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# Effect of drip lateral spacing and irrigation regime on yield, irrigation water use efficiency and net return of tomato and onion production in the Kobo Girrana valley of Ethiopia

*Solomon Wondatir[1], Zeleke Belay[1], Gizaw Desta[2]*

1. *Sirinka Agricultural Research Center, PO Box.74, Woldia, Ethiopia*
2. *Amhara Region Agricultural Research Institute (ARARI), PO Box 527, Bahir Dar, Ethiopia*

*Corresponding author: solwondatir@gmail.com*

**Abstract:** The irrigation system in Kobo-Girrana valley is extensively developed into modern drip irrigation using ground water sources. Tomato and onion are among the major vegetables grown under drip irrigation. However, the drip lateral spacing is fixed to 1m for all irrigated crops. This lead to low crop water productivity, loss of land, less net return income and un-optimized irrigation production. An on-station experiment was conducted to determine the effect of drip line spacing and irrigation regime on yield, irrigation water use efficiency and net return income. The experiment was carried out for two consecutive irrigation seasons in 2010/11 and 2011/12 at Kobo irrigation research station. The experimental treatments were: two lateral spacing of single row and double row corresponding to each test crop and three irrigation regime (Kp = 0.8, 1.0 and 1.2). The results revealed that an interaction effect between the lateral spacing and irrigation regime was obtained in marketable yield and water productivity of test crops. Application of 0.8 Kp with 2m lateral spacing and 1.2 Kp with 1m lateral spacing provided relatively higher marketable yield of tomato and onion, respectively. Similarly, high water productivity was recorded with same irrigation depths and spacing regimes as to the yield. This result generally revealed that one lateral design for each two plant rows gave high net income than the one lateral design for each one plant row for drip irrigated fresh marketable yield of onion and tomato. An optimized production and irrigation efficiency can be attained by applying irrigation depth adjusted by the given pan coefficients and drip lateral spacing in Kobo areas.

**Key words**: Drip spacing, marketable yield, water productivity, Pan Coefficient, Kobo

## Introduction

Onion and Tomato are among the major vegetable crops grown in Kobo Girana valley. Recently, use of drip irrigation for these crops has increased through government assisted ground water resources. Currently significant area is under drip irrigation development. However, the drip lateral spacing is fixed to 1m for all irrigated crops. This lead to low crop water productivity, loss of land, less net return income and un-optimized irrigation production. Lateral spacing is always a compromise b/n optimal water distribution and lateral cost. So, it is imperative to investigate whether spacing adjustment and using one lateral pipe between two plant rows is effective and economical in terms of initial investment cost and irrigation management efficiency. As a result, this study was conducted to determine the effect of drip line spacing and irrigation regime on yield, net return and irrigation water use efficiency.

## Methodology

The experiment was carried out in Kobo irrigation sites for two consecutive years of 2011 and 2012 for onion and tomato. Kobo research station is situated at 12.08° N latitude and 39.28°E longitudes at an altitude of 1470 masl. The 15 years mean annual rainfall is about 630 mm and average daily reference evapotranspiration rate of 5.94 mm. The soil type in the experimental site is silty clay loam which has average infiltration rate of 8 mm/hr, pH value of 7.8, average FC and PWP of 11.5% and 3.2% on volume basis, respectively.

The drip system was gravitational type which stand 1.5 m head difference from the ground and consisted of PE laterals of 16 mm in diameter and PE manifold pipeline of 32 mm diameter. The discharge rates of the emitters were calculated as 0.9l/h and emitter spacing was chosen as 0.50 m. The experimental design was factorial RCBD with 4 replications. Six treatments were composed from two factors: lateral spacing (single and double) and three irrigation regimes (0.8, 1 and 1.2). For tomato and onion 1 m and 2 m lateral spacing and 0.5 and 1 m lateral spacing were used, respectively**.** The amounts of irrigation water applied (I$m^3$) in the irrigation treatments were determined by Class A pan evaporation using the equation given below:

$$I = A*Ep*Kp*P$$

where A – is the plot area ($m^2$)

Ep – is the cumulative pan evaporation amount for the 4-days irrigation interval

Kp – is the coefficient of pan evaporation (i.e. Kp =0.8, 1.0 and 1.2) and

P – is the percentage of wetted area (Pw) or percentage

For tomato and onion 30 and 10cm plant spacing was used respectively.

