# II) Agricultural Water Management

## 1. Effects of Micro-Dosing Fertilizer and Irrigation Water under Drip Irrigation for Onion (*Allium cepa* L.) in Northern Ethiopia

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### Abstract

*The most significant variables affecting bulb yield in Ethiopia's irrigated agriculture onion production systems are irrigation water amount and irrigated fertilizer application rates. Due to significant water savings and improved water and fertilizer use efficiencies, drip irrigation has gradually been adopted in North Ethiopia for onion farming. However, it is still unknown what the best irrigation water and fertilizer application rates should be for drip-irrigated onions. Field experiments were conducted in 2019/2020 and 2020/2021 to investigate the effects of irrigation water and fertilizer application rates on onion production and productivity. The trial consisted of four recommended Nitrogen (N) and Phosphorus ($P_2O_5$) micro dosing fertilizer rates ($F_1$-125%, $F_2$-100%, $F_3$-75%, and $F_4$-50%) and three irrigation water levels ($I_1$-100%, $I_2$-75%, and $I_3$-50%). The interaction of water amount and micro-*

*yield, yield-related components, and water productivity. Based on the combined analysis of variances, the yield, yield-related components, and water productivity had a highly significant*

*-dosing fertilizer*

*rates. Onion production and water use efficiency (WUE) increased significantly with higher irrigation water amount and micro-dosing fertilizer application rate. However, applying less than 100% of the irrigation water amount was not beneficial to the above parameters. In the two-season study, the maximum onion yields of 39.22 $tha^{-1}$ were obtained in $F_1I_1$, which had a WUE of 8.20 $Kgm^{-3}$. Considering all growth, yield, and yield-related components, the combination of 172.5 N & 86.25 $P_2O_5$ $Kgha^{-1}$ micro dosing fertilizer rate and 100% irrigation water amount per irrigation was the best drip-irrigated onion pattern. These findings may provide a scientific basis for drip-irrigated onion irrigation water and micro dosing fertilizer management in northern Ethiopia.*

**Keywords:** Drip irrigation, Micro dose fertilizer, Nitrogen, Onion Phosphorus, Water,

## Introduction

Onion is one of the most important cash crops grown by small-scale farmers, allowing them to enhance their income and consequently improve their standard of living (Dessalegn and Aklilu, 2003). It is commonly used as a condiment to enhance food flavor (Enchalew *et al.*, 2016). Almost all spicy foods include onion as a vital element for culinary purposes (Halvorson *et al.*, 2008). It is regarded as an essential component of the human diet (Raber *et al.*, 2022, Metrani *et al.*, 2020). It is high in various minerals and vitamins (Raemaekers, 2001, Shahrajabian *et al.*, 2020). It is also very significant in Ethiopian cuisine for the creation of traditional meals. Some plant parts are edible; the bulbs and lower section of the stem are the most commonly used as a flavoring or vegetable in stews (Griffiths *et al.*, 2002). According to CSA data (2018/19), the production and productivity of onions in Ethiopia and the Amhara region are predicted to be 9.3 and 13.1 $tha^{-1}$, respectively.

Micro-dosing fertilizer application increases fertilizer efficiency and yields while lowering input and investment costs (Blessing *et al.*, 2017, Kubheka, 2015, Nouri *et al.*, 2017). This is an efficient method of fertilizer application since the fertilizer is administered next to the plants, ensuring a high rate of uptake (Sime and Aune, 2020, Vandamme *et al.*, 2018). When compared to traditional application methods, it was found to enhance yields by 44% to 120% and farmers' revenue by 52% to 134% (Tabo *et al.*, 2011, Fatondji *et al.*, 2011). It is especially significant in irrigated agriculture, where huge amounts of fertilizer must be applied to meet crop requirements while preventing leaching loss (Ibrahim *et al.*, 2016, De Baerdemaeker, 2013). According to Sathya *et al.*, (2008), the appropriate combination of water and nutrients is the key to enhancing produce both quantity and quality.

