

The Effect Of Soil Moisture Levels On Growth And Yield Of Tomatoes: A Case Study Of Nakoma Sub County, Bugiri District

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Abstract

This study examined the effects of different soil moisture levels on the growth and yield of tomatoes in Nakoma Sub County, Bugiri District, Uganda. A randomized complete block design (RCBD) was used with four soil moisture treatment levels: T1 (25% field capacity), T2 (50% field capacity), T3 (75% field capacity), and T4 (100% field capacity), each replicated three times. Two improved tomato varieties, namely Tengeru 97 and Heinz 1370, were subjected to the different moisture treatments under controlled field conditions over a single growing season of 120 days. Growth parameters including plant height, number of leaves, stem girth, days to first flowering, and days to first fruiting were measured at two-week intervals. Yield parameters including number of fruits per plant, average fruit weight, and total yield per hectare were recorded at harvest. Results indicated that T3 (75% field capacity) produced the most favorable growth and yield outcomes for both tomato varieties, with significantly higher plant heights, greater leaf counts, earlier flowering, and superior yields compared to treatments T1, T2, and T4. Total yield at T3 was 38.6 tonnes per hectare for Tengeru 97 and 34.2 tonnes per hectare for Heinz 1370, compared to the control (T4 at full field capacity) which yielded 29.4 and 26.8 tonnes per hectare respectively. Water deficit conditions (T1 and T2) significantly suppressed growth and yield, while waterlogged conditions (simulated at T4 when irrigation was combined with seasonal rainfall) also reduced yields compared to T3. The study concluded that maintaining soil moisture at approximately 75% of field capacity optimized tomato growth and yield under the climatic and soil conditions of Nakoma Sub County. Irrigation scheduling targeting 75% field capacity was recommended for tomato farmers in Bugiri District.

Keywords: Soil Moisture, Tomato Growth, Tomato Yield, Field Capacity, Irrigation, Randomized Complete Block Design, Bugiri District, Uganda

Background of the Study

Tomato (*Solanum lycopersicum* L.) was one of the most economically important vegetable crops in Uganda and across sub-Saharan Africa, serving as both a major source of dietary nutrition and a significant income-generating crop for smallholder farmers (FAO, 2019). Tomatoes were rich in vitamins C and A, lycopene, and various antioxidants, making them a nutritionally valuable component of the Ugandan diet. The crop was grown throughout Uganda under both rainfed and irrigated conditions, with significant production concentrated in the Eastern, Central, and Western regions of the country. The Uganda Bureau of Statistics had documented steady increases in tomato production over the preceding decade, driven by growing urban demand, expanding regional export markets in South Sudan, Democratic Republic of Congo, and Rwanda, and increased government support for vegetable production through extension services and input subsidy programs (UBOS, 2020).

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Despite the growing importance of tomato cultivation in Uganda, production yields per hectare remained substantially below achievable potential, with national average yields estimated at approximately 12 to 15 tonnes per hectare compared to experimental station yields of 40 to 60 tonnes per hectare under optimized management conditions (MoAAIF, 2019). The gap between actual and potential yields was attributable to multiple factors including poor varieties, inadequate pest and disease management, suboptimal fertilizer application, and inadequate water management practices. Of these factors, water management through irrigation and soil moisture optimization was increasingly recognized as among the most critical determinants of tomato productivity, particularly in the context of increasing climatic variability that was causing more frequent and severe dry spells in traditionally rainfed production areas of Uganda (Zziwa et al., 2017).

Soil moisture was a fundamental determinant of plant physiological processes including photosynthesis, respiration, nutrient uptake, and cell expansion, all of which directly influenced plant growth rates and ultimately crop yields. Research on tomato water relations had consistently demonstrated that the crop was sensitive to both deficit and excess soil moisture conditions at different stages of its growth cycle (Patane & Cosentino, 2010). Water deficit during vegetative growth suppressed leaf area development and reduced the photosynthetic capacity of the plant, while water deficit during flowering and fruit set caused flower drop, reduced fruit set percentage, and compromised fruit size and quality. Conversely, excess soil moisture conditions led to soil anoxia, root hypoxia, and the proliferation of soil-borne pathogens such as *Phytophthora infestans* and *Fusarium* species that caused significant yield losses through root rot and vascular wilt diseases (Dorais et al., 2001).

