Effect of Drip Lateral Spacing and Irrigation Amount on Tomato and Onion Crops Water Productivity at Kobo Girrana Valley, Ethiopia.

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Abstract

Irrigation system in Kobo-Girrana valley is extensively developed into modern drip irrigation using groundwater 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 leads 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 amount 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 laterals spacing of single (1m) row and double (2m) row corresponding to each test crop and three irrigation amounts (pan coefficients /PC/ = 0.8, 1.0 and 1.2). The experimental design was factorially arranged in RCBD. The experimental results revealed that there was an interaction effect between the lateral spacing and irrigation amounts on marketable yield and water productivity of the test crops. Application of 0.8 PC with 2m lateral spacing and 1.2 PC with 1m lateral spacing provided a relatively higher marketable yield of tomato and onion respectively. Similarly, high water productivity was recorded with the same irrigation depths and spacing. 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.

Keywords: *Drip irrigation, irrigation schedule, lateral spacing, marketable yield, water productivity*

Introduction

Irrigation water plays a main role for agricultural growth, which enhances the cropping intensity of high value crops and also increasing the productivity of crops. Hence irrigation water plays a great contribute to sustain reduction of rural poverty too. Ethiopia is the country which endowed with abundant water resources and huge irrigable lands for irrigation agriculture (Awualchew *et al.*, 2010; EPCC, 2015).

Despite this, much of the available irrigation water is applied through the conventional surface irrigation method, where the efficiency of water is very low. The low irrigation water-use efficiency not only reduces the anticipated outcomes from investments in the water resources sector of the country, but also creates environmental problems, such as lowering of the water table due to over-exploitation of sub-surface water resources, water logging and soil salinity, thereby affecting the yields adversely.

In order to reduce the water stress in agricultural sector and to improve the efficiency of existing irrigation systems, various initiatives have been taken in Ethiopia in recent years. Of these, drip irrigation has been practiced relatively in large scale in Amhara region; specifically, in Kobo Girana Valley. Since moisture stress is completely absent in drip irrigation, the productivity of crops is found to be significantly higher than those cultivated under flood irrigation (Namara *et al.*, 2005; Narayanamoorthy, 2004; Shah and Keller, 2014).

Drip irrigation has a multiple advantage; it offers improved yields, requires less water, and decreases the cost of tillage, and reduces the amount of fertilizer and other chemicals to be applied to the crop. Because drip irrigation makes it possible to place water precisely where it is needed and to apply it with a high degree of uniformity at very low flow rates, it decreases both surface runoff and deep percolation. These features make drip irrigation potentially much more efficient than other irrigation methods, which can translate to significant water savings (Hanson *et al.*, 1996).

Thus, in Kobo Girana Valley use of drip irrigation for vegetable crops has increased through government assisted ground water resources development program. Currently significant area is under drip irrigation development. Onion and Tomato are among the major vegetable crops grown in Kobo Girana valley.

However, the drip lateral spacing is fixed to 1m for all irrigated crops. This leads to low crop water productivity, loss of land, less net return income and un-optimized irrigation production. Lateral spacing is always a compromise between 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 amount on yield, net return, and irrigation water use efficiency.

Materials and Methods

The experiment was carried out at Kobo irrigation site for two consecutive years of 2011 and 2012 for onion and tomato. Kobo research station is situated at 12.08^0 N latitude and 39.28^0 E longitudes at an altitude of 1470 m above sea level. The 15 years mean annual rainfall is about 630mm and average daily reference evapo-transpiration 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 the gravitational type which stands 1.5m head difference from the ground and consisted of PE laterals of 16mm in diameter and PE manifold pipeline of 32mm diameter. The discharge rates of the emitters were calculated as 0.9l/hr. and emitter spacing was chosen as 0.50m. The experimental design was factorial RCBD with 4 replications. Six treatments were composed of two factors: lateral spacing (single and double) and three irrigation depths (80%, 100%, and 120%). For tomato and onion, 1m & 2m lateral spacing and 0.5 & 1m 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:

$$I = A * E_p * K_p * P$$

Where;