Efficient water utilization in any irrigation system is becoming increasingly crucial, particularly in arid and semiarid regions where water is scarce (Deng *et al.*, 2006, Girma and Jemal, 2015). Drip irrigation is one of the most efficient irrigation technology methods that will allow the application of light and the way of watering plants regularly and with a volume of water approaching plant consumptive use (Fereres *et al.*, 2003, El-Hendawy *et al.*, 2008, Eranki *et al.*, 2017). Many countries' experience has shown that switching from surface irrigation to drip systems can reduce water use by 30% to 60% while increasing crop yields at the same time (Kifle *et al.*, 2022). Several researchers (Deshmukh and

Hardaha, 2014, El-Hendawy *et al.,* 2008, Feleafel and Mirdad, 2013, Vijayakumar *et al.,* 2010) have observed that drip irrigation offers various advantages. It saves water and labor by reducing traditional losses such as deep percolation, runoff, and soil water evaporation; fertilizer application is more exact and uniform; and nutrient uptake by roots is improved (Munir *et al.,* 2021, Munir *et al.,* 2019, Bravdo and Proebsting, 1993). It is not a replacement for other tried and true watering systems. The objectives of this study were to identify the suitable micro-dosing fertilizer application and the amount of water to be irrigated, as well as to analyze the effect of water and fertilizer amount interaction under drip irrigation for onion production.

## Materials and Methods

*Description of Study Area:* The experiment was conducted in two consecutive irrigation seasons (2019/20 and 2020/2021) at the Aybra main research site in sekota woreda. The location is at latitude 12.72568 and longitude 39.02004 in the northeastern Amhara region (Figure 1). The elevation of the study area is 1929 m.a.s.l. The long-term average precipitation in the area is receives 689.6 mm/year, with peak precipitation from July to the end of August, accounting for more than 90% of the annual precipitation (Figure 2). Average daily temperatures range from 12.6 $^{o}{}_{C}$ to 27.4 $^{o}{}_{C,}$ with an average temperature of 20$°_{C}$ (Figure 2).

