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Determination of Watering Regime for Optimal Production of Hortitom 1 and Hortitom 3 Genotypes of *Solanum lycopersicum* L. (Tomatoes) under Screenhouse Conditions

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Abstract Water availability is a major limiting factor for tomato production, particularly under changing climate conditions. This study investigated the effects of eight watering regimes twice daily (T1), once daily (T2), every 2 days (T3), every 3 days (T4), every 4 days (T5), every 5 days (T6), every 6 days (T7), and continuous waterlogging (T8) on growth, yield, and fruit nutritional quality of two Nigerian tomato genotypes (Hortitom 1 and Hortitom 3) under screenhouse conditions. The experiment was laid out in a 2 × 8 factorial arrangement in a completely randomized design with five replicates. Both genotypes exhibited 100% survival under all non-waterlogged treatments, while continuous waterlogging (T8) resulted in 100% mortality. Hortitom 1 and Hortitom 3 attained their maximum plant height at T5 (watering every 4 days), recording 58.70 cm and 62.50 cm respectively. Fruit yield (fresh weight) was highest in Hortitom 1 under T1 (5.25 g per fruit) and in Hortitom 3 under T7 (7.75 g per fruit). Nutritional composition was significantly influenced by genotype and watering regime. Crude protein content peaked at 2.06% in Hortitom 1 under T5 and 1.85% in Hortitom 3 under T4. These results demonstrate clear genotypic differences in response to water availability. Hortitom 1 performed best under moderate water stress (T5) for vegetative growth and nutritional quality, while Hortitom 3 showed superior fruit yield under more severe water restriction (T7). Both genotypes are highly susceptible to waterlogging but tolerant to drought. The findings provide genotype-specific irrigation recommendations that can enhance water-use efficiency while maintaining or improving fruit nutritional quality in tomato production under screenhouse conditions.

Keywords Drought; Waterlogging; Tomato genotypes; Growth; Nutritional quality; *Solanum lycopersicum*

1 Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and consumed vegetables worldwide. It is valued for its rich nutritional profile, including vitamins A, C, and E, as well as lycopene antioxidants that reduce risks of cardiovascular diseases and cancers (Bai and Lindhout, 2022; Natali et al., 2025). The crop also plays key economic and industrial roles. Native to western South America, particularly Peru and Ecuador, tomatoes were domesticated in Mexico. Spanish explorers introduced them to Europe in the 16th century. Initially grown as ornamentals due to their resemblance to nightshade plants, they later became a global culinary staple (Donoso et al., 2022).

Tomatoes exhibit extensive morphological and genetic diversity. This diversity has produced genotypes adapted to various climates, diseases, and consumer preferences. Wild relatives contribute key traits, such as drought and salinity resistance from *Solanum pimpinellifolium*. Other species, including *S. peruvianum*, *S. chilense*, *S. habrochaites*, and *S. pennellii*, provide tolerances to extreme conditions, pathogens, pests, and cold (Razifard et al., 2020; Blanca et al., 2022).

Successful tomato cultivation depends on optimal environmental and agronomic factors. Well-drained loamy soils with pH 5.5-6.8 and high organic matter support root health, nutrient uptake, and disease prevention (Jones, 2021). Clay soils hinder drainage, while sandy soils require irrigation and amendments. Ideal temperatures range from 20°C to 25°C for growth, flowering, and fruiting. High temperatures (>30°C) cause flower abortion, and low temperatures (<10°C) impair pollination. Farmers mitigate these using greenhouses or shade nets (Sharma et al., 2020). Adequate light is essential for photosynthesis and fruit ripening, with supplementation needed in low-light regions.

Water stress during critical growth stages reduces yields and triggers disorders like blossom-end rot. Effective countermeasures include drip irrigation (40%-60% efficiency gains), deficit irrigation, and mulching to control evaporation, regulate soil temperature, and suppress weeds (Fereres and Soriano, 2020; Makhadmeh et al., 2022; Ayana and Olika, 2024). Water is central to tomato physiology, driving cell expansion, nutrient uptake, and fruit development. Drought-induced deficits limit biomass, fruit set, and nutrient profiles, while excesses cause other issues (Bastías et al., 2020; Nguyen et al., 2021; Burato et al., 2024). Genotypic variations, such as deeper roots or osmotic adjustments, enhance tolerance (Alam et al., 2021). However, limited data exist on how irrigation regimes affect growth, yield, and fruit nutritional quality in newly developed Nigerian tomato genotypes, Hortitom 1 and Hortitom 3, under screen house conditions.

In the face of water scarcity and climate variability, tomatoes require precise irrigation to sustain yields and quality (Ray and Majumder, 2024). Evaluating watering regimes for Hortitom 1 and Hortitom 3 through different irrigation methods can improve water use efficiency, root nutrient uptake, and loss reduction while maintaining nutritional content (Gheysari et al., 2021). Such insights can guide farmers toward optimal practices, enhance nutritional output for consumers, and inform breeders about genotype-environment interactions for resilient varieties (Santos et al., 2021). Therefore, this study aims to assess the impact of varying watering levels on growth, yield parameters, and fruit nutritional composition of Hortitom 1 and Hortitom 3 under screen house conditions.

2 Materials and Methods

2.1 Location of the experiment

This experiment was carried out at the screen house of the Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba-Akoko, Nigeria (latitude 7.2 ^{0}N, longitude 5.44 ^{0}E).