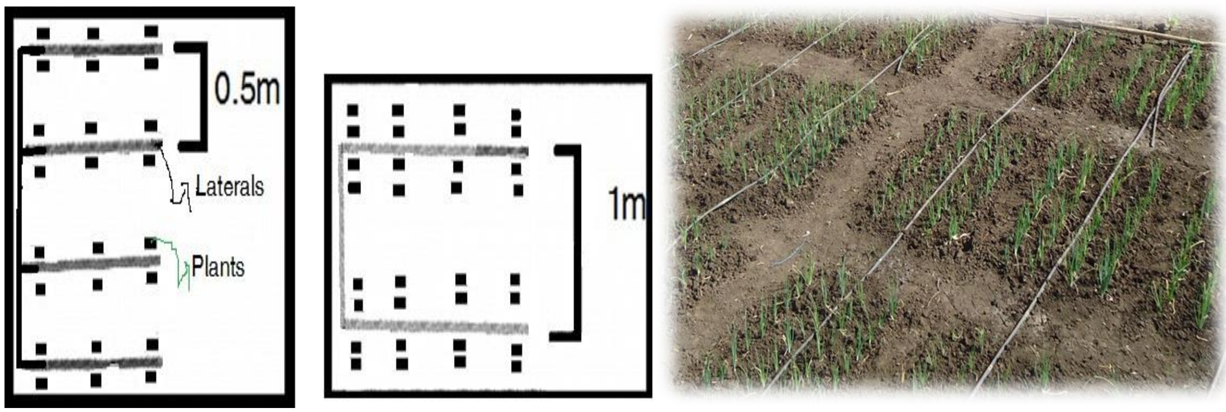
I = is the plot area (m^2),

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

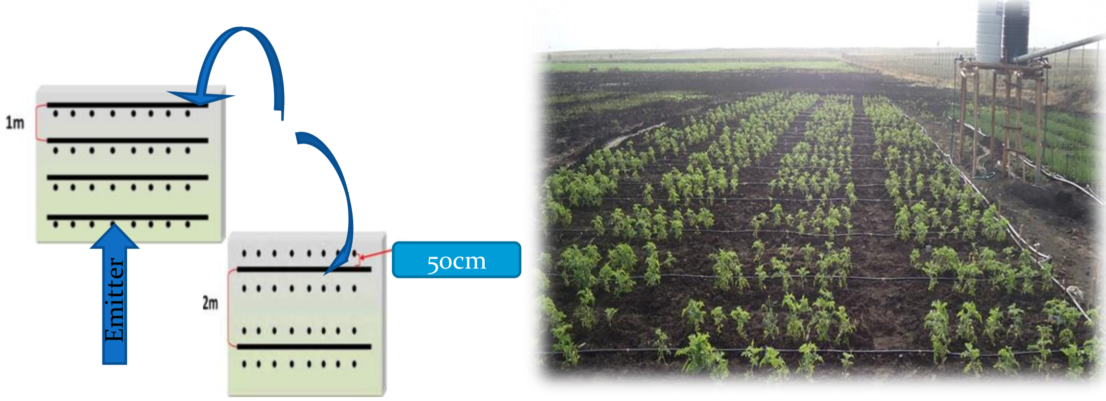
Kp = is the coefficient of pan evaporation (i.e. Kp =0.8, 1.0 & 1.2) and

P = is the percentage of wetted area (P) or percentage

The spacing between plants was 30 and 10cm for tomato and onion respectively.



(a) Onion



(b) Tomato

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

The percentages of the wetted area (P) were determined by methods from Keller and Bliesner (1990) and Yildirim (2003). The P was the average horizontal area wetted in the top 15 30 cm of the crop root zone as a percentage of each lateral line area. Thus, the percentages of wetted area measured in the experimental site were 90% or 45% for the 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-days irrigation interval. Irrigation water use efficiency (IWUE) 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 (m^3).

The economic analysis was carried out through the net benefit investment method; i.e. by subtracting total annual costs from total annual benefits. The other economic analysis parameter cost-

operating costs in the project life periods. The total production cost was calculated from the results of investment, operation and production costs. The market price of each vegetable crop in the production year was used for the estimation of total income.

Result and Discussion

Results

There was an interaction effect between drip lateral spacing and irrigation depths on water productivity of onion and tomato. While there were no interaction effects on bulb yield of onion and tomato.