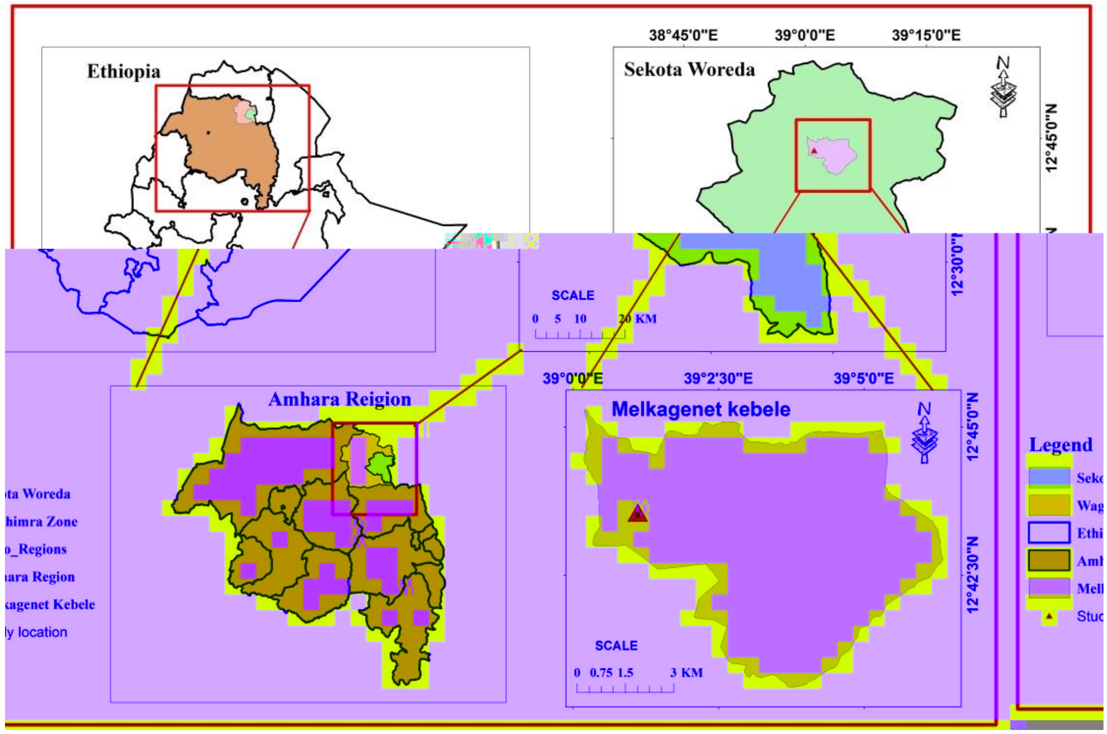


Figure 1. Location map of study area

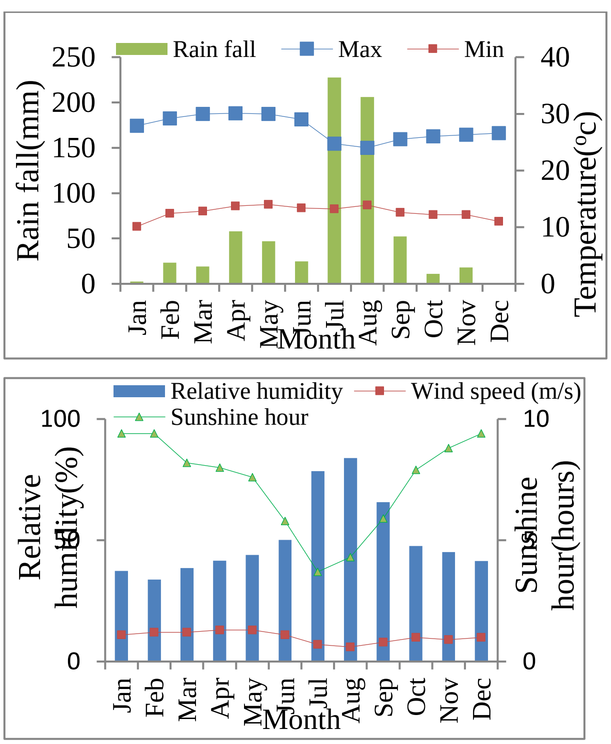


Figure 2. Weather conditions for the crop growing season (2019/20-2020/21)

*Experimental Design:* The experimental design was a randomized completed block design with three replications in a factorial arrangement. The experiment was designed with twelve treatments that included two factors such as three irrigation levels (100, 75, and 50% , refered as $I_1$, $I_2$, & $I_3$ respectively) and four micro-dosing fertilizer application levels like 172.5Nitrogen (N) & 86.25 Phosphorus ($P_2O_5$), 138 N & 69 $P_2O_5$, 103.5 N & 51.75 $P_2O_5$, and 69 N & 34.5 $P_2O_5$ Kgha$^{-1}$ or 125, 100, 75, & 50% of recommended Nitrogen and Phosphorus fertilizer rates, refered as $F_1$, $F_2$, $F_3$, & $F_4$ respectively.

