# Determination of Optimal Irrigation Scheduling for Onion *(Allium cepa* L.) in Fogera, North Western Ethiopia

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## Abstract

*The experiment was conducted in the 2017/18 and 2018/19 dry season at Fogera national research and training center, to determine the optimum irrigation scheduling based on the available soil moisture depletion levels for onion. The experiment was laid out in RCBD with three replications with treatments randomly assigned to the experimental plots. Six available soil moisture depletion levels (60, 80, 100, 120, 140, and 160%) were used. The two-year combined Analysis result indicated that different available soil moisture depletion levels had, very highly significant (P < 0.0001) significant effect on bulb weigh, bulb diameter, marketable yield, and water productivity. The highest marketable bulb yield and water productivity (35222.2 kg ha-1 and 7.06kg/m3) were recorded at 80% available soil moisture depletion levels (ASMDL) and also the lowest unmarketable bulb yield (1513.9 kg/ha) was recorded at the rate of 80% ASMDL. However, the lowest marketable yield, the lowest water productivity, and the highest unmarketable bulb yield (28722.2 kg ha-1, 5.29 kg/m3, and 5236.1 kg/ha) were recorded at 160%ASMDL. Very highly significant (P < 0.0001) plant height and bulb length differences were observed due to the treatments. The highest plant height and bulb length (66.33cm and 5.62cm, respectively) were recorded at 60% AMADL. However, different soil moisture depletion levels showed no significant difference in the stand count of onion. The highest water use efficiency on onion yield (7.06 kg/m3) was obtained at 80% ASMDL whereas the minimum water use efficiency (5.29 kg/m3) was recorded at 160% ASMDL. Therefore, based on the findings of the current experiment, it is recommended that using 80%ASMDL for the furrow irrigation system for the onion to be grown in areas around Fogera and similar agroecology as the best options to increase yield and water use efficiency for the production of onion.*

**Keywords:** ASMDL, onion, irrigation, water use

## Introduction

Irrigation practice is one of the major technologies for increasing crop production in Ethiopia whose major economic development is dependent on agricultural production. The country has experienced severe drought occasions due to uneven distribution of rain-fall in both temporal and spatially occurrences for the last many years (Awulachew *et al,*2007). Onion (*Allium cepa* L.) is the most chief crop, widely grown as a horticultural crop of in the world (Brewster JL, 1997). It is widely cultivated as a source of revenue by many farmers in numerous parts of the world. Onion is one of the most important vegetable crops in Ethiopia. It is widely cultivated as cash crop and is the most important commercialized horticultural crop among smallholder farmers' and private large-scale farmers. The country has a great potential of water source and irrigable land to produce onion throughout the year (Awulachew, 2010). Hence, this study was conducted to determine the optimum irrigation scheduling based on the available soil moisture depletion levels for onion at Fogera. Onion productions in Fogera district is mainly for market demand by irrigation during dry season. Even though areas increase, the productivity of onion is much lower than other African countries (CSA, 2015). The low productivity could be attributed to the lack of optimal soil and water management practices and others reasons. The crop is shallow rooted and sensitive to water stress. As result the crop is commonly given light and frequent irrigation to avoid water stress (Doornebos and Kassam, 1979). Maximum yield could be obtained with the achievement of the entire crop water requirements. Too much water is not good for many crops. In the study area, there is no adequate irrigation water management. Due to Poorly managed irrigation, water has serious adverse effects in some case water logging and increased soil salinity with destruction of soil's productivity potential in another way crops which suffer most from water shortages. The performance of many irrigation projects in Ethiopia very poor due to, Inadequate water management, Farmers tend to over or under irrigate their fields, poorly designed irrigation scheduling, used Inappropriate technology both at the farm and system levels. Therefor Irrigated agriculture should be become more efficient through better water management (Awulachew *et al* 2007). The onion bulb yields depend on the amount of irrigation water and the time of application (Shock *et al*, 1998). Irrigation scheduling is important for developing best management practices for irrigated areas (Ali *et al*., 2011). In most case, in Ethiopia irrigation fields have not been monitored for their moisture content before and after irrigation. Even though, irrigation practiced has been long time, farmers experience in this regard was very limited. Hence, Irrigation water management is not efficient where modern irrigation system has developed four decades before in the middle Awash Valley (Awulachew *et al.*,2007). Therefore, monitoring on farm available soil moister depletion levels and irrigation scheduling are efficient technology which help to improve irrigation water management and increase irrigation water use at field condition. Traditional irrigation practices are being used for cultivating onion crops in different areas. However, irrigation water requirement including irrigation scheduling are not known. Allen et al, (1998) has expressed the soil moisture depletion level for onion should be 0.25. However, the recommendations are needed to be verified on the operational environment since the crop water requirement is dependent on the type of soil and climatic condition. Crop water requirements vary in time and space due to climate, management, phonological stage of the crop, and cultivar, then, their assessment must be local (Doorenbos and Pruitt, 1977). For effective use of available water resource, it is relevant to determine the amount of water need by the crop and the right time of water application (irrigation scheduling).