In Nakoma Sub County, located in Bugiri District in the Eastern Region of Uganda, tomato cultivation had become an important livelihood activity for a significant proportion of smallholder farming households, particularly following the expansion of irrigation water availability through small-scale irrigation schemes developed with support from the Ministry of Agriculture, Animal Industry and Fisheries (Ashiraf et al., 2023). However, farmers in the area had reported persistent challenges with tomato yields that were attributed by agricultural extension workers to poor irrigation management practices, with many farmers either under-irrigating during dry periods or over-irrigating in ways that created waterlogging and root disease problems (Allan et al., 2023). The absence of locally relevant, empirically validated recommendations on optimal soil moisture management for tomatoes in the specific agroecological conditions of Bugiri District meant that extension advice was largely based on generalized recommendations that may not have been appropriate for the local soil types, temperature regimes, and humidity conditions of Nakoma Sub County (Alex & Julius, 2024). The present study was therefore designed to generate location-specific evidence on the effects of different soil moisture levels on tomato growth and yield to inform more precise irrigation recommendations for farmers in the area (Audrey & Kazaara, 2025).

The scientific literature on tomato water relations was extensive, but much of the foundational research had been conducted in temperate European and North American agricultural systems with conditions substantially different from those prevailing in the tropical, semi-humid climate of Eastern Uganda (Patane & Cosentino, 2010; Kuscu et al.,

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2014). The few studies conducted in East African conditions, such as those by Kimaro et al. (2012) in Tanzania and Nyakundi (2015) in Kenya, had generally supported the hypothesis that intermediate soil moisture levels around 60 to 80% of field capacity produced optimal tomato growth and yield outcomes, but had not examined the specific conditions of Bugiri District's Nakoma Sub County with its characteristic ferralitic soils, bimodal rainfall patterns, and mean annual temperatures ranging from 21 to 28 degrees Celsius. The present study therefore sought to contribute geographically specific agronomic knowledge to the body of evidence on tomato water management in East African smallholder farming systems.

PROBLEM STATEMENT

Tomato farmers in Nakoma Sub County, Bugiri District had been experiencing inconsistent and frequently unsatisfactory crop yields despite investing in inputs including improved seed varieties, fertilizers, and access to irrigation water through sub-county irrigation schemes(Collins et al., 2023). Agricultural extension workers in the district had identified irrigation management practices, particularly the lack of knowledge about appropriate soil moisture levels for tomato production, as a significant contributing factor to these yield inconsistencies. However, no empirical field study had been conducted in Nakoma Sub County or the broader Bugiri District context to determine the soil moisture levels that optimized tomato growth and yield under local agro-ecological conditions. In the absence of locally validated recommendations, farmers were making irrigation decisions based on intuition, tradition, or generalized guidelines that did not account for the specific soil type, climatic conditions, and tomato varieties prevalent in the area(Journal et al., 2023). This study was therefore conducted to generate empirical evidence on the effects of different soil moisture levels on the growth and yield of tomatoes in Nakoma Sub County, Bugiri District, providing a basis for locally relevant and scientifically grounded irrigation recommendations.

MAIN OBJECTIVE

The main objective of this study was to determine the effect of different soil moisture levels on the growth and yield of tomatoes in Nakoma Sub County, Bugiri District, Uganda.

Specific Objectives:

- i. To assess the effect of different soil moisture levels on the vegetative growth parameters of tomatoes in Nakoma Sub County.
- ii. To determine the effect of different soil moisture levels on the reproductive and yield parameters of tomatoes.
- iii. To identify the optimal soil moisture level for maximizing tomato yield in Nakoma Sub County, Bugiri District.

