

Research Article

Evaluation of the Effects of Irrigation and Inorganic Fertilizers Management on Yield and Water Productivity of Tomato

Zelalem Shelemew* , Anbese Ambomsa , Bariso Bati , Dulo Husen ,
Ayub Jalde 

Oromia Agricultural Research Institute, Adami Tulu Agricultural Research Center, Ziway, Ethiopia

Abstract

Efficient use of water and fertilizers by crops calls for revised or new agricultural crop management practices to sustain agricultural production. Improved irrigation and fertilizer management will be needed to reduce nutrient leaching from horticultural crops. Over-irrigation increases the leaching of nitrogen (nitrogen is very soluble in water) and hence the amount of applied nitrogen required for maximum yield. This experiment was conducted at Adami Tulu Agricultural Research Center with the objective of evaluating the effects of different irrigation levels and N-fertilizer rates on yield and yield components of tomato. The treatments of the experiment had factorial combinations of four irrigation levels of watering and five N-fertilizer amounts. The results revealed that different fertilizer rate produced higher tomato with the amount of water applied. The growth, yield and yield contributing characters like plant height, fruit length, fruit diameter, and fruit weight per plant were influenced significantly by different levels of irrigation and fertilizer rate. Whereas, the interaction between Irrigation levels and nitrogen rate were all also significant for all characters of yield components. Maximum grain yield of 115.64 qt ha⁻¹ was recorded in plots treated with nitrogen dose of 110 kg ha⁻¹ when compared to other treatments. Similarly, maximum tomato yield of 117.94 qt ha⁻¹ was recorded in 100% ETc of applied water while minimum yield of 89.4 and 108.70 qt ha⁻¹ was harvested from plots sown with 125% ETc water applied and application of 90 kg N ha⁻¹ respectively. It can be concluded from these results that 100% ETc of applied water and fertilizer N at the rate of 110 kg ha⁻¹ produced economical crop of tomato under climatic conditions of the study area.

Keywords

Irrigation Depth, Fertilizer Rate, Water Use Efficiency, Applied Water

1. Background

Worldwide, fresh water availability for irrigation is decreasing because of increasing competition from urban and industrial development, degrading irrigation infra-structure and water quality [17]. Full irrigation, with very low water productivity, has caused increasing in water requirement

much than needed water [18].

In semiarid and arid climatic conditions and occasionally even in humid climates, an optimum water supply depends on irrigation. Mostly, water is supplied by surface irrigation via open channels, flooding and furrows, but the efficiency of

*Corresponding author: yewl.as.ge@gmail.com (Zelalem Shelemew)

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water use is rather low. Typically, one third to one half of the applied water, carrying with it considerable amounts of nutrients, may not be used by a crop. Water use efficiency is much higher in pressurized irrigation systems, ranging from 70% to 95%. Such systems allow for a good control of water and nutrient supply and minimize losses. Major constraints to the use of pressurized irrigation are the initial capital investment, maintenance costs and availability of expertise in the use of the system.

Improved irrigation and fertilizer management will be needed to reduce nutrient leaching from horticultural crops. This will probably involve applying fertilizer and water more frequently, but in smaller quantities than currently practiced. The result should more closely match water and fertilizer supply to crop demand. Over-irrigation increases the leaching of nitrogen (nitrogen is very soluble in water) and hence the amount of applied nitrogen required for maximum yield.

Plant nutrition is one of the significant factors affecting plant production. Nitrogen is among the essential elements for proper growth and development of plants and hence it is the yield-limiting factor in several areas especially in soils with low organic matter content [19]. Although N supply can improve productivity, the blanket recommendation for N fertilizer application is common in agricultural production [16]. Several studies have indicated that plant yield and plant N concentration can be increased by increasing N fertilization, but the NUE might be decreased [30, 32]. Previous findings have revealed that the PFP and AE reduced with an increase in N fertilizer rate and the highest market yield and optimum economic yield were obtained with the N rates of 271 and 265 kg/ha, respectively [14, 38].

Water stress is the other most important environmental factors that limit crop production [10]. On the other hand, too much use of irrigation water leads to inefficient water use [39]. Hence, for better tomato water use efficiency, emphasis should be given to the efficient use of water, both to get better yields and to optimize water use [22]. The research result by [27] indicated that the highest marketable yield was obtained by supplying 100% ETc amounted to 66.4 t/ha as the mean value of three cultivars, whereas only 6.21 t/ha was achieved in non-irrigated treatment (the control). However, WUE was highest in the treatment receiving 50% ETc and amounted to 1.09 kg/m³.

Both irrigation and nitrogen fertilizer applications are among the essential factors affecting the growth and fruit yield of tomato [12, 25, 33, 2, 21, 7, 37]. Moreover, several studies have investigated the interaction effects of irrigation and fertilization on NUE and WUE [3-5, 8, 13, 34, 37, 40]. Though nitrogen and water are key factors for tomato growth and yield, their optimum integration is not well identified, especially in the study area. Thus, optimizing irrigation level and nitrogen fertilizer rates are crucial for adopting them as a management tool for boosted tomato yield as well as for better nutrient and water use efficiencies. The present study was aimed to assess the effects of irrigation water and nitrogen

fertilizer levels on tomato yield, nutrient residue, as well as water and nutrient use efficiencies.