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

Lateral spacing	Marketable yield (tone/ha)		Water productivity (kg/m^3)		Irrigation regime	Marketable yield (tone/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 (0.05)	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

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

Lateral spacing and Irrigation depth	Seasonal irrigation amount (mm)		Marketable yield (ton ha^{-1})		Water productivity (kg m^{-3})	
	Onion	Tomato	Onion	Tomato	Onion	Tomato
Single row, 80% PC	461.5	449.79	18.26	17.55	4.02	1.601
Single row, 100% PC	576.9	562.24	18.21	18.21	3.36	2.293
Single row, 120% PC	692.3	674.69	20.55	15.88	3.06	2.098
Double row, 80% PC	230.8	224.9	21.76	23.41	6.91	6.130
Double row, 100% PC	288.5	281.12	22.06	21.85	9.85	5.330
Double row, 120% PC	346.1	337.35	23.54	19.33	7.63	3.343
LSD(0.05)			ns	ns	0.65**	0.4230**
CV (%)			10.2	18.1	11	12

*-significant difference NS= non-significant at 5% **-high significant difference PC- pan coefficient

Table 3. Economic analysis of drip lateral spacing for onion crop

Treatments	Amount of irrigation water (mm) (1)	Irrigation water (m^3 ha^{-1}) (2)	Irrigation duration for the irrigation season (h) (3)	Labor cost for irrigation (birr h^{-1}) (4)	Total cost for irrigation labor (birr) (5)= (3*4)	Pump cost (birr) (6) (irrigation cycle*unit pump cost) (2*3)	Crop production cost (birr ha^{-1}) (7)	Irrigation system cost for 1ha (birr ha^{-1}) (8)	Yearly cost of the irrigation system (birr/ha) (9)=(8/7years)	Total cost for 1 year (birr ha^{-1}) (10)=(5+6+7+9)	Yield (kg ha^{-1}) (11)	Sale price (birr kg^{-1}) (12)	Gross income per ha (birr $ha^{-1}year^{-1}$) (13)=(11*12)	Net income (birr $ha^{-1}year^{-1}$) (14)=(13-10)
1	461.5	4615	90.25	3	270.75	384.58	10000	21444.05	3063.44	13718.77	18260	4	73040	59321.23
2	576.9	5769	112.82	3	338.46	480.75	10000	21444.05	3063.44	13882.65	18210	4	72840	58957.35
3	692.3	6923	135.38	3	406.14	576.92	10000	21444.05	3063.44	14046.50	20550	4	82200	68153.50
4	230.8	2308	45.13	3	135.39	192.33	10000	15768.3	2252.61	12580.33	21760	4	87040	74459.67
5	288.5	2885	56.42	3	169.26	240.42	10000	15768.3	2252.61	13718.77	22060	4	88240	75577.71
6	346.1	3461	67.68	3	203.04	288.42	10000	15768.3	2252.61	13882.65	23540	4	94160	81415.93

Table 4. Economic analysis of drip lateral spacing for tomato crop

Treatment	Amount of irrigation water (mm) (1)	Irrigation water (m^3 ha^{-1}) (2)	Irrigation duration for the irrigation season (h) (3)	Labor cost for irrigation (birr h^{-1}) (4)	Total cost for irrigation labor (birr) (5)=(3*4))	Pump cost (birr) (6)	Crop production cost (birr ha^{-1}) (7)	Irrigation system cost for 1ha (birr ha^{-1}) (8)	Yearly cost of the irrigation system (birr/ha) (9)=(8/7years)	Total cost for 1 year (birr ha^{-1}) (10)=(5+6+7+9)	Yield (kg ha^{-1}) (11)	Sale price (birr kg^{-1}) (12)	Gross income (birr ha^{-1} $year^{-1}$) (13)=(11*12)	Net income (birr ha^{-1} $year^{-1}$) (14)=(13-10)
1	449.79	4498	250	3	750	374.83	7000	15768.3	2252.61	10377.44	17550	2.5	43875	33498
2	562.24	5622	312	3	937	468.5	7000	15768.3	2252.61	10658.11	18210	2.5	45524	34867
3	674.69	6747	375	3	1124	562.25	7000	15768.3	2252.61	10938.86	15880	2.5	39700	28761
4	224.9	2249	125	3	375	187.42	7000	12513.8	1787.69	9350.11	23410	2.5	58525	49175
5	281.12	2811	156	3	469	234.25	7000	12513.8	1787.69	9490.94	21850	2.5	54625	45134
6	337.35	3374	187	3	562	281.17	7000	12513.8	1787.69	9630.86	19330	2.5	48325	38694

Discussion

Onion

Effects of lateral spacing and irrigation depths on onion bulb yield and water productivity

As observed in table 1; lateral spacing and different irrigation depths had a separate significant effect on marketable yield of onion. However, there was no interaction effect between different lateral spacing and irrigation depths 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 irrigation depth and 0.5m with 100% of irrigation depth respectively. In table 2 above, lateral spacing and different irrigation depths separately affects water productivity and had an interaction effect on water productivity of onion. Maximum 9.85 and minimum 3.06kg/m^3 water productivity were existed due to the effects of a double row with 100% irrigation depth and single row with 120% irrigation depth respectively. The value of water productivity was decreased as the amount of irrigation amount increased.

