

Research Article

Evaluation of Deficit Irrigation and Fertilizer Levels on Water Productivity and Yield of Tomato at Hawa Galan District, Western Oromia, Ethiopia

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Abstract

This study was conducted to address the critical challenges of water scarcity and inefficient input use in tomato production. The specific objectives were: 1) to evaluate the water productivity of tomato under different combinations of irrigation levels and fertilizer rates, 2) to quantify the amount of irrigation water saved using these combinations, and 3) to recommend the best water and fertilizer-saving technique for the study site. A factorial experiment was arranged in a Randomized Complete Block Design with three replications. The treatments included three irrigation levels (50%, 75%, and 100% of crop evapotranspiration - ETc) and three fertilizer (NPS) rates (50%, 75%, and 100% of the recommended amount). The results showed that the combination of 75% ETc and 75% fertilizer rate (150 kg NPS ha⁻¹) achieved the highest water productivity (8.39 kg ha⁻¹ mm⁻¹) and a high yield of 23,901 kg ha⁻¹, which was statistically on par with the full irrigation and fertilizer treatment. This optimal treatment resulted in water savings of 25% (94.95 mm) compared to the full irrigation regime. It is concluded that applying 75% of both the recommended irrigation water (ETc) and fertilizer rate is the best technique for the study site, enabling significant resource conservation without compromising yield. This strategy is recommended for extension to farmers to enhance sustainable productivity.

Keywords

Water Productivity, Deficit Irrigation, Fertilizer Levels, Tomato Production

1. Introduction

The Ethiopian government has made a firm commitment to reduce the poverty rate by half through its endorsement of the Millennium Development Goals (MDGs). Among the strategic interventions being pursued to achieve this objective is the development of irrigation infrastructure. One significant challenge facing Tomato production in irrigated settings is the

uncertainty surrounding the optimal amount of fertilizer to apply and how it interacts with different quantities of irrigation water [1].

As the world's population continues to grow rapidly, the pressure on our limited freshwater resources intensifies. Irrigated agriculture is the largest consumer of these pre-

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cious water resources, and without effective management, this can lead to the abandonment of agricultural land, further compounding the issue. With a burgeoning population and declining water availability for agriculture, the future of food security is threatened. The agriculture sector now faces the daunting challenge of producing more food with less water, which necessitates increasing Crop Water Productivity (CWP). Achieving a higher CWP entails either maintaining current production levels with less water or increasing production using the same volume of water [2-4].

In the Western region, tomato cultivation during the dry season relies heavily on traditional irrigation methods. Farmers often apply irrigation water without adhering to a structured irrigation schedule [5-8]. This conventional method overlooks critical factors, including crop water needs, soil-water relationships, yield responses of different varieties, water scarcity, and current climatic conditions [9-12].

In light of these challenges, this experiment was initiated to assess how tomatoes respond to various irrigation levels, grounded in the principles of allowable soil moisture depletion and the appropriate rates of fertilizer application. The insights gained from this study aim to inform better irrigation practices and enhance the productivity of tomato farming in irrigated environments.

Specific objectives

- 1) To evaluate the water productivity of Tomato under different combinations of irrigation levels and fertilizer rates at the study sites.
- 2) To quantify the amount of water saved under different combinations of irrigation levels and fertilizer rates and
- 3) To recommend the best water and fertilizer-saving technique for the study sites.

3. Results and Discussions

Table 2. Combined mean squares of some parameters.