Chemical pollution by nitrate and phosphorus in water bodies is increasing due to the extensive, uncontrolled application of fertilizers. Agricultural fertilizers currently stand as the main non-point source of water pollution. Nitrate pollution in groundwater was detected in 49 out of the 50 states of the USA in 1992 [20]. Different authors have identified optimum surface fertigation techniques resulting in minimum fertilizer losses and maximum distribution uniformity of fertilizer [28, 1, 29, 6]. In addition, surface fertigation has been reported to lead to specific advantages as compared to the mechanical application of fertilizers. Among them: low energy and labor requirements; potential for small and frequent fertilizer applications; and reduction in soil compaction and crop damage resulting from machine traffic [26].

Efficient use of water and fertilizers by crops calls for revised or new agricultural crop management practices to sustain agricultural production [31]. The increase in agricultural production in the world, including that in arid and semiarid areas, has been achieved through application of modern agricultural technologies, comprising a combination of irrigation and heavy doses of fertilizer [11]. As a result, as much as 40% of global food production derives from irrigated agriculture. However, a large amount of the irrigation water used is lost due to inappropriate irrigation practices.

Therefore, today's agriculture sector faces a complex series of challenges to cope with the demands for sustainable management and production, which entails an increase in food production to ensure food security while using less water per unit of output [36], and reducing nitrogen (N) fertilizer losses through leaching. This is particularly important in sub-Saharan Africa, where a major expansion in irrigated agricultural area is expected to occur in the near future, since only 7.7 million ha out of a potential 38 million ha are currently in operation.

Thus, to maximize the production and productivity of tomato, an experiment on fertilizer and water requirements of the crop should be done. Moreover, fertilizer requirements may be affected by amount and frequency of irrigation water. On the other hand water use efficiency is highly dependent on plant nutrient and, supply. Within this project was initiated with the objectives of evaluating the responses of tomato to amount of irrigation and rate of fertilizer application and determining optimum rate of inorganic fertilizer combined with optimum amount of water.

2. Materials and Methods

The activity was undertaken at Adami Tulu agricultural research center at on station for two consecutive years. It was conducted to evaluate the effect of the amount of water and inorganic fertilizer management on the yield and water productivity of processing tomato. The experiments were laid out in RCBD with three replications.

The treatments for the experiment consist of three levels of irrigation depths (D):

D1: 50% ETC,

D2: 75% ETC,

D3: 100% ETC,

D4: 125% ETC and

Three fertilizer rates (R):

R1: 100% of recommended fertilizer application

R2: 120% of recommended fertilizer application

R3: 110% of recommended fertilizer application

R4: 90% of recommended fertilizer application

R5: 80% of recommended fertilizer application

Urea was applied in split. The predetermined amount of irrigation water was applied to each plot using Parshall flume. Data were analyzed using SAS 9.2 statistical software.

Table 1. Treatment combination.

Treatments			
T1	D1R1	T11	D3R1
T2	D1R2	T12	D3R2
T3	D1R3	T13	D3R3
T4	D1R4	T14	D3R4
T5	D1R5	T15	D3R5
T6	D2R1	T16	D4R1
T7	D2R2	T17	D4R2
T8	D2R3	T18	D4R3
T9	D2R4	T19	D4R4
T10	D2R5	T20	D4R5

The experimental field plot layouts were made by dividing the field into 3 blocks and 60 plots and each experimental plot has plot size of 3 m by 4 m. The plots and blocks were had a buffer zone of 1 m and 1.5 m between plots and blocks respectively.

Materials such as Parshall flume, double ring infiltrometer, Auger, core samplers, meter, pegs, meteorological data, Cropwat 8.0 software, and FAO publications were used. CROPWAT8.0 software is used to determine daily crop water requirement. The amounts of water supplied to each plot were measured using 3 inch calibrated standard Parshall flume. Double ring infiltrometer is used to determine soil infiltration rate. Auger and core samplers are used to take soil samples from the experimental field.

The experimental field was prepared by plowing with tractor driven implement. It was prepared thoroughly by harrowing, leveling and ridging manually. Tomato seed was used for the experiment. It was raised on nursery bed and transplanted to the experimental field plots. Furrows spaced

at 70 cm will be used and transplanted at row and plant spacing of 70 and 30 cm, respectively. To ensure the plant establishment common irrigations were provided to all plots before commencement of the differential irrigation. All cultural practices other than variable factors are standard practices recommended for the area. Weeding and inter-row cultivations were performed by hand hoeing when deemed necessary. Disease and pest management were made as per recommendation of agronomist at the research center.