To achieve equal stands of onion seedlings, each treatment receives an equivalent amount of irrigation water up to seedling establishment. Irrigation water was applied at three-day intervals. The drip irrigation system was employed to apply the necessary amount of irrigation water. Each irrigated treatment consisted of six 3 m long lateral lines. The emitters on the lateral line were spaced 20 cm apart. For 45 days, the Bombay red onion variety was raised in a nursery bed. The transplanting to field plots of 1.2 m x 3 m row planting with 20 cm x 10 cm spacing (between rows in the lateral line x plants in rows) was used respectively.
Treatment Combination:

T1 = $F_1$-172.5 N & 86.25 $P_2O_5$ Kgha$^{-1}$ + $I_1$-100% ETc with drip irrigation system
T2 = $F_1$-172.5 N & 86.25 $P_2O_5$ Kgha$^{-1}$ + $I_2$-75% ETc with drip irrigation system
T3 = $F_1$-172.5 N & 86.25 $P_2O_5$ Kgha$^{-1}$ + $I_3$-50% ETc with drip irrigation system
T4 = $F_2$-138 N & 69 $P_2O_5$ Kgha$^{-1}$ + $I_1$-100% ETc with drip irrigation system
T5 = $F_2$-138 N & 69 $P_2O_5$ Kgha$^{-1}$ + $I_2$-75% ETc with drip irrigation system
T6 = $F_2$-138 N & 69 $P_2O_5$ Kgha$^{-1}$ + $I_3$-50% ETc with drip irrigation system
T7 = $F_3$-103.5 N & 51.75 $P_2O_5$ Kgha$^{-1}$ + $I_1$-100% ETc with drip irrigation system
T8 = $F_3$-103.5 N & 51.75 $P_2O_5$ Kgha$^{-1}$ + $I_2$-75% ETc with drip irrigation system
T9 = $F_3$-103.5 N & 51.75 $P_2O_5$ Kgha$^{-1}$ + $I_3$-50% ETc with drip irrigation system
T10 = $F_4$-69 N & 34.5 $P_2O_5$ Kgha$^{-1}$ + $I_1$-100% ETc with drip irrigation system
T11 = $F_4$-69 N & 34.5 $P_2O_5$ Kgha$^{-1}$ + $I_2$-75% ETc with drip irrigation system
T12 = $F_4$-69 N & 34.5 $P_2O_5$ Kgha$^{-1}$ + $I_3$-50% ETc with drip irrigation system
Water productivity (WP) was calculated as the ratio of crop production per unit area in terms of onion bulb to crop evapo-transpiration (mm), and was expressed in kilograms of onion bulb per m$^3$ of used water (Kahlon, 2017, Wakchaure *et al.,* 2018).

$$T \qquad \frac{\text{s ep mph s sr mar f ypf}}{\text{e i vhi pmi vi h yt s l ev i m}}$$

Water is applied directly to the plot, with no consideration for conveyance or distribution losses (Bhalage *et al.,* 2015, Battikhi and Abu-Hammad, 1994), and an irrigation application efficiency of 90% is assumed.

*Data Collection and Analysis:* Meteorological data, including rainfall, temperature, humidity, wind speed, and sunshin hour, were obtained from the closest climatic stations to the experimental sites. Soil texture, bulk density (Bd), pH, organic matter (OM), total Nitrogen (TN), available Phosphorus (AP), electrical conductivity of soil (ECe), field capacity (FC), permanent wilting point (PWP), and moisture content were all determined. Data on onion plant growth and yield parameters were measured and recorded in real time from a net plot area of 2.4 $m^2$ using the standard protocols outlined below.

*Plant Height* **(cm):** At physiological maturity, the plant heights of five randomly selected plants were measured from the soil surface to the top of the tallest leaf, and the mean values were computed for further investigation (Nigatu, 2016, Nigatu *et al.*, 2018).

*Bulb Weight* **(g):** The weight of five randomly selected bulbs was weighted per plot using sensitive balance, and the mean bulb weights were computed and used for further analysis (Tekle, 2015).

*Bulb Diameter* **(cm):** The average bulb sizes atharvest from each plot were determined by measuring the diameters of five randomly selected bulbs with a caliper (Ketema *et al.*, 2013).

*Total Bulb Yield* **(t ha$^{-1}$):** Total onion yield was calculated by adding marketable and unmarketable bulb yields (Tekle, 2015). The weight of such bulbs obtained from the net plot area was measured in kilograms using a sensitive balance and expressed as tonnes per hectare.

