Determination of Optimal Irrigation Scheduling for Onion (*Allium cepa* L.) in Raya Valley, Northern Ethiopia

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Abstract

Irrigation technologies that save water are necessary to assure the economic and environmental sustainability of commercial agriculture. Precision irrigation scheduling is critical to improving irrigation efficiency. A field experiment was conducted to evaluate the responses of onion to irrigation regime (when and how much) and to identify water productivity under optimal irrigation regime. The study was conducted for three non-consecutive years at Mehoni Agricultural Research Center, Raya valley, Ethiopia. Five irrigation scheduling (60% ASMDL, 80% ASMDL, 100% ASMDL (FAO recommended ASMDL), 120% ASMDL and 140% ASMDL were used. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Bomby Red variety of onion was used for this experiment. Results showed that onion marketable, total bulb yield and water productivity was significantly affected by irrigation scheduling. The highest marketable onion bulb yields of 27.45, 26.92 and 26.76 ton/ha were obtained from treatment 60% ASMDL, 80% ASMDL and 100% ASMDL, respectively. The lowest yield of 24.45 and 24.32 ton/ha was obtained from treatment 120% ASMDL and 140% ASMDL respectively. The highest water productivity (WP) of onion 5.81 kg/m^3 was obtained from treatment of FAO recommended available soil moisture depletion level followed by +20 % FAO recommended ASMDL, while the lowest value of 4.74 kg/m^3 was obtained from treatment -40% or 140% FAO recommended ASMDL. Therefore, based on the current findings, application of irrigation scheduling for onion in study and similar agro - climatic area and soil type application of irrigation at 100% ASMDL or FAO recommended gives highest bulb yield and water productivity.

Introduction

The ever-increasing world population and the demand for additional water supply by industrial, municipal, and agricultural sectors exert a lot of pressure on renewable water resources forcing the agricultural sector to use the available irrigation water efficiently to produce more food to meet the increasing demand (Andarzian *et al.,* 2011).

Determining crop yield response to irrigation is crucial for crop selection, economic analysis and for practicing effective irrigation management strategies.

Furthermore, this enables to know the time of irrigation as well as to optimize yield, water use efficiency and ultimate profit (Payero etal., 2009). Under limited irrigation water supply, irrigation scheduling is also very useful in determining irrigation strategies. Irrigation scheduling is one of the most important tools for developing best management practices for irrigated areas (Pejic et al., 2008). Irrigation scheduling is the technique of applying water on a timely and accurate basis to the crop, and is the key to conserving water and improving irrigation performance and sustainability of irrigated agriculture (Lopez, 2004).

Jensen, M.E., (1980). referred to irrigation scheduling as "a planning and decision-making activity that the farm manager or operator of an irrigated farm is involved in before and during most of the growing season". Irrigation scheduling has been described as the primary tool to improve water use efficiency, increase crop yields, increase the availability of water resources, and provoke a positive effect on the quality of soil and ground water.

Irrigation scheduling involves making a decision on how much and when to apply it. Three factors influence the decision: water needs by the crop (evapotranspiration), water availability, and water holding capacity of the soil (Mohamed and Makki, 2005).

Modern scientific irrigation scheduling uses a single approach or combination of weather-, soil- or plant-based approaches. This may involve estimating the earliest date to permit efficient irrigation or the latest date to avoid the detrimental effects of water stress on the crop (Ritchie and Johnson, 1991).

