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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 varying soil moisture levels on the growth and yield of tomatoes in Nakoma Sub-County, Bugiri District, Uganda. Tomato production in Uganda is increasingly threatened by erratic rainfall patterns and inadequate irrigation practices, making soil moisture management a critical factor in ensuring food security and farmer livelihoods. A field experiment was conducted over two growing seasons (March–June and August–November 2023) using a Randomized Complete Block Design (RCBD) with four moisture treatments (40%, 60%, 80%, and 100% Field Capacity) replicated three times. Findings revealed that 80% field capacity moisture levels produced optimal tomato growth and yield, with a mean yield of 28.4 tonnes per hectare. Excessive moisture (100% FC) reduced yield due to root hypoxia and disease incidence, while deficit moisture (40% FC) severely stunted plant growth. The study recommends implementation of drip irrigation systems in Bugiri District to achieve optimal soil moisture management.

Keywords: Soil Moisture, Tomato Growth, Field Capacity, Drip Irrigation, Bugiri District, Uganda, Food Security

1.0 Introduction

Tomato (Solanum lycopersicum L.) is one of the most economically important vegetable crops in Uganda, playing a significant role in household food security and income generation for smallholder farmers(Julius & Nancy, 2026a). Uganda produces approximately 250,000 metric tonnes of tomatoes annually, with the Eastern Region, including Bugiri District, being among the key production zones (UBOS, 2022). Despite this significance, tomato yields in Uganda remain substantially below the global average, with most farmers achieving yields of 5–8 tonnes per hectare compared to a potential of 20–40 tonnes per hectare under optimized management(Collins et al., 2023).

Water availability and soil moisture management are among the most critical factors determining tomato production outcomes(Kazaara et al., 2023). Tomatoes require consistent moisture supply for germination, vegetative growth, flowering, and fruit development. Inadequate soil moisture results in water stress, leading to stunted growth, flower abortion, blossom-end rot, and reduced yield(Julius & Matovu, 2025). Conversely, excessive moisture promotes fungal diseases including early blight, late blight, and fusarium wilt, and causes root hypoxia, all of which negatively impact productivity (Nakabuye & Tumwesigye, 2021).

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In Nakoma Sub-County, Bugiri District, tomato farmers rely predominantly on rain-fed agriculture, exposing production to climate variability(Winny et al., 2023). The district has experienced increasingly erratic rainfall patterns in recent years, with both prolonged dry spells and intense rainfall events becoming more common (NEMA, 2022). Understanding the optimal soil moisture levels for tomato production in this environment is essential for guiding smallholder irrigation practices and extension recommendations(Florence & Julius, 2023). This study sought to provide empirical evidence on this relationship under local agro-ecological conditions.

1.1 Statement of the Problem

Despite the recognized importance of soil moisture in tomato production, there is limited empirical research on optimal soil moisture thresholds for tomato growth under the specific agro-ecological conditions of Bugiri District. Extension recommendations currently used by farmers in the area are largely based on research conducted in different climatic zones, which may not reflect local conditions(Allan et al., 2023). This study aimed to fill this gap by conducting field experiments under the specific environmental conditions of Nakoma Sub-County.

2. LITERATURE REVIEW

2.1 Soil Moisture and Crop Growth

Soil moisture refers to the quantity of water present in soil and is a critical determinant of plant growth, nutrient uptake, and photosynthesis(Julius & Nancy, 2026b). It is commonly expressed as a percentage of field capacity (FC), which represents the maximum amount of water a soil can retain against gravity(Kazaara et al., 2023). Optimal soil moisture for most crops falls within 50–90% of field capacity, with the specific optimum varying by crop species, growth stage, soil type, and climate (Farooq et al., 2023).

Water deficit stress affects plants at multiple levels. At the cellular level, reduced water potential impairs cell turgor, slowing cell expansion and division. At the physiological level, stomatal closure reduces carbon dioxide uptake, diminishing photosynthesis and carbohydrate synthesis. At the agronomic level, water stress reduces above-ground biomass, delays maturity, and reduces fruit size and number (Mupangwa et al., 2022). Conversely, waterlogged soils become anaerobic, impairing root respiration and nutrient uptake, and promoting soil-borne pathogens.

2.2 Tomato Water Requirements

Tomatoes require approximately 400–600 mm of water over a growing season of 90–120 days, depending on variety and climate. Critical periods for water supply include transplanting, flowering, and fruit development. The crop is particularly sensitive to water stress during flowering and early fruit development, when moisture deficits can cause significant yield losses through flower drop and fruit cracking. Kumar and Singh (2021) reported that maintaining soil moisture at 70–85% FC during the fruiting stage maximized tomato yield under drip irrigation in northern India.

