Determination of Irrigation Requirement and Irrigation Schedule of Onion at Ribb and Kobo Irrigation Schemes, Amhara Region

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Abstract

Irrigation scheduling is an essential daily water management practice for small holder farmers who are growing irrigated crops. It is a plan to determine when and how much water to apply for a given crop in order to maintain optimum plant growth. Field experiments were conducted to determine the irrigation water requirement and irrigation scheduling of onion at Ribb in Fogera district and Kobo irrigation schemes of the Amhara region during 2010 and 2011 irrigation seasons. Irrigation requirement and optimal irrigation scheduling for onion was determined using CROPWAT version 8. In the field verification trial, combination of different levels of irrigation depths and irrigation frequencies were selected on the bases of CROPWAT model and local water application experiences of the farmers. Factorial combination of two irrigation intervals (4 and 7 days) and four fixed and one variable irrigation depths were the treatments at Ribb. At Kobo research station, factorial combination of 5, 7, and 9 days irrigation intervals and 23, 30, and 38 mm irrigation depths were used. The treatments were arranged in randomized complete block design with three replications. Bombay red and Adama red onion varieties were planted at Ribb and Kobo.

The results have shown significant difference in marketable and total yield as well as the water use efficiency.

Introduction

In Ethiopia, the population is growing rapidly and is expected to continue growing, which inevitably lead to increased food demand. To maintain self-sufficiency in food supply, one viable option is to raise the production and productivity per unit of land through irrigation. Proper amount and timing of irrigation water applications is a crucial decision for a farm manager to meet the water needs of the crop to prevent yield loss and maximize the irrigation water use efficiency resulting in beneficial use and conservation of the local water resources (Richard et.al 1998).

Onion need frequent irrigation to maintain the soil water demand through out the growing period. Irrigation scheduling highly matters in onion production. This is because onion is extremely sensitive to water stress. Regardless of the type of irrigation system used, both yield and quality can suffer if irrigation is delayed and available soil moisture is allowed to drop too low (Shock et al., 2010). Studies made in Turkey gave clear proof that the bulb and dry matter production of onion were highly dependent on appropriate water supply (Serhat and Cigdem, 2009).

Among the common irrigated vegetables, onion (Allium cepa L.) shares the largest in both area coverage and local consumption in Ethiopia. Particularly, it is the popular vegetable grown under irrigation in most of the traditional and the recent modern irrigation schemes in Amhara region. However, the largest production of onion is not supported with improved water management practices to improve its productivity and bulb quality. There is lack of location specific research results of how much water and when to irrigate onion. Therefore, the objective of the current study was to determine the crop water requirement and irrigation schedule of onion grown under irrigation for specific localities of Kobo and Fogera districts.

Materials and Methods

Description of the Study Areas

The experiments were conducted at Ribb and Kobo irrigation schemes for two years (2010 and 2011). Ribb is located at about 60 kilometres from Bahir Dar to the Northeast direction in Fogera wereda. It is situated at 11^{0}69 56‘! O! mbujuvef! boe! 48^{0}55 66‘! F! longitude and at an altitude of 1800m a.s.l. The average annual rainfall of the area is about 1118 mm. The mean maximum and minimum temperatures are 27.3 ^{0}C and 11.3^{0}C respectively. The highest temperature (29.5^{0}C) of the area occurs from February to May. The lowest temperature (9.8^{0}C) occurs in January. The soil type is generally Fluvial in its nature.

Kobo research station is located at about 50 km from Woldia town to the Northeast direction in Kobo district and situated at 12.08^0 N latitude and 39.28^0 E longitude and at an altitude of 1470 m a.s.l. The 15 year mean annual rainfall is about 630 mm and average and maximum daily reference evapotranspiration rate of 5.94 mm and 7.69 mm respectively. The soil type in the experimental site is silty clay loam with FC and PWP of 11.5% and 3.2% on volume basis respectively. The site is characterized by average infiltration rate of 8 mm/hr and pH value of 7.8. Some of the physical and chemical properties of the soils of the experimental field were presented in Table 1.