*Data Analysis:* The collected onion growth and yield parameters were subjected to analysis of variance (ANOVA) using R 4.2.2 software. Based on the variance analysis results, the mean separation was done using Least Significant Difference (LSD) at 1% level of significance (Gomez and Gomez, 1984).

*Partial Budget Analysis (PBA):* A partial budget analysis was used to determine the economic benefit of just using fertilizer, drip material, and irrigation water for onion production. It can be used to compare the effect of a technology change on farm costs and returns. This budgeting method is referred to as partial since it does not include all production costs, but only those that alter or vary between the farmer's existing production methods and the planned on-farm production practices (CIMMYT, 1988).

The following data were used for PBA: Variable costs (NP fertilizers and water depths which vary between treatments). Onion yield per hectare resulting from each treatment and it was adjusted by 10% decrement for each treatment. Farm price - prices of harvested onion which is currently about 15 Ethiopian ETB per Kg. The fixed costs included: drip materials, land preparation, planting, weeding, seed, chemical and harvesting costs which have invested equally for each treatment.

The main components of PBA, such as total revenue, net income, change in variable cost, change in return, and marginal cost of return should be greater than 100%, were calculated, and a decision on which fertilizer rate and water depth is more profitable for farmers was made based on net income and marginal rate of return.

**Results and Discussions**

*Soil Characteristics:* The water content of the soil at field capacity and permanent wilting point are determined to be 26.22 and 14.85%, respectively (Table 1). The volumetric water content at field capacity ranged from 26.59 to 25.86%. The top 0 to 30 cm had a higher average water content of field capacity of 26.59%, whereas the subsurface soil 30 to 60 cm had a lower field capacity value of 25.86%. The moisture content of the soil at the permanent wilting point varied with depth, reaching as high as 16.10% at the top (0 to 30 cm) and as low as 13.61% at the subsurface soil (30 to 60 cm).

Total available moisture (TAW), which is the depth of water that a crop can absorb through its root system of onion, is directly related to the difference in field capacity and the permanent wilting threshold. The total available soil moisture was 113.7 $mmm^{-1}$ of soil depth, with a maximum infiltration rate of 40 $mmh^{-1}$. As a result, topsoil contains the highest concentration of TAW, while subsurface soil contains smaller quantities (Table 1).

**Table 1 Soil properties**

| Soil parameters | Soil depth (cm) | | |
|---|---|---|---|
| | 0 - 30 | 30 - 60 | Average |
| Bd ($gcm^{-3}$) | 1.38 | 1.57 | 1.47 |
| OM (%) | 1.12 | 1.01 | 1.06 |
| pH | 6.60 | 6.70 | 6.65 |
| TN (%) | 0.07 | 0.06 | 0.06 |
| AP (ppm) | 13.56 | 18.13 | 15.85 |
| ECe (ds/m) | 0.12 | 0.22 | 0.17 |
| Water content | | | |
| FC (vol. %) | 26.59 | 25.86 | 26.22 |
| PWP (vol. %) | 16.10 | 13.61 | 14.85 |
| TAW (mm/m) | 104.90 | 122.50 | 113.70 |
| Irrigation water | | | |
| pH | | 6.90 | |
| ECw (ds/m) | | 0.22 | |

***(*)** ECw = Electrical conductivity of water*

The interaction effects of irrigation water amount and NP fertilizers were highly significantly ($P \leq 0.01$) affected by plant height, bulb diameter, bulb weight, yield, and water productivity, according to the combined analysis of variances (Table 2).

diameter, which was much greater than all other treatments (Figure 3). The treatment that received $I_3$ and $F_3$ of the required fertilizer delivery had the smallest bulb diameter. Water deficits of up to $I_3$ resulted in bulb diameters less than the mean value of 6.04 cm.