LITERATURE REVIEW

Theoretical Framework

This study was grounded in the Crop Water Productivity (CWP) framework, which posited that crop yield was a function of the volume and timing of water supply relative to crop water requirements at each growth stage (Molden, 1997). The CWP framework emphasized that maximizing crop yield per unit of water applied required understanding the crop's stage-specific sensitivity to water stress and calibrating irrigation to maintain soil moisture within the

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optimal range for each stage. The framework was complemented by Penman-Monteith's evapotranspiration theory, which provided the scientific basis for calculating crop water requirements based on climate variables and crop-specific coefficients, enabling the calculation of field capacity maintenance levels required under different environmental conditions.

Tomato Water Requirements and Soil Moisture

Tomato had a total crop water requirement typically ranging from 400 to 800 mm per growing season, depending on the duration of the growing period, mean temperatures, solar radiation, and humidity (Doorenbos & Kassam, 1979). Research by Patane and Cosentino (2010) in Mediterranean conditions demonstrated that tomato yield was maximized at soil moisture levels maintained between 70 and 80% of field capacity during the fruit set and enlargement stages, while moderate deficit irrigation in the range of 50 to 70% field capacity was associated with increased fruit quality parameters including higher soluble solids content and lycopene concentration. Studies by Kuscü et al. (2014) in Turkey confirmed that the relationship between soil moisture and tomato yield followed a curvilinear pattern, with yield increasing steeply from low moisture levels to an optimum and declining at excessive moisture levels due to oxygen deprivation and associated root dysfunction.

In sub-Saharan African conditions, research by Kimaro et al. (2012) in Tanzania examined the performance of tomato varieties under different irrigation frequencies and found that maintaining soil moisture at approximately 75% of field capacity through drip irrigation produced significantly higher yields than either deficit irrigation (50% field capacity) or conventional furrow irrigation that frequently resulted in temporary waterlogging. A study by Ademiluyi and Bamiro (2013) in Nigeria reported that tomato plants subjected to water deficit at the vegetative stage showed significantly reduced plant height, lower leaf area index, and fewer number of flowers compared to well-watered controls, with yield reductions of 35 to 55% under severe deficit conditions. These findings collectively established a scientific foundation for the investigation of soil moisture effects on tomato growth and yield under the specific conditions of Nakoma Sub County.

Growth Stage Sensitivity to Water Stress

Research on the growth stage sensitivity of tomato to water stress had established a clear hierarchy of vulnerability across the crop's developmental stages. The most sensitive stages to water deficit were identified as germination and seedling establishment, flowering and anthesis, and fruit set and early enlargement, during which even brief periods of water deficit could cause irreversible yield losses through failed germination, flower abortion, and reduced fruit set percentage (Doorenbos & Kassam, 1979). The vegetative growth stage had intermediate sensitivity to water deficit, with mild stress leading to reduced leaf area development but without necessarily causing permanent physiological damage if rewatered promptly. The fruit ripening stage was the least sensitive to mild water deficit and research suggested that controlled deficit irrigation during this stage could even improve fruit quality parameters such as dry matter content, soluble solids, and shelf life without significant yield penalties (Dorais et al., 2001). These stage-specific sensitivity patterns had important implications for irrigation scheduling in smallholder tomato production

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systems, where water availability might be limited and strategic deployment of available water across critical growth stages could optimize yield outcomes.

Soil Type Effects on Moisture Retention and Crop Response

The relationship between irrigation water application and soil moisture content was mediated by soil physical characteristics including texture, structure, and organic matter content, which determined the soil's water retention capacity and drainage properties. Ferralitic soils, characteristic of Bugiri District and much of Eastern Uganda, were typically well-drained loamy to clay-loam soils with moderate water retention capacity and good structural stability. These soil characteristics meant that irrigation management recommendations developed for sandier soils with lower water retention would not be directly transferable, as the ferralitic soils would maintain moisture at higher volumetric levels for longer periods following irrigation events. Understanding the specific water retention characteristics of Nakoma Sub County's ferralitic soils was therefore essential for translating field capacity percentage targets into practical irrigation scheduling recommendations for local farmers.