Source of Variation	DF	Mean square									
		DM	PH	NFPF	FW (gr)	UMY (t/ha)	MY (t/ha)	TY (t/ha)	CWUE	IWUE	WP
NPS	2	617.37	10.65	371.69	3100.22	3470.93	68949.35	98971.02	686.27	336.01	11.59
WL	2	1413.6	110.80	393.00	6304.53	3849.13	54337.23	81195.81	562.81	275.8	16.74
REP	2	25.92	395.28	730.93	10232.72	501.53	50130.50	60660.72	420.49	206.08	9.10
NPS*WL	4	338.98	79.43	234.69	7766.72	3227.89	12256.90	26090.34	180.88	88.63	3.107

The analysis of variance indicated that NPS and water level had no statistically significant effect ($P < 0.05$) on plant height, number of fruit per plant, and fruit weight. However, there

2. Materials and Methods

The experiment involves two factors, making it a factorial experiment. The two independent variables used are three levels of irrigation water (1, $\frac{3}{4}$, and $\frac{1}{2}$ of the irrigation requirement (ET_c)) combined with three (1, $\frac{3}{4}$, and $\frac{1}{2}$ of the recommended) fertilizer rates.

It is a factorial experiment because there are two variables taken into consideration. Three irrigation water levels and three fertilizer rates are the two independent variables that are used. The three irrigation water levels are one, one-half, and one-quarter of the irrigation requirement (ET_c). The same partition is used for determining the fertilizer rate.

The amount of irrigation water to be applied with full irrigation treatments is the crop water requirement that is computed with the aid of the CROPWAT model [13]. Quarter and half irrigation levels were computed from the software output.

Randomized Complete Block Design with three replications was used. The plot had an area of 3 m x 6 m, which is 18m². One (1) m between plots and a 1.5 m wide road between replications was used. A summary of experimental treatments is combined as listed in the following Table 1:

Table 1. Summary of treatment combination.

Water Level	Fertilizer
Full ET_c	Recommended fertilizer (200kg/ha)
$\frac{3}{4}ET_c$	$\frac{3}{4}$ fertilizer (150kg/ha)
$\frac{1}{2}ET_c$	$\frac{1}{2}$ fertilizer (100kg/ha)

were some numerical differences between treatments.

Table 3. Interaction effect of NPS and WL on days to maturity.

NPS (kg/ha)	Water Level (%ETc)		
	H	T	F
100	92.7 ^{cd}	99.3 ^c	126.7 ^a
150	90.3 ^d	122.7 ^{ab}	123.0 ^b
200 (Recommended rate)	117.3 ^b	125.3 ^a	125.0 ^a
CV	3.62		
LSD	4.11		

Where: H=50%ETc | T=75%ETc | F=100%ETc

Applying the full irrigation amount (100% crop Evapotranspiration) resulted in the longest recorded maturation period—over 125 days. This suggests that a full irrigation regime, coupled with the recommended fertilizer rate, considerably delays crop ripening. A conclusion – the more frequently water is applied to crops through irrigation, the fresher they remain and the longer it takes for them to mature – can be drawn from this scenario [14, 15].

Table 4. Interaction effect of NPS and WL on Total Yield (kg ha⁻¹).

NPS kg ha ⁻¹	WL		
	H	T	F
100	9633 ^d	11544 ^{bcd}	9933 ^{cd}
150	11478 ^{bcd}	23901 ^a	15613 ^b
200 (Recommended rate)	11857 ^{bcd}	15410 ^b	14461 ^{bc}
CV	17.6		
LSD	4197.91		

The highest yield recorded was 23901 kg ha⁻¹, achieved with the application of a combination of nitrogen, phosphorus, and sulfur (NPS) at a rate of 150 kg NPS ha⁻¹ along with 75% of the crop's evapotranspiration (ETc). This was followed closely by treatments of 150 kg NPS with 100% ETc and 200 kg NPS with 75% ETc. Consequently, it is possible to save about 25% of these key inputs from the recommended rates and depths while still achieving nearly the maximum crop yield. This approach allows for reduced water and fertilizer usage while maintaining Tomato yields comparable to those obtained with full water levels and the recommended fertilizer rates. Results presented in Table 4 demonstrate that lower inputs of water and fertilizer can still produce tomato yields statistically similar to those achieved with the full (recom-

mended) levels.

Table 5. Interaction effect of NPS and WL on crop Water Productivity.