Table 1. Selected soil properties for the study sites (Ribb and Kobo)

Location	Depth (cm)	pH	EC mmohs/g	% OM	Av.K mg/kg
Kobo	0-30	8.05	0.125	4.25	0.49
	30-60	7.60	0.09	3.65	0.36
Ribb	20	6.02	0.042	3.29	0.52
	40	5.96	0.047	3.12	0.52

Where: EC- electrical conductivity, OM-organic matter, Av.K-available Potassium

Experimental set up

The experiments are conducted in *two phases*.

Phase One: *Estimation of net irrigation requirements and optimal scheduling*

CROPWAT version 8.0 for Windows was used to generate the crop water requirement and the irrigation schedule for onion in the study areas. Calculations of the crop water requirements and irrigation schedule were carried out taking inputs of climate, soil and crop data. In order to estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature) LOCCLIM, local climate estimator software (FAO, 1992) was used at Ribb where there is no class A meteorological stations and to estimate missing data at Kobo. The estimator uses real mean values from the nearest neighbouring stations and it interpolates and generates climatic data values for the study site. Assuming 90% and 80 % application efficiency at Ribb and Kobo respectively, the gross water requirement was calculated.

Phase Two: ***Verifying the CROPWAT generated scheduling***

Principally, CropWat outputs generated by default were used to identify irrigation timing of when 100% of readily available moisture occurs and application depth where 100% of readily available moisture status is attained. To verify the CroWat output, field experiments were carried out for two consecutive years at Kobo and Ribb. Rainfall data was recorded and used for daily adjustment of the application depth when there was an occurrence of unpredictable and too much amount of rainfall than the predetermined irrigation depth.

At Ribb, a total of 10 treatments which are a combination of irrigation depth and irrigation interval were selected (Table 2). Based on the model estimate and farmers traditional practice in the area, at Ribb two irrigation intervals, i.e. 4 and 7 days were selected. The amounts of irrigation depths were selected systematically depending on these two intervals and length of onion growing period (LGP). The treatments are composed of four levels of fixed depths at all stages, and one variable depth applied at four growth stages (initial stage, crop development stage, mid-season stage and late season stage). These five water levels were estimated independently for 4 and 7 days irrigation intervals. Fixed application depths were included in the treatment purposely. This is because; they are easily taken by farmers as compared to the variable depths which need frequent adjustment throughout the crop growing season.

At Kobo, initially the optimum CROPWAT generated depth and interval was determined (30 mm and 7 days). A factorial combination of three irrigation intervals (5, 7, and 9 days) and three irrigation depths (23, 30, 38 mm) were used which are based on initial estimated CROPWAT generated depth (CWGD) and plus or minus 25% of the optimum depth (Table 2). The experimental design was RCB with three replications at both Ribb and Kobo.

Table 2. Treatment setup in 2010 and 2011

Ribb			Kobo		
Irrigation Interval (days)	Irrigation Depth (mm)	Seasonal irrigation (mm)	Irrigation Interval (days)	Irrigation Depth (mm)	Seasonal irrigation (mm)
4	17	425	5	30	630
4	20	500	7	30	450
4	24	600	9	30	390
4	27	675	5	23	483
4	20 (initial stage: 20 days) 27 (dev. stage: 30 days) 24 (mid season stage: 30 days) 17 (late season stage: 15 days)	559	7	23	345
7	31	434	9	23	299
7	33	462	5	38	798
7	37.5	525	7	38	570
7	40	560	9	38	494
7	33 (initial stage: 20 days) 37.5 (dev. stage: 30 days) 40 (mid season stage: 30 days) 31 (late season stage: 15 days)	502			

