# 4. Effect of Nitrogen Rate and Irrigation Regime on Tomato (*Solanum lycopersicum* L.) Yield in Efratanagidim District, North Shoa, Amhara Region, Ethiopia

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## Abstract

*Application of optimum water and fertilizer is an important factor in improving crop productivity. A field experiment was conducted in Eferatagidim district, North Shoa, Amhara, Ethiopia, during the irrigation season of 2019 and 2020 with the objective of determining N rate and irrigation depth for optimum tomato yield. The experiment consisted of factorial combinations of three-irrigation depths (75% ETc, 100% ETc and 125% ETc) and four N rates (0, 46, 92 and 138 Kgha$^{-1}$N). The treatments were laid out in a split plot design with four replications. The main plot was arranged for the irrigation regime while the sub plot was for the Nitrogen rates. Data on growth, yield, and yield-related traits of tomatoes include; plant height, number of fruit clusters per plant, fruit length, fruit diameter, number of marketable fruit, number of un-marketable fruit, the total number of fruit, marketable fruit yield, un-Marketable fruit yield, total yield were collected. Data were subjected to analysis of variance using R studio. The results indicated that the experimental site had low total Nitrogen content and application of N fertilizer significantly improved tomato yield. Increasing irrigation depth also significantly increased tomato yield. The result indicated that the highest mean marketable fruit yield (35903 Kgha$^{-1}$) was obtained from the combined application of 125% ETc with 92 Kgha$^{-1}$ N while the lowest (13655 Kgha$^{-1}$) marketable fruit yield was obtained from 75% ETc with 92 Kg a$^{-1}$ N. The partial budget analysis also indicated that the highest net benefit (266272.1 ETB) as well as acceptable marginal rate of return (1240) for the invested capital were recorded from the combined application of 125% ETc with 92 Kgha$^{-1}$ N. Therefore, application of 125% ETc with 92 Kgha$^{-1}$ N resulted in highest net benefit.*

**Keyword:** ETc, Irrigation regime, N rate, Tomato

## Introduction

Tomato (*Solanum lycopersicum* L.) is the most widely grown vegetable in the world. The crop is a reach source of vitamin, mineral and antioxidant, which are important for human diets. The crop also contains lycopene, which is responsible for reducing different cancers and neurodegenerative diseases (Srinivasan, 2010). The crop is one of the most profitable crop providing a higher income for farmers. According to FAO (2016), the production of Tomato is estimated to be 55,000 tons in 2013 but showed a decreasing trend compared with the production recorded in 2011 (81,738 tons). The possible reason attributed to disease and pest (such as tutaabsoluta and late blight), poor agronomic practice, shortage of improved varieties, poor quality seed and post-harvesthandling practice.

Nutrient especially Nitrogen and Phosphorus can be the major limiting factor for plant growth and development next to sunlight and water. Nitrogen is essential for building up of protoplasm and protein which is responsible for cell division and initial meristematic activity (Singh and Kumer, 1996). It also promotes flower and fruit setting of tomato. Thus, Nitrogen has a positive effect on tomato growth and development in soil with limited N supplies (Hokam *et al.*, 2011). Next to Nitrogen fertilizer, Phosphorus containing fertilizers is the second most important input for increasing crop production. High level of Phosphorus throughout root zone is essential for rapid root development and for good utilization of water and other nutrient by the plant. Tomatoes have the greatest demand for Phosphorus at the early stages of development (Csizinszky, 2005).

In Ethiopia, fertilizer rates especially N and P were determined for tomato in some parts of Ethiopia. But the rate, for instance the fertilizer recommendation for N ranged between 56-230 Kgha$^{-1}$ and for P ranged from 48-137 Kgha$^{-1}$ (Balemi, 2008; Etissa *et al.*, Recently, our research center with the support of AGP project conducted production constraint assessment on AGP supported district Efratanagidm. The result of the assessment indicated that; Onion and tomato were the most important vegetable crops and there was no fertilizer recommendation for these crops. Thus, the present study was proposed with the objectives of determining N rate and irrigation regime for optimum tomato yield in Efratanagidm districts.