NPS kg ha ⁻¹	WL		
	H	T	F
100	5.07 ^{bc}	4.05 ^{cd}	2.61 ^d
150	6.04 ^b	8.39 ^a	4.11 ^{cd}
200 (Recommended rate)	6.24 ^b	5.41 ^{bc}	3.80 ^{cd}
CV	20.3		
LSD	1.79		

The highest water productivity of 8.39 kg/ha/mm was achieved with the application of 150 kg NPS ha⁻¹ and at a water level of 75% ETc. This approach yields high returns with lower water input, aligning with the crop-per-drop principle at three-fourths of both variables – the fertilizer rates and irrigation water levels.

Table 6. Interaction effect of NPS and WL on CWUE.

NPS kg ha ⁻¹	WL		
	H	T	F
100	25.36 ^d	30.4b ^{cd}	26.15 ^{cd}
150	30.22 ^{bcd}	62.93 ^a	41.11 ^b
200 (Recommended rate)	31.22 ^{bcd}	40.57 ^b	38.07 ^{bc}
CV	17.6		
LSD	11.05		

The maximum water use efficiency for the crop was achieved through the application of 150 kilograms of nitrogen-phosphorus-sulfur (NPS) fertilizer per hectare. This optimal efficiency was attained while maintaining irrigation at 75% of the crop's evapotranspiration rate (ETc), which is determined by a specific model that calculates the crop water requirements. Additionally, this scenario involved using 75% of the recommended rate of inorganic fertilizer, ensuring that both nutrient supply and water management were effectively balanced to enhance overall crop performance.

Table 7. Interaction effect of NPS and WL on IWUE.

NPS kg ha ⁻¹	WL		
	H	T	F
100	17.75 ^d	21.28 ^{bcd}	18.31 ^{cd}
150	21.15 ^{bcd}	44.05 ^a	28.78 ^b
200 (Recommended rate)	21.85 ^{bcd}	28.40 ^b	26.65 ^{bc}
CV	17.6		
LSD	7.73		

The results from our research reveal significant variations in key performance indicators, including yields (both my yield and total yield), Water Use Efficiency (WUE), and water productivity across different treatment groups, with a statistical significance level of $P < 0.05$.

Notably, when applying 150 kg/ha of NPS fertilizer, farmers can achieve higher yields while utilizing only 75% of the total water available (379.8 mm). This strategic application not only enhances crop productivity but also conserves a significant amount of water, enabling the irrigation of a larger command area with the saved water—specifically, 25% of the evapotranspiration, which amounts to 94.95 mm.

It is important to acknowledge that inorganic fertilizers often remain out of reach for smallholder farmers due to financial constraints. Yet, the findings of our study provide valuable insights that could benefit even those who cannot afford fertilizers, making these outcomes particularly desirable for a wider range of agricultural practitioners.

4. Conclusion and Recommendation

The ability of plant roots to absorb dissolved nutrients at the optimal time can significantly enhance crop performance. This phenomenon may account for the improved results observed when using reduced amounts of water and fertilizer compared to the conventional recommended rates.

Specifically, for tomato production in irrigated systems, it is advisable for farmers operating within the designated regions and similar agroecologies to adopt a strategy that involves applying only 75% of the crop's evapotranspiration coefficient (ETc), which is determined using the CROPWAT model, to manage their water inputs. Additionally, it is recommended that they utilize 75% of the fertilizer rate that agronomists suggest for optimal growth.

To effectively implement these strategies, the agricultural extension system plays a crucial role in educating and promoting these practices to farmers. By disseminating information and providing support, the extension system can help farmers maximize their yields while conserving resources,

ultimately contributing to more sustainable agricultural practices.

Abbreviations

WUE	Water Use Efficiency
ETc	Crop's Evapotranspiration Coefficient
MDGs	Millennium Development Goals
CWP	Crop Water Productivity
NPS	Nitrogen, Phosphorus, and Sulphur
WL	Water Level

Conflicts of Interest

The authors declare no conflicts of interest.

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