METHODOLOGY

Study Site Description

The study was conducted at an experimental farm established in Nakoma Sub County, Bugiri District, located at approximately 0° 34' N latitude and 33° 45' E longitude at an elevation of approximately 1,100 meters above sea level. The site received mean annual rainfall of approximately 1,200 mm distributed in a bimodal pattern with the long rains from March to May and the short rains from October to November. Mean daily temperatures ranged from 19°C to 28°C. The site's soils were classified as ferralitic loamy clay soils with a field capacity of approximately 32% volumetric water content and a permanent wilting point of approximately 14% volumetric water content, as determined by laboratory analysis of soil samples collected from the experimental plots.

Experimental Design and Treatments

A Randomized Complete Block Design (RCBD) was used with four soil moisture treatment levels as the main treatment factors, crossed with two tomato varieties as a secondary factor, giving eight treatment combinations, each replicated three times. The experiment therefore comprised 24 plots, each measuring 3 meters by 4 meters with 1-meter buffer strips between adjacent plots. The four moisture treatment levels were: T1 = 25% of field capacity (severe deficit), T2 = 50% of field capacity (moderate deficit), T3 = 75% of field capacity (optimal irrigation), and T4 = 100% of field capacity (full irrigation). The two tomato varieties were Tengeru 97, an open-pollinated variety widely used by smallholder farmers in Eastern Uganda, and Heinz 1370, an improved hybrid variety with documented yield potential under East African conditions. Soil moisture was monitored using calibrated tensiometers installed at 15 cm and 30 cm depths in each plot, with irrigation water applied whenever tensiometer readings indicated that moisture had fallen below the target treatment level.

Data Collection

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Growth parameters were measured at 14-day intervals commencing at 14 days after transplanting and continuing to 84 days after transplanting. Measurements included plant height (using a measuring tape from soil surface to growing apex), number of functional leaves per plant, stem girth at 5 cm above ground level (using a vernier caliper), and visual assessment of plant vigor. Phenological parameters including days to first flower opening and days to first fruit set were recorded per plot by daily observation. Yield parameters including number of fruits per plant, average fruit weight per fruit (using a digital scale), and total fresh fruit yield per plot were recorded at each of four sequential harvesting events, and plot yields were extrapolated to hectare basis for comparative analysis. All data were collected following standard agronomy research protocols to ensure accuracy and consistency across all plots and replications.

Data Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25 and GenStat statistical software(Nelson et al., 2022). Analysis of Variance (ANOVA) was conducted for each measured parameter to test for significant differences among treatment means, with the level of significance set at $p \leq 0.05$. Where ANOVA indicated significant treatment effects, means were separated using the Least Significant Difference (LSD) test at the 5% significance level. Two-way ANOVA was used to examine interaction effects between soil moisture treatments and tomato varieties for yield parameters. Pearson correlation coefficients were computed between soil moisture levels and key yield parameters to quantify the strength and direction of the moisture-yield relationship. All figures were calculated based on measurements from all three replicates per treatment.

RESULTS

Plant Height at Different Growth Stages (cm)

Treatment	14 DAT	28 DAT	42 DAT	56 DAT	70 DAT	LSD (0.05)
T1 (25% FC) - Tengeru 97	12.3a	24.6a	38.1a	52.4a	64.2a	
T2 (50% FC) - Tengeru 97	14.1b	30.2b	47.3b	66.8b	82.1b	
T3 (75% FC) - Tengeru 97	15.8c	38.4c	61.7c	88.3c	112.6c	
T4 (100% FC) - Tengeru 97	15.2c	35.8bc	57.3bc	81.2bc	102.4bc	
T1 (25% FC) - Heinz 1370	11.8a	22.9a	35.4a	48.7a	60.1a	

Treatment	14 DAT	28 DAT	42 DAT	56 DAT	70 DAT	LSD (0.05)
T2 (50% FC) - Heinz 1370	13.6b	28.7b	44.9b	63.4b	78.6b	
T3 (75% FC) - Heinz 1370	15.1c	36.8c	58.9c	84.1c	107.3c	
T4 (100% FC) - Heinz 1370	14.6bc	33.7bc	54.6bc	77.3bc	97.8bc	
LSD (0.05)	1.28	2.87	4.31	5.92	7.14	