**Materials and Methods**

The experiment was conducted in Eferatagidm district, North Shewa Zone of the Amhara Regional State during irrigation season of 2019 and 2020. The district is 139 kilometers away from the zonal capital, DebreBirhan town and 273 km from Addis Ababa along Dessie road. Efratanagidm district lies between 10°5'N-100 32'N and 39° 50'E- 390 0' E latitude and longitude (Figure ). The topography of the district is generally rugged and broken, with many hills and ridges, making most part of the area unsuitable for agriculture, even though cultivated. The major land use pattern of the district includes croplands 47%, forest and bush 23%, and grazing 10%. The district is well known by its underground and surface water like rivers and streams. Nazero, Jewuha and Jara are the three big rivers known in the Woreda (EGDOA, 2019). The dominant crops cultivated in the district are Sorghum (*Sorghum bicolor)*, Tef ([*Eragrostis tef (Zucc.) Trotter*], Maize (*Zea mays*), Mungbean (*Vigna radiate*), Haricot bean (*Phaseolus vulgaris)*, Onion (*Allium cepa)* and tomato (*Solanum lycopersicum)*. Disease and pest, lack of access on improved technologies, shortage of post-harvesthandling techniques of onion and tomato, and lack of fertilizer recommendations are some of the challenges for crop production in the district (Chanyalew *et al.*, 2018). The long-term rain fall, maximum and minimum temperature of the district were presented in Table .

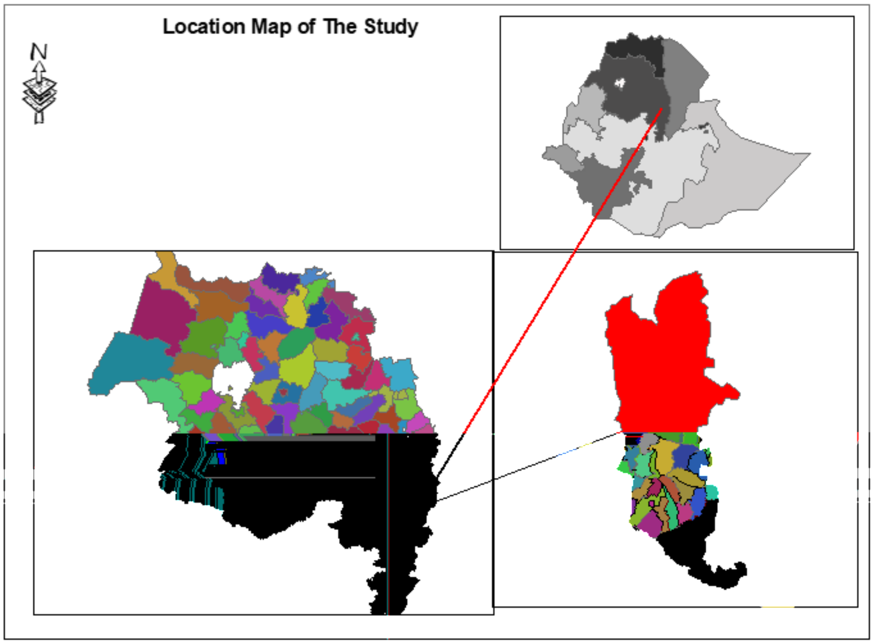


**Figure 1. Location map of the study**

The treatments were consisted of factorial combination of four levels of Nitrogen (0, 46, 92 and 138 Kgha$^{-1}$N) and three levels of irrigation depth expressed as a percentage of potential Evapotranspiration (ETc) i.e. IRR1 (75% ETc), IRR2 (100% ETc) and IRR3 (125% ETc). The experiment was laid out in split plot design with four replications. The main plot was assigned to irrigation depth and frequency while the sub plot was to-Nitrogen rate. The experimental field was prepared following the conventional tillage practice before planting. The space between blocks and plots were 1.5 and 1m respectively. Ridge was constructed between block and plot to control movement of water and fertilizer from one plot to the other. The gross plot size for the main plot was 56.4 m$^2$ and for the sub plot was 9.6 m$^2$ which is 4 rows and 8 plants per row. The harvestable plot size was 4.8 m$^2$.

Tomato variety *Kochero* and *Weyno* were used as a test crop for the first and second year of the experiment. The reason for varietal difference was attributed to the fact that un-availability of the seed of Kochero variety from the market. Seedlings were grown on seedbed for one month. The seedlings were supplied with N nutrient from urea.  Uniform seedlings with their growth were transplanted to the prepared ridges in spacing of 30 cm and 100 cm for plants and rows respectively. Irrigation depth and frequency was applied based on the recommendation of DBARC (Debra birhan

Agricultural Research Center) (Table). The required amount of depth of irrigation water in each growth stage were determined using FAO CROPWAT 8.1 model (Table ). Then the required amount of irrigation water applied for each treatment were calculated by multiplying the depth of irrigation water with the area of the plots. The water was applied with cane method. The depth of effective rainfall during the growth period were deducted from the depth of irrigation water with the respective growth period (Table ). Disease and pest were regularly monitored and treatment were applied based on the recommendations of research.