2.2 Sources of materials for the experiment

Two tomato (*Solanum lycopersicum* L.) genotypes, Hortitom 1 and Hortitom 3, were obtained from the National Horticultural Research Institute (NIHORT), Ibadan, Oyo State, Nigeria. The soil was analyzed for physical and chemical properties using the standard methods of AOAC (1985). It was shade-dried and passed through a 2-mm sieve before analysis.

2.3 Soil collection and preparation

Topsoil (0-15 cm depth) was collected from an arable farmland within the premises of Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria. The soil was sieved to remove debris and thoroughly mixed to obtain a homogeneous medium. Approximately 14 kg of prepared soil was filled into each perforated polythene pot. Tomato seedlings raised in the nursery for 3 weeks were transplanted into perforated polythene pots filled with 14 kg of topsoil; only pots for waterlogged conditions were not perforated.

2.4 Experimental setup

The potted plants were watered regularly for two weeks after transplanting for proper seedling establishment. Thereafter, they were differentially exposed to eight watering regimes: watering twice daily (T1), once daily (T2), every 2 days (T3), every 3 days (T4), every 4 days (T5), every 5 days (T6), every 6 days (T7) and completely waterlogged (T8). Pots were laid out on the screen house floor in a completely randomized design (CRD) with each treatment replicated five times. It was a 2 x 8 factorial experiment with genotype as Factor A at 2 levels, and watering regime as Factor B at 8 levels. Except waterlogging condition that was permanently flooded, each potted plant received approximately 380 ml of water at every watering time. This was the volume required to keep the soil at field capacity based on 36% field capacity of the soil. Standard agronomic practices including weeding and pest control were carried out during the experiment.

2.5 Data collection

Plant height was measured from the soil surface to the apical bud using a meter rule. Stem girth was measured at 2 cm point above the base of the plant. The number of fully expanded leaves was counted manually on each plant. The leaf area was measured using the leaf area meter (LI-COR 300 model). The number of branches produced per plant was counted manually. At harvest, plants were carefully uprooted, washed and separated into leaves, roots and stems. Root growth was determined by measuring the root length using a meter rule, and the number of roots was counted manually. Fresh weight was measured immediately after harvest, while dry weight was obtained after oven-drying at 80°C to constant weight, using Melter PC 180. Dry weight of plant parts (roots, stems, and leaves) was also measured. Yield in terms of fresh and dry mass of the fruit was also assessed using an electronic weighing balance.

2.6 Laboratory analysis of tomato fruits

Dried tomato fruits were ground into fine powder for analysis. Fiber content was determined by boiling the sample in 1.25% H_2SO_4 and 1.25% NaOH, followed by washing and drying. Other parameters of proximate composition were analyzed using the standard methods of AOAC (1985) in which the mixture was boiled until a clear solution was obtained, and allowed to cool at room temperature. The resulting solution was quantitatively transferred into a calibrated flask and completed to 25 ml with distilled water. Moisture, crude protein, crude fat, carbohydrate and ash contents were calculated using relevant formulas. N was analyzed using the macro Kjeldahl method, while P was determined using ammonium-vanadomolybdate reagent and a calibration curve. Potassium contents were assayed through flame emission photometry. calcium contents by Ethylenediaminetetraacetic acid (EDTA) titration.

2.7 Statistical analysis

All data collected were subjected to two-way Analysis of Variance (ANOVA) using SPSS (Version 27.0). Where significant differences were observed among treatment means, Tukey's Honest Significant Difference (HSD) test was used at 95% confidence level to perform post-hoc comparisons.

3 Results

3.1 Soil used for planting

The soil used for planting was a sandy soil with 5.60 pH, 6.19% clay, 4.29% silt, 89.7% sand, 2.89% C, 0.14% N, 9.02 mg/kg P, 6.24 mg/kg Ca, 1.84 mg/kg Mg, 0.34 mg/kg Na, 0.23 mg/100 K, 0.20 mg/kg H, and 8.86 mg/kg CEC. It had 1.12 mg/cm3 bulk density, 36.13% field capacity, and 19.08% permanent wilting point.

3.2 Effect of watering regime on percentage survival and growth of two genotypes of *Solanum lycopersicum*

Table 1 below shows the effects of different watering regime on the survival of two *Solanum lycopersicum* genotypes. Irrigation treatments T1 to T7, applied from twice daily up to once every six days, resulted in 100% survival. In contrast, T8, which involved constant waterlogging, led to total plant death. For plant height, Hortitom1 plants measured between 41.25±3.53 cm under T7 and 58.70±6.32 cm under T5, achieving notably taller growth in T5. Hortitom 3 produced taller plants overall than Hortitom 1, with heights from 53.50±0.65 cm in T2 to 62.50±0.65 cm in T5. Stem girth in Hortitom1 varied from 2.25±0.10 cm in T6 to 2.63±0.24 cm in T1, showing no significant differences between regimes. Hortitom 3 also maintained consistent stem girth across treatments, between 2.70±0.20 cm in T5 and 2.90±0.13 cm in T2. The number of leaves in Hortitom 1 rose significantly from 11.75±0.41 leaves under T1 to 31.13±0.47 leaves under T7. Hortitom 3 displayed the opposite trend, peaking at 33.50±0.65 leaves in T1 and dropping to lower values of 19.00±0.41 in T5. Leaf area in Hortitom 1 spanned 24.15±0.31 cm² in T7 to 26.48±0.40 cm² in T1 and T3, differing significantly from other treatments. Hortitom 3 had leaf areas from 26.35±0.64 cm² in T5 to 27.31±0.08 cm² in T3. Number of roots was greater in T5 (7.50±1.04) than T7 (4.00±0.41), while root length remained similar across all treatments.