# Materials and Methods

## Description of the Study area

The experiment was conducted in the 2017/18 and 2019/19 dry season at Fogera National Research and Training Center, south Gonder zone, Amhara regional state. Fogera is geographically located, at 11.59$^{O}$N latitude, 37.38$^{O}$E longitude with an average altitude of 1800 m.a.s.l. the study area has the average monthly minimum, maximum temperature, and mean annual rainfall of 12.6$^{O}$c, 27.8$^{O}$c, and 1248 mm respectively.

## Soil sampling and analysis

Soil analysis was done using disturbed soil samples which were collected from the representative location of the field and the textural class was determined by using the pipette method in the laboratory. Based on the result of the laboratory analysis the soil textural class of the experimental field was sandy loam. Some physical and chemical properties of the soils are shown in Tables 1and 2. Soil moisture at field capacity (FC) and permanent wilting point (PWP) were determined in the soil laboratory.

For this purpose, soil samples were collected from three depths (0-20 cm, 20-30 cm and 30-60 cm). Soil moisture content at field capacity and permanent wilting point measurements were analyzed using pressure plate apparatus by applying a suction of 0.33 and 15 bars, respectively to a saturated soil sample. Soil moisture content of the field was measured by gravimetric at every 15cm to maximum rooting depth of the crop. The soil samples were taken by soil auger at the depth from 0 to 60 cm in 15 cm interval. Soil water content was determined by oven dry method gravimetrically. The gravimetric water content was converted into volumetric content using the bulk density of each layer and then accumulated across depths to calculate the water stored within the soil. According to FAO 33 (Doorenbos,1986) the root zone of the onion is 0.3m to 0.5m. The bulk density was determined using undisturbed soil samples which were collected by core samples from three depths (0-20 cm, 20-40 cm and 40-60 cm), oven dried for 24hr at 105°C and weighed for determination of dry weight. The soil ρb can be calculated using the formula: ρb = Ms/Vs where ρb is soil bulk density in Mg $m^{-3}$, Ms. is the weight of the dry soil sample in Mg, and vs. is the volume of the soil sample in $m^3$ (Han *et al*., 2016). Bulk density is usually expressed in megagrams per cubic meter (Mg/m3) but the numerically equivalent units of g/$cm^3$ (Cresswell and Hamilton, 2002). The result of bulk density of the soil in the experimental field has a small variation with its depth. It varied between 1.22 (g/cm3) and

1.31(g/cm3) from the top to the sub surface layer of the soil. The subsurface soil has slightly higher compaction than the top soil layer. It may be due to different reasons. The average bulk density of the soil in experimental field was found 1.26 (g/cm3) (Table 1).

| Soil depth (cm) | FC (%) | PWP(%) | Bulk density ($gm/cm^3$) | Textural status (%) | | | Textural class | TAW (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | Clay | Silt | Sand | | |
| 0-20 | 45.62 | 24.37 | 1.22 | 13.97 | 24.44 | 61.59 | Sandy loam | 51.85 |
| 20-40 | 41.29 | 26.11 | 1.24 | 14.4 | 23.2 | 62.4 | Sandy loam | 37.65 |
| 40-60 | 39.22 | 27.12 | 1.31 | 15.25 | 23.85 | 60.9 | Sandy loam | 31.70 |
| Total available water in 60 cm | | | | | | | | 121.2 |
| According to FAO Total available water in effective root zone of onion is 50 cm 101mm | | | | | | | | |

| Soil depth (cm) | 0-20 | 20-40 | 40-60 |
|---|---|---|---|
| pH-H2O (1:2:5) | 6.08 | 5.77 | 6.25 |
| EC(Cs/cm) (1:2:5) | 0.12 | 0.08 | 0.08 |
| Exchangeable Na | 1.25 | 2.23 | 1.07 |
| Exchangeable K | 0.26 | 0.34 | 0.31 |
| Exchangeable Ca | 30.10 | 37.09 | 26.66 |
| Exchangeable Mg | 9.58 | 15.62 | 7.62 |
| Sum of cations | 41.18 | 55.27 | 35.65 |
| Exchangeable Na %(ESP) | 2.96 | 4 | 2.22 |