**Table 1. Depth of Irrigation water during the growth period**

| | | Depth of irrigation water (mm) | | |
|---|---|---|---|---|
| Month | Growth Period | 75% ETC | 100% ETC | 125% ETC |
| January | Initial | 22.3 | 29.7 | 37.1 |
| January | Initial | 22.3 | 29.7 | 37.1 |
| January | Initial | 22.3 | 29.7 | 37.1 |
| January | Initial | 22.3 | 29.7 | 37.1 |
| January/February | Developmental | 22.3 | 29.7 | 37.1 |
| February | Developmental | 40.1 | 53.4 | 66.8 |
| February | Developmental | 40.1 | 53.4 | 66.8 |
| March | Mid | 62.3 | 83.1 | 103.9 |
| March | Mid | 62.3 | 83.1 | 103.9 |
| April | Late | 62.3 | 83.1 | 103.9 |
| April | Late | 62.3 | 83.1 | 103.9 |
| Total irrigation depth (mm) | | 440.8 | 587.7 | 734.6 |
| Total irrigation water ($m^3ha^{-1}$) | | 4407.9 | 5877.2 | 7346.4 |

Equal amount of P (40 $Kgha^{-1}$) was applied to all plots at planting from TSP. N was applied in splithalf at planting and the resthalf after 45 days after transplanting the seedlings from urea.

Rain gauge was installed in the experimental field to collect rainfall data. The rainfall (effective rainfall) were deducted from the amount of irrigation water applied when it occurs in the irrigation interval. A total of 11 days in 2019 and 9 in 2020 were recorded with days having effective rainfall (Table ). The long-term metrological data of the station also indicated that the experimental area received 177.5 mm rain during these years (Table 3).

**Table 2. Effective rainfall recorded during the growth period**

| Year | Date | Growth stage | Effective rainfall (mm) | Year | Date | Growth stage | Effective rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | April 3, 2019 | Late | 5 | 2 | April 6, 2020 | Late | 18 |
| 1 | April 4, 2019 | Late | 10 | 2 | April 10, 202 | Late | 12 |
| 1 | April 5, 2019 | Late | 30 | 2 | April 11, 2020 | Late | 9 |
| 1 | April 8, 2019 | Late | 14 | 2 | April 15, 2020 | Late | 24 |
| 1 | April 14, 2019 | Late | 2 | 2 | April 18, 2020 | Late | 14 |
| 1 | April 15, 2019 | Late | 5 | 2 | April 21, 2020 | Late | 8 |
| 1 | April 16, 2019 | Late | 14 | 2 | April 22, 2020 | Late | 31 |
| 1 | April 17, 2019 | Late | 35 | 2 | April 27, 2020 | Late | 18 |
| 1 | April 21, 2019 | Late | 7 | 2 | April 29, 2020 | Late | 8 |
| 1 | April 17, 2019 | Late | 3 | | | | |
| 1 | April 30, 2019 | Late | 18 | | | | |

**Table 3. Long-term metrological data of the experimental field**

| Month | Mean Rain fall (mm)* | Mean Max temperature (ºC)** | Mean Min temperature (ºC)** |
|---|---|---|---|
| January | 32.1 | 27.4 | 10.4 |
| February | 45.1 | 28.5 | 11.0 |
| March | 83.0 | 29.8 | 12.9 |
| April | 177.5 | 30.2 | 13.9 |
| May | 51.3 | 32.2 | 14.0 |
| June | 70.7 | 33.6 | 14.8 |
| July | 203.6 | 31.2 | 15.4 |
| August | 357.3 | 29.4 | 15.0 |
| September | 461.5 | 30.1 | 14.1 |
| October | 35.2 | 29.8 | 11.2 |
| November | 61.2 | 29.0 | 9.5 |
| December | 23.3 | 28.0 | 9.0 |

** = Average of 40 years, ** = Average of 31 years*

Composite surface soil samples (0-20 cm depth) were collected before planting for the determination of soil physico-chemical properties. The samples were air dried, ground and passed through a 2 mm sieve for most parameters except for OC and TN which passed through 0.5 mm sieve. Soil texture was determined by hydrometer method (Bouyoucos, 1951). Soil pH was measured with digital pH meter potentiometerically in supernatant suspension of 1:2.5 soil to distilled water ratio (Van Reeuwijk, 1992). Cation exchange capacity (CEC) was determined by 1M ammonium acetate method at pH 7 (Chapman, 1965) whereas organic carbon (OC) was determined by the dichromate oxidation method (Walkley and Black, 1934). Total N in the soil was measured by the micro kjeldhal method (Jackson, 1958.). Available P was analyzed by Olsen method (Olsen, 1954) colorimetrically by the ascorbic acid- molybdate blue method (Watanabe and Olsen, 1965).

*Data Collection:* The following data were collected at different growth stages of tomato.

*Plant Height (cm):* Ten plants were selected randomly from each experimental plot to measure plant height by a steel tape from the ground to the main apex during 50% flowering. The average values were considered for analysis.

