Determination of Irrigation Regime for Onion at Jari, North Eastern Amhara, Ethiopia

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Abstract

*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. This experiment was conducted to determine the crop water requirement of onion (Adama Red variety) in Tehuledere District from 2011 to 2012. The experiment was conducted in RCBD design with 3 replications on a gross plot size of 3m*3m. The experimental treatments are nine with a factorial combination of three irrigation depths (19, 25 and 35mm) and three irrigation intervals (5, 8 and 10days). Irrigation water use efficiency function was used for the comparison of water to yield response factors. There was no interaction effect among the treatments across each year in bulb weight, bulb yield, and water productivity. There was significant difference in average bulb weight, marketable yield, total yield, and water productivity among the treatments. The application of 35mm depth of water with 5 days irrigation interval (770mm as seasonal water requirement) gave maximum marketable bulb yield. While the maximum water productivity of 7.366 kg m^{-3} was obtained from the application of 25mm irrigation depth in 10 days irrigation interval (seasonal irrigation demand of 280mm). In this experiment, optimum yield and optimum water productivity were observed from the application of 19 mm irrigation application depth at 5 days irrigation interval with a total seasonal irrigation demand of 418 mm. Hence, irrigators can irrigate onion with 5 days irrigation interval with irrigation application depth of 19 mm (75% of the CROPWAT generated depth) for onion for Tehuledere district and similar agro-ecologies.*

Keywords: *Crop water requirement; irrigation depth, irrigation interval, water productivity*

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 the food supply, one viable option is to raise the production and productivity per unit of land through agriculture, mainly through irrigation. Agriculture is the main water user but information on agricultural water use is nonexistent. Predominantly no reliable data on the area of small-scale irrigation is available and most irrigation infrastructures are not effectively used. The study site, Jare small scale irrigation scheme /SSI/ is located within Upper Mile River sub-basin, which is a tributary to Awash River basin. According to the Agricultural and Rural Development Office annual report, Tehuledere district has a cultivable land of 16,133ha and an irrigable land of 7,300ha and from this 6,670ha was irrigated in the irrigation season; included household level water storage ponds; but due to data collection and recording gaps the reliability of the figure exaggerated (Annual report of ARDO, 2014).

Irrigated agriculture is a complex that is influenced by weather, labor, irrigation scheduling, on-farm water management, farming practices/ agronomic, crop selection, cropping pattern, soil equity, cost recovery, marketing, and organizational aspects. Poor management of available water for irrigation, both at system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (Food and Nations, 1996). Awulachew (2019), reported that improving low-performing schemes specifically small-scale irrigation schemes requires incorporating applied research on irrigated agriculture.

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 the Amhara region. However, the largest producer of onion is not supported with improved water management practices to improve its productivity and bulb quality. Onions need frequent irrigation to maintain high soil moisture. Irrigation scheduling highly matters in onion production. This is because; onions are 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 .

The study area is endowed with different water sources from irrigation schemes and water harvesting ponds, which can have a capacity to irrigate large amounts of land. However, in most of the irrigation schemes whether traditional or modern, the irrigation water management practices followed by farmers are traditional and poor in water management and utilization. In Jare irrigation scheme most of the time the irrigation system is a rigid type of rotation and it takes around 15 days for a cycle. As a result, it has been affecting the production of vegetable crops in the irrigation scheme, particularly on onion crop. Although the area is reached in water resources, due to poor cropping patterns and lack of appropriate water resource management techniques, the scheme has not been giving the expected production services.

Proper amount and timing of irrigation water application 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 (Allen *et al.*, 1998). There is a lack of location-specific research results of how much water and when to irrigate onion. Therefore, this research was conducted to determine the irrigation water requirement and irrigation scheduling of onion under irrigation in specific localities of Tehuldere areas.