## Determine the effective root depth and crop coefficient

According to FAO 33 (Doorenbos,1986) the crop coefficient (kc) value of the crop has at initial stage ranges from 0.4 to 0.6, the development season from 0.7 to 0.8, the mid-season from 0.95 to 1.1 and the late season from 0.85 to 0.9. The growth periods of an onion crop are 120 days in the field were: vegetative period initial 15 days, development days; mid 40 and late period 35 days. in this study the kc value of the crop at initial and mid-season was taken the mean value were given in FAO 33 was given 0.5 and 1.0 respectively. However, at development and late season the kc value of the crop was not constant because of crop physiologically change. The crop coefficient for the growing period, kc is the coefficient that has the most room for error between FAO56 default value and actual value. The crop coefficient (kc) relating reference evapotranspiration (ETo) to water requirements (ETm) for different development stages after Onion, in common with most vegetable crops, is sensitive to water deficit. Climatic adjustment on the Mid- and End of season coefficients create little change, maybe 5%, or 10% at the most. When there are a significant number of rain or irrigation events this value could be off by as much as 100%. To determine the exact kc value of the crop at development and late season during the experiment was develop a function based on the growing season of the crop (fig 2&3). The crop has a shallow root system with roots concentrated in the upper 0.3m soil depth. In general, 100 percent of the water uptake occurs in the first 0.3 to 0.5rn soil depth (D = 0.3-0. 5 m). To meet full crop water requirements (ETm) the soil should be kept relatively moist. Based on FAO 33 the onion crop 100% of the water uptake occurs in the first 0.3m to 0.5m at initial and maximum soil depth, respectively. The TAW in the soil depends on the effective root depth of the crop. After transplanting the root depth gradually increased to reach at the mid-season. After mid stage the root zone depth could be constant. The net amount of water required depends on soil TAW in the plant root zone and the ability of a particular crop to tolerate moisture stress. The root depth of a crop also influences the maximum amount of water which can be stored in the root zone. It is better to corelate the root depth with the crop growing season (fig 1). The kc value and root depth based on the crop growth stage as shown in Table3.

| | | | | | |
|---|---|---|---|---|---|
| | Initial | Development | Mid | Late | |
| | 15 | 30 | 40 | 35 | 120 |
| | 0.5 | Y=0.0167x+0.5 | 1 | Y=-0.0029x+1 | |
| | 0.3 | Y=0.0044x+0.3 | 0.5 | 0.5 | |