*Number of Fruit Clusters***:** the number of fruit clusters per plant was counted at physiological maturity from randomly selected five plants. The average values were considered for analysis.

*Fruit Length and Diameter (cm):* Ten fruits of different size (very large, large, medium, small and very small) were collected from each selected plant and the length and diameter of each fruit was measured by using a digital caliper. The mean diameter of a fruit was obtained by adding the diameter of all the selected fruits and then dividing the sum by the number of selected fruits. The average values were considered for the analysis.

*Total Number of Fruit ($ha^{-1}$):* The sum total number of fruits of successive harvests of pink to full-ripe stage where dropped fruits were not considered at all.

*Marketable Fruit Yield (Kg***):** fruits whose diameter was > 3cm and which were free of damage from the net plot area were considered marketable at each harvest using a sensitive balance. The total marketable fruit yield is the sum of successive harvests.

*Unmarketable Fruit Yield (Kg):* fruits whose diameter were ≤ 3cm and which were damaged by insect, diseases, sun burn, etc. from the net plot area were considered as unmarketable yield. The total unmarketable fruit yield is the sum of successive harvests.

*Total Fruit Yield (Kg):* This was obtained by adding average marketable and un marketable fruit yield of successive harvests.

*Statistical Analysis:* The collected data were subjected to two factors analyses of variance (ANOVA) to evaluate the main and interaction effect of the factors (irrigation regime and N rate) on the selected parameters using R studio. Where ever the treatment effects were significant, mean separation was made using the Duncan's multiple range test at 5% level of significance. Correlation coefficients was calculated to study the associative relations among the measurement traits according to Gomez and Gomez (1984). Correlation between parameters were computed when applicable according to Gomez and Gomez (1984).

*Partial Budget Analysis:* Based on the procedures described by CIMMYT (1988), the economic analysis was done using partial budget analysis. For partial budget analysis, the variable cost of fertilizer and labor were taken at the time of planting and during other operations. Price of tomato fruit yield was also considered. The return was calculated as total gross return minus total variable cost. Net benefits and costs that vary between treatments were used to calculate the marginal rate of return to invested capital as we move from a less expensive to a more expensive treatment. To draw farmers' recommendations from marginal analysis in this study, 100% return to the investments was used as reasonable minimum acceptable rate of return.

**Results and Discussion**

*Soil Physicochemical Properties (Before Planting):* The laboratory analysis result of the soil-physicochemical properties of the experimental soil is presented in

Table  Pre-sowing soil analysis result indicated that the textural class of the soil is clay. The mean pH of the soil was 7.12 which is in the neutral soil reaction (Hazelton and Murphy, 2016). This indicated that the pH of the soil is suitable for the production of most crops including tomatoes. The soil's potential CEC (29.3 cmolc/Kg) was in the high range (Landon, 2014). According to Tadesse *et al.,* (1991) the soil's organic carbon and total Nitrogen content was in the low range. Therefore, the application of N-containing fertilizer is mandatory for increasing tomato yield. The exchangeable K content of the soil is rated as very high (Berhanu, 1980). Similarly, Kassie *et al.*, (2019) also reported that high K content in the study area. According to the rating developed by Olsen (1954) for the irrigated area, the soil available P content of the experimental soil is high. The same author classified the soil Olsen available P content of irrigated soil as < 12 $mgKg^{-1}$ is low, 12-17 $mgKg^{-1}$ marginal, 18-25 $mgKg^{-1}$ is adequate and > 25 $mgKg^{-1}$ is high. Similarly, others authors also reported that yhe high available Phosphorus content of the study area with a mean value of (Tesfay *et al.,* 2020; Temeche *et al.*, 2021; Temeche *et al.*, 2022)

**Table 4. Soil Physico-chemical properties of the experimental soil**

| Sample # | Textural class | *BD (gcm$^3$) | pH (1:2.5) | CEC (cmo(+) Kg$^{-1}$) | EX.K (cmo(+) Kg$^{-1}$) | AV.P (ppm) | OC (%) | OM (%) | T.N (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Clay (S=20%, C=44%, Si=36%) | 1.36 | 7.14 | 29.3 | 1.45 | 29.33 | 1.38 | 2.37 | 0.147 |
| 2 | Clay (S=20%, C=46%, Si=34%) | 1.42 | 7.12 | | 1.48 | 28.76 | 1.39 | 2.39 | 0.133 |
| 3 | Clay (S=16, C=40, Si=36) | 1.41 | 7.1 | | 1.23 | 29.68 | 1.36 | 2.35 | 0.133 |
| Mean | Clay | 1.39 | 7.12 | 29.3 | 1.39 | 29.3 | 1.38 | 2.37 | 0.14 |

**BD = Bulk density; CEC = Cation exchange capacity; EX.K = Exchangeable Potassium; AV.P = Available Phosphorus; OM = Organic matter; T.N = Total Nitrogen; S = sand; C = clay; Si = silt*