The field experiments were carried out from December to April at Ribb and from February to June at Kobo. The test crop onion, variety Adama red at Kobo and Bombey red at Ribb, was planted on 1.8 m by 2 m plot size at Kobo and 2.4m by 3m at Ribb with 40 cm spacing between furrows, 20cm between plant rows and 10 cm between plants. DAP fertilizer was applied at a rate of 200 kg ha^{-1} at planting and 100 kg Urea ha^{-1} was applied half at planting and the remaining half at 45 days after planting. All the agronomic practices were equally done for each treatment. Agronomic data such as stand count, total bulb yield, marketable yield, bulb diameter, bulb weight, and unmarketable yield were collected. Irrigation water productivity was calculated as the ratio of crop yield (marketable yield) and applied irrigation water.

Results and Discussion

Results at Kobo

As it is presented in Table 3, the ANOVA result shows that treatment and treatment by year interaction effects were significant for most agronomic parameters of onion at Kobo. The ANOVA shows that year variation and its interaction with treatment were significantly different, thus need to discuss separately. Even though the optimum seasonal irrigation water requirement which was estimated by CROPWAT was 450 mm applied in 15 irrigations, the field experiment verified that the irrigation requirement should be increased up to 570 mm in 15 irrigations at Kobo. Though irrigation requirement is location specific, similar study on onion done in Turkey showed that seasonal water requirement ranges from 350 to 450 mm for optimum bulb yield depending on the environmental conditions of each year (Halim and Mehmet, 2001).

Table 3. ANOVA for marketable, unmarketable, total yield and water productivity at Kobo (2010 and 2011)

		Mean Square				
Sources of variation	df	Marketable yield	Total yield	Bulb Weight	Bulb diameter	Water productivity
Yr	1	1.944**	0.934**	2.12**	0.0975**	0.204**
Trt	8	4.125**	1.982**	4.49*	0.2069**	0.433*
Rep(Yr)	4	0.698	0.923	1.07	0.0548	0.210
Yr*Trt	8	5.834*	2.803*	6.35*	0.2926*	0.612**
Error	34	3.516	3.433	7.78	0.3583	0.749

Where: Yr-year, Trt-treatment, Rep.-Replication, df- Degree of freedom and ** highly significant

In 2011, the overall productivity was high as compared to the first year. All agronomic parameters respond significantly to water application depth at different application intervals (Table 4 and 5). Maximum (33.7 t ha^{-1}) and minimum (19.3t ha^{-1}) marketable yields were obtained by applying 38 mm every 5 days and 23 mm every 9 days interval respectively. With respect to the water use efficiency (WUE), except the application of 38 mm every 5 days, all have comparable WUE ranging between 4.3 and 6.5 kg m^{-3}. The highest WUE (6.5 kg m^{-3}) was obtained by applying 23 mm every 9 days and the lowest WUE (4.22 kg m^{-3}) was recorded by applying 38 mm every 5 days interval. The highest bulb weight (72.7 g) was obtained by the application of 38mm every 5 days followed by the application of 38 mm every 7 days (70.0 g). In general, although there is highest yield of onion by applying 38 mm every 5 days, the water productivity was the lowest. Similar study conducted at Melkasa found that 50 mm of water application at 3-6 days interval gave the highest yield with the optimum water use efficiency (Lemma and Hearth, 1992). Therefore, considering the two year results independently an optimum marketable yield of16.8 t ha^{-1} and 27.6 t ha^{-1} as well as water productivity of 3.21 kg m^{-3} and 5.33 kg m^{-3} were obtained by applying 38 mm every 7 days in 2010 and 2011 respectively.