Table 1 Effect of watering regime on percentage survival and growth of two genotypes of *Solanum lycopersicum*

Parameter	Tomato genotype	Watering regime							
		T1	T2	T3	T4	T5	T6	T7	T8
Plant survival (%)	H1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00
	H3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00
Plant height (cm)	H1	47.25±1.99^{a}	53.13±9.44^{a}	46.35±2.75^{a}	55.25±1.03^{a}	58.70±6.32^{a}	58.07±5.94^{a}	41.25±3.53^{a}	-
	H3	54.50±0.65^{a}	53.50±0.65^{a}	57.50±0.65^{b}	61.50±0.65^{cd}	62.50±0.65^{d}	58.50±0.65^{b}	59.50±0.65^{bc}	-
Stem girth (cm)	H1	2.63±0.24^{a}	2.39±0.21^{a}	2.35±0.22^{a}	2.43±0.21^{a}	2.38±0.11^{a}	2.25±0.10^{a}	2.33±0.12^{a}	-
	H3	2.73±0.13^{a}	2.90±0.13^{a}	2.73±0.23^{a}	2.88±0.13^{a}	2.70±0.20^{a}	2.85±0.12^{a}	2.78±0.22^{a}	-
Number of leaves	H1	11.75±0.41^{a}	14.80±0.56^{b}	18.55±0.61^{c}	21.88±0.47^{d}	24.88±0.47^{e}	28.00±0.53^{f}	31.13±0.47^{g}	-
	H3	33.50±0.65^{e}	29.50±0.65^{d}	25.50±0.65^{c}	21.50±0.65^{ab}	19.00±0.41^{a}	22.50±0.65^{b}	26.50±0.65^{c}	-
Leaf area (cm^2)	H1	26.48±0.40^{c}	26.10±0.38^{bc}	26.48±0.22^{c}	26.35±0.16^{c}	25.97±0.31^{bc}	24.97±0.13^{ab}	24.15±0.31^{a}	-
	H3	27.00±0.26^{a}	27.11±0.19^{a}	27.31±0.08^{a}	26.97±0.22^{a}	26.35±0.64^{a}	26.62±0.20^{a}	26.62±0.19^{a}	-
Number of roots	H1	5.55±0.61^{ab}	6.25±0.25^{ab}	4.75±1.03^{ab}	6.50±0.87^{ab}	7.50±1.04^{b}	4.75±0.75^{ab}	4.00±0.41^{a}	-
	H3	7.25±0.85^{a}	7.25±0.25^{a}	5.25±0.25^{a}	5.00±0.71^{a}	5.50±0.65^{a}	6.50±1.32^{a}	6.75±0.48^{a}	-
Root length (cm)	H1	5.60±0.61^{a}	4.58±0.64^{a}	5.40±0.51^{a}	5.45±0.57^{a}	4.60±0.47^{a}	3.58±0.41^{a}	3.80±0.43^{a}	-
	H3	6.10±0.91^{ab}	5.83±0.53^{ab}	6.88±0.51^{b}	5.13±0.60^{ab}	4.20±0.63^{ab}	3.85±0.16^{a}	3.40±0.62^{a}	-

Note: Each value is a mean ± S.E. of 5 replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at $P \geq 0.05$ (Tukey HSD test). T1: watering twice daily; T2: watering once daily; T3: watering every two days; T4: watering every three days; T5: watering every four days; T6: watering every five days; T7: watering every six days; T8: continuous waterlogging; H1: Hortitom 1 genotype; H3: Hortitom 3 genotype

3.3 Effect of water stress on biomass

The impact of watering regimes on biomass components shown in (Table 2) in two *Solanum lycopersicum* genotypes, Hortitom 1 and Hortitom 3. In Hortitom 1, fresh and dry leaf weights remained consistent across treatments at about 9.00 g and 5.51 g, respectively, while root numbers were notably higher under T5 (7.50±1.04) than T7 (4.00±0.41), though root length, fresh root weight, and dry root weight showed no differences. Stem biomass decreased steadily with water restriction, with fresh stem weight falling from 15.43±0.22 g in T1 to 10.38±0.27 g in T7, and dry stem weight from 9.13±0.43 g to 4.53±0.28 g. For Hortitom 3, fresh leaf weight increased significantly under T7 (16.75±2.10 g) compared to T1 (8.50±2.06 g), but dry leaf weight stayed similar. Root numbers did not vary, root length peaked at T3 (6.88±0.51 cm), and fresh root weight rose from 3.75±0.48 g in T2 to 7.75±0.48 g in T7, with dry root weight highest in T7 (4.92±0.42 g). Stem fresh and dry weights declined gradually from T1 (17.05±0.13 g and 10.03±0.41 g) to T7 (13.88±0.37 g and 5.70±0.20 g).