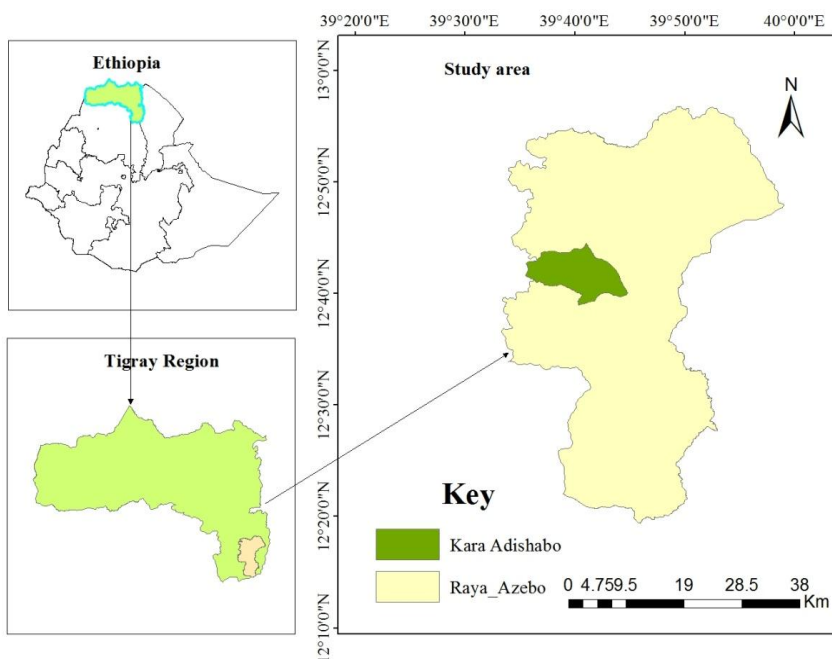Keeping all above points in mind, the field experiment was planned, to1 0 0 1 IrlJET1BT1

Figure 1. Map of the study area

Climatic characteristics

The average climatic data (Maximum and minimum temperature, relative humidity, wind speed, and sun shine hours) on monthly basis of the study area were collected from the near meteorological station. The potential evapotranspiration ETo was estimated using CROPWAT software version 8.

January	11.5	27.2	73	69	7.9	18.4	3.33
February	12.8	27.1	70	86	9.4	22.0	4.02
March	13.5	29.5	68	86	8.7	22.4	4.44
April	13.8	29.7	67	95	8.7	22.9	4.65
May	15.3	32.5	58	52	9.1	23.3	4.69
June	15.8	35.0	60	43	8.6	22.2	4.70
July	15.6	31.5	90	52	6.5	19.1	4.04
August	15.0	29.7	95	43	6.5	19.3	3.89
September	14.3	30.8	74	52	6.6	19.2	3.96
October	13.1	29.8	69	86	9.2	22.0	4.36
November	12.1	28.6	67	69	9.0	20.1	3.77
December	11.3	27.1	69	69	8.8	19.0	3.40

Experimental Design and treatment combination

The experiment was designed as randomized complete block (RCBD) arrangement with three replications. The experiment included five levels of soil water depletion. the five level of ASMDL are (60% ASMDL, 80% ASMDL, 100% ASMDL (FAO recommended ASMDL), 120% ASMDL and 140% ASMDL). Predetermined amount of irrigation water were applied to each plot using Partial flume.

ASMDL 1	60% ASMDL
ASMDL 2	80% ASMDL
ASMDL 3	ASMDL*
ASMDL 4	120% ASMDL
ASMDL 5	140% ASMDL

*ASMD is available soil moisture depletion level according to FAO (33)

Selected Soil and Water Properties of the Study Area

The result of the soil analysis from the experimental site showed that the average composition of sand, silt and clay percentages were 15, 27 and 58%, respectively. Thus, according to the USDA soil textural classification, the percent particle size determination for experimental site revealed that the soil texture could be classified as clay soil (Table 3).

Moreover, the pH value of the experimental site was 7.3. According to (Tekalign 1991), soils having pH value in the range of 6.73 to 7.3 are considered neutral soils. And this value falls in the pH range that is very conducive for most vegetables and onion production.

The analysis of the irrigation water showed that pH value of 7.7 and ECw value of 0.46 dS m $^{-1}$ were obtained. According to (FAO 1999), water salinity has classification the irrigation water quality of the study area was classified at medium.

The pH of irrigation water is not a problem by itself, but it is an indicator of other problems such as sodium and carbonates. According to (Bryan *et al.* (2007), the irrigation water was classified in the study area slight to moderate (7- 8) in terms of pH (Table 3).