*Effect of Irrigation Regime on Mean Growth, Yield Component* that tomato crop should be irrigated at full water requirement to get maximum fruit yield. The higher marketable yield (31.504 $tha^{-1}$) and total yield (37.65 $tha^{-1}$) were obtained from 100% ETc and the lowest marketable yield (18.841 $tha^{-1}$) and total yield (25.02 $tha^{-1}$) was obtained from deficit level of 50%ETc in Arbaminch Zuria Woreda in SNNPR region (Habtewold and Gelu, 2019). Bekele (2017) also reported that treatment receiving 100 % ETc irrigation level has a 6.94 % and 15.19 % yield increment as compared to 75% and 50% ETc irrigation level, respectively. The same authors also reported that application of 100 % ETc level has a significant yield difference with 50% ETc level but it is at par with that of 75 % ETc level.

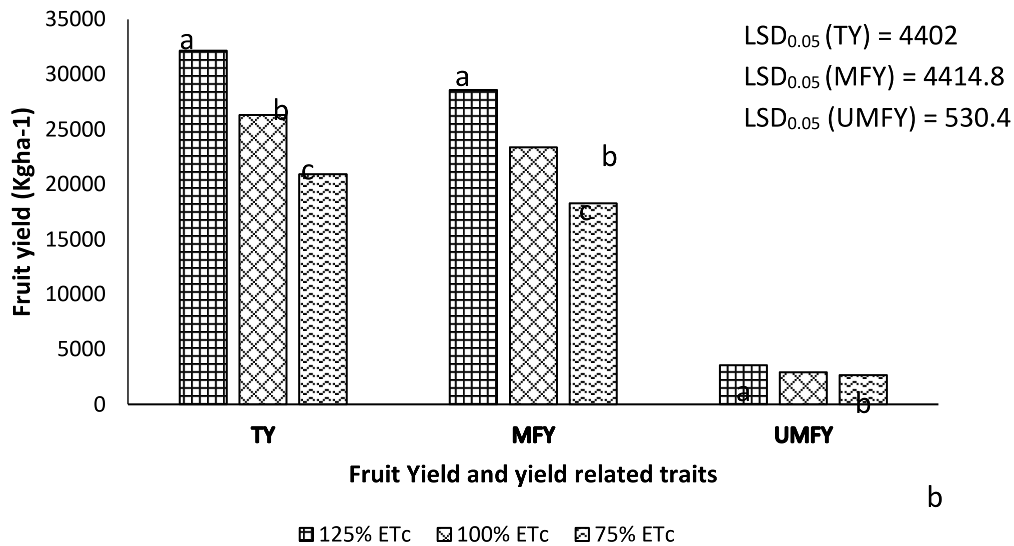


**Figure 2. Fruit yield of tomato as influenced by different irrigation regime**

*Effect of Nitrogen Fertilizer on Mean Growth, Yield Component and Yield of Tomato*

Nitrogen is one of the most limiting nutrients, affecting plant growth and yield worldwide (Du *et al.,* 2017; Li *et al.,* 2021). Nitrogen is a crucial nutrient for the physiological and metabolic process in a tomato; adequate N availability increases marketable yield (Akter *et al.,* 2015).

Tomato yield is constrained by poor soil fertility management and lack of site-specific fertilizers recommendation (Etissa *et al.,* 2013; Ortas, 2013; Biramo *et al.,* 2019; Alia *et al.,* 2020; Mohammed, 2020). Our result also confirmed that the soil of the experimental site is low in soil total N (Table 4). Therefore, application of N containing fertilizer is mandatory for the test crop.

The role of application of N nutrient in increasing tomato yield are well-documented (Weston and Zandstra, 1989; Aman and Rab, 2013; Etissa *et al.,* 2013; Kebede and Woldewahid, 2014; Bilalis *et al.,* 2018; Kaniszewski *et al.,* 2019; Abera *et al.,* 2020) and as the rate of N fertilizer increased, the yield of tomato also increased (Warner *et al.,* 2004).

The effect of different rate of Nitrogen fertilizer on fruit length, fruit diameter, number of marketable fruit, and total yield was non-significant. Nevertheless, it significantly affected plant height ($P \leq 0.05$), number of fruit cluster per plant ($P \leq 0.001$), number of un-marketable fruit $P \leq 0.01$), total number of marketable fruit ($P \leq 0.01$), marketable fruit yield ($P \leq 0.01$), and un-marketable fruit yield ($P \leq 0.01$). The result of the analysis indicated that, increasing N fertilizer rate resulted in a progressive increase nearly all the collected parameters (Table ). The highest number of fruit cluster per plant (11.7), total number of fruit (849124), and marketable fruit yield (25516 Kgha$^{-1}$) were observed from application of 138 Kg N increased the respective parameters by 23.2% (2.2), 75.4% (364972), 29.8% (5856.8 Kgha$^{-1}$) compared with the lowest result recorded from N un-fertilized plot, respectively (Table ). The highest value of number of unmarketable fruit yield (83444) was observed from application of 92 Kgha$^{-1}$ N. This treatment increased the respective parameters by 102.6% (40970) compared with the lowest yield observed from N un-fertilized plot (Table 5).