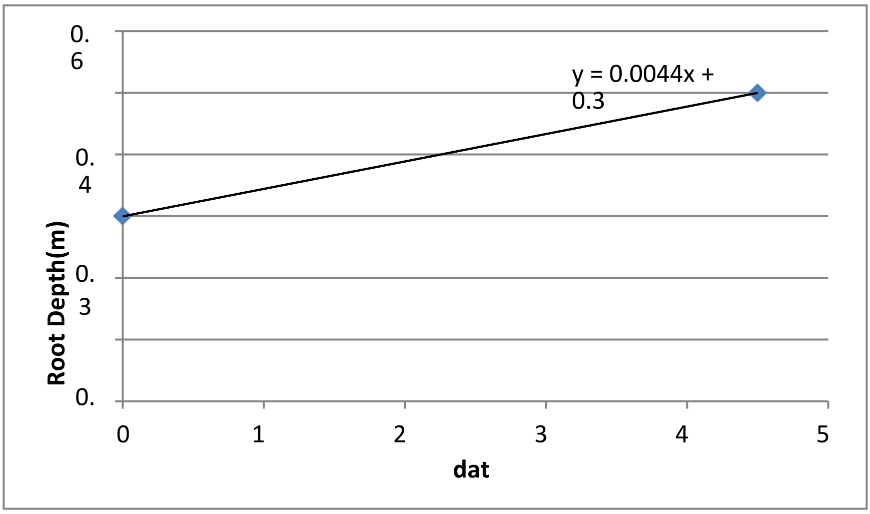

Figure 1. Growth of Effective root depth of onion at development stage

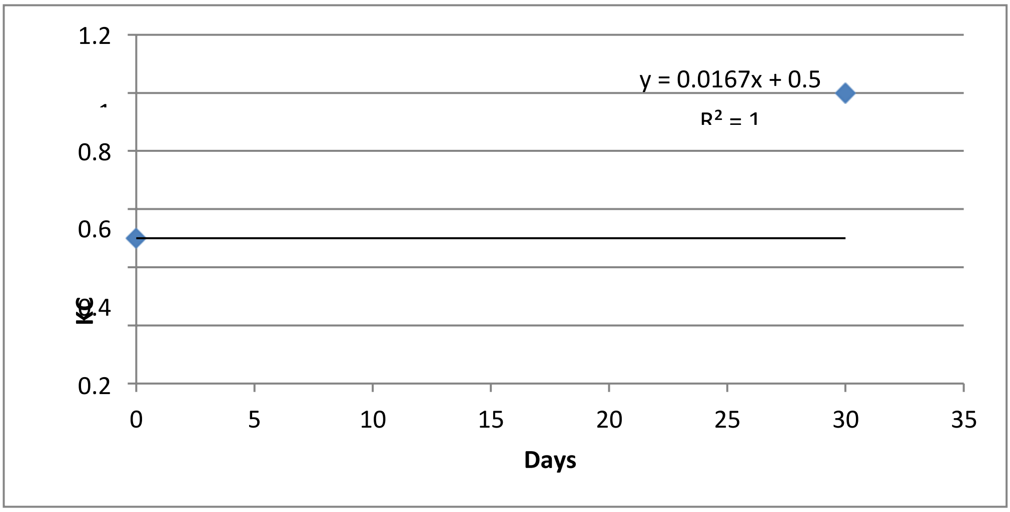


Figure 2. KC value of onion at development stage

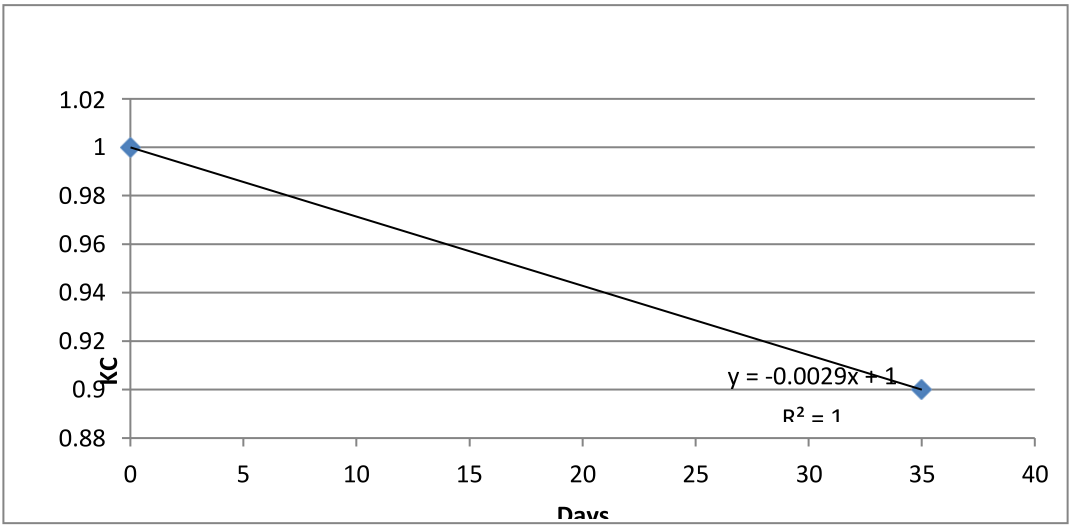


Figure 3: Growth of KC value of onion at late stage

| Climatic parameter | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | Dec. | Jan. | Feb. | Mar. | | Nov. | Dec. | Jan. | Feb. | Mar. |
| T max. ( $^{o}c$) | 26.4 | 26.3 | 26.6 | 28.1 | 29.5 | | 26.8 | 26.7 | 27.0 | 28.6 | 29.8 |
| Tmin.( $^{o}c$) | 8.8 | 7.6 | 8.5 | 10.3 | 13.2 | | 11.3 | 8.9 | 8.5 | 10.3 | 12.9 |
| RH (%) | 57.0 | 53.3 | 49.8 | 44.3 | 42.1 | | 57 | 54 | 50.0 | 45.0 | 42.0 |
| Sunshine (hr.) | 9.5 | 9.7 | 9.5 | 9.6 | 9.1 | | 9.5 | 9.8 | 9.5 | 9.6 | 9.1 |
| U2($ms^{-1}$) | 0.7 | 0.6 | 0.7 | 0.7 | 0.9 | | 0.68 | 0.6 | 0.7 | 0.7 | 0.9 |
| RF. (mm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETo(mm/day) | 3.9 | 3.7 | 3.8 | 4.3 | 5 | | 3.9 | 3.7 | 3.7 | 4.3 | 5.0 |