Crop water requirements (ET_c) were calculated from climatic data by directly integrating the effect of crop characteristics into reference crop evapotranspiration. FAO Penman-Monteith method was used for determining reference crop evapotranspiration (ET_o). The Penman-Monteith equation is given by equation:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

where:

ET_o = Reference evapotranspiration (mm/day), R_n = Net radiation at the crop surface (MJ/m² per day), G = Soil heat flux density (MJ/m² per day), T = Mean daily air temperature at 2 m height (°C), U₂ = Wind speed at 2 m height (m/sec), e_s = Saturation vapor pressure (kPa), e_a = Actual vapor pressure (kPa), e_s - e_a = Saturation vapor pressure deficit (kPa), Δ = Slope of saturation vapor pressure curve at temperature T (kPa/°C), γ = Psychrometric constant (kPa/°C).

Experimentally determined ratios of ET_c and ET_o, called crop coefficients (K_c), are used to relate ET_c to ET_o as given by equation:

$$ET_c = ET_o \times K_c \quad (2)$$

where: ET_c = crop evapotranspiration (mm/day), ET_o = reference crop evapotranspiration (mm/day) and K_c = crop coefficient.

Irrigation Requirement (IR) can be estimated from the expression:

$$IR = CWR - \text{Effective rainfall} \quad (3)$$

Where, IR in mm, CWR in mm and effective rainfall which is part of the rainfall that entered into the soil and made available for crop production in mm.

Irrigation schedule, when to irrigate and how much water to apply per irrigation, is one of the most important tools for best management of irrigated agriculture. Irrigation schedule was worked out using CropWat 8 windows. In the model, one of the computation methods for the optimal irrigation scheduling for no yield reduction is the irrigation given at 100% readily available soil moisture depletion to refill the soil to its field capacity. The RAW will be computed from the expression:

$$RAW = p * TAW \quad (4)$$

where RAW in mm, p is in fraction for allowable soil moisture depletion for no stress, and TAW is total available water in mm.

The total Available soil Water (TAW) is computed from the soil moisture content at field capacity (FC) and permanent wilting point (PWP) using the following expression:

$$TAW = \frac{(FC - PWP) * BD * Dz}{100} \quad (5)$$

where FC and PWP in % on weight basis, BD is the bulk density of the soil in gcm^{-3} , and Dz is the maximum effective root zone depth in mm.

The bulk density, BD, is the mass of a soil in a unit volume for undisturbed soil condition and is expressed on dry weight basis of the soil as:

$$BD = \frac{Ms}{Vs} \quad (6)$$

where Ms is the weight of oven dry soil, and Vs is the volume of the same soil in cm^3 .

Considering the daily CWR, TAW, Dz and p, the irrigation interval will be computed from the expression:

$$\text{Interval (days)} = \frac{RAW}{CWR} \quad (7)$$

where RAW in mm and CWR in mm day^{-1} .

The gross irrigation requirement, IRg, in a particular event will be computed from the expression:

$$IRg = \frac{\text{Interval} * CWR}{Ea} \quad (8)$$

where IRg is mm, interval in days, CWR in mm day^{-1} and Ea is the Irrigation water application efficiency in fraction.

Data collected

Data that were taken includes, soil data, climatic data, Plant height, Number of Branch/plant, Number fruit per plant, Number of cluster per plant, fruit weight, fruit width, fruit length, and yield and water productivity. Data collected were subjected to analysis of variance using SAS 9.2 software. Whenever treatment effects were found to be significant, treatment means will be compared using the least significant difference (LSD) method.

3. Results and Discussions

Interaction effects of irrigation depth and fertilizer rate on total yield and fruit weight

There is significance difference on total yield on interaction effects, the highest total yield 91.43 Qt/ha were recorded on treatment 7 (T7: D2R2) which is the interaction effect of 75% ETC with 120% of recommended fertilizer application. Irrigation treatment due to the sufficient level of irrigation and optimal fertigation, which also resulted in the highest fruit yield [15, 22-24] and the lowest were recorded 64.16 Qt/ha on treatment 1 (T1:D1R1) which is the interaction effect of 50% ETC with 100% of recommended fertilizer application. There is only significance difference T7 with T1, T11, T12, T13, T14, T19 and T20. But there is no significance difference between other treatments. In line with the present study, Wang and Xing [35] reported higher tomato yield at moderate irrigation (75% ETC) interacted with a high fertilizer level (240 kg N/ha).

Table 2. The interaction effect of irrigation depth and fertilizer rate on total yield, fruit weight, fruit width and fruit length.