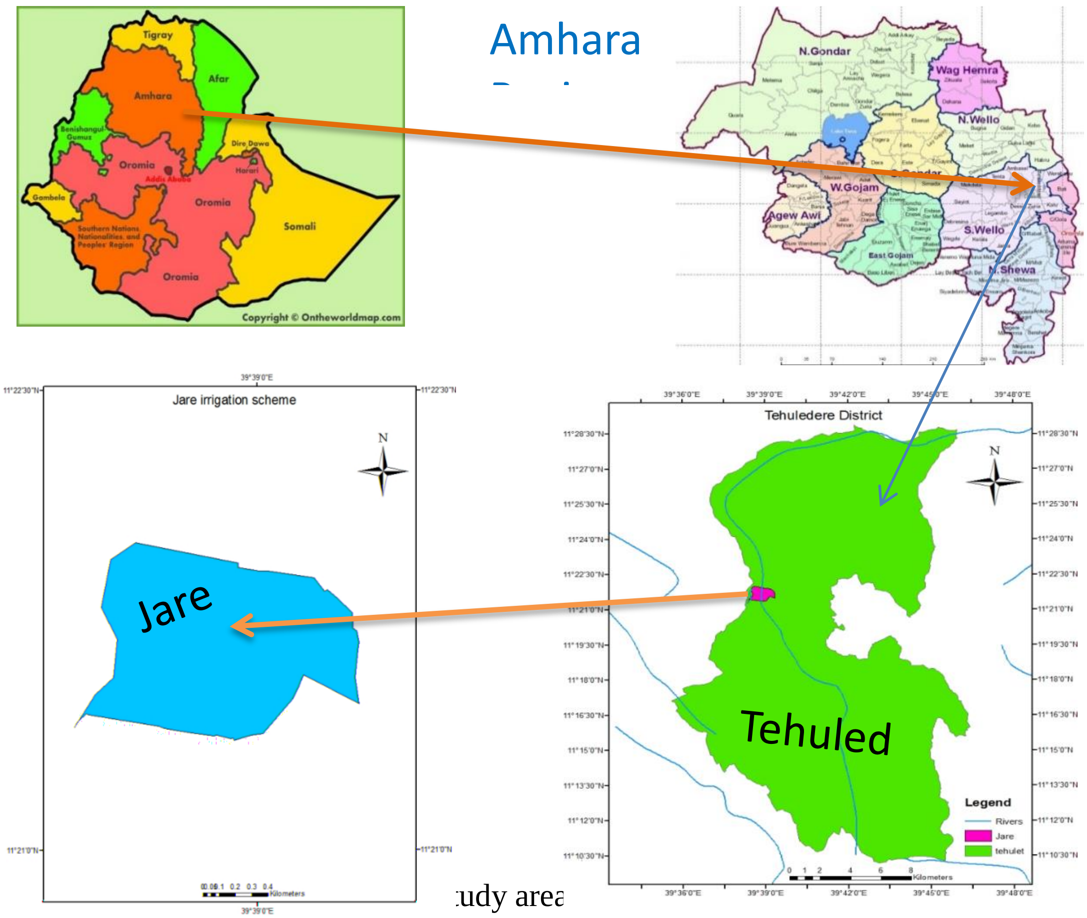
Materials and Methods

Description of the Study Area

The experiment was conducted for two consecutive years from 2011 to 2012 in the South Wollo zone of Tehuledere district at Jare sub center research farm. The study area is located at 437km from Addis Abeba and 7km from Haik town nearby the main asphalt road. Geographically, the area lies in the global positioning from 11^{o} ^{o}

of 1680m above sea level. According to CSA (2007) report, the district has a total population of 117,877; of whom 59,300 are men and 58,577 are women. It covers an area of 405.37 square kilometers and contains notable landmarks include the monasteries of Debre Egziabeher and Hayk Istifanos. The mean annual rainfall is 1020.8mm and average annual temperature ranges from 12.20^{0}c to 26.70^{o}c respectively. The area is categorized under sub-moist -ecological zone. The soil in the experimental site is texturally clay loam.

The soil has a pH of 6.8. Average daily pan evaporation amount is around 3.98mm/day. Jare small scale irrigation scheme is a check basin type of diversion system; the head work has no water flow control gates.



:udy area

The irrigation scheme has total household beneficiaries of 537 (446 Male and 91 Female). The initial total command (nominal) area was 168 ha but currently, it is declined to 146 ha. The slope of the area ranges up to 50% in the downhill of the watershed and 2% in the lower part of the scheme. The primary soil type in the study area is the tropical plateau black clay soil with some distribution of brown soil and new alluvial, and the soil is sticky and hardened with poor content of organic matter and nutrients, lower capacity of holding moisture, soil and fertilizer (ORDA, 2005).

minimum flow comes from the surrounding areas, the bottom hill of the upper watershed, (Kezikaze River, Tirngo, Wulko, and Muk Wuha springs). The irrigation system was constructed for demonstration purpose, so as to serve as a sample model of demonstration for a wide range of

and Programming in Jari-

Generally, the scheme has an advanced design and structural systems of night storage and rainwater harvesting ponds connected with the irrigation canal networks, but currently, it is not as such satisfactory in services. The implementation of water harvesting ponds with irrigation system in the watershed was initiated by South-South Cooperation agreement signed among the Ethiopian government, FAO and the Chinese government. Prior to the implementation of the project, feasibility studies supported by FAO were carried out in the watershed by Chinese and Ethiopian experts in 2002 and 2005. The total investment budget for the construction of engineering, biological and other measures was 7,192,611ETH birr; the engineering cost covers 84.74% of the total (ORDA, 2005). Currently, the operation and management of the scheme have been led by WUAs.