Economic analysis and evaluation of onion

As showed in table 3 and 4 above; Economic 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, labor cost for irrigation and pump cost were estimated. The production costs were computed by considering all production inputs (i.e. costs of seeds, plowing of land, transplanting, hoeing, weeding, pesticide, fertilizer, harvesting, etc.) for onion and tomato. The production costs were similar for each treatment and calculated as 10,000.00birr/ha for onion and 7,000birr/ha for tomato in the production season. On the other hand, drip irrigation system costs can vary greatly, depending on the crop (plant, and therefore, emitter spacing and hose) (Solomon, 1988).

Thus, based on lateral length, connections, tapes, and drippers for the treatment in which the lateral spacing was 1m 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, 2m lateral spacing had 20.64% less investment cost than 1m lateral spacing. The investment cost of a 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 81,415.93birr. On the other hand, less net income of 58,957.35birr was obtained in 0.5m lateral spacing with 80% irrigation amount. 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.

Tomato

Effects of lateral spacing and irrigation depths on tomato fruit yield and water productivity

There was a highly significant difference in marketable tomato yield due to different lateral spacing. There was no significant difference in marketable fruit yield of tomato among different irrigation amounts. A maximum of 21.53ton/ha marketable fruit yield was obtained due to the effect of double lateral spacing. There was no interaction effect in marketable fruit yield of tomato due to lateral spacing and irrigation amounts. The amount of marketable yields was slightly decreasing as the amount of irrigation water applied increased. The maximum (23.41tone/ha) and minimum (15.88tone/ha) marketable yield of tomato were obtained due to effects of double row spacing with 80% irrigation depth and single row spacing with 120% irrigation depth.

For tomato crops, the irrigation water use efficiencies range from 1.6 - 6.13kg/m^3 depending upon treatments. The maximum irrigation water use efficiency of 6.13kg/m^3 was obtained from double lateral spacing (2m) with 80% irrigation depth. This might be related to the wider lateral spacing and low depth of application; which used a low amount of total irrigation water. Similarly, Hao *et al.* (2013) 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 irrigation depth. Furthermore, IWUEs differ considerably 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 the yield per unit land area. In addition, water management strategies and practices should be considered in order to produce more crops with less water.

Economic analysis and evaluation of tomato

The production costs were similar for each treatment and calculated as 7,000birr/ha for tomato in the production season. Based on lateral length, connections, tapes, and drippers for the treatment in which the lateral spacing of 2m lateral spacing had 20.64% less investment cost than 1m lateral spacing. The investment cost of the drip system was calculated similarly with the above onion crop. The lowest 28,761.00birr and highest 49,175.00birr yearly net income were obtained due to treatments of single row spacing (1m) with 120% irrigation amount and double row spacing (2m) 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 tomato.

Conclusion and Recommendation

In the experimental study of onion, 692mm irrigation water amount in 0.5m lateral spacing with 120% irrigation depth gave a marketable yield of 20.55ton/ha. However, the highest fresh marketable yield of onion (23.54tone/ha) was obtained by the effect of 1m lateral spacing with 120% pan coefficient which requires a total seasonal irrigation requirement of 346mm. A maximum water use efficiency of 9.85kg/m^3 was recorded by 1m lateral spacing with 100% irrigation depth followed by 7.1kg/m^3 water use efficiency of 1m lateral spacing with 120% irrigation depth for onion.

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, 1m lateral spacing with 120% irrigation amount was given the highest as 81,415.93birr yearly net income return.

For tomato drip lateral spacing determination study, the maximum marketable yield 23.41tone/ha was obtained by treatment effects of 2m lateral spacing with 80% irrigation depth to which total seasonal irrigation water amount of 225mm. Similarly, 2m lateral spacing with 80% irrigation depth gave the maximum water use efficiency of 6.13kg/m^3. Fresh marketable yield slightly decreases as the irrigation amount increases. To get optimum tomato production using one lateral pipe for two plant rows and 80% pan coefficient of irrigation amount 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 the treatment of 2m lateral spacing by 80% pan coefficient contributes for a high economical yearly net return income of 49,175birr.

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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