This finding is consistent with those of Tolossa (2021), Bhasker *et al.*, (2018), Enchalew *et al.*,(2016), who found that a high amount of soil moisture application leads to a high photosynthetic area, plant height, and a large number of leaves, resulting in a large bulb diameter.

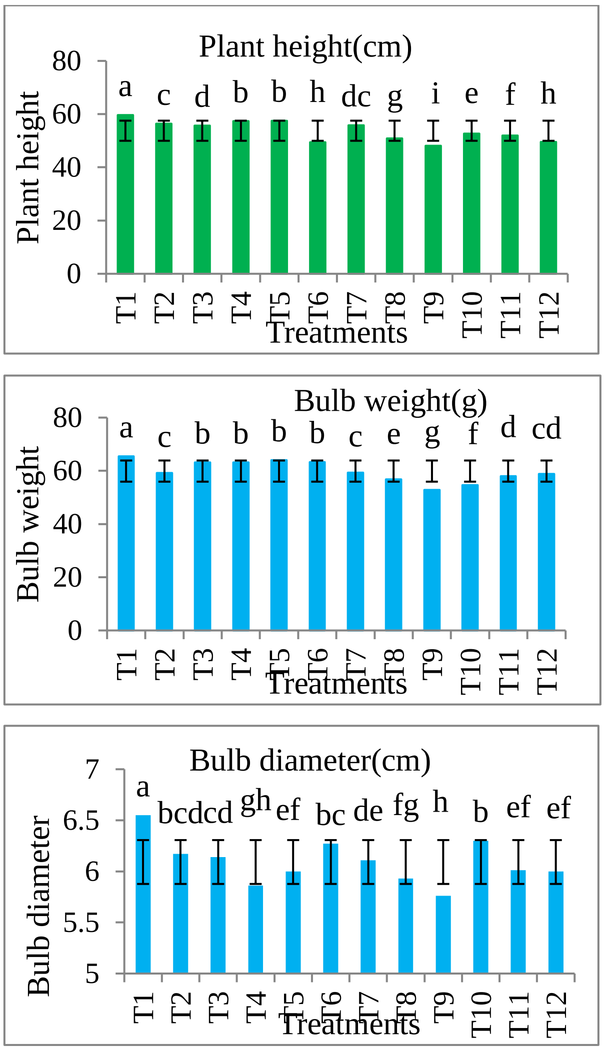


Figure 3. Comparison of the yield related components in different irrigation and fertilizer management (in each column, averages with the same letter, do nothave a significant difference at the 1% level based on the LSD).

*Yield and Water Productivity of Onion:* The two years combined analysis revealed that applying $F_1$ of the recommended Nitrogen and Phosphorus from among the applied fertilizer rates increased onion bulb yield (Figure 4). Because onion is a shallow-rooted crop, it requires a high Nitrogen amount during the growing season (Halvorson *et al.*, 2008); nevertheless, if the amount of N provided lowers, the plant P need decreases as well. The water intake and nutrient absorption in plants are highly associated. When plant roots absorb water, dissolved nutrients are transported to the onion's root surface. On the other side, water intake is reduced, as is nutrient supply to the root system.

The use of $I_1$ at three-day irrigation intervals resulted in a better yield than the applications of $I_2$ and $I_3$, although there is no significant difference between the deficit treatments. Though the soil moisture status was not monitored during irrigation, the moisture difference between the two water depths used is not significant. As a result, applying these two treatments should result in about comparable soil moisture conditions.

