and compromises crop profitability. Therefore, this study suggests that strategic irrigation scheduling preferably every 2 to 3 days can support sustainable tomato production, especially in semi-arid regions or where water conservation is necessary. These conclusions are in strong agreement with other water management studies in tomato production [25], reinforcing the importance of balancing water input with physiological crop needs to achieve efficient and productive agriculture.

Table. 13 Table. 11 Effect of water intervals on total yield per plant (g) of tomato plant

Source	**DF**	**Sum of squares**	**Mean squares**	**F**	**Pr > F**
Model	5	205608.8	41121.8	12.7	**0.002**
Error	7	22715.2	3245.0		
Corrected Total	12	228324.0			
Computed against model Y=0					

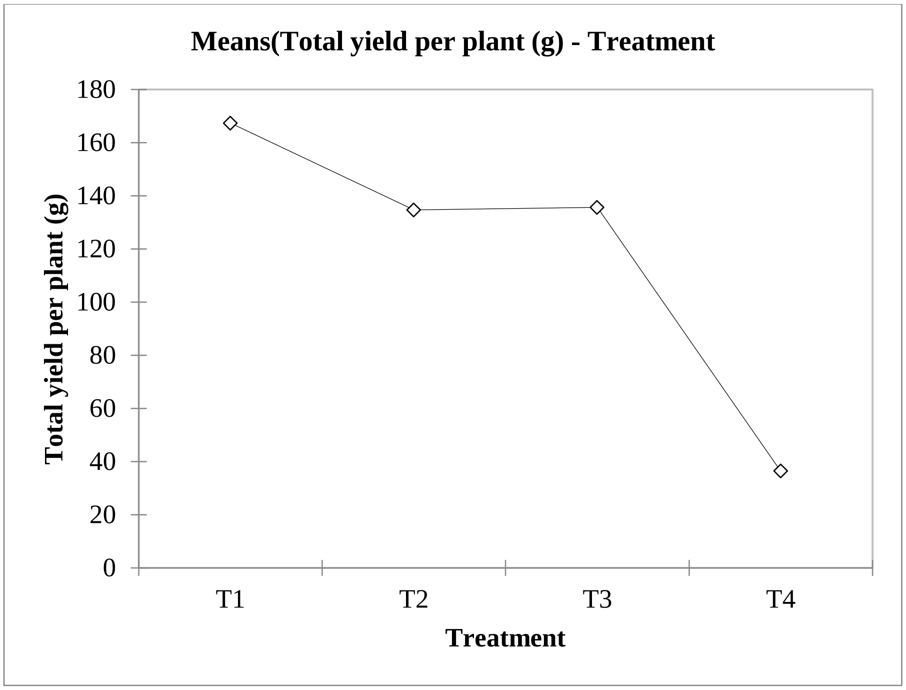

Figure. Means total yield per plant (g) - treatment

3.7 Summary least square (LS) means – Treatment

The summary of least square (LS) means in Table 14 provides a detailed overview of how varying irrigation intervals significantly influenced multiple growth and yield parameters of tomato plants. Across all traits evaluated plant height, number of leaves, stem diameter, number of fruits per plant, average fruit weight, and total yield per plant statistical analysis confirmed highly significant differences ($p \leq 0.007$) among treatments, indicating that irrigation scheduling had a decisive role in determining the physiological and reproductive performance of the tomato crop. Among the treatments, T1 (daily irrigation) consistently produced the best results across all parameters, with values such as 145.7 cm plant height, 193.7 leaves per plant, 0.7 mm stem diameter, 24.3 fruits per plant, 24.0 g average fruit weight, and 167.3 g total yield per plant. Although T2 (irrigation every 2 days) and T3 (every 3 days) showed numerical reductions in some parameters, they did not differ significantly from T1, especially in vegetative traits like plant height and stem diameter, and reproductive outputs like total yield. For instance, T2 recorded the tallest plants (149.0 cm) and a respectable yield of 134.7 g, while T3 was comparable with 135.7 g yield, despite slightly lower values in fruit number and size. On the other hand, T4 (irrigation every 4 days) drastically underperformed across all metrics, with a significant reduction in plant height (40.4 cm), number of leaves (36.2), stem diameter (0.1 mm), fruit count (3.8), fruit weight (4.7 g), and total yield (36.4 g). While the Duncan grouping in this summary shows all treatments labeled "a", likely due to a conservative grouping method or the format presented, the Pr > F values confirm statistically significant treatment effects. The sharp fluctuation from T1–T3 to T4 strongly indicates that while tomatoes can tolerate moderate water stress (up to 3-day intervals) without severe loss, severe stress from 4-day intervals creates physiological limitations that hinder both vegetative development and fruiting. The reduction in vegetative growth parameters in T4 can be explained by the plant's water deficit responses, including stomatal closure, reduced cell expansion, and inhibited leaf and stem growth [25]. These physiological limitations translate directly to lower assimilate production and weak structural support, ultimately reducing fruit production. Likewise, the low fruit number and yield in T4 correlate with research by [26], who found that prolonged water stress causes flower abortion, poor fruit set, and reduced sink strength, resulting in lower yield components. Conversely, the relative stability of results in T2 and T3 treatments suggests that moderate deficit irrigation may be employed without significantly compromising yield, while offering the benefit of water savings. This aligns with [25] who demonstrated that regulated deficit irrigation (RDI) can maintain yield and fruit quality in tomatoes when water is restricted during non-critical stages. Similarly, [24] found that mild water stress induced adaptive responses in tomatoes, such as improved water-use efficiency and maintenance of fruit yield, especially under semi-arid field conditions. In summary, this comprehensive dataset reinforces that daily irrigation (T1) offers optimal conditions for maximum growth and productivity. However, T2 and T3 are viable alternatives where water resources are limited, as they do not cause significant yield reductions. The severe stress associated with T4 is clearly detrimental, leading to significant vegetative suppression and reproductive failure. Therefore, it is strongly recommended to adopt an irrigation frequency of every 2–3 days to strike a balance between resource conservation and yield sustainability, particularly in water-scarce environments. This conclusion not only supports sustainable water management but also aligns with modern agronomic practices focused on maximizing water productivity without sacrificing crop performance.