3.4 Phenological and yield parameter

Table 3 outlines water regime impacts on days to first flowering and fruit yield parameters in *Solanum lycopersicum* genotypes Hortitom 1 and Hortitom 3. Watering regimes impacted days to first flowering in both genotypes: Hortitom 1 flowered soonest under T1 (39.75±0.32 days), with delays increasing to 65.00±2.42 days in T7. Hortitom 3 flowered later than Hortitom 1 in every case, starting at 47.50±0.65 days in T1 and extending to 71.50±0.65 days in T7. Hortitom 1 produced a steady 5.63±0.13 to 6.50±0.20 fruits per plant across treatments with no differences, alongside slightly reduced fresh fruit weights from 3.75±0.63 g to 5.25±0.32 g under drier conditions; notably, fruit length and breadth grew larger, from 16.25±0.32 cm and 18.18±0.38 cm in T1 to peaks of 19.50±0.20 cm and 21.88±0.13 cm in T6/T7. Hortitom 3 showed greater variability, with fruits numbering 3.00±0.41 to 6.00±0.41 (highest in T4), fresh weights climbing in T5-T7 to 7.75±0.48 g in T7, and dry weights maximizing at 4.92±0.42 g in T7 yet fruit length shrank from 42.35±0.65 cm in T1 to 18.35±0.65 cm in T7, while breadth fell from 75.28±0.65 cm to 51.28±0.65 cm.

3.5 Proximate and minerals composition

The results in Table 4 reveal the proximate and mineral compositions of *Solanum lycopersicum* genotypes; Hortitom 1 and Hortitom 3 across water regimes T1-T7. Hortitom 1 generally displayed higher and more variable proximate values than Hortitom 3. Moisture content in Hortitom 1 spanned 14.28±0.05% (T3) to 19.00±0.13% (T4), exceeding Hortitom 3's narrower 15.80±0.22% (T6) to 18.71±0.04% (T3). Fat remained stable and comparable, with Hortitom 1 at 0.87±0.01% (T2) to 1.14±0.02% (T5) versus Hortitom 3 from 0.83±0.00% (T1) to 1.12±0.00% (T2). Ash was broader in Hortitom 1 (3.66±0.01% at T6 to 5.08±0.04% at T5) than Hortitom 3 (3.56±0.01% at T6 to 4.99±0.02% at T7). Crude fiber showed Hortitom 1 ranging lower to higher (5.01±0.00% at T2 to 8.31±0.03% at T6) compared to Hortitom 3 (6.03±0.01% at T1 to 8.27±0.05% at T3). Crude protein was consistently superior in Hortitom 1 (1.10±0.01% at T2 to 2.06±0.05% at T5) over Hortitom 3 (1.05±0.01% at T1 to 1.85±0.09% at T4). Carbohydrates peaked much higher in Hortitom 1 (67.37±0.23% at T7 to 74.22±0.16% at T2) than in Hortitom 3 (66.41±0.08% at T7 to 70.65±0.03% at T2).

For minerals, patterns were more mixed but often favoured Hortitom 1 in range and peaks. Calcium in Hortitom 1 went from 15.85±0.05 mg/kg (T2) to 22.55±0.15 mg/kg (T6), closely matching Hortitom 3, ranging from 14.80±0.10 mg/kg (T3) to 22.75±0.25 mg/kg (T4), though the latter edged higher at its max. Potassium was notably higher in Hortitom 1 (25.60±0.20 mg/kg at T6 to 35.95±0.45 mg/kg at T1) versus Hortitom 3 (24.45±0.15 mg/kg at T4 to 32.30±0.20 mg/kg at T2). Magnesium spanned wider in Hortitom 1 (19.40±0.10 mg/kg at T6 to 26.15±0.15 mg/kg at T5) than Hortitom 3 (18.60±0.10 mg/kg at T5 to 23.37±0.04 mg/kg at T6). Iron reached a higher peak in Hortitom 1 (1.27±0.00 mg/kg at T3 to 2.01±0.00 mg/kg at T4) over Hortitom 3 (1.33±0.00 mg/kg at T4 to 1.73±0.01 mg/kg at T3). Phosphorus was similar, with Hortitom 1 at 8.92±0.19 mg/kg (T4) to 14.04±0.07 mg/kg (T2) and Hortitom 3 at 9.11±0.12 mg/kg (T6) to 14.17±0.05 mg/kg (T4). Nitrogen was marginally higher in Hortitom 1 (0.18±0.00 mg/kg at T1/T2 to 0.33±0.01 mg/kg at T5) than Hortitom 3 (0.17±0.00 mg/kg at T1 to 0.30±0.02 mg/kg at T4). These trends indicate Hortitom 1's superior nutritional profile under water stress variability.

Table 2 Effect of watering regime on the vegetative biomass of two genotypes of *Solanum lycopersicum*