Source: Primary Data, 2025

Table 1 presents mean plant height measurements at five time points from 14 to 70 days after transplanting (DAT) for both tomato varieties under the four soil moisture treatments. Values within columns followed by the same lowercase letter were not significantly different at the LSD 5% level. The results demonstrated a consistent and statistically significant pattern across all measurement periods whereby T3 (75% field capacity) produced the tallest plants for both tomato varieties, followed by T4 (100% field capacity), T2 (50% field capacity), and T1 (25% field capacity) in descending order. By 70 DAT, Tengeru 97 plants under T3 had attained a mean height of 112.6 cm, significantly taller than plants under T4 (102.4 cm), T2 (82.1 cm), and T1 (64.2 cm). The superior height performance of T3 over T4 was particularly noteworthy as it suggested that maintaining soil moisture below full field capacity was actually more conducive to vegetative growth than maintaining moisture at full capacity, which was consistent with research indicating that excessive soil moisture impeded root oxygen uptake and nutrient absorption, thereby limiting the mobilization of carbon and nitrogen compounds required for shoot elongation. Plants under T1, which experienced severe moisture deficit throughout the growing period, consistently recorded the lowest plant heights and showed visible symptoms of water stress including leaf rolling, reduced leaf size, and premature leaf senescence, particularly during the dry spell that occurred between weeks 6 and 9 of the growing season. The growth responses of Heinz 1370 under the different moisture treatments followed the same rank order as Tengeru 97 but at slightly lower absolute heights, reflecting the inherent morphological differences between the two varieties. The magnitude of differences between T3 and T1 increased progressively with plant age, from 3.5 cm at 14 DAT to 52.5 cm at 70 DAT for Tengeru 97, confirming the cumulative growth suppression effects of sustained moisture deficit over the growing season.

Number of Fruits Per Plant and Average Fruit Weight

Treatment	No. Fruits/Plant	Avg Fruit Wt (g)	% Marketable Fruits	Fruit Set %
T1 (25% FC) - Tengeru 97	12.4a	42.3a	54.2a	38.6a
T2 (50% FC) - Tengeru 97	18.7b	62.8b	68.4b	56.3b
T3 (75% FC) - Tengeru 97	28.6c	89.4c	86.7c	78.9c
T4 (100% FC) - Tengeru 97	23.1bc	74.6bc	73.2bc	68.4bc
T1 (25% FC) - Heinz 1370	10.9a	38.7a	51.3a	34.2a
T2 (50% FC) - Heinz 1370	16.4b	58.3b	64.8b	52.6b
T3 (75% FC) - Heinz 1370	25.4c	83.7c	83.4c	74.6c
T4 (100% FC) - Heinz 1370	21.3bc	68.9bc	70.1bc	63.7bc
LSD (0.05)	2.64	6.87	4.23	5.81

Source: Primary Data, 2025

Table 2 presents the fruit production parameters for both tomato varieties under the four soil moisture treatments. The data revealed highly consistent and statistically significant effects of soil moisture treatment on all fruit production metrics. T3 (75% field capacity) produced significantly greater numbers of fruits per plant, higher average fruit weights, higher percentages of marketable fruits, and higher fruit set percentages compared to all other treatments for both varieties. Tengeru 97 plants under T3 produced an average of 28.6 fruits per plant compared to 23.1 under T4, 18.7 under T2, and only 12.4 under T1 (Nelson et al., 2023). This pattern clearly demonstrated that moderate soil moisture deficit relative to full field capacity was superior to full field capacity for fruit production, likely because the slight osmotic stress at 75% field capacity stimulated the production of photoassimilates and directed more carbohydrate resources toward reproductive organs rather than vegetative growth, a phenomenon documented in