**Table 5. Main effect Nitrogen fertilizer on growth, yield related and yield of tomato**

| N Rate | *PH | NFCPP | NUUMF | TNUF | MFY | UMFY |
|---|---|---|---|---|---|---|
| 0 | 61.2$^{ab}$ | 9.5$^{c}$ | 39925$^{b}$ | 484152$^{b}$ | 19659.2$^{b}$ | 2394.8$^{b}$ |
| 46 | 58.7$^{b}$ | 10.4$^{bc}$ | 74166$^{a}$ | 576640$^{ab}$ | 23795.1$^{a}$ | 3101.4$^{ab}$ |
| 92 | 63.5$^{a}$ | 11.4$^{ab}$ | 83444$^{a}$ | 656057$^{ab}$ | 24689.3$^{a}$ | 3517.4$^{a}$ |
| 138 | 64.5$^{a}$ | 11.7$^{a}$ | 80895$^{a}$ | 849124$^{a}$ | 25516$^{a}$ | 3150.6$^{ab}$ |
| LSD0.05 | 4.3 | 1.02 | 23795 | 350846.8 | 3220.9 | 841.7 |

**PH = Plant height; NFCPP = number of fruit cluster per plant; NUUMF = Number of un-marketable fruit; TNUF= Total number of fruit; MFY = Marketable fruit yield; UMFY = Un-Marketable fruit yield*

*Interaction Effect of Irrigation Regime and Nitrogen Rate on Mean Growth, Yield Component and Yield of Tomat:* In vegetable crop production, nutrient and water management are related and optimal management of one program necessitates good management of the other (Hochmuth and Hanlon, 2010). Du *et al.,* (2017) reported that there were significant interactions between the amount of irrigation water and applied N on tomato. Our result also confirmed that the interaction of irrigation amount and N rate was significant. Tomato plants are sensitive to water stress (Berihun, 2011). Suboptimal application of nutrients and low soil fertility status especially N and P also adversly affect tomato yield (Pandey *et al.*, 1996; Mehta *et al.*, 2000; Balemi, 2008). Combined over years, only number of unmarketable fruits, marketable fruit yield and unmarketable fruit yields were significantly influenced by the interaction of irrigation regime and Nitrogen rate (Tables 6 and 7 (Other parameters were not significantly influenced by the interaction of irrigation regime and N rate. The highest (118986) number of unmarketable fruit yield was obtained from the combined application of 75% ETc with 92 $Kgha^{-1}$ N, while the lowest (34791) was obtained from 75% ETc with 0 $Kgha^{-1}$ N (Table 6). In addition, the highest (4160 $Kgha^{-1}$) unmarketable fruit yield was recorded from the combined application of 125% ETc with 92 $Kgha^{-1}$ N and the lowest (2250 $Kgha^{-1}$) was recorded from the combined application of 75% ETc with 0 Kg N $ha^{-1}$. The highest (35903 $Kgha^{-1}$) and lowest (13655 $Kgha^{-1}$) marketable fruit yield observed with from combined application of 125% ETc with 92$Kgha^{-1}$ N and 75% ETc with 92$Kgha^{-1}$ N, respectively (Table 6). The result indicated that there was a consistent yield increment with increasing the irrigation in all levels of N rate. Nevertheless, the yield increment in all levels irrigation regime with application of N nutrient was not consistent. Indicating that yield of tomato mainly determined with application of irrigation water. Similarly, different scholars reported the effect of irrigation water and nutrient on tomato yield (Berihun, 2011; Edossa *et al.*, 2014; Xiukang and Yingying, 2016; Benti *et al.*, 2017; Wang and Xing, 2017; Wu *et al.*, 2021)