Biomass parameter (g)	Tomato genotype	Watering regime							
		T1	T2	T3	T4	T5	T6	T7	T8
Leaf fresh weight	H1	9.00±1.47^{a}	9.00±1.78^{a}	8.25±1.38^{a}	5.00±1.22^{a}	8.00±0.71^{a}	7.00±0.91^{a}	5.00±0.71^{a}	-
	H3	8.50±2.06^{a}	9.75±1.49^{ab}	13.75±1.93^{ab}	12.50±0.96^{ab}	12.50±1.32^{ab}	13.50±0.65^{ab}	16.75±2.10^{b}	-
Stem fresh weight	H1	15.43±0.22^{c}	15.28±0.62^{c}	13.85±0.67^{bc}	13.03±0.91^{bc}	12.23±0.34^{ab}	11.63±0.36^{ab}	10.38±0.27^{a}	-
	H3	17.05±0.13^{d}	17.43±0.38^{d}	16.95±0.13^{d}	16.35±0.21^{cd}	15.75±0.17^{bc}	14.78±0.11^{ab}	13.88±0.37^{a}	-
Root fresh weight	H1	5.00±0.41^{a}	4.75±0.48^{a}	3.75±0.48^{a}	3.75±0.48^{a}	4.25±0.63^{a}	4.00±0.58^{a}	4.00±0.41^{a}	-
	H3	4.75±0.48^{ab}	3.75±0.48^{a}	5.50±0.65^{abc}	4.75±0.75^{ab}	7.25±0.48^{bc}	6.67±0.88^{bc}	7.75±0.48^{c}	-
Leaf dry weight	H1	5.51±1.74^{a}	5.55±1.42^{a}	3.75±1.85^{a}	2.16±0.85^{a}	6.60±2.92^{a}	2.04±0.79^{a}	1.14±0.29^{a}	-
	H3	5.86±1.69^{a}	5.98±2.23^{a}	7.29±2.05^{a}	8.34±0.60^{a}	8.43±0.78^{a}	9.29±0.96^{a}	10.48±1.09^{a}	-
Stem dry weight	H1	9.13±0.43^{b}	8.88±0.34^{b}	7.45±0.59^{b}	7.45±0.31^{b}	5.58±0.21^{a}	5.03±0.43^{a}	4.53±0.28^{a}	-
	H3	10.03±0.41^{d}	9.15±0.46^{cd}	8.25±0.37^{bc}	7.20±0.35^{ab}	7.03±0.41^{ab}	6.48±0.41^{a}	5.70±0.20^{a}	-
Root dry weight	H1	0.81±0.19^{a}	1.75±0.41^{a}	0.97±0.29^{a}	0.73±0.28^{a}	1.05±0.06^{a}	0.83±0.27^{a}	0.74±0.17^{a}	-
	H3	2.64±0.27^{ab}	1.18±0.39^{a}	2.80±0.77^{ab}	2.56±0.60^{a}	1.82±0.38^{a}	3.10±0.36^{ab}	4.92±0.42^{b}	-
Total biomass	H1	15.24±2.21^{ab}	18.58±2.0^{b}	12.80±1.52^{a}	13.63±1.16^{a}	13.71±1.69^{a}	12.90±0.71^{a}	13.03±0.91^{a}	-
	H3	13.43±0.72^{a}	11.92±0.77^{a}	17.65±0.88^{ab}	15.57±0.97^{ab}	18.38±0.93^{b}	15.71±0.47^{a}	16.35±0.21^{ab}	-

Note: Each value is a mean ± S.E. of 5 replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at $P \geq 0.05$ (Tukey HSD test). T1: watering twice daily; T2: watering once daily; T3: watering every two days; T4: watering every three days; T5: watering every four days; T6: watering every five days; T7: watering every six days; T8: continuous waterlogging; H1: Hortitom 1 genotype; H3: Hortitom 3 genotype

Table 3 Effect of watering regime on the phenological and yield parameters of two genotypes of *Solanum lycopersicum*

Growth parameters	Tomato genotype	Watering regime							
		T1	T2	T3	T4	T5	T6	T7	T8
Number of days to first flowering	H1	39.75 ± 0.32^{a}	40.00 ± 0.20^{a}	43.75 ± 1.80^{ab}	45.75 ± 1.65^{ab}	52.00 ± 2.35^{bc}	60.00 ± 2.80^{cd}	65.00 ± 2.42^{d}	-
	H3	47.50 ± 0.65^{a}	51.50 ± 0.65^{b}	55.50 ± 0.65^{c}	59.50 ± 0.65^{d}	63.50 ± 0.65^{e}	67.50 ± 0.65^{f}	71.50 ± 0.65^{g}	-
Number of fruit	H1	6.50 ± 0.20^{a}	6.50 ± 0.20^{a}	5.75 ± 0.14^{a}	6.00 ± 0.20^{a}	6.00 ± 0.20^{a}	5.63 ± 0.13^{a}	5.63 ± 0.24^{a}	-
	H3	5.50 ± 0.65^{ab}	4.50 ± 0.65^{ab}	3.50 ± 0.65^{ab}	6.00 ± 0.41^{b}	3.00 ± 0.41^{a}	5.50 ± 0.65^{ab}	4.50 ± 0.65^{ab}	-
Fruit fresh weight (g)	H1	5.25 ± 0.32^{a}	5.00 ± 0.20^{a}	4.00 ± 0.46^{a}	4.00 ± 0.41^{a}	4.25 ± 0.63^{a}	3.75 ± 0.63^{a}	4.00 ± 0.41^{a}	-
	H3	4.75 ± 0.48^{ab}	3.75 ± 0.48^{a}	5.50 ± 0.65^{abc}	4.75 ± 0.75^{ab}	7.25 ± 0.48^{bc}	6.50 ± 0.65^{bc}	7.75 ± 0.48^{c}	-
Fruit dry weight (g)	H1	0.81 ± 0.19^{a}	1.75 ± 0.41^{a}	0.97 ± 0.29^{a}	0.66 ± 0.30^{a}	1.05 ± 0.06^{a}	0.85 ± 0.19^{a}	0.74 ± 0.17^{a}	-
	H3	2.64 ± 0.28^{ab}	1.68 ± 0.65^{a}	2.80 ± 0.77^{ab}	2.55 ± 0.60^{a}	1.81 ± 0.39^{a}	2.93 ± 0.28^{ab}	4.92 ± 0.42^{b}	-
Fruit length (cm)	H1	16.25 ± 0.32^{a}	18.00 ± 0.20^{bc}	17.50 ± 0.20^{b}	18.50 ± 0.20^{cd}	19.25 ± 0.14^{de}	19.50 ± 0.20^{e}	19.25 ± 0.14^{de}	-
	H3	42.35 ± 0.65^{g}	38.35 ± 0.65^{f}	34.35 ± 0.65^{e}	30.35 ± 0.65^{d}	26.35 ± 0.65^{c}	22.35 ± 0.65^{b}	18.35 ± 0.65^{a}	-
Fruit breadth (cm)	H1	18.18 ± 0.38^{a}	20.00 ± 0.20^{b}	19.50 ± 0.20^{b}	20.50 ± 0.20^{b}	21.38 ± 0.24^{bc}	21.50 ± 0.20^{cd}	21.88 ± 0.13^{d}	-
	H3	75.28 ± 0.65^{g}	71.28 ± 0.65^{f}	67.28 ± 0.65^{e}	63.28 ± 0.65^{d}	59.28 ± 0.65^{c}	55.28 ± 0.65^{b}	51.28 ± 0.65^{a}	-