Methodology

The test crop onion (Adma Red variety) was selected from secondary data sources of farming system survey reports and by preliminary assessments of field surveys on major irrigation schemes that found in the South Wollo zone. Meteorological data was taken from a local climate estimator of New- LocClim software program. The trial was conducted in two phases;

First phase: Net Irrigation Requirements and optimal scheduling were estimated

Calculations of crop water requirements and irrigation scheduling were carried out by CROPWAT4W Smith (1992) with inputs of climatic, crop and soil data. Firstly, crop water requirement was determined by inserting Crop data: crop type, planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction); a set of typical crop coefficient data files that are default in the program were also used. Climatic data: average 10 years meteorological data of (1) maximum and minimum temperature; (2) wind speed; (3) sunshine hours; (4) relative humidity; and (5) rainfall were used. Soil data: total available moisture (TMA), maximum infiltration rate (8mm/hr), maximum rooting depth (70cm) and 40% soil moisture depletion fraction were used for determination of irrigation scheduling. Canning irrigation application method was used in bounded flatbed plots and considering 80% irrigation application efficiency was used for gross irrigation calculation.

Second phase: Validating the irrigation Result on Field

For the determination of optimal irrigation scheduling, CROPWAT by default used the options; irrigation timing: irrigate when 100% of readily available moisture occurs and application depth: refill to 100% of readily available moisture, this irrigation scheduling theoretically gives no yield reduction. By adjusting 25% up and down from optimal irrigation scheduling, nine treatments which were the combination of 3 irrigation depths and 3 irrigation intervals were set.

Table 1. Experimental treatments combination

No	Treatments	Irrigation depth (mm)	Seasonal irrigation requirements (mm)
1		25mm*,8days*	350
2		25mm*,5days	550
3		25mm*,10 days	280
4		19mm, 8days	266
5		19mm,5days	418
6		19mm,10days	209
7		35mm, 8days	490
8		35mm,5days	770
9		35mm,10days	385

*CWGD-cropwat generated depth *OPT- optimum time of applications

For the verification of the results, a field trial was carried out for two years. The experiment was conducted in RCBD design with 3 replications in an experimental gross plot size of 3m*3m. The spacing between plants and rows were 10cm and 20cm respectively. The onion was grown from starting February, 19 to June, 05; taken 110days total length of the growing period. Blanket fertilizer recommendation of urea100kg/ha split application and Dap50kg/ha were applied. Prior to planting, all plots were irrigated with an equal amount of water up to the field capacity and continued irrigating up to 2 weeks to increase the survival rate of transplant onion plants.

Irrigation water productivity function was used for the comparison of water to yield response. Irrigation water productivity (IWP) is generally defined as crop yield per water used to produce the yield (Howell, 1996; Viets, 1962). Thus, IWP was calculated as fresh weight (kg) obtained per volume of irrigation water applied (m^3).

$$IWP = \frac{\boldsymbol{Yield}}{\boldsymbol{Water\ applied}}$$

IWP 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). For statistical analysis Gen Stat Release 13.3 statistical software at $p<0.05$ was used to evaluate the effects of treatments on the yield and yield components of onion.

Results and Discussions

Analysis of rainfall occurrences

The model expected rainfall value was estimated at 95% probability of occurrence. The total model expected rainfall value was 210mm, which was lower than the actual rainfall existed in 2011year (i.e. 221.1mm). While in 2012 the expected rainfall was higher than from the actual rainfall, which was 171mm. However, the monthly distribution variability was more indicative instead of the total rainfall; to observe how much the existed rainfall was matching with the expected. The only larger variation of the actual rainfall by 55mm occurred during the 2011 year at the month of May. On the other hand, except in 2012 in April, the expected values were compatible with the actual rainfall occurred during both years. As a result, the total crop water requirement of onion would be the summation of both rainfalls occurred and irrigation applied.