Table 4. Mean values of total bulb yield, marketable yield, bulb diameter, bulb weight and water productivity in 2010 at Kobo

Treatments	Total yield (t ha^{-1})	Marketable yield (t ha^{-1})	Bulb diameter (cm)	Bulb weight (g)	Water productivity (kg/m^3)
30mm,7days	13.3 ^{b}	12.95 ^{bcd}	3.80 ^{bc}	29.60 ^{ab}	3.09 ^{a}
30mm,5days	13.4 ^{ab}	13.05 ^{abc}	3.63 ^{bc}	28.60 ^{ab}	2.13 ^{abc}
30mm,9days	9.14 ^{cd}	8.94 ^{de}	3.50 ^{bc}	21.70 ^{bc}	2.34 ^{ab}
23mm, 7days	6.28 ^{e}	5.97 ^{f}	3.47 ^{cd}	22.13 ^{bc}	1.79 ^{d}
23mm,5days	9.91 ^{cd}	9.74 ^{de}	3.33 ^{cd}	22.87 ^{abc}	2.05 ^{bcd}
23mm,9days	8.55 ^{de}	6.53 ^{ef}	2.87 ^{d}	19.80 ^{c}	2.86 ^{a}
38mm, 7days	16.83 ^{a}	16.79 ^{a}	3.83 ^{b}	25.97 ^{ab}	3.21 ^{a}
38mm,5days	16.02 ^{ab}	15.94 ^{ab}	4.10 ^{a}	33.40 ^{a}	2.01 ^{cd}
38mm,9days	11.33 ^{bc}	11.24 ^{cd}	3.53	22.1^{bc}	2.29 ^{ab}
Mean	11.63	11.24	3.56	3.563	2.50
CV (%)	15.1	16.6	16.6	5.8	15.9
LSD (0.05)	3.04	3.23	0.30	0.3595	7.023

Table 5. Mean values of total bulb yield, marketable yield, bulb diameter, bulb weight and water productivity in 2011 at Kobo

Treatments	Total yield (t ha^{-1})	Marketable yield (t ha^{-1})	Bulb diameter (cm)	Bulb weight (g)	Water productivity (kg/m3)
30mm,7days	20.15 ^{bc}	19.9^{bc}	5.00 ^{bc}	56.61	4.69
30mm,5days	27.09 ^{ab}	26.78^{a}	5.27 ^{ab}	62.18	4.30
30mm,9days	20.26 ^{abc}	20.17^{abc}	4.47 ^{c}	46.75	5.20
23mm, 7days	20.69 ^{abc}	20.42 ^{abc}	4.90 ^{bc}	52.05	6.00
23mm,5days	23.92 ^{ab}	23.43^{ab}	5.00 ^{bc}	57.35	4.95
23mm,9days	19.44 ^{c}	19.23^{c}	5.07 ^{ab}	56.04	6.50
38mm, 7days	27.99 ^{a}	27.52 ^{a}	5.50 ^{ab}	70.07	5.33
38mm,5days	33.66 ^{a}	33.66^{a}	5.83 ^{a}	72.73	4.22
38mm,9days	29.12 ^{a}	29.12^{a}	5.27 ^{ab}	62.99	5.90
Mean	24.70	24.47	5.14	59.6	5.23
CV (%)	18.3	18.7	6.4	16.4	18.5
LSD (0.05)	7.82	7.90	0.573	ns	ns

Results at Ribb

As can be seen in Table 6, year and year by treatment effect showed significant difference at Ribb/!I fodf !x f!dbo u!combine two years data. Generally reduction in the amount of most biological traits (yield and yield related traits) was seen during the second year. This is primarily due to the occurrence of pest (onion thrips) during the irrigation season. Even if the results of the biological parameters are low as compared to the previous year, the trend is more or less similar with the first year.