Note: Each value is a mean ± S.E. of 5 replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at $P \geq 0.05$ (Tukey HSD test). T1: watering twice daily; T2: watering once daily; T3: watering every two days; T4: watering every three days; T5: watering every four days; T6: watering every five days; T7: watering every six days; T8: continuous waterlogging; H1: Hortitom 1 genotype; H3: Hortitom 3 genotype

Table 4 Effect of watering regime on the fruit proximate and mineral compositions of two genotypes of *Solanum lycopersicum*

Proximate/Mineral composition	Tomato genotype	Watering regime							
		T1	T2	T3	T4	T5	T6	T7	T8
Moisture (%)	H1	17.61±0.06^{d}	15.13±0.13^{b}	14.28±0.05^{a}	19.00±0.13^{e}	15.00±0.02^{b}	16.41±0.08^{c}	17.44±0.06^{d}	-
	H3	18.65±0.00^{cd}	15.86±0.05^{a}	18.71±0.04^{d}	16.80±0.22^{b}	18.01±0.01^{c}	15.80±0.22^{a}	18.21±0.03^{cd}	-
Fat (%)	H1	1.06±0.06^{b}	0.87±0.01^{a}	1.12±0.00^{b}	1.02±0.03^{a}	1.14±0.02^{b}	1.13±0.02^{b}	1.07±0.06^{b}	-
	H3	0.83±0.00^{a}	1.12±0.00^{c}	0.99±0.02^{abc}	0.93±0.08^{ab}	0.97±0.01^{abc}	0.84±0.01^{ab}	1.01±0.01^{bc}	-
Ash (%)	H1	5.02±0.00^{d}	3.68±0.01^{a}	4.19±0.06^{b}	3.70±0.01^{a}	5.08±0.04^{d}	3.66±0.01^{a}	4.50±0.01^{c}	-
	H3	4.05±0.00^{b}	3.89±0.03^{b}	3.60±0.10^{a}	4.64±0.00^{c}	4.94±0.02^{d}	3.56±0.01^{a}	4.99±0.02^{d}	-
Crude fibre (%)	H1	5.39±0.02^{a}	5.01±0.00^{a}	7.47±0.12^{c}	5.67±0.12^{b}	7.93±0.08^{cd}	8.31±0.03^{d}	8.01±0.21^{cd}	-
	H3	6.03±0.01^{a}	7.24±0.00^{c}	8.27±0.05^{e}	6.59±0.01^{b}	7.94±0.08^{d}	7.90±0.07^{d}	7.95±0.02^{d}	-
Crude protein (%)	H1	1.12±0.01^{a}	1.10±0.01^{a}	1.68±0.01^{c}	1.99±0.02^{d}	2.06±0.05^{e}	1.34±0.02^{b}	1.74±0.01^{c}	-
	H3	1.05±0.01^{a}	1.26±0.00^{b}	1.83±0.00^{d}	1.85±0.09^{d}	1.54±0.01^{c}	1.53±0.01^{c}	1.45±0.02^{bc}	-
Carbohydrate (%)	H1	69.81±0.10^{c}	74.22±0.16^{e}	71.27±0.02^{d}	68.65±0.28^{b}	68.80±0.11^{b}	69.16±0.12^{c}	67.37±0.23^{a}	-
	H3	69.43±0.01^{b}	70.65±0.03^{c}	66.63±0.20^{a}	69.21±0.19^{b}	66.61±0.05^{a}	70.39±0.13^{c}	66.41±0.08^{a}	-
Calcium (mg/kg)	H1	20.40±0.10^{d}	15.85±0.05^{a}	17.40±0.00^{b}	21.80±0.30^{e}	18.50±0.10^{c}	22.55±0.15^{e}	20.40±0.30^{d}	-
	H3	18.50±0.10^{c}	17.05±0.15^{b}	14.80±0.10^{a}	22.75±0.25^{d}	17.80±0.30^{bc}	16.65±0.15^{b}	17.50±0.30^{bc}	-
Potassium (mg/kg)	H1	35.95±0.45^{e}	30.65±0.05^{c}	27.45±0.35^{b}	27.70±0.20^{b}	31.05±0.35^{c}	25.60±0.20^{a}	32.80±0.30^{d}	-
	H3	28.60±0.10^{bc}	32.30±0.20^{e}	29.30±0.20^{c}	24.45±0.15^{a}	27.65±0.15^{b}	30.60±0.10^{d}	28.35±0.25^{bc}	-
Magnesium (mg/kg)	H1	25.60±0.20^{c}	23.65±0.15^{b}	19.85±0.25^{a}	19.80±0.30^{a}	26.15±0.15^{c}	19.40±0.10^{a}	20.50±0.30^{a}	-
	H3	20.55±0.15^{b}	23.15±0.05^{d}	21.75±0.05^{c}	20.40±0.10^{b}	18.60±0.10^{a}	23.37±0.04^{d}	21.70±0.20^{c}	-
Iron (mg/kg)	H1	1.85±0.01^{f}	1.44±0.00^{b}	1.27±0.00^{a}	2.01±0.00^{g}	1.81±0.00^{e}	1.50±0.00^{c}	1.65±0.00^{d}	-
	H3	1.65±0.00^{e}	1.37±0.00^{b}	1.73±0.01^{f}	1.33±0.00^{a}	1.48±0.00^{c}	1.72±0.00^{f}	1.62±0.00^{d}	-
Phosphorus (mg/kg)	H1	12.20±0.10^{d}	14.04±0.07^{e}	9.57±0.01^{b}	8.92±0.19^{a}	10.67±0.02^{c}	12.18±0.03^{d}	10.94±0.01^{c}	-
	H3	10.67±0.01^{c}	13.16±0.01^{e}	12.30±0.17^{d}	14.17±0.05^{f}	13.13±0.01^{e}	9.11±0.12^{a}	9.58±0.01^{b}	-
Nitrogen (mg/kg)	H1	0.18±0.00^{a}	0.18±0.00^{a}	0.27±0.00^{c}	0.32±0.01^{d}	0.33±0.01^{d}	0.22±0.01^{b}	0.28±0.00^{c}	-
	H3	0.17±0.00^{a}	0.20±0.00^{ab}	0.29±0.00^{d}	0.30±0.02^{d}	0.25±0.00^{c}	0.25±0.01^{c}	0.23±0.00^{bc}	-