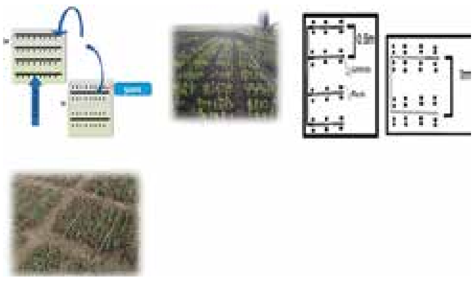

*Figure 1. Schematic layout of laterals and plants in the experimental plots for tomato and onion*

The percentages of wetted area were determined by methods from Keller and Bliesner (1990) and Yildirim (2003). The Pw was the average horizontal area wetted in the top 15–30 cm of the crop root zone as a percentage of the each lateral line area. Thus, the percentages of wetted area measured in the experimental site were 90or 45% for lateral spacing of single or double, respectively. The first irrigation for all plots was based on water deficit that would be needed to bring the 0–60 cm layer of soil to field capacity. Subsequent irrigations were applied considering the 4-day irrigation interval. Irrigation water use efficiency is generally defined as crop yield per water used to produce the yield (Viets 1962; Howell 1996). Thus, IWUE was calculated as fresh fruit weight (kg) obtained per unit volume of irrigation water applied (m3). The net income for each treatment was computed by subtracting all the production costs from gross incomes. All calculations were done based on a unit area of 1 ha (Koral and Altun 2000; Inan 2001).

# Result and discussion

## Effects of treatments on marketable yield of onion and tomato

As observed in Table 1, lateral spacing and different irrigation regimes had a separate significant effect on marketable yield of onion. However, there were no interaction effects between different lateral spacing and irrigation regimes (pan coefficients) on marketable yield of onion. The highest and the lowest marketable bulb yield of 23.54 and 18.21 ton/ha were obtained due to the effects of 1m lateral spacing with 120% of pan amount and 0.5 m with 100% of pan amount, respectively.

Lateral spacing highly affected marketable fruit yield but different irrigation amounts didn't show a significant effect on marketable fruit yield of tomato. A maximum of 21.53 ton/ha marketable fruit yield was obtained due to the effect of double lateral spacing. There was no an interaction effect of plant spacing and irrigation amounts on marketable yield of tomato. The amount of marketable yields was slightly decreased as the amount of irrigation water applied increased. The maximum (23.41 ton/ha) and minimum (15.88 tone/ha) marketable yield of tomato was obtained due to effects of double row spacing with 80% pan coefficient and single row spacing with 120% pan coefficient.

*Table 1. Main effects of lateral spacing and irrigation amount on marketable yield and water productivity of onion and tomato*

| Lateral spacing | Marketable yield (ton/ha) | | Water productivity (kg/m$^3$) | | Irrigation regime | Marketable yield (ton/ha) | | Water productivity (kg/m$^3$) | |
|---|---|---|---|---|---|---|---|---|---|
| | Onion | Tomato | Onion | Tomato | | Onion | Tomato | Onion | Tomato |
| Single | 19.01 | 17.21 | 3.48 | 1.997 | 80% | 20.01 | 20.48 | 6.93 | 3.87 |
| double | 22.45 | 21.53 | 8.13 | 4.935 | 100% | 20.14 | 20.03 | 5.5 | 3.81 |
| | | | | | 120% | 22.04 | 17.60 | 4.99 | 2.72 |
| LSD | 1.24** | 2.06** | 0.38** | 0.244** | | 1.515* | ns | 0.46** | 0.299** |
| CV(%) | 10.2 | 18.1 | 11 | 12 | | 10.2 | 18.1 | 11 | 12 |
| GM | 20.73 | 19.37 | 5.80 | 3.466 | | 20.73 | 19.37 | 5.80 | 3.466 |

*-significant difference **-high significant difference.

*Table 2. Interaction effects of lateral spacing and irrigation amount on marketable yield and water productivity of onion and tomato*

| Lateral spacing and Irrigation Regime | Seasonal irrigation amount (mm) | | Marketable yield (tone/ha) | | Water productivity (kg/m$^3$) | |
|---|---|---|---|---|---|---|
| | Onion | Tomato | Onion | Tomato | Onion | Tomato |
| Single row, 80% pan coefficient | 461.5 | 449.79 | 18.26 | 17.55 | 4.02 | 1.601 |
| Single row, 100% pan coefficient | 576.9 | 562.24 | 18.21 | 18.21 | 3.36 | 2.293 |
| Single row, 120% pan coefficient | 692.3 | 674.69 | 20.55 | 15.88 | 3.06 | 2.098 |
| Double row, 80% pan coefficient | 230.8 | 224.9 | 21.76 | 23.41 | 6.91 | 6.130 |
| Double row, 100% pan coefficient | 288.5 | 281.12 | 22.06 | 21.85 | 9.85 | 5.330 |
| Double row, 120% pan coefficient | 346.1 | 337.35 | 23.54 | 19.33 | 7.63 | 3.343 |
| LSD | | | ns | ns | 0.65** | 0.4230** |
| CV (%) | | | 10.2 | 18.1 | 11 | 12 |
| GM | | | 20.73 | 19.37 | 5.80 | 3.466 |

*-significant difference **-high significant difference.