Treatments	Total yield	fruit weight (kg)	fruit width	fruit length
T1	64.164 ^b	0.13273 ^{bdc}	3.3600 ^{fbdc}	4.7267 ^{bac}
T2	79.634 ^{ab}	0.13833 ^{abc}	3.4933 ^{bac}	4.7600 ^{bac}
T3	80.378 ^{ab}	0.15657 ^a	3.7467 ^a	5.0733 ^a
T4	75.497 ^{ab}	0.14396 ^{ab}	3.4600 ^{bdc}	4.9133 ^{bac}
T5	80.359 ^{ab}	0.13991 ^{abc}	3.3733 ^{fbdc}	4.7667 ^{bac}
T6	73.508 ^{ab}	0.12731 ^{bdc}	3.3967 ^{fbdc}	4.7400 ^{bac}
T7	91.436 ^a	0.13408 ^{bdc}	3.4267 ^{bdc}	4.7467 ^{bac}
T8	73.833 ^{ab}	0.13269 ^{bdc}	3.3933 ^{fbdc}	4.7267 ^{bac}
T9	76.973 ^{ab}	0.13615 ^{abcd}	3.1867 ^{fe}	4.7533 ^{bac}
T10	82.648 ^{ab}	0.14337 ^{ab}	3.6133 ^{ba}	5.0000 ^{ba}
T11	64.801 ^b	0.11596 ^d	3.3867 ^{fbdc}	4.5800 ^c
T12	72.468 ^b	0.11536 ^d	3.3600 ^{fbdc}	4.5933 ^c
T13	70.105 ^b	0.13123 ^{bdc}	3.3000 ^{fedc}	4.9333 ^{bac}

Treatments	Total yield	fruit weight (kg)	fruit width	fruit length
T14	68.220 ^b	0.11730 ^d	3.1600 ^f	4.5667 ^c
T15	74.331 ^{ab}	0.13908 ^{abc}	3.5867 ^{ba}	4.8200 ^{bac}
T16	72.521 ^{ab}	0.12222 ^{dc}	3.2267 ^{fed}	4.7467 ^{bac}
T17	79.494 ^{ab}	0.12372 ^{bdc}	3.4067 ^{fedc}	4.7733 ^{bac}
T18	78.062 ^{ab}	0.11733 ^d	3.3267 ^{fedc}	4.7933 ^{bac}
T19	72.403 ^b	0.12823 ^{bdc}	3.3800 ^{fedc}	4.6800 ^{bc}
T20	70.831 ^b	0.12795 ^{bdc}	3.3800 ^{fedc}	4.7867 ^{bac}
LSD	18.95	0.0209	0.2563	0.3714

The fruit weight on Table 2 shows there is highly significance difference between the treatments in interaction effects, the highest fruit weight 0.156 kg were recorded on treatment 3 (T3: D1R3) which is the interaction effect of 50% ETC with 110% of recommended fertilizer application and the lowest were recorded 0.115 kg on treatment 12 (T12:D3R2) which is the interaction effect of 100% ETC with 120% of recommended fertilizer application. There is significance difference T3, T4, T10 with T11, T12, T14 and T18. There is no significance difference between the treatments of T1, T2, T4, T5, T6, T7, T8, T9, T10, T13, T15, T17, T19 and T20.

Interaction effects of irrigation depth and fertilizer rate on fruit width and fruit length

There is highly significance difference on interaction effects between the treatments on fruit width, the highest fruit width 3.74 cm were recorded on treatment 3 (T3: D1R3) which is the interaction effect of 50% ETC with 110% of recommended fertilizer application and the lowest were recorded 3.16 cm on treatment 14 (T14:D3R4) which is the interaction effect of 100% ETC with 90% of recommended fertilizer application. There is highly significance difference between the treatments of T3, T10, and T15 with the treatments of T9, T14 and T16 but there is no significance difference between the treatments of T1, T5, T4, T6, T8, T11, T12, T13, T14, T17, T19 and T20.

There is also highly significance difference on fruit length in interaction effects between the treatments, the highest fruit length 5.07 cm were recorded on treatment 3 (T3: D1R3) which is the interaction effect of 50% ETC with 110% of recommended fertilizer application and the lowest were recorded 4.56 cm on treatment 14 (T14:D3R4) which is the interaction effect of 100% ETC with 90% of recommended fertilizer application. There is significance difference between the treatments of T3, T10 with T11, T12 and T14 but there is no significance difference among the treatments of T1, T2, T4, T5, T6, T7, T8, T9, T10, T13, T15, T16, T17, T18, T19 and T20.

Yield and yield parameters in the year 2021/22

Fruit width and Fruit length

As shown in Table 4 second year result the combined effect of irrigation depth with fertilizer rate application showed a significance difference on fruit width and fruit length. There is highly significance difference on treatment combination of T3 (D1R3: 50% ETc and 110% of fertilizer rate) with T11 (D3R1: 100% ETc and 100% of fertilizer rate), T15 (D3R5: 100% ETc and 80% of fertilizer rate), T16 (D4R1: 125% ETc and 100% of fertilizer rate), T17 (D4R2: 125% ETc and 120% of fertilizer rate) and T19 (D4R4: 125% ETc and 80% of fertilizer rate) and also there were significance difference shows on T11 (D3R1: 100% ETc and 100% of fertilizer rate) with that treatments of T5 (D1R5: 50% ETc and 80% of fertilizer rate), T8 (D2R3: 75% ETc and 110% of fertilizer rate) and T10 (D2R5: 75% ETc and 80% of fertilizer rate) on fruit width and the rest have no significant different between the treatment combination Table 5. The result in line with [9, 15, 22] an inadequate irrigation rate could decrease tomato yields to some extent while improving fruit quality.