Note: Each value is a mean ± S.E. of 5 replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at $P \geq 0.05$ (Tukey HSD test). T1: watering twice daily; T2: watering once daily; T3: watering every two days; T4: watering every three days; T5: watering every four days; T6: watering every five days; T7: watering every six days; T8: continuous waterlogging; H1: Hortitom 1 genotype; H3: Hortitom 3 genotype

3.6 Leaf total chlorophyll content

Table 5 illustrates the impact of water regimes on leaf chlorophyll content (µm) in *Solanum lycopersicum* genotypes Hortitom 1 and Hortitom 3. Hortitom 1 exhibited total chlorophyll ranging from 36.46 µm under T4 (watering every three days) to a peak of 66.92 µm under T6 (every five days), with high values also at T5 (64.53 µm), indicating optimal retention under moderate water stress. In contrast, Hortitom 3 displayed substantially higher total chlorophyll peaks at 82.00 µm (T3, every two days) and 84.61 µm (T4, every three days), far exceeding other treatments, driven by elevated chlorophyll a in these regimes while chlorophyll b remained lower but slightly increased. Overall, Hortitom 3 outperformed Hortitom 1 in maximum chlorophyll accumulation, particularly under frequent watering, suggesting better photosynthetic adaptation to specific regimes.

Table 5 Effect of watering regime on the leaf chlorophyll content (mg/g fresh weight) of two genotypes of *Solanum lycopersicum*

Tomato genotype	Chlorophyll content (mg/g fresh weight)	Watering regime							
		T1	T2	T3	T4	T5	T6	T7	T8
	a	22.83	28.10	19.16	16.79	29.27	29.84	23.36	-
Hortitom 1	b	23.98	27.36	20.07	19.67	35.26	37.08	23.04	-
	Total	46.82	55.46	39.23	36.46	64.53	66.92	46.39	-
	a	22.15	22.00	68.21	67.86	21.19	28.33	26.31	-
Hortitom 3	b	22.76	21.80	13.79	16.75	22.32	29.82	25.15	-
	Total	44.91	43.81	82.00	84.61	43.51	58.15	51.45	-

Note: Each value is a mean of 5 replicates. T1: watering twice daily; T2: watering once daily; T3: watering every two days; T4: watering every three days; T5: watering every four days; T6: watering every five days; T7: watering every six days; T8: continuous waterlogging; H1: Hortitom 1 genotype; H3: Hortitom 3 genotype

4 Discussion

Tomato genotypes Hortitom 1 (H1) and Hortitom 3 (H3) demonstrated distinct physiological adaptations to water stress regimes, from optimal twice daily watering (T1) to severe restriction every six days (T7), with complete mortality under waterlogging (T8) due to root hypoxia (Sharma and Pathak, 2020).