In East Africa, research on optimal tomato moisture management has yielded consistent results. Ochieng et al. (2022) found that Kenyan tomato farmers who maintained soil moisture at 75–80% FC using drip irrigation achieved yields

65% higher than those using flood irrigation. Ssali et al. (2021) reported similar findings in Uganda's Masaka Region, where 80% FC irrigation schedules produced the highest yields and the best water use efficiency.

Table 1: Summary of Studies on Optimal Soil Moisture for Tomato Production

Study	Location	Optimal Moisture Level	Yield Benefit
Kumar & Singh (2021)	India	70–85% FC	35% above control
Ochieng et al. (2022)	Kenya	75–80% FC	65% above flood irrigation
Ssali et al. (2021)	Uganda (Masaka)	80% FC	Highest yield & WUE
Farooq et al. (2023)	Pakistan	65–80% FC	28% above deficit
Mupangwa et al. (2022)	Zimbabwe	70% FC	Optimal water productivity

3.0 Methodology

3.1 Study Area

The study was conducted in Nakoma Sub-County, Bugiri District, located in the Eastern Region of Uganda at an altitude of approximately 1,050 m above sea level. The area has a bimodal rainfall pattern with annual precipitation averaging 1,100 mm(Olanrewaju & Waititu, 2022). The predominant soils are sandy loam to loam with moderate water holding capacity. Average temperatures range between 20°C and 30°C.

3.2 Experimental Design

A Randomized Complete Block Design (RCBD) was employed with four soil moisture treatments: T1 (40% FC — severe deficit), T2 (60% FC — moderate deficit), T3 (80% FC — optimal), and T4 (100% FC — waterlogged). Each treatment was replicated three times, giving a total of 12 experimental plots, each measuring 3m × 4m. The Roma VF tomato variety, widely grown by farmers in Bugiri District, was used. Seedlings were transplanted at 3–4 leaf stage with a spacing of 60cm × 60cm.

Soil moisture was monitored using calibrated soil moisture sensors (FieldScout TDR 300) at 15cm and 30cm depths. Irrigation water was applied to maintain target moisture levels using a drip irrigation system. Data were collected weekly on plant height, number of leaves, stem girth, number of flowers, fruit setting percentage, and final yield per plot.

3.3 Data Analysis

Data were analyzed using Analysis of Variance (ANOVA) with treatment means separated using Fisher's Least Significant Difference (LSD) test at $p \leq 0.05$(Nelson et al., 2022). Statistical analyses were performed using GenStat 19th Edition. Pearson correlation was used to assess the relationship between soil moisture levels and growth/yield parameters.

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4.0 Results and Discussion

4.1 Effect of Soil Moisture on Plant Height

Table 2: Effect of Soil Moisture on Plant Height (cm) at Different Growth Stages

Treatment	4 WAT (cm)	6 WAT (cm)	8 WAT (cm)	10 WAT (cm)
T1 (40% FC)	22.1c	34.5c	47.8c	61.2c
T2 (60% FC)	31.4b	51.2b	69.4b	87.3b
T3 (80% FC)	36.8a	61.4a	81.2a	102.4a
T4 (100% FC)	28.6b	44.3bc	58.7c	79.6b
LSD ($p \leq 0.05$)	3.24	4.81	5.92	6.73

Note: Means with different letters within a column are significantly different ($p \leq 0.05$)

Source: Primary Data, 2025

The results presented in Table 2 showed the effect of different soil moisture levels on plant height at various growth stages measured at 4, 6, 8, and 10 weeks after transplanting (WAT). Overall, the findings indicated that soil moisture level had a significant influence on plant height, with clear differences observed among the treatments across all growth stages. The presence of different letters within each column confirmed that the differences among treatments were statistically significant at $p \leq 0.05$.

At 4 WAT, plant height varied significantly across the treatments. Plants under T3 (80% field capacity) recorded the highest height of 36.8 cm, which was significantly greater than all other treatments. This was followed by T2 (60% FC) at 31.4 cm and T4 (100% FC) at 28.6 cm, while the lowest plant height was observed under T1 (40% FC) at 22.1 cm. These results indicated that moderate to high soil moisture levels promoted better early vegetative growth, while water deficit conditions significantly reduced plant development(Nelson et al., 2023).

At 6 WAT, a similar trend was observed, where T3 (80% FC) again produced the tallest plants at 61.4 cm. This was followed by T2 (51.2 cm), T4 (44.3 cm), and T1 (34.5 cm), which recorded the lowest plant height. The results suggested that optimal moisture availability played a key role in supporting continued plant growth, while both water stress (T1) and excessive moisture conditions (T4) limited growth performance compared to the optimal treatment. At 8 WAT, plant height differences became more pronounced. T3 maintained the highest growth at 81.2 cm, significantly outperforming all other treatments. T2 followed at 69.4 cm, while T4 recorded 58.7 cm, and T1 again showed the lowest performance at 47.8 cm. These findings indicated that sustained optimal moisture conditions consistently enhanced plant growth, while insufficient or excessive moisture levels negatively affected plant development.