The highest fruit width was gained 4.68 cm in treatment combination of T3 (D1R3: 50% ETc and 110% of fertilizer rate) followed by 4.43 cm, 4.31cm and 4.30cm from T10 (D2R5: 75% ETc and 80% of fertilizer rate), T1 (D1R5: 50% ETc and 80% of fertilizer rate) and T8 (D2R3: 75% ETc and 110% of fertilizer rate) respectively. The lowest were recorded 2.91 cm from treatment combination of T19 (D4R4: 125% ETc and 90% of fertilizer rate).

ANOVA analysis of fruit length indicated that there is also a significance on treatment combination of T3 (D1R3: 50% ETc and 110% of fertilizer rate) with T11 (D3R1: 100% ETc and 100% of fertilizer rate), T15 (D3R5: 100% ETc and 80% of fertilizer rate), T17 (D4R2: 125% ETc and 120% of fertilizer rate) and T19 (D4R4: 125% ETc and 80% of fertilizer rate) and also there were significance difference showed that on T10 (D2R5: 75% ETc and 80% of fertilizer rate) with that treatments of T11 (D3R1: 100% ETc and 100% of fertilizer rate) and T19 (D4R4: 125% ETc and 80% of fertilizer rate).

The highest fruit length was recorded 5.34 cm in treatment combination of T3 (D1R3: 50% ETc and 110% of fertilizer rate) followed by 5.19 cm, 5.02 cm and 5.01 cm from T10 (D2R5: 75% ETc and 80% of fertilizer rate), T1 (D1R5: 50% ETc and 80% of fertilizer rate) and T2 (D1R2: 50% ETc and 120% of fertilizer rate) respectively. The lowest were indicated 3.37 cm from treatment combination of T19 (D4R4: 125% ETc and 90% of fertilizer rate).

The main effect of irrigation depth and fertilizer rate on Fruit width and length, fruit weight and total yield in 2021/22.

Fruit weight and Total yield

As shown in Table 4 there is significant difference on irrigation depth on fruit weight and total yield as main effect. Similarly 50% ETc showed that the highest fruit weight and total yield 1.99 kg and 121.26 Qt/ha and the least were rec-

orded on 125% ETc 1.64 kg/plant and 89.4 Qt/ha and respectively. Even if the highest fruit weight and total yield were recorded on 50% ETc there is no significance difference with 100% ETc of water applied.

Fertilizer Rate: there is no significance difference on fruit weight per plant and total yield when applying different rate of fertilizer rate in the second year trial, but the highest fruit weight per plant and total yield were different with first year results which lies on 110% of recommended fertilizer rate application which were recorded 1.89 kg/plant and 115.64 Qt/ha on fruit weight per plant and total yield which shows an increasing trend from first year yield and the lowest fruit weight per plant 1.77 kg/plant and similarly low yield were recorded 108.7 Qt/ha of 90% of recommended fertilizer rate of application on both parameters.

Table 3. Interaction effect of irrigation depth and fertilizer rate on Fruit width and length, fruit weight and total yield.

Treatments		Fruit width (cm)	Fruit length (cm)	Fruit weight (kg/plant)	Total Yield (Qt/ha)
T1	D1R1	4.24 ^{abc}	5.02 ^{abc}	1.86 ^{abc}	121.35 ^{ab}
T2	D1R2	4.24 ^{abc}	5.01 ^{abc}	1.90 ^{abc}	101.96 ^{ab}
T3	D1R3	4.68 ^a	5.34 ^a	1.99 ^{abc}	113.23 ^{ab}
T4	D1R4	4.01 ^{abcd}	4.46 ^{abcd}	2.26 ^a	144.63 ^a
T5	D1R5	4.31 ^{ab}	4.93 ^{abc}	1.96 ^{abc}	125.12 ^{ab}
T6	D2R1	4.12 ^{abc}	4.88 ^{abc}	1.63 ^{abc}	112.89 ^{ab}
T7	D2R2	3.61 ^{abcd}	4.13 ^{abcd}	1.89 ^{abc}	131.18 ^{ab}
T8	D2R3	4.30 ^{ab}	4.75 ^{abc}	1.63 ^{abc}	119.71 ^{ab}
T9	D2R4	4.12 ^{abc}	4.73 ^{abc}	1.63 ^{abc}	111.10 ^{ab}
T10	D2R5	4.43 ^{ab}	5.19 ^{ab}	1.88 ^{abc}	100.98 ^{ab}
T11	D3R1	3.13 ^{cd}	3.81 ^{cd}	1.99 ^{abc}	93.24 ^{ab}
T12	D3R2	3.54 ^{bcd}	4.08 ^{abcd}	1.76 ^{abc}	111.93 ^{ab}
T13	D3R3	3.95 ^{abcd}	4.51 ^{abcd}	2.04 ^{ab}	143.23 ^a
T14	D3R4	3.76 ^{abcd}	4.43 ^{abcd}	2.09 ^{ab}	127.98 ^{ab}
T15	D3R5	3.49 ^{bcd}	3.93 ^{bcd}	1.75 ^{abc}	113.31 ^{ab}
T16	D4R1	3.55 ^{bcd}	4.10 ^{abcd}	1.61 ^{abc}	111.29 ^{ab}
T17	D4R2	3.57 ^{bcd}	4.27 ^{abcd}	1.58 ^{bc}	100.58 ^{ab}
T18	D4R3	3.65 ^{abcd}	4.17 ^{abcd}	1.91 ^{abc}	86.39 ^{ab}
T19	D4R4	2.91 ^d	3.37 ^d	1.33 ^c	51.11 ^b
T20	D4R5	3.81 ^{abcd}	4.41 ^{abcd}	1.77 ^{abc}	97.63 ^{ab}
LSD		1.12	1.26	0.68	85.01
CV		17.2	17.1	22.4	46.35