The total available water (TAW) that is the amount of water that a crop can extract from its root zone is directly related to variation in FC and PWP and its root depth. Onion root depth extends only to 60 cm and hence the TAW of onion is 103.2 mm. TAW of the experimental site soil was found to be 172.04mm per

meter depth (Table 4).

Sand	%	15
Silt	%	27
Clay	%	58
Textural class		Clay
pH	-	7.3
ECe (by 25°C)	dS m $^{-1}$	0.12
pH	-	7.7
ECw	dS m $^{-1}$	0.46

1.1	44.34	28.7	170.04

Experimental procedure and management practice

The size of each individual plots had kept at 2.8 m*3 m. The spacing between plots and blocks were 2 m and 3 m, respectively. The spacing between onion plants and rows was kept at 10 cm and 20 cm, respectively. Each plot has 8 rows of onion plants with double row and 30 plants in each row with a total plant population of 400 in each plot. Each experimental treatment was fertilized with recommended fertilizer application, that was 100kg/ha and 100kg/ha of DAP and Urea respectively. The full dose of DAP was applied at transplanting, whereas Urea was applied by splitting into two parts, half first three weeks after transplanting and the rest just at mid-stage. All cultural practices were done to all treatments in accordance to the recommendation made for the area. Irrigation water was applied as per the treatment to refill the crop root zone depth close to field capacity.

Irrigation scheduling

The net depth of water required (dnet) was determined by the equation provided by

$$d_{net} = TAW \times P$$

Where

d_{net} = Net depth of water required (mm)

P = Allowable soil moisture depletion by the crop

TAW = Total available soil moisture (mm/m).

The number of days between two subsequent irrigations, irrigation scheduling, was determined by using equation.

$$IF = d_{net} / ETc$$

Where

IF   = Irrigation frequency (days)

d_{net}= Net depth of water required (mm)

ETc   = Crop evapotranspiration (mm/day)

The crop evapotranspiration used in irrigation frequency determination was determined by using equation.

ETc = ETo × Kc

Where

ETc = Crop evapotranspiration (mm/day)

ETo = References evapotranspiration (mm/day)   Kc = crop coefficient

Calculation of water productivity

Water productivity (WP) is the amount of onion bulb yield per irrigation water applied.

$$WP = \frac{\text{harvested grain yield}}{\text{total water used}}$$

Where, WP is crop water productivity (kg/m³), harvested bulb yield (kg/ha) and total water used is the seasonal crop water consumption by evapotranspiration (m³/ha).

Statistical Analysis

Analyses of variances for the data recorded were conducted using SAS 9.1 statistical software carried out using least significance difference (LSD) test at 5% probability used for mean separation when the analysis of variance indicated the presence of significant treatment differences.

Results and Discussion

Irrigation Water Requirements of Onion

The water requirement of onion was computed for the growing season using the CROPWAT 8 computer program with climate, soil and crop input data from the study area. The values of ETo estimated using CROPWAT model based on climate parameters need to be adjusted for actual crop ET. The crop water requirement of the tested crop is calculated by multiplying the ETc with crop coefficient (Kc).

Pre-irrigation and common irrigation were applied for all plots uniformly without considering the treatments variation for transplanting and enhance better establishment of transplanted onion. Pre-irrigation was done before one day of transplanting. Two common irrigation after transplanting was applied to refill the moisture to field capacity of the effective root depth.

According the seasonal irrigation water requirement of onion for 100% ASMDL was in the study area 446.9 mm. This amount of water for each treatment was needed for 60% ASMDL,

Table 5. Effects of optimal irrigation scheduling on Plant height(cm), Number of leaf per plant, Bulb length (cm) and Bulb diameter (cm)

Treatment	PH	NL	BL	BD
60% ASMDL	40.1	10.16[ab]	5.16	5.5
80% ASMDL	46.9	10.6[a]	5.05	6.01
ASMDL*	44.5	10.2[ab]	5.11	5.62
120% ASMDL	47.2	9.8[c]	5.2	5.75
140% ASMDL	43.1	9.5[c]	5.3	5.66[a]
$LSD_{0.05}$	NS	0.5	NS	NS
CV (%)	9.1	2.6	4.2	4.5

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $P < 0.05$; LSD= least significant difference; CV = Coefficient of variation.