**Table *6*. Interaction effect of irrigation depth and N on growth, yield related and yield of tomato**

| | *NUUMF | | | MFY ($Kgha^{-1}$) | | | UMFY ($Kgha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| N Rate | 75%ETc | 100% ETc | 125% ETc | 75% ETc | 100% ETc | 125% ETc | 75% ETc | 100% ETc | 125% ETc |
| 0 | 34791$^{e}$ | 40340$^{de}$ | 44643$^{de}$ | 17127$^{fg}$ | 19299$^{def}$ | 22551$^{cdef}$ | 2250$^{c}$ | 2386$^{c}$ | 2548$^{bc}$ |
| 46 | 58898$^{cde}$ | 58553$^{cde}$ | 105048$^{ab}$ | 23942$^{cde}$ | 26277$^{bc}$ | 26329$^{bc}$ | 2493$^{bc}$ | 2929$^{abc}$ | 3882$^{ab}$ |
| 92 | 118986$^{a}$ | 69225$^{bcde}$ | 62122$^{cde}$ | 13655$^{g}$ | 24510$^{bcd}$ | 35903$^{a}$ | 2897$^{abc}$ | 3495$^{abc}$ | 4160$^{a}$ |
| 138 | 99073$^{abc}$ | 67440$^{bcde}$ | 76172$^{bcd}$ | 18385$^{efg}$ | 23429$^{cde}$ | 29571$^{b}$ | 2931$^{abc}$ | 2908$^{abc}$ | 3613$^{abc}$ |
| LSD 0.05 | | 41214.2 | | | 5578.8 | | | 1457.9 | |

**NUUMF = Number of un-marketable fruit; MFY = Marketable fruit yield; UMFY = Un-Marketable fruit yield*

**Table *7*. Mean square value of the collected parameters**

| Source of variation | Mean squares values with respective degrees of freedom in parenthesis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *PH | NFCPP | FL | FD | NUMF | NUUMF | TNUF | MFY | UMFY | TY |
| | | | | | Year 1 | | | | | |
| Rep (3) | $778^{**}$ | $23,2^{*}$ | $1.7^{ns}$ | $0.7^{ns}$ | $6.2E+11^{ns}$ | $7E+09^{ns}$ | $7.4E+11^{ns}$ | $7E+07^{ns}$ | $4556870^{*}$ | $95636739^{ns}$ |
| IRR (2) | $105^{ns}$ | $3.3^{ns}$ | $2.1^{ns}$ | $2.2^{ns}$ | $3.3E+11^{ns}$ | $1.3E+09^{ns}$ | $3E+11^{ns}$ | $8E+08^{*}$ | $9927332^{**}$ | $967940020^{**}$ |
| Ea (6) | 43 | 2.5 | 4.2 | 2.8 | 2.9E+11 | 2.9E+09 | 2.8E+11 | 7E+07 | 822555 | 65659571 |
| N (3) | $160^{ns}$ | $24.4^{***}$ | $0.6^{ns}$ | $3^{ns}$ | $4.8E+11^{ns}$ | $9.8E+09^{**}$ | $5.8E+11^{ns}$ | $2E+08^{**}$ | $5281912^{ns}$ | $218834398^{**}$ |
| IRR*N (6) | $24^{ns}$ | $4.8^{ns}$ | $8.4^{*}$ | $2.1^{ns}$ | $3E+11^{ns}$ | $4.8E+09^{*}$ | $3.1E+11^{ns}$ | $1E+08^{**}$ | $656831^{ns}$ | $136686523^{**}$ |
| Eb (27) | 55 | 2.5 | 2.5 | 1.7 | 3.4E+11 | 1.7E+09 | 3.4E+11 | 3E+07 | 2184225 | 36020610 |
| CV (a) | 12.7 | 22.4 | 0 | 0 | 121.1 | 81.8 | 109.8 | 26.1 | 37.4 | 22.5 |
| CV (b) | 17.1 | 17,2 | 0 | 0 | 118.4 | 79.4 | 108.9 | 22.2 | 37.9 | 20.6 |
| | | | | | Year 2 | | | | | |
| Rep (3) | $497.4^{**}$ | $52.5^{**}$ | $3.4^{ns}$ | $1.3^{ns}$ | $1.06E+11^{*}$ | $6.6E+09^{*}$ | $1.6E+11^{*}$ | $1.9E+08^{ns}$ | $3818861^{ns}$ | $246606106^{ns}$ |
| IRR (2) | $23.4^{ns}$ | 1.1 | $4.2^{ns}$ | $4.4^{ns}$ | $1.22E+10^{ns}$ | $1.8E+09^{ns}$ | $2.2E+10^{ns}$ | $1.2E+07^{ns}$ | $947568^{ns}$ | $13416668^{ns}$ |
| Ea (6) | 35.7 | 27.0 | 8.3 | 5.6 | 1.66E+10 | 1.3E+09 | 2.5E+10 | 4.9E+07 | 919165 | 57370435 |
| N (3) | $141.3^{***}$ | $39.2^{***}$ | $1.3^{ns}$ | $6^{ns}$ | $7.19E+10^{**}$ | $9.6E+09^{***}$ | $1.3E+11^{***}$ | $1.4E+08^{***}$ | $3616510^{*}$ | $188747611^{***}$ |
| IRR*N (6) | $31.9^{ns}$ | $3.8^{*}$ | | | | | | | | |