Table 6. ANOVA for marketable, unmarketable, total yield and water productivity at Ribb (2009/10 and 2010/11)

		Mean Square				
Source	df	Marketable yield (t ha^{-1})	Unmarketable Yield (t ha^{-1})	Total yield (t ha^{-1})	Bulb Weight (g)	Water productivity (kg/m^3)
Yr	1	556.7**	34.7**	869.4**	5360	18.5**
Tret	9	45.4**	2.7**	41.4**	183.3	3.6**
Rep(Yr)	4	2.9	2.1**	2.97	278.2	0.09
Yr*Tret	9	35.01**	3.1**	29.1	284.3	1.53**
Error	36	1.59	0.4	2.07	85.4	0.057

Where: Yr-year, Trt-treatment, Rep Replication, Df Degree of freedom, and ** highly significant

The irrigation water requirement of onion at Ribb was found to be 462 mm. As can be clearly seen in Tables 7 and 8, almost all biological parameters respond considerably for irrigation depth at a given irrigation frequency. There was statistically significant difference in mean values of marketable yield. Application of 33 mm of water at 7 days interval brought the highest marketable yield of 33.8 and 19.0 t ha^{-1} in 2009/10 and 2010/11 respectively. The least yield of 19.5 t ha^{-1} in 2009/10 and 14.9 t ha^{-1} in 2010/11 was obtained with the application of 20 mm irrigation depth at 4 days irrigation interval. The unmarketable yield is also statistically significant. The lowest value (0.89 t/ha) was obtained with application of 37.5mm of irrigation water at 7 days interval. Total yield also showed statistically significant difference. The highest total yield (34.9 t/ha) and acceptable unmarketable yield (1.2 t/ha) was recorded with application of 33mm of water at 7 days interval.

Application of 33mm water at 7 days interval gave a better water productivity (7.1 kg/m^3) and 40 mm with 7 days interval brought the least (3.5 kg/m^3). The yield response for water at different water level over years is indicated in Fig. 1.

Table 7. Mean of marketable, total yield and water productivity in 2009/10 at Ribb

Treatments	Marketable yield($t\ ha^{-1}$)	Total yield ($t\ ha^{-1}$)	Water prod. (kg/m^3)	Bulb dia. (mm)	Bulb weight (g)
4D-17mm	24.5^{c}	26.6^{dc}	5.3^{b}	19.1^{e}	80.1^{d}
4D-20mm	19.5^{d}	21.6^{e}	3.6^{de}	19.4^{e}	78.0^{d}
4D-24mm	22.2^{c}	26.4^{dc}	3.6^{de}	25.8^{dc}	85.1^{d}
4D-27mm	27.6^{b}	30.7^{b}	3.93^{de}	31.1^{ba}	101.9^{ba}
4D-(20mm, 27mm, 24mm, 17mm)	22.47^{c}	24.5^{d}	4.0^{dc}	27.5^{bc}	86.1^{bdc}
7D-31mm	17.71^{d}	20.8^{e}	4.37^{c}	31.3^{ba}	77.8^{d}
7D-33mm	33.8^{a}	34.9^{a}	7.07^{a}	23.0^{de}	111.7^{a}
7D-37.5mm	24.5^{c}	25.5^{dc}	4.4^{c}	25.0^{dc}	85.7^{dc}
7D-40mm	22.4^{c}	27.6^{c}	3.57^{e}	34.5^{a}	101.6^{bac}
7D-(33mm, 37.5mm, 40mm, 31mm)	17.7^{d}	19.8^{e}	3.7^{de}	32.8^{a}	92.7^{bdc}
Mean	23.2	25.8	4.35	26.9	90.1
CV(%)	5.7	5.8	5.64	9.3	10.4
Lsd (0.05)	2.28	2.56	0.42	0.43	16.1

Table 8. Mean of marketable, total yield and water productivity in 2010/11 at Ribb