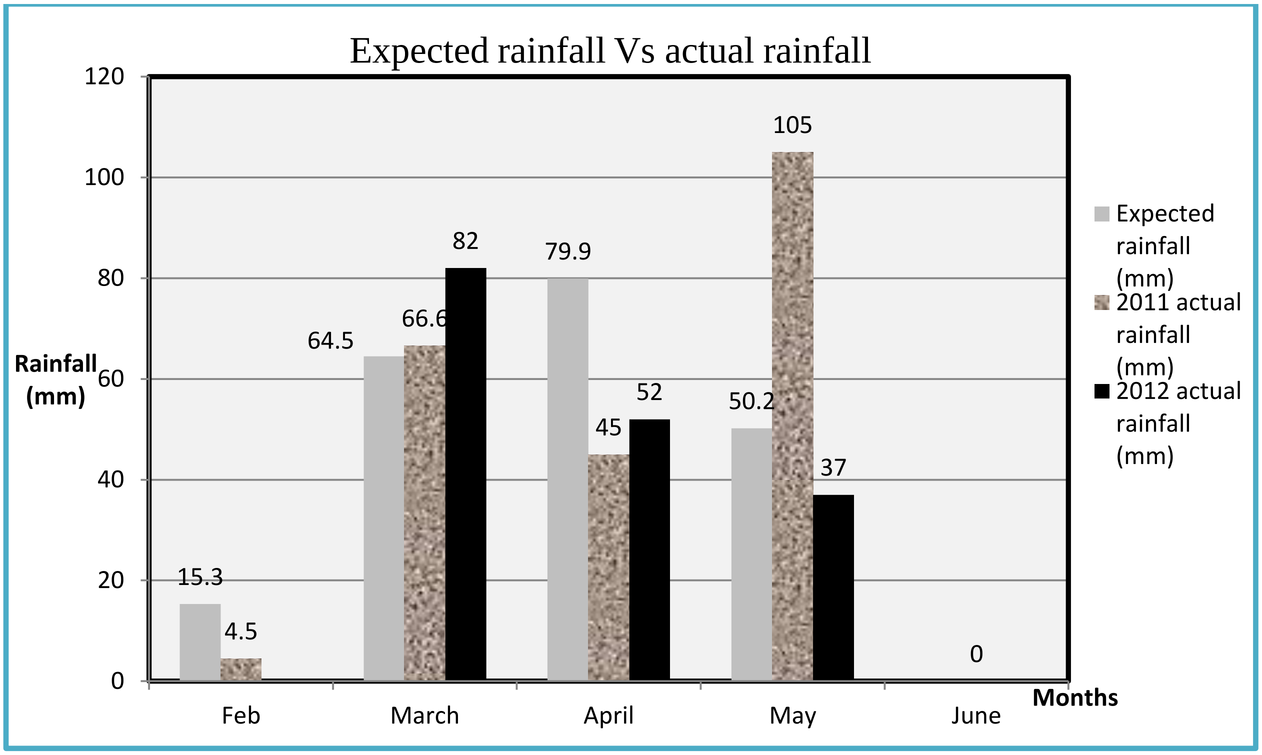


Figure 2. Expected rainfall VS actual rainfall occurrences

Results of yield and yield components

In an average bulb weight, marketable yield and water productivity; there was no significant difference between treatments across years. However, there was a significant difference in total yield.

Treatment effects on average bulb weight, marketable yield and water productivity

The combined effect of the two years result showed that there was a significant difference between treatments in average bulb weight. The maximum and minimum average bulb weight of 70.07gm and 51.37gm were obtained due to the application of 35mm in 10 days irrigation interval and 19mm in 10days irrigation interval respectively. It indicated that bulb weight was affected by the depth of application. As observed in table 2, there was a highly significant difference between treatments in marketable yield. Application of 35mm depth with 5days of irrigation interval (770mm a seasonal water requirement) which needs 22 irrigation cycles gave a maximum yield of 19.46 ton ha^{-1}. On the other hand, the lowest marketable yield of 9.58 ton ha^{-1} was obtained due to the application of 19 mm irrigation depth with 10days irrigation interval. Treatments which have similar irrigation interval of 5 days with irrigation depths of 25mm and

19 significant difference in marketable yield. Relatively, treatments of 5 days irrigation interval with different irrigation depths gave maximum marketable yields. The effect of treatments in both years in total bulb yield was varied. In the first year, the maximum total bulb yield of 16.66 ton ha^{-1} was obtained due to the application of 25 mm irrigation depth with 5 days irrigation interval. While in the second-year application of 35mm irrigation depth in 5 days irrigation interval gave the maximum total bulb yield of 26.56 ton ha^{-1}. The combined result of the two years was 21.12 ton ha^{-1} due to the application of 35 mm irrigation depth with 5days irrigation interval.