## Experimental Design

The experiment was laid out in RCBD with three replications, in which the soil moisture depletion levels (ASMDL) were randomly assigned to the experimental plots. Treatments included six levels of soil water depletion. The 100%ASMD was used as a check available soil moisture depletion level according to FAO (33). Each row accommodated about 70 plants. Treatment descriptions are presented in Table 4. A seed of the Bombay Red onion variety was transplanted to field plots on at the mid November in 2017/18 and 2018/19 dry season. The plot size was 5 m × 4.5 m=21 $m^2$ area. The distance between blocks and plots were 3 m and 1.5 m receptively. The crop was planted in rows with two rows in a bed. To prevent water leakage into the plots, it has enough space between blocks and plots. The plant and row spacings were 0.07m and 0.6m, (0.2m ridge and 0.4m furrow), respectively. In this experiment, surface and furrow irrigation method was used. Each plot has got seven furrows and 14 planting rows.

| Treatment | Description |
|---|---|
| SMD1 | 60% ASMDL |
| SMD2 | 80% ASMDL |
| SMD3 | 100%ASMDL |
| SMD4 | 120% ASMDL |
| SMD5 | 140% ASMDL |
| SMD 6 | 160% ASMDL |

100%ASMD is available soil moisture depletion level according to FAO (33)

## Data collected

Date about irrigation were collected with respect to irrigation amount applied at every event, rainfall record, and soil moisture content before every irrigation event. irrigation time and amount per irrigation at ever event, daily ETo based on daily weather variables and soil moisture content. Daily weather variables on rainfall, air temperature (Maximum and Minimum), wind speed, relative humidity (RH), wind speed at 2 m height ($U_2$) and sunshine hours were recorded. Soil moisture content before every irrigation event was measured using oven dry.

The crop data was collected from the experimental unites in the middle rows by methods of sampling technique to avoid border effects for data collection on growth, yield and yield components of onion. The sampled plants were selected randomly and carefully from middle five rows by avoiding two rows to take care of border effect.

Yield and yield components related data were recorded on date of plating, date of growing stage. plant height, leaf height, bulb diameter, bulb weight, bulb length, marketable and unmarketable yield and other necessary data were recorded from the date of planting to the date on which the experiment was harvested. Leaf height (cm) was measured on five randomly taken plants using measuring tape at physiological maturity and their mean were computed. Plant height(cm**)** was computed for five randomly selected plants using measuring tape from the ground level up to the tip of the leaf in the experimental plot at physiological maturity. Bulb weight (gr plant $^{-1}$) was measured on five randomly selected single onion bulbs and their average weight were computed. Bulb diameter(cm) was measured at the widest circumstance of the bulb of five sample plants in each experimental unit. Bulb diameter and bulb length measured by using automatic caliper. Marketable yield (kg/ha) was measured for healthy and non-diseased, non- rotten, non-white (different varieties), non-spilt, average to large sized Bombay Red onion bulbs were recorded from sampled plant. Unmarketable onion (kg/ha) is including split, decayed, rotten, non-white (different varieties), diseased and under sized bulbs.

### Statistical Analysis

Analyses of variance (ANOVA) was used for agronomic and irrigation-based data. All data collected were managed and compared with Least Square of Differences (LSD) and when the treatments effect was found significant, mean difference was tested using LSD test at 95%. Results of Growth, Yields and Yield component parameters were analyzed using SAS computer package version 9.0.

## Result and Discussion

### WUE and Water use characteristics of onion

Irrigation frequency and crop water requirement values ranged from 10 to 23 and 353.15mm in 2017/18 and from 10 to 22 and 365.15mm in 2018/19, respectively (Table 6). Doorenbos and Kassam (1986) have reported that onion yields of 35 - 45 t ha$^{-1}$ could be obtained with 350 - 550 mm of water using furrow irrigation. Frequent irrigation is required to prevent cracking of the bulb and forming of 'doubles'. Adequate water supply is essential for a high-quality crop. Water use efficiency (WUE) simply