The combined effect of treatments showed that there is also a significance difference on both parameters fruit weight per

plant and total yield. There is a significance difference on treatment combination of T4 (D1R4: 50% ETc and 90% of

fertilizer rate) with T17 (D4R2: 125% ETc and 120% of fertilizer rate) and T19 (D4R4: 125% ETc and 90% of fertilizer rate) and also there is significance difference between T13 (D1R3: 50% ETc and 110% of fertilizer rate) and T14 (D3R4: 100% ETc and 90% of fertilizer rate) with T19 (D4R4: 125% ETc and 90% of fertilizer rate) on fruit weight per plant. The highest fruit weight per plant were gained 2.26 kg/plant from treatment combination of T4 (D1R4: 50% ETc and 90% of fertilizer rate) followed by 2.09 kg/plant and 2.04 kg/plant T14 (D3R4: 100% ETc and 90% of fertilizer rate) and T13 (D1R3: 50% ETc and 110% of fertilizer rate) respectively.

From Table 5 the combined effect of treatments showed that significance different on total yield. There is a significance difference in combined effect of T4 (D1R4: 50% ETc and 90% of fertilizer rate) and T13 (D1R3: 50% ETc and 110% of fertilizer rate) with that of T19 (D4R4: 125% ETc and 90% of fertilizer rate). The maximum yield 144.63 Qt/ha and 143.23 Qt/ha were gained on both from combined effect of T4 (D1R4: 50% ETc and 90% of fertilizer rate) and T13 (D1R3: 50% ETc and 110% of fertilizer rate) followed by 131.18 Qt/ha T7 (D2R2: 75% ETc and 120% of fertilizer

rate) and the minimum were 51.11 Qt/ha recorded from T19 (D4R4: 125% ETc and 90% of fertilizer rate).

Plant height and Number of branch per plant

Combined effect of irrigation depth and fertilizer rate on plant height and number of branch per plant

The combined effect showed that there is a significance difference on plant height on both years. There is a significance difference on 1st year analysis between the treatments of T11: D3R1: 100% ETc and 100% of fertilizer rate with that of treatments T3: D1R3: 50% ETc and 110% of fertilizer rate, T5: D1R5: 50% ETc and 80% of fertilizer rate, T9: D2R4: 75% ETc and 90% of fertilizer rate, T15: D3R5: 100% ETc and 50% of fertilizer rate, T16: D4R1: 125% ETc and 100% of fertilizer rate, T17: D4R2: 125% ETc and 120% of fertilizer rate and T18: D4R3: 125% ETc and 110% of fertilizer rate but the others haven't shown any significance differences between the treatments. On the 2nd year analysis there only shown significance difference between the treatments of T15: D3R5: 100% ETc and 80% of fertilizer rate and T3: D1R3: 50% ETc and 110% of fertilizer rate, but no significance difference on the rest treatments shows.

Table 4. Interaction effect of plant height and number of branches per plant.