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tomato water relations literature as deficit irrigation-induced source-sink rebalancing. Average fruit weight showed the same treatment ranking, with T3 producing the heaviest fruits at 89.4 grams for Tengeru 97, compared to T4 at 74.6 grams, T2 at 62.8 grams, and T1 at a critically low 42.3 grams per fruit. The T1 fruit weight figure was particularly concerning as it reflected not only reduced cell expansion due to water deficit during fruit growth but also the high proportion of blossom end rot affected fruits that characterized water-stressed tomato plants, a disorder directly caused by calcium deficiency resulting from disrupted xylem transport under deficit water conditions. The percentage of marketable fruits, defined as fruits meeting minimum size, color uniformity, and defect-free surface quality standards for fresh market sale, was highest under T3 at 86.7% and lowest under T1 at 54.2%, a difference of 32.5 percentage points that had direct implications for the commercial value of the crop to farmers in Nakoma Sub County. The fruit set percentage similarly confirmed T3 as the optimal treatment, with 78.9% of flowers successfully setting fruit compared to 38.6% under T1, further demonstrating the severe penalty imposed by water deficit on the critical flowering and fruit set developmental stages.

Yield Components and Total Yield per Hectare

Treatment	Total Yield (t/ha)	Days to Flower	Days to Harvest	Yield Index
T1 (25% FC) - Tengeru 97	14.7a	38.4c	98.2c	0.38
T2 (50% FC) - Tengeru 97	22.4b	34.1b	91.3b	0.58
T3 (75% FC) - Tengeru 97	38.6d	29.7a	84.6a	1.00
T4 (100% FC) - Tengeru 97	29.4c	31.2a	86.8a	0.76
T1 (25% FC) - Heinz 1370	12.3a	40.1c	101.4c	0.36
T2 (50% FC) - Heinz 1370	19.8b	36.2b	93.7b	0.58
T3 (75% FC) - Heinz 1370	34.2d	31.4a	87.2a	1.00
T4 (100% FC) - Heinz 1370	26.8c	33.1a	89.4a	0.78
LSD (0.05)	3.12	2.18	3.47	—

Source: Primary Data, 2025

Table 3 presents the total yield per hectare, days to first flowering, days to harvest, and yield index for both tomato varieties under all four soil moisture treatments. The yield index was calculated as the ratio of each treatment's total yield to the maximum yield observed (T3), with T3 therefore having a yield index of 1.00. The results unequivocally

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identified T3 (75% field capacity) as the treatment producing the highest total yield for both tomato varieties. Tengeru 97 achieved the highest yield of 38.6 tonnes per hectare under T3, compared to 29.4 t/ha under T4 (a 31.3% yield advantage for T3), 22.4 t/ha under T2 (a 72.3% advantage), and 14.7 t/ha under T1 (a 162.6% advantage). These yield differentials were all statistically significant at the 5% level. Heinz 1370 showed a comparable pattern, with yields of 34.2 t/ha under T3, 26.8 t/ha under T4, 19.8 t/ha under T2, and 12.3 t/ha under T1. The superiority of T3 over T4 in terms of yield was consistent with the theory that mild soil moisture deficit (maintaining at 75% rather than 100% field capacity) stimulated more efficient water use and optimized the balance between vegetative and reproductive growth, as previously discussed. The T4 treatment's lower yield relative to T3 was also partly attributable to the excessive soil moisture conditions that prevailed during the rainy season portions of the experiment, when natural rainfall additions to T4 plots temporarily exceeded field capacity, creating conditions analogous to waterlogging that suppressed root function and promoted Pythium-related root diseases, contributing to yield reductions relative to the T3 treatment that maintained moisture at a slightly lower and more consistently aerobic level. Days to first flowering followed an inverse pattern with yield, with T1 plants requiring the most days to flower (38.4 for Tengeru 97) and T3 plants flowering earliest (29.7 days), consistent with the physiological principle that plants under water stress delayed reproductive development as a drought avoidance strategy while well-watered plants proceeded through developmental phases more rapidly. Days to harvest similarly showed that T3 and T4 plants matured approximately 13 days earlier than T1 plants, representing a commercially significant difference in the ability of farmers to access markets and achieve higher prices for early-season production.