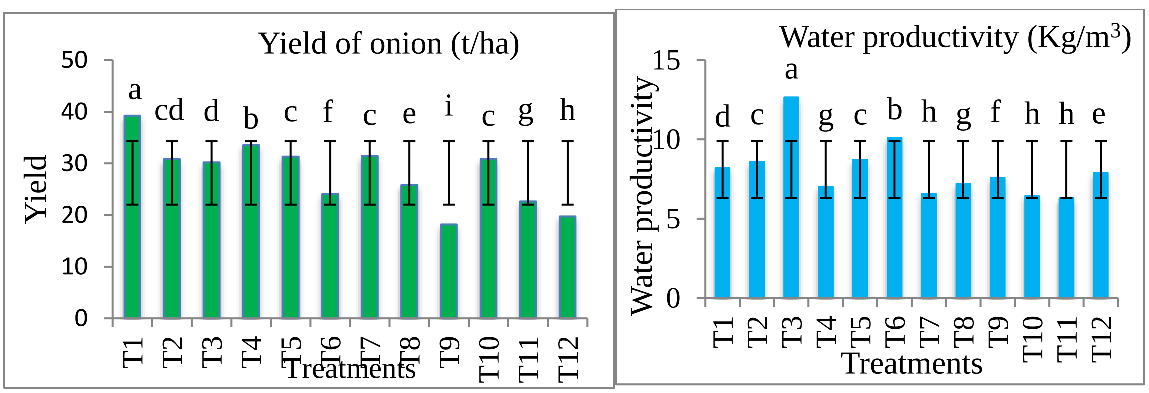


Figure 4. Comparison of the bulb yield, water productivity under different irrigation and fertilizer management.

The interaction effects between irrigation and fertilizer treatments had significant ($P \leq 0.05$) influence on water productivity of onion (Figure 4). The water productivity, however, decreased with increasing depth of irrigations, whereas fertilizer application significantly increased water productivity at all irrigation levels. Thus, $F_1$ recommended fertilizer rate with $I_1$ decreased water productivity of onion as compared to the application of $F_1$ fertilizer rate with $I_3$.

A significant depth of water was saved 50% in the application of $F_1$ recommended micro dosing fertilizer rate with $I_3$ irrigation water amounts. The result showed that a significant depth of water (2382.25 $m^3ha^{-1}$) was saved without significant yield reduction in 50% deficit as compared to full demand irrigation (Table 3). Hence diverting this saved water to another irrigable land to increase the area irrigated may compensate for decreases in crop yields. This could be used to irrigate an additional land of 0.99 ha with a yield benefit of 29.85 $tha^{-1}$ of onion crop production.

The experimental results from field trials confirmed that with deficit irrigation strategies and appropriate micro dosing fertilizer application it is possible to increase crop productivity, WUE and save water for irrigation. This could be especially important for areas facing drought and limited water resources for agricultural production of onion. Similar findings reported that the photosynthesis could be improved by optimizing water and fertilizer applications (Zhang *et al.*, 2017, Wang *et al.*, 2014) and biomass yield (Mon *et al.*, 2016), can ultimately increase crop yield and crop water and fertilizer use efficiency (Albrizio *et al.*, 2010, Dar *et al.*, 2017, Li *et al.*, 2010). Mansouri-Far *et al.*, (2010) reported that irrigation water can be conserved and yield maintained (as a sensitive crop to drought stress) under water-limited conditions.

**Table 3. Amount of water saved and yield reduction of onion**

| Treatments | Irrigation water ($m^3ha^{-1}$) | Tuber yield ($tha^{-1}$) | Water saved (%) | Yield reduction (%) |
|---|---|---|---|---|
| T1 | 4776.00 | 37.18 | 0 | 0 |
| T2 | 3582.50 | 31.59 | 25 | 15.03 |
| T3 | 2393.75 | 30.15 | 50 | 18.90 |
| T4 | 4776.00 | 35.12 | 0 | 0 |
| T5 | 3582.50 | 28.64 | 25 | 18.45 |
| T6 | 2393.75 | 23.41 | 50 | 33.34 |
| T7 | 4776.00 | 28.88 | 0 | 0 |
| T8 | 3582.50 | 27.13 | 25 | 6.06 |
| T9 | 2393.75 | 18.93 | 50 | 34.45 |
| T10 | 4776.00 | 27.01 | 0 | 0 |
| T11 | 3582.50 | 21.15 | 25 | 21.69 |
| T12 | 2393.75 | 18.96 | 50 | 29.80 |