Treatments		Plant height (cm)		Number of branches per plant (NBP)	
		1 st year	2 nd year	1 st year	2 nd year
T1	D1R1	48.13 ^{ab}	60.13 ^{ab}	6.20 ^{abc}	4.00 ^{bc}
T2	D1R2	46.86 ^{ab}	65.00 ^{ab}	5.53 ^{abc}	4.40 ^{ab}
T3	D1R3	49.46 ^a	58.73 ^b	5.86 ^{abc}	3.80 ^c
T4	D1R4	47.00 ^{ab}	62.73 ^{ab}	5.60 ^{abc}	4.33 ^{ab}
T5	D1R5	48.53 ^a	61.33 ^{ab}	6.73 ^a	4.27 ^{ab}
T6	D2R1	47.06 ^{ab}	60.00 ^{ab}	5.60 ^{abc}	4.00 ^{bc}
T7	D2R2	46.73 ^{ab}	62.47 ^{ab}	5.66 ^{abc}	4.33 ^{ab}
T8	D2R3	44.86 ^{ab}	62.07 ^{ab}	6.20 ^{abc}	4.40 ^{ab}
T9	D2R4	50.20 ^a	62.27 ^{ab}	5.40 ^{bc}	4.27 ^{ab}
T10	D2R5	47.00 ^{ab}	64.60 ^{ab}	5.80 ^{abc}	4.20 ^{abc}
T11	D3R1	41.53 ^b	63.73 ^{ab}	5.13 ^{bc}	4.00 ^{bc}
T12	D3R2	46.20 ^{ab}	67.13 ^{ab}	5.33 ^{bc}	4.00 ^{bc}
T13	D3R3	44.66 ^{ab}	68.07 ^{ab}	5.80 ^{abc}	4.47 ^a
T14	D3R4	45.33 ^{ab}	66.33 ^{ab}	5.00 ^c	4.33 ^{ab}
T15	D3R5	49.33 ^a	68.73 ^a	5.80 ^{abc}	4.20 ^{abc}
T16	D4R1	50.40 ^a	66.27 ^{ab}	5.53 ^{abc}	4.27 ^{ab}
T17	D4R2	50.86 ^a	63.40 ^{ab}	6.40 ^{ab}	4.33 ^{ab}
T18	D4R3	49.60 ^a	64.47 ^{ab}	6.33 ^{ab}	4.33 ^{ab}
T19	D4R4	47.80 ^{ab}	62.93 ^{ab}	5.66 ^{abc}	4.40 ^{ab}

Treatments		Plant height (cm)		Number of branches per plant (NBP)	
		1 st year	2 nd year	1 st year	2 nd year
T20	D4R5	47.26 ^{ab}	64.00 ^{ab}	6.20 ^{abc}	4.33 ^{ab}
LSD		6.9	9.69	1.28	0.41
CV		8.8	9.19	13.3	5.9

The highest plant height was recorded on the 2nd year trial analysis of on the treatments of 68.73 cm on T15: D3R5: 100% ETc and 80% of fertilizer rate applied followed by 68.07 and 67.13 on T13: D3R3: 100% ETc and 110% of fertilizer rate and T12: D3R2: 100% ETc and 120% of fertilizer rate respectively. The least was 58.73 cm on treatment of T3: D1R3: 50% ETc and 110% of fertilizer rate.

The combined effect on Table 4 shows there is highly significance difference between the treatments on number of branches per plant (NBP) on both years. There is a significance difference on treatment T5: D1R5 with T9: D2R4, T11: D3R1, T12: D3R2 and T14: D3R4 and also there is a significance shows between T17: D4R2, T18: D4R3 with that of T14: D3R4 on the 1st year results. On the 2nd year results the significance difference treatment showed differ with that of 1st year these were T13: D3R3 with that of T11: D3R1, T12: D3R2, T6: D2R1, T1: D1R1 and T3: D1R3 and also significance difference shows on T3: D1R3 with most of the treatments showed on Table 4. On this table also the numbers of branches per plant of the 2nd year result were decreased from the 1st year results. The highest numbers of branches per plant were recorded on the 1st year result gained which was 6.73 on T5: D1R5 followed by 6.40 and 6.33 on T17: D4R2 and T18: D4R3 respectively. The lowest was 5.00 on

T14: D3R4.

Even if the number of branches per plant were shows decreased in all treatments the highest 4.47 were recorded on treatment combination of T13: D3R3 followed by 4.40 the same value showed on three treatments which are on T2: D1R2, T8: D2R3 and T19: D4R4. The lowest treatment 3.80 was on T3: D1R3.

Number of cluster per plant and number of fruit per plant

The combined effect of irrigation depths and fertilizer rates on numbers of cluster per plant shows highly significance difference between the treatments on both years result. At the 1st year T5: D1R5 and T18: D4R3 significantly different with that of T2: D1R2, T4: D1R4, T8: D2R3 and T11: D3R1. The combined effect also increased by somewhat at the 2nd year of number of cluster per plants. The maximum were recorded 14.80 on T5: D1R5 followed by 14.46 of T18: D4R3 and the least were recorded 9.53 on T11: D3R1 at the 1st year.

The 2nd year results that shows significance difference between the treatments were T13: D3R3 with that of T1: D1R1, T6: D2R1 and T3: D1R3 and also there is significance between T15: D3R5 and T3: D1R3. The highest were recorded 17.53 on T13: D3R3 followed by 16.80 at T15: D3R5 and the least were 11.80 recorded from T3: D1R3.

Table 5. The interaction/combined effect of number of cluster per plant and number of fruit per plant.