Correlation Between Soil Moisture and Yield Parameters

Variable Pair	Pearson r	p-value	Interpretation
Soil moisture % FC - Plant height	0.783	0.000	Strong positive
Soil moisture % FC - Number of fruits	0.812	0.000	Strong positive
Soil moisture % FC - Avg fruit weight	0.798	0.000	Strong positive
Soil moisture % FC - Total yield t/ha	0.831	0.000	Strong positive
Soil moisture % FC - Marketable %	0.774	0.000	Strong positive
Soil moisture % FC - Days to flower	-0.691	0.000	Moderate negative

Source: Primary Data, 2025

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Table 4 presents Pearson correlation coefficients examining the relationships between soil moisture level (expressed as percentage of field capacity) and six key growth and yield parameters across all treatment levels. All correlations were statistically significant at the 0.001 level. The strongest positive correlation was observed between soil moisture level and total yield per hectare ($r = 0.831$), confirming that within the range of moisture levels examined (25% to 100% field capacity), increases in soil moisture were strongly positively associated with increases in total yield. It was important to interpret this correlation in the context of the non-linear optimum observed in the treatment comparison, where the highest yield was achieved at T3 (75% FC) rather than at T4 (100% FC), indicating that the linear correlation captured the overall positive trend across the moisture range but did not fully describe the curvilinear relationship that included the slight yield decline at full field capacity. The correlation between soil moisture and number of fruits per plant ($r = 0.812$) was the second strongest, reflecting the critical importance of adequate soil moisture during the flowering and fruit set stages, which were the most moisture-sensitive phases of the tomato growth cycle. Average fruit weight was strongly positively correlated with soil moisture ($r = 0.798$), confirming that cell expansion during fruit development, which was directly driven by turgor pressure maintained through adequate water supply, was systematically impaired under moisture deficit conditions. The negative correlation between soil moisture and days to first flowering ($r = -0.691$) confirmed the finding from Table 3 that plants under higher moisture regimes flowered earlier, reflecting the ability of adequately hydrated plants to allocate photoassimilates efficiently to reproductive organs without the developmental delay imposed by drought stress responses. Collectively, the correlation analysis reinforced the finding from the treatment comparisons that soil moisture management was a critical determinant of tomato production outcomes in Nakoma Sub County.

ANOVA Summary for Total Yield

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	1.42	0.71	0.89	0.432
Soil Moisture (SM)	3	1842.6	614.2	768.4	0.000
Variety (V)	1	124.8	124.8	156.1	0.000
SM × V Interaction	3	18.4	6.13	7.67	0.003
Error	14	11.2	0.80		
Total	23	1998.4			

Source: Primary Data, 2025

Table 5 presents the analysis of variance results for total yield per hectare. The ANOVA confirmed that both the main effect of soil moisture treatment and the main effect of tomato variety were highly significant sources of variation in

total yield ($p < 0.001$ for both). The soil moisture treatment accounted for by far the largest proportion of total sum of squares (1842.6 out of 1998.4), confirming that soil moisture level was the dominant determinant of yield variation in this experiment. The variety main effect was also highly significant, reflecting the genuine yield differences between Tengeru 97 and Heinz 1370 that were consistent across all moisture treatments. The significant soil moisture by variety interaction ($F = 7.67$, $p = 0.003$) indicated that the two varieties did not respond identically to the different moisture treatments, with Tengeru 97 showing a proportionally greater yield advantage over Heinz 1370 under the T3 treatment compared to other treatments. This interaction was agronomically important as it suggested that variety selection and irrigation management were not fully independent decisions: the optimal irrigation regime for Tengeru 97 under Nakoma Sub County conditions (T3) was the same as for Heinz 1370, but the magnitude of benefit from optimal irrigation was greater for Tengeru 97, supporting its preferential recommendation for irrigated production systems in the area. Replication effects were non-significant ($p = 0.432$), confirming the effectiveness of the experimental blocking in minimizing soil variability effects within the experimental site and ensuring that the observed treatment effects were attributable to the moisture treatments rather than spatial soil heterogeneity.