*Partial Budget Analysis:* Partial budget analysis was done for combined result on the bulb yield of onion. The result showed that, $I_1$ irrigation water application at 3 days with $F_1$ recommended Nitrogen and Phosphorus fertilizers rate has the highest net benefit, this could be considered profitable only if its rate of return is higher than 100% (CIMMYT, 1988). But as Table 4 below shows its marginal rate of return (MRR) is 42.92 % which is much less than 100%. Other rates such as ($F_1$:$I_2$); ($F_1$:$I_3$); ($F_2$:$I_2$); ($F_2$:$I_3$); ($F_3$:$I_2$); ($F_3$:$I_3$); ($F_4$:$I_1$); ($F_4$:$I_2$); ($F_4$:$I_3$) micro dosing fertilizer rates and irrigation water depths 3 days interval is marked as dominated. Because as their costs increased against $F_3$ recommended fertilizer rate with $I_1$ irrigation water at 3 days interval, their net benefit did not increase, therefore all these rates are rejected. Hence, the partial budget analysis result revealed that $F_3$ recommended micro dosing fertilizer rate with $I_1$ irrigation water depth at 3 days interval applications gave a maximum benefit for farmers over the other rates (Table 4).

**Table 4: Partial budget analysis for the effects of irrigation and fertilizer on onion yield (tha$^{-1}$).**

| Treatments | Unadjusted yield | Adjusted yield | Total benefit | Cost that vary | Net benefit | MRR (%) |
|---|---|---|---|---|---|---|
| T1 | 39.22 | 35.298 | 529470 | 8789 | 520681 | 42.92 |
| T2 | 30.82 | 27.738 | 416070 | 8789 | 407281 | D |
| T3 | 30.22 | 27.198 | 407970 | 8789 | 399181 | D |
| T4 | 33.51 | 30.159 | 452385 | 7034 | 445351 | 14.92 |
| T5 | 31.31 | 28.179 | 422685 | 7034 | 415651 | D |
| T6 | 24.08 | 21.672 | 325080 | 7034 | 318046 | D |
| T7 | 31.44 | 28.296 | 424440 | 5279 | 419161 | 3.38 |
| T8 | 25.81 | 23.229 | 348435 | 5279 | 343156 | D |
| T9 | 18.20 | 16.38 | 245700 | 5279 | 240421 | D |
| T10 | 30.87 | 27.783 | 416745 | 3524 | 413221 | D |
| T11 | 22.62 | 20.358 | 305370 | 3524 | 301846 | D |
| T12 | 19.70 | 17.73 | 265950 | 3524 | 262426 | D |

## Conclusions and Recommendation

The effects of Nitrogen and Phosphorus and irrigation levels were assessed by examining their effects on yield and yield components of onion. Irrigation water amount and micro dosing fertilizer rate is the major limiting factor for increased production and productivity of onion. Therefore, the combined interaction of irrigation water amount and micro dosing fertilizer rate application practices under drip irrigation is a suitable and most efficient practice for sustainable production in water scarce area like Wag-himra, Ethiopia. The maximum bulb diameter, bulb weight, plant height, and total bulb yield associated with application of $F_1$ recommended micro dosing fertilizer rate with $I_1$ irrigation water amount. However, to maximize water productivity of onions, $F_1$ recommended micro dosing fertilizer rate and $I_3$ water deficit irrigation should be used together. As a result of the partial budget analysis, the $F_1$, $F_2$, and $F_3$ recommended micro dosing fertilizer rates combined with the irrigation water amount given at $I_1$ applications sound economically and can be recommended for onion production in the studied area and similar agro-ecologies.

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