4.1 Effect on growth parameters

Water stress regimes showed genotypic differences in vegetative growth. In Hortitom 1, plant height peaked under moderate stress (T5), reflecting adaptive enhancements typical of mild drought responses that optimize resource allocation (Alomari-Mheidat et al., 2024; Mustapha et al., 2025). Conversely, Sillo (2022) noted generally reduced height and stem diameter under deficits, underscoring genotype dependency, while Hortitom 3 consistently displayed taller plants, indicative of superior water use efficiency (Tüzel et al., 2025). Leaf number progressed upward in Hortitom 1 from T1 to T7, enabling sustained production amid restriction, aligning with leaf area adjustments for stress acclimation (Koch et al., 2019). Hortitom 3, however, exhibited declines at intermediate intervals, potentially signaling adaptive senescence to conserve water (Petrović et al., 2021). Leaf area fluctuated markedly in Hortitom 1 but remained stable in Hortitom 3, suggesting the latter's conservative strategy for optimized transpiration (Razouk et al., 2022; Chiofalo et al., 2025). Stem girth showed remarkable stability across treatments in both, a trait likely genetically governed to preserve vascular function under fluctuating moisture (Rodriguez et al., 2021; Amankwaa-Yeboah et al., 2023). Reproductive timing was also disturbed, with both genotypes experiencing progressively delayed first flowering under rarer watering, attributable to curtailed carbon fixation and hormonal shifts (Fernández-García et al., 2021; Sillo et al., 2022).

4.2 Effect on biomass accumulation

Hortitom 1 preserved stable fresh and dry leaf weights across regimes, minimizing photosynthetic losses, while root numbers surged under moderate drought to exploit deeper soil water, though stem biomass decline progressively, showing resource shifts from structure to acquisition (Arif et al., 2022; Kou et al., 2022). In Hortitom 3, fresh leaf weights increased with decreasing irrigation frequency, implying leaf carbon gain (Flexas et al., 2020); root fresh and dry weights similarly amplified. Stem biomass declined steadily in both genotypes, a conserved response to curtail non essential growth (Tüzel et al., 2025).

4.3 Effect on yield components

Yield responses revealed adaptive strategies under water stress. Hortitom 1 kept fruit numbers fairly steady, with slight drops in fresh weight but clear gains in fruit length and width during water shortages, directing more resources to individual fruits for bigger sizes (Poomkokrak et al., 2024; Zahedifar et al., 2025). In comparison, Hortitom 3 had greater changes in fruit count and size, boosting fresh and dry weights with less frequent watering while fruit length and width decreased, matching patterns of stress-induced fruit drop and limited growth (Medyouni et al., 2021; Zhang et al., 2025).

4.4 Effect on fruit nutritional and proximate compositions

Irrigation frequency greatly affects the quality of tomato fruits. In Hortitom 1, watering every 2-5 days raised moisture, crude fiber, and protein levels by concentrating these nutrients with less water dilution (Hasanuzzaman et al., 2021; Wadood et al., 2024). Hortitom 3 showed similar changes, with varying levels of moisture, fat, ash, fiber, and protein that improved under the same moderate stress. Minerals and heavy metals also shifted: Hortitom 1 built up more calcium during moderate stress to help it adapt, while potassium was highest with frequent watering to support water balance and leaf pore control (White and Broadley, 2020). Factors like genotype root links and soil microbe effects further shaped these trends (Ojewumi et al., 2025; Tripodi et al., 2025).

4.5 Effect on total chlorophyll content

Chlorophyll levels, which show how well plants photosynthesize, improved best under mild water limits. Hortitom 1 built up higher total chlorophyll, chlorophyll a, and chlorophyll b with watering every few days, helping it capture light more effectively (Flexas et al., 2021; Akhlaq et al., 2025; Atanassova et al., 2025). Hortitom 3 reached even higher peaks under certain moderate watering schedules, pointing to strong photosystem activity and built-in toughness for its type, even though drought often slows photosynthesis overall (Argentel-Martínez et al., 2024; Karami et al., 2025).

5 Conclusion and Recommendations

In conclusion, the two tomato genotypes exhibited distinct responses to different watering regimes, highlighting the importance of genotype-specific irrigation management. Hortitom 1 performed optimally under moderate water stress (watering every 4 days, T5), where it achieved maximum plant height and the highest crude protein content. Hortitom 3, on the other hand, showed superior fruit yield under more severe water restriction (watering every 6 days, T7). Both genotypes attained their highest plant height at T5, demonstrating good tolerance to moderate drought conditions.

The study further revealed that continuous waterlogging (T8) caused complete mortality in both genotypes, indicating high susceptibility to excess water. However, both Hortitom 1 and Hortitom 3 displayed strong drought tolerance, maintaining 100% survival even under watering intervals of up to six days.

These findings suggest that adopting genotype-specific watering regimes can significantly improve water productivity and fruit quality in resource-limited environments. For optimal performance, Hortitom 1 should be irrigated every 4 days, while Hortitom 3 performs better with irrigation every 6 days under screenhouse conditions. Both varieties should be grown only on well-drained soils to avoid waterlogging.

Future studies should validate these results under field conditions across different seasons and soil types to enhance the applicability of the recommendations for smallholder farmers.

Author’s contribution

Otitoloju Kekere designed and supervised the research, and prepared draft of the manuscript. Hepzibah Tofunmi Oyetunde set up the experiment and collected data. Hepzibah Tofunmi Oyetunde and Joseph Kolade Afolabi co-designed and monitored the experimental process. Joseph Kolade Afolabi performed statistical analyses of the data. All authors read and approved the final manuscript.

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