Marketable bulb yield

The mean marketable bulb yield of onion was significant ($P < 0.05$) difference on the different treatment of available soil moisture depletion level (ASMDL). The highest marketable bulb yield was obtained from treatments which received 60% FAO recommended ASMDL followed by 80% and 100% FAO recommended ASMDL with the result of 27.45, 26.92 and 26.72 ton/ha respectively. The lowest marketable bulb yield of onion (24.32 ton /ha) was recorded from the treatment of 140% or +40% FAO recommended ASMDL. There was no statistically differences observed among 120% ASMDL and 140% ASMDL on marketable bulb yield of onion (Table 6).

The better performance of yield parameters with 100 per cent may be attributed to significant increase in growth parameters. The result was in agreement with the finding of (Bagali et al. 2012) reported that scheduling of drip irrigation onion at shorter interval with higher level of irrigation recorded significantly higher bulb yield. Similar results for higher bulb yield were reported by Anonymous (2001 and 2002) and Hanson and May (2004).

Total bulb yield

The mean total bulb yield was significant ($P < 0.05$) difference on the different treatment of available soil moisture depletion level (ASMDL). The highest total bulb yield (29.58, 28.81 and 28.51 ton/ ha) was obtained from the treatment of 60% ASMD, 80% ASMDL and 100% FAO recommended ASMDL respectively. In the other hand, the lowest value of total yield of onion (26.34 and 26.47 ton/ha) was recorded from the treatment of 140% and 120% FAO recommended available soil moisture depletion level.

The result of the current study is in agreement with the finding of (Bagali et al. 2012) reported that scheduling of drip irrigation onion at shorter interval with higher level of irrigation recorded significantly higher bulb yield.

Water productivity of onion

The effect of different irrigation scheduling levels was significant ($P < 0.05$) on onion water productivity. As showed in Table 6, the highest water productivity of onion was recorded from the treatments 100% FAO recommended ASMDL which has given 5.81 kg/m^3 followed by +20% FAO recommended ASMDL. The minimum water productivity 4.7 kg/m^3 was obtained from 60% or -40% FAO recommended ASMDL. Due to the reason of too much water frequently irrigated water and low water productivity.

Table 6. Effects of optimal irrigation scheduling on Marketable bulb yield (ton/ha), Un marketable bulb yield (ton/ha, Total bulb yield (ton/ha) and Water productivity (kg/m³) of onion

Treatment	MBY	UMBY	TBY	WP
60% ASMDL	27.45[a]	2.13	29.58[a]	4.74[c]
80% ASMDL	26.92[a]	1.89	28.81[a]	5.12[bc]
ASMDL*	26.76[a]	1.77	28.53[a]	5.81[a]
120% ASMDL	24.45[b]	2.02	26.47[b]	5.47[ab]
140% ASMDL	24.32[b]	2.01	26.34[b]	5.35[b]
LSD$_{0.05}$	1.51	NS	1.61	0.45
CV (%)	3.7	14.3	5	4.6

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $P < 0.05$; LSD= least significant difference; CV = Coefficient of variation.

Conclusion and Recommendation

The experiment was conducted to study the effect of irrigation scheduling on plant height, bulb diameter, bulb length, bulb yield and WP of onion. The result showed that there was significant difference among the treatments regarding bulb yield and water productivity of onion. Based on the obtained results of the effect of different irrigation schedules, the highest bulb yield was obtained from the treatment of 60% ASMD, 80% ASMDL and 100% ASMDL without significance difference among the three treatment. In the other hand, the higher water productivity of onion was obtained from 100% FAO recommended ASMDL. Therefore, based on the current findings, application of irrigation scheduling for onion in study and similar agro - climatic area and soil type application of irrigation at 100% ASMDL or FAO recommended gives highest bulb yield and water productivity.

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