Table 2. Effects of treatments on bulb weight, marketable yield and water productivity

Treatments	Bulb weight (gm.)	Marketable yield (ton ha^{-1})	Water productivity (kg m^{-3})
25mm, 8days	58.33ab	12.12c	3.60d
25mm, 5days	63.30ab	18.19ab	3.45d
25mm, 10 days	64.17ab	16.26b	7.37a
19mm, 8days	51.57b	13.03c	5.04b
19mm, 5days	59.40ab	17.28ab	4.32c
19mm,10days	51.37b	9.58d	4.76bc
35mm, 8days	62.70ab	15.96b	3.39d
35mm,5days	66.87 a	19.46a	2.74e
35mm,10days	70.07a	16.12b	4.29c
CV (%)	18.2	12.7	12.3
Grand mean	60.9	15.33	4.329

The same letters are not significantly different (P <0.05),

Table 3. Effects of treatments on total bulb yield

Treatments	Total bulb yield (ton/ha)		
	2010/11	2011/12	Combined
25mm,8days	11.87	13.32	12.59
25mm,5days	16.66	21.3	18.98
25mm,10 days	16.25	16.90	16.57
19mm, 8days	12.89	13.93	13.41
19mm,5days	17.12	19.02	18.07
19mm,10days	8.82	11.08	9.95
35mm, 8days	13.85	19.35	16.60
35mm,5days	15.69	26.56	21.12
35mm,10days	14.98	18.03	16.50
CV (%)	7.23	21.74	12.5
Grand mean	14.24	17.72	15.98

The marketable yield slightly increased as the amount of seasonal irrigation water increased but the irrigation interval was affecting the consistency. However, the determined total seasonal

seasonal irrigation amount estimated by a crop watt model was 350mm but the field experiment verified that the seasonal irrigation amount can be reached up to 770m. The yield increment was not yet reached at the maximum level and not turned as the amount of irrigation increases. Water productivity can be increased by increasing the yield per unit of land area. In, water management strategies and practices should be considered in order to produce more crops with less water. The highest water productivity of 7.37kg/m^3 was observed due to the application of 25mm irrigation depth with 10 days irrigation interval (seasonal irrigation demand of 280mm), and the lowest was found due to the effect of application depth of 35mm with 5 days irrigation interval which required 770mm seasonal irrigation amount. However, the only bulb yield increment was 3.2ton/ha by adding an extra amount of 490mm.

There were no significant differences between treatments in marketable bulb yields due to the application of 19, 25, 35mm application depths with 5days irrigation interval. However, the application of 19mm depth of application with 5 days irrigation interval had the highest water productivity of 4.32kg m^{-3} than the two treatments. It had optimum water productivity and could save about 352 mm seasonal irrigation water with 2.18 ton ha^{-1} yield reduction from treatment 8. The saved amount of irrigation water can irrigate an additional irrigable land of 84% and 46% of treatments 5 and 8 respectively.

In this experiment, frequent irrigation was more productive than prolonged irrigation application intervals. Research results conducted at Werer and Melkasa Agricultural Research Centers showed that onion was found to respond better at frequent rather than prolonged intervals of irrigation which is 50mm water at 3-6 days interval (Michael, 2001; Lemma and Hearth 1992). According to Zeleke and Solomon 2013, research finding in Kobo area application of 125% of CROPWAT generated depth which is about 38 mm at 7 days interval gave the highest marketable yield of 28.0 ton ha^{-1}. As a result, relatively application of 19mm irrigation depth with 5 days irrigation interval is advisable in areas like Jare which has water resource management utilization problems.

Conclusions and Recommendations

In this experiment, optimum yield and functional water productivity were existed due to the application of 19mm irrigation application depth at 5 days interval with around a total seasonal irrigation demand of 418mm which could save irrigation water to irrigate additional irrigation land. Crop watt generated depth (25mm) of application and optimum time of application (8 days) are not recommendable but further research is necessary for specific depths of application in 5 days irrigation interval. As a result, in the study area around Tehuledere and areas which have similar agro-ecology and soil characteristics, irrigators can irrigate onion with a frequent 5 days irrigation interval with irrigation application depth of 19mm (75% of the CROPWAT generated depth).

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