Treatments	Marketable yield ($t\ ha^{-1}$)	Total yield ($t\ ha^{-1}$)	Water Productivity (kg/m^3)	Bulb diameter (mm)	Bulb weight (g)
4D-17mm	14.6^{c}	16.0^{e}	3.1^{dc}	20.4^{c}	77.3
4D-20mm	14.9^{c}	16.3^{de}	2.73^{fe}	20.3^{c}	76.9
4D-24mm	19.1^{a}	19.8^{ba}	3.07^{dce}	20.3^{c}	68.6
4D-27mm	17.9^{ba}	18.6^{bdac}	2.6^{f}	21.3^{bc}	66.8
4D-(20mm, 27mm, 24mm, 17mm)	15.4^{c}	16.9^{dec}	2.8^{dfe}	21.2^{bc}	68.6
7D-31mm	19.3^{a}	19.6^{ba}	4.8^{a}	21.1^{bc}	68.1
7D-33mm	19.0^{a}	20.3^{a}	4.0^{b}	21.8^{bac}	67.8
7D-37.5mm	17.9^{ba}	18.6^{bdac}	3.2^{c}	20.6^{c}	67.1
7D-40mm	16.0^{bc}	17.5^{bdec}	2.5^{f}	22.8^{ba}	71.5
7D-(33mm, 37.5mm, 40mm, 31mm)	17.5^{ba}	18.7^{bac}	3.7^{b}	23.7^{a}	79.0
Mean	17.2	18.2	3.24	21.3	71.2
CV(%)	6.95	7.6	7.2	5.7	12.8
Lsd (0.05)	2.05	2.38	0.399	0.21	ns

Where: 4D-17mm:17mm water applied every 4 days, and so on.

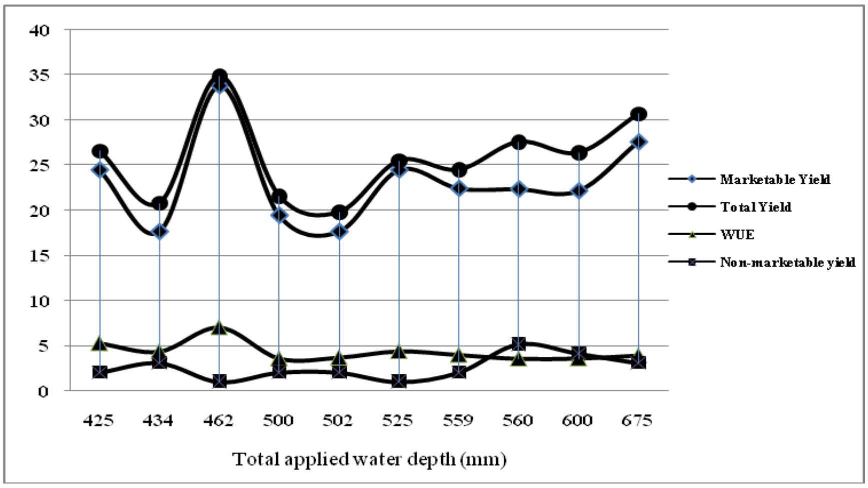

Fig 1. Yield function: marketable yield (MY) - t ha^{-1}, unmarketable yield (UMY) - t ha^{-1}, total yield (TY) - t ha^{-1} and Water productivity (WUE) - kg/m3)

Conclusion and Recommendations

In Ribb area, two irrigations for establishment and a total of 14 (fourteen) irrigations afterwards were applied during the growing season. The irrigation water requirement was found to be 462 mm. Application of 33 mm irrigation depth at 7 days interval gave significantly better marketable yield, total yield, water productivity and bulb weight as compared to the optimum level. At Kobo, the irrigation requirement is a bit higher than the amount determined by CropWat model. It is 25% more than the normal CropWat estimated value for the area. a need to validate CropWat for Kobo condition.

In general, in Fogera area onion can be irrigated with 33mm water at 7 days interval with an optimum yield range between 20 and 34 t ha^{-1} and water productivity between 4 and 7 kg m^{-3}. In case of Kobo, application of 125% of CROPWAT generated depth which is about 38 mm at 7 days interval gave the highest marketable yield between 17.0 and 28.0 t ha^{-1} and water productivity between 3.2 and 5.3 kg m^{-3}. This implies that there is a need to validate the CROPWAT model under local conditions.

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