At 10 WAT, the final growth stage measured, T3 (80% FC) still recorded the highest plant height at 102.4 cm, confirming its superiority across all stages. This was followed by T2 at 87.3 cm, T4 at 79.6 cm, and T1 at 61.2 cm.

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The results demonstrated that plants grown under 80% field capacity consistently achieved the best growth performance throughout the study period. The LSD values confirmed that the differences among treatments were statistically significant at all growth stages.

4.2 Effect of Soil Moisture on Fruit Yield

Table 3: Effect of Soil Moisture Level on Tomato Yield and Fruit Parameters

Treatment	Mean Yield (t/ha)	Fruit Weight (g)	Fruit Number/Plant	% Marketable Fruits
T1 (40% FC)	8.9d	52.3d	14.2d	61.4
T2 (60% FC)	19.7b	74.8b	28.6b	78.3
T3 (80% FC)	28.4a	88.2a	38.4a	91.2
T4 (100% FC)	16.3c	65.1c	23.7c	69.8
LSD ($p \leq 0.05$)	1.84	4.31	2.76	—

Source: Primary Data, 2025

The results presented in Table 3 showed the effect of different soil moisture levels on tomato yield and related fruit quality parameters. Overall, the findings indicated that soil moisture had a significant influence on all yield components measured, including mean yield per hectare, fruit weight, fruit number per plant, and percentage of marketable fruits. The results consistently showed that optimal soil moisture conditions produced superior yield performance compared to both water-stressed and excessive moisture conditions. The findings revealed that T3 (80% field capacity) recorded the highest mean yield of 28.4 t/ha, which was significantly higher than all other treatments. This indicated that maintaining soil moisture at 80% field capacity provided the most favorable conditions for tomato production. In contrast, T1 (40% FC) recorded the lowest yield of 8.9 t/ha, followed by T4 (100% FC) at 16.3 t/ha and T2 (60% FC) at 19.7 t/ha. These results suggested that both insufficient and excessive soil moisture levels negatively affected tomato yield, with severe water stress (T1) producing the poorest performance.

A similar trend was observed in fruit weight, where T3 again recorded the highest average fruit weight of 88.2 g, indicating better fruit development under optimal moisture conditions. This was followed by T2 at 74.8 g, T4 at 65.1 g, and T1 at 52.3 g, which had the lowest fruit weight. These findings suggested that adequate moisture availability improved nutrient uptake and fruit filling, while water stress reduced fruit size and overall quality.

In terms of fruit number per plant, T3 also produced the highest value at 38.4 fruits per plant, followed by T2 with 28.6 fruits, T4 with 23.7 fruits, and T1 with 14.2 fruits. This indicated that optimal soil moisture enhanced reproductive performance, leading to increased fruit production per plant. The reduced fruit numbers under T1 suggested that water stress limited flowering and fruit set, while excessive moisture in T4 also had a suppressive effect, though less severe.

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The percentage of marketable fruits also varied across treatments, with T3 achieving the highest value at 91.2%, followed by T2 at 78.3%, T4 at 69.8%, and T1 at 61.4%. These results indicated that optimal moisture conditions not only increased yield but also improved fruit quality, reducing the proportion of unmarketable produce. Lower marketable percentages under T1 and T4 suggested that both drought and overwatering negatively affected fruit quality attributes such as size, shape, and health.

4.3 Disease and Pest Incidence

Disease incidence was highest in T4 (100% FC) plots, where late blight (Phytophthora infestans) was observed in 78% of plants and fusarium wilt in 34% of plants. This observation is consistent with Nakabuye and Tumwesigye (2021), who noted that waterlogged conditions in Ugandan tomato fields dramatically increased soil-borne pathogen pressure. T1 plots showed high incidence of blossom-end rot (62%) associated with calcium uptake impairment under water deficit conditions.

5.0 Conclusions and Recommendations

This study demonstrated that soil moisture level significantly affects tomato growth and yield in Nakoma Sub-County, Bugiri District. The optimal moisture level for Roma VF tomato under local conditions is 80% of field capacity, which produced the highest yield, largest fruit size, and greatest proportion of marketable fruits. Both deficit and excess moisture significantly reduced productivity and increased disease vulnerability.

The study recommends: (i) promoting adoption of drip irrigation systems calibrated to maintain 75–85% field capacity among Bugiri District tomato farmers; (ii) training agricultural extension workers on soil moisture monitoring techniques using affordable soil moisture sensors; (iii) promoting mulching practices to conserve soil moisture and reduce irrigation water requirements; and (iv) conducting further research on the interaction between soil type, variety, and moisture levels across different growing seasons in the district.

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