Treatments		Number of cluster per plant (NCP)		Number of fruit per plant (NFP)	
		1 st year	2 nd year	1 st year	2 nd year
T1	D1R1	11.86 ^{bcde}	12.4 ^{bc}	46.40 ^{abc}	35.40 ^{ab}
T2	D1R2	11.13 ^{de}	13.93 ^{abc}	44.60 ^{bc}	45.13 ^{ab}
T3	D1R3	14.13 ^{abc}	11.80 ^c	54.00 ^{ab}	32.27 ^b
T4	D1R4	11.66 ^{cde}	15.80 ^{abc}	44.46 ^{bc}	47.33 ^a
T5	D1R5	14.80 ^a	15.07 ^{abc}	58.93 ^a	45.67 ^a
T6	D2R1	12.00 ^{bcde}	12.40 ^{bc}	50.20 ^{ab}	36.13 ^{ab}
T7	D2R2	11.86 ^{bcde}	13.93 ^{abc}	46.53 ^{abc}	37.72 ^{ab}
T8	D2R3	11.46 ^{cde}	13.80 ^{abc}	43.05 ^{bc}	38.07 ^{ab}
T9	D2R4	14.06 ^{abc}	13.87 ^{abc}	49.71 ^{ab}	42.73 ^{ab}

Treatments		Number of cluster per plant (NCP)		Number of fruit per plant (NFP)	
		1 st year	2 nd year	1 st year	2 nd year
T10	D2R5	13.13 ^{abcd}	13.87 ^{abc}	48.60 ^{abc}	35.93 ^{ab}
T11	D3R1	9.53 ^e	15.07 ^{abc}	35.40 ^c	42.53 ^{ab}
T12	D3R2	11.73 ^{bcde}	15.93 ^{abc}	45.06 ^{bc}	39.40 ^{ab}
T13	D3R3	12.73 ^{abcd}	17.53 ^a	49.00 ^{ab}	46.93 ^a
T14	D3R4	12.26 ^{abcde}	16.27 ^{abc}	44.66 ^{bc}	46.20 ^a
T15	D3R5	12.13 ^{abcde}	16.80 ^{ab}	52.60 ^{ab}	47.07 ^a
T16	D4R1	12.20 ^{abcde}	13.93 ^{abc}	48.93 ^{ab}	38.87 ^{ab}
T17	D4R2	12.53 ^{abcd}	13.87 ^{abc}	49.66 ^{ab}	39.27 ^{ab}
T18	D4R3	14.46 ^{ab}	13.60 ^{abc}	55.66 ^{ab}	44.60 ^{ab}
T19	D4R4	11.73 ^{bcde}	14.33 ^{abc}	47.90 ^{abc}	42.20 ^{ab}
T20	D4R5	12.06 ^{abcde}	16.13 ^{abc}	55.46 ^{ab}	47.47 ^a
LSD		2.78	4.92	13.46	13.24
CV		13.6	20.5	16.7	19.2

The number of fruit per plants on both year results shows a significance difference on the combined effect and also the values were decreased at the 2nd year results. The treatments that have significant different between them were T5: D1R5 with that of T14: D3R4, T12: D3R2, T11: D3R1, T4: D1R4 and T5: D1R2 at the 1st year result and the maximum number of fruit were 58.93 from T5: D1R5 followed by 55.66 and 55.46 of T18: D4R3 and T20: D4R5 respectively. The minimum were observed 35.40 on T11: D3R1.

The 2nd year also showed that there is a significance difference between the treatments. The treatment that shows significance difference was T3: D1R3 with that of T4: D1R4, T5: D1R5, T13: D3R3, T14: D3R4, T15: D3R5 and T20: D4R5. The highest fruit 47.47 were gained from T20: D4R5 followed by 47.33 and 47.07 from T4: D1R4 and T15: D3R5 respectively. Similarly the lowest were 32.27 recorded on T3: D1R3.

4. Conclusion and Recommendation

High temperature and low humidity cause high crop evapotranspiration, therefore high amount of water has to be applied to meet the crop requirement. Since most of the soils in this area are sandy with low organic matter content and low water holding capacity (WHC), if water is applied more than the WHC of the soil, there will be water and nutrients loss due to leaching.

As conclusion the irrigation depth of 100% ETC observed the highest yield of tomato as compared with the others and as

main effect of fertilizer rate when 110% of recommended fertilizer rate applied give the highest yield of tomato. The interaction effect of irrigation depth and fertilizer rate application the highest yield of tomato observed on treatment of (T13: D3R3) which is the interaction effect of 100% ETC with 110% of recommended fertilizer applied were recommended.

Abbreviations

D	Depth of Irrigation
R	Rate of Fertilizer
CWR	Crop Water Requirement
LSD	Least Significant Difference
PWP	Permanent Wilting Point
BD	Bulk Density

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Author Contributions

Zelalem Shelemew: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project ad-

ministration, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing

Anbese Ambomsa: Data curation, Investigation, Supervision

Bariso Bati: Data curation, Funding acquisition, Project administration, Visualization

Dulo Husen: Data curation, Supervision

Ayub Jalde: Data curation, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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