**PH = Plant height; NFCPP = number of fruit cluster per plant; FL = Fruit length; FD = fruit diameter; NUMF = Number of marketable fruits; NUUMF = Number of un-marketable fruit; TNUF = Total number of fruits; MFY = Marketable fruit yield; UMFY = Un-Marketable fruit yield; TY = Total yield; Ea = Error term for the main plot; Eb = Error term for the sub plot*

*Partial Budget Analysis:* According to the dominance analysis of the mean value; application of 75% ETc with 92 Kg N, 75% ETc with 138 Kg N, 100% ETc with 0 $Kgha^{-1}$ N, 100% ETc with 138 Kg N, 125% ETc with 0 Kg N, 125% ETc with 46 Kg N and 125% with 138 Kg N were dominated by other treatments (1240) for the invested capital.

Table ). Likewise, the combined application of 75% CWR with 46 Kg N, 100% CWR with 46 Kg N and 125% CWR with 92 Kg N Were fulfilled the reasonable minimum acceptable rate of return (MRR) (100%). The result indicated that the highest MRR was obtained from 75% CWR with 46 Kg N. Likewise, the combined application of 125% CWR with 92 Kg N also gave the minimum acceptable MRR. Hence, the highest net benefit (266272 ETB) and MRR (3890) were recorded from the combined application of 125% ETc with 92 $Kgha^{-1}$ N and 75% ETc with 46 $Kgha^{-1}$ N respectively (1240) for the invested capital.

Table ). Therefore, application of 125% ETc with 92 $Kgha^{-1}$ N resulted in highest net benefit as well as acceptable rate of return (1240) for the invested capital.

**Table *8*. Partial budget analysis**

| Treatment | Mean (MFY) | *FGP | GB | CF | CL | TVC | NB | D | MB | MC | MRR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 75ETc*0 N | 17127 | 8.5 | 145580 | 0 | 21600 | 21600 | 123980 | DM | 0 | 0 | |
| 75% ETc *46 N | 23942 | 8.5 | 203508 | 1450 | 21600 | 23050 | 180458 | | 56477 | 1450 | 3890 |
| 75% ETc *92 N | 13655 | 8.5 | 116067 | 2900 | 21600 | 24500 | 91567 | DM | | | |
| 75% ETc *138 N | 18385 | 8.5 | 156272 | 4350 | 21600 | 25950 | 130322 | DM | | | |
| 100% ETc *0 N | 19299 | 8.5 | 164049 | 0 | 28800 | 28800 | 135249 | DM | | | |
| 100% ETc *46 N | 26277 | 8.5 | 223352 | 1450 | 28800 | 30250 | 193102 | | 12644 | 7200 | 160 |
| 100%ETc*92 N | 24510 | 8.5 | 208338 | 2900 | 28800 | 31700 | 176638 | | -16464 | 1450 | -1140 |
| 100%ETc*138 N | 23429 | 8.5 | 199148 | 4350 | 28800 | 33150 | 165998 | DM | | | |
| 125%ETc*0 N | 22551 | 8.5 | 191679 | 0 | 36000 | 36000 | 155679 | DM | | | |
| 125%ETc*46 N | 26329.2 | 8.5 | 223798 | 1450 | 36000 | 37450 | 186348 | DM | | | |
| 125%ETc*92 N | 35903 | 8.5 | 305172 | 2900 | 36000 | 38900 | 266272 | | 89634 | 7200 | 1240 |
| 125%ETc*138 N | 29571 | 8.5 | 251354 | 4350 | 36000 | 40350 | 211004 | DM | | | |

**FGP=Farm gate Price of tomato; GB=Gross benefit; CF=Cost of fertilizer; CL= Cost of labour; TVC= Total variable cost; NB= Net benefit; D= Dominance; DM= Dominated treatment; MC= Marginal cost; MB= Marginal benefit; MRR= Marginal rate of return*

## Conclusion and Recommendation

Tomato is Ethiopia's widely-grown vegetable crop but its production is affected by multiple biotic and abiotic factors and the average yield from farmer's fields is far below the crop potential. limited availability of improved cultivars that are suitable for different purposes, insect pest and disease, suboptimal application of nutrients and low soil fertility status especially N and P, water shortage are some of factor that infulence tomato production.

Irrigation regime and N nutrient application significantly affected most of the parameters under study. Significantly, the highest (35903 $Kgha^{-1}$) marketable tomato yield was observed with application of 125% ETc with 92 $Kgha^{-1}$ N. This treatment combination was also resulted in acceptable minimum rate of return for the invested capital. Therefore, application of 125% ETc with 92 $Kgha^{-1}$ N was recommended for tomato production in Eferatagidim district and similar areas.

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