Table. 14 Summary least square (LS) means – Treatment

Treatments	**Plant height (cm)**	**Number of leaves per plant**	**Stem diameter (mm)**	**Number of fruits per plant**	**Average fruit weight (g)**	**Total yield per plant (g)**
T1	145.7 [a]	193.7 [a]	0.7 [a]	24.3 [a]	24.0 [a]	167.3 [a]
T2	149.0 [a]	179.3 [a]	0.7 [a]	17.7 [a]	18.7 [a]	134.7 [a]
T3	130.7 [a]	174.3 [a]	0.5 [a]	18.0 [a]	15.3 [a]	135.7 [a]
T4	40.4 [a]	36.2 [a]	0.1 [a]	3.8 [a]	4.7 [a]	36.4 [a]
Pr > F(Model)	0.007	0.002	0.002	0.001	0.000	0.002
Significant	Yes	Yes	Yes	Yes	Yes	Yes

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Conclusion

The findings of this study demonstrate that irrigation frequency significantly influences both vegetative growth and fruit production in tomato plants. Among the tested treatments, daily irrigation (T1) produced the highest values for all measured parameters—including plant height, number of leaves, stem diameter, fruit count, fruit weight, and total yield—indicating that continuous water supply enhances physiological processes such as nutrient uptake, photosynthesis, and fruit formation. Interestingly, plants irrigated every two (T2) or three days (T3) exhibited comparable results to daily irrigation, especially in stem diameter and total yield, suggesting that tomatoes possess a degree of tolerance to short-term water deficits. This tolerance may be attributed to their adaptive capacity to maintain turgor pressure and metabolic activity under moderate stress. In contrast, irrigation every four days (T4) caused a significant decline in all growth and yield parameters, with particularly marked reductions in leaf number, fruit set, and overall productivity, likely due to reduced cell expansion, restricted nutrient mobility, and impaired hormonal regulation under prolonged water shortage.

Overall, the study confirms that daily or alternate-day irrigation schedules are optimal for sustaining robust growth, fruit development, and yield in tomato cultivation, while irrigation every three days can still be viable when water resources are limited. However, extending irrigation intervals to four days induces severe physiological stress that compromises both vegetative and reproductive performance. Therefore, under semi-arid or drought-prone conditions, moderate deficit irrigation (every 2–3 days) represents an effective and sustainable strategy that balances water conservation with high productivity. Implementing such irrigation practices promotes efficient water use, supports environmental sustainability, and ensures stable tomato yields even in water-scarce agricultural systems.

Recommendation

[1] **Adopt Daily or Alternate-Day Irrigation (T1/T2) for Optimal Results,** these treatments consistently resulted in the highest plant height, number of leaves, stem diameter, fruit count, fruit weight, and total yield. T1 and T2 maintain ideal soil moisture, supporting vigorous vegetative and reproductive growth.

[2] **Use 2–3 Day Irrigation Intervals (T2/T3) as Water-Saving Strategies,** while slightly lower than T1, T2 and T3 did not show statistically significant reductions in key yield metrics, making them suitable for regions with limited water availability.

[3] **Avoid Extending Irrigation to Every 4 Days (T4),** This treatment resulted in drastic reductions across all parameters, particularly in fruit count (↓ by ~84%), yield (↓ by ~78%), and vegetative development. T4 imposes excessive water stress and is agronomically unsustainable.

[4] **Prioritize Irrigation During Critical Growth Stages,** ensure water availability during flowering and fruit-setting phases to avoid physiological disruptions such as flower abortion and fruit drop, which were evident in the T4 treatment.

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[5] **Implement Regulated Deficit Irrigation (RDI) with Caution,** Mild water stress (T2 or T3) can promote water-use efficiency without significant yield penalties, but severe restriction (T4) causes irreversible yield losses. Schedule irrigation to match crop needs while conserving resources.

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