DISCUSSION OF RESULTS

The findings of this study provided comprehensive empirical evidence that soil moisture level exerted a powerful and statistically significant effect on all measured parameters of tomato growth and yield under the agro-ecological conditions of Nakoma Sub County, Bugiri District. The consistent superiority of the T3 treatment (75% field capacity) across all growth and yield metrics for both tomato varieties confirmed the study's a priori hypothesis that an intermediate moisture level would outperform both deficit and excessive moisture regimes, consistent with the established scientific literature on tomato water relations.

The finding that T3 (75% FC) produced higher yields than T4 (100% FC) was particularly significant for irrigation management recommendations in the area, as it demonstrated that irrigation to full field capacity was not only unnecessary but actually counterproductive for yield maximization. This finding could be explained by two complementary mechanisms. First, the slight osmotic stress at 75% FC stimulated physiological processes associated with reproductive development, including enhanced production of growth regulators such as abscisic acid that promoted fruit set and reduced vegetative competition with reproductive sinks. Second, the temporary waterlogging events at T4 during high-rainfall periods created hypoxic root conditions that impaired nutrient uptake and root health, particularly promoting *Pythium* root rot infection that was observed in T4 plots during field monitoring. The T1 (25% FC) results confirmed that severe moisture deficit was most damaging, consistent with international literature on tomato water stress (Patane & Cosentino, 2010; Kuscü et al., 2014) and the East African regional studies by Kimaro et al. (2012) and Nyakundi (2015).

The significant variety by treatment interaction underlined the importance of conducting locally specific research rather than relying solely on generalized recommendations, as it confirmed that the relative performance of the two varieties was not constant across moisture regimes. The higher yield response of Tengeru 97 to optimal irrigation may have reflected this variety's better adaptation to the ferralitic soils of Bugiri District, its possibly superior root architecture for moisture extraction, or its more robust disease resistance profile that preserved yield potential under the various stress conditions encountered across the growing season.

CONCLUSIONS

This study conclusively demonstrated that soil moisture levels significantly affected the growth and yield of tomatoes in Nakoma Sub County, Bugiri District, Uganda. Maintaining soil moisture at 75% of field capacity (T3 treatment) produced the most favorable outcomes across all measured growth parameters including plant height, number of leaves, stem girth, and phenological development, as well as all yield parameters including number of fruits per plant, average fruit weight, marketable fruit percentage, fruit set percentage, and total yield per hectare.

The T3 treatment yielded 38.6 tonnes per hectare for Tengeru 97 and 34.2 tonnes per hectare for Heinz 1370, significantly exceeding yields under all other treatments. Both severe water deficit (T1 at 25% FC) and excessive moisture (T4 at 100% FC during combined irrigation and rainfall periods) reduced tomato growth and yield, confirming the importance of balanced soil moisture management. The study concluded that irrigation scheduling targeting 75% of field capacity represented the optimal water management strategy for tomato production in Nakoma Sub County under the prevailing soil and climate conditions.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made. Agricultural extension workers in Bugiri District were urged to promote irrigation scheduling practices that maintained soil moisture at approximately 75% of field capacity for tomato production, using practical field moisture assessment tools such as the 'feel method' or affordable tensiometers to guide irrigation timing and volumes. The Ministry of Agriculture, Animal Industry and Fisheries was recommended to include the findings of this study in the development of region-specific tomato production guidelines for Eastern Uganda that explicitly addressed optimal irrigation management under the area's bimodal rainfall conditions. Tomato farmers in Nakoma Sub County were advised to install soil moisture monitoring tools in their fields and to adjust irrigation frequency and volume based on monitored soil moisture levels rather than fixed schedules, as this would enable them to maintain moisture closer to the optimal 75% field capacity level throughout the growing season.

The Tengeru 97 variety was recommended as the preferred variety for irrigated tomato production in Nakoma Sub County, given its higher yield response to optimal irrigation management compared to Heinz 1370. Future research was recommended to investigate the economic returns to different irrigation management strategies for smallholder

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tomato farmers in Bugiri District, to examine the effects of deficit irrigation on tomato quality parameters including lycopene content and shelf life, and to evaluate the performance of drip irrigation systems compared to surface irrigation methods in maintaining optimal soil moisture levels under local conditions.

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