# Irrigation water use efficiency

As indicated in Tables 2 and 3 above, lateral spacing and different irrigation regimes separately affect water productivity and had an interaction effects on water productivity of onion. Maximum 9.85 and minimum 3.06kg/m$^3$ water productivity existed due to the effects of double row with 100% pan coefficient and single row with 120% pan coefficient, respectively. The value of water productivity decreased as the amount of irrigation amount increased.

For tomato crops, the irrigation water use efficiencies ranges from 1.6–6.13kg/m$^3$ depending up on treatments. The maximum irrigation water use efficiency of 6.13kg/m$^3$ was obtained from double lateral spacing (2m) with 80% pan coefficient. Similarly, Mbarek and Boujelben (2004) showed that IWUE was greatest with double rows in the tomatoes grown in the greenhouse. Generally the highest water use efficiencies occurred in double lateral spacing with small pan coefficients. Furthermore, IWUEs differ considerable among the treatments and generally tends to increase with a decline in irrigation (Howell 2006). IWUE is an important factor when considering irrigation systems and water management and probably will become more important as access to water becomes more limited (Shdeed 2001). On the other hand, water productivity can be increased by increasing yield per unit land area. In addition, water management strategies and practices should be considered in order to produce more crops with less water.

### Economical analysis and evaluation

Economical analysis and evaluation were computed by using the results of this study based on investment, operation and production costs. Based on the irrigation amount of each treatment in the growing season irrigation duration, labour cost for irrigation and pump cost were estimated. The production costs were computed by considering all production inputs (i.e. costs of seeds, ploughing of land, transplanting, hoeing, weeding, pesticide, fertilizer, harvesting etc.) for onion and tomato. The production costs were similar for each treatment and calculated as Ethiopian birr (ETB) 10,000.00/ha for onion and ETB 7000/ha for tomato in the production season. On the other hand, drip irrigation system costs can vary greatly, depending on crop (plant and therefore, emitter spacing and hose) (Solomon 1998).

Thus, based on lateral length, connections, tapes and drippers for the treatment in which the lateral spacing was 1 m and the investment costs were 26% less than in the treatment in which the lateral spacing was 0.5 m for onion. And for tomato, 2 m lateral spacing had 20.64% less investment cost than 1 m lateral spacing. The investment cost of drip system was calculated with 7 years life period (Enciso et al. 2005). According to the calculation for onion 1m lateral spacing with 120% irrigation amount gave the maximum yearly net income of ETB 81,415.93. On the other hand, less net income of ETB 58,957.35 was obtained in 0.5 m lateral spacing with 80% irrigation amount. And for tomato, the lowest ETB 28,761.00 and highest ETB 49,175.00 yearly net income were obtained due treatments of single row spacing (1 m) with 120% irrigation amount and double row spacing (2 m) with 80% irrigation amount, respectively. This result generally revealed that one lateral design for each two plant rows gave high net income than the one lateral design for each one plant row for drip irrigated fresh marketable yield of onion and tomato.

## Conclusion

In the experimental study of onion, 692 mm irrigation water amount in 0.5 m lateral spacing with 120% pan coefficient gave a marketable yield of 20.55 ton/ha. However the highest fresh marketable yield of onion (23.54 ton/ha) was obtained by the effect of 1 m lateral spacing with 120% pan coefficient which requires a total seasonal irrigation requirement of 346mm.

A maximum water use efficient of 9.85 kg/m$^3$ was recorded by 1 m lateral spacing with 100% pan coefficient followed by 7.1 kg/m$^3$ water use efficiency of 1 m lateral spacing with 120% pan coefficient.

Investment costs in the design of one lateral for two crop rows were 27% less because the length of laterals, dripper numbers and connections were fewer than the design of one lateral for each crop row. Also the yield obtained was high compared to the treatment with one lateral for each row. Consequently, economic analysis based on investment and production costs, yields obtained, amounts of irrigation water applied per ha, was done to compare these two treatments. As a result, 1 m lateral spacing with 120% irrigation amount was given the highest as ETB 81,415.93 yearly net income return.

For tomato drip lateral spacing determination study the maximum marketable yield of 23.41 t/ha was obtained by treatment effects of 2 m lateral spacing with 80% pan coefficient to which total seasonal irrigation water amount of 225 mm.

Similarly 2 m lateral spacing with 80% pan coefficient gave the maximum water use efficiency of 6.13 $kg/m^3$. Fresh marketable yield slightly decreases as the irrigation regime increases. To get optimum tomato production using one lateral pipe for two plant rows and 80% pan coefficient of irrigation regime is recommendable.

Drip irrigation cost of double row lateral spacing was 20.64% less than a single lateral spacing for each crop rows. A maximum marketable yield obtained in treatment of 2 m lateral spacing by 80% pan coefficient contribute for a high economical yearly net return income of ETB 49,175.

An optimized production and irrigation efficiency can be attained by applying irrigation depth adjusted by the given pan coefficients and drip lateral spacing in Kobo areas.

Generally in Kobo Girana area double lateral spacing is more economical than a single lateral spacing design for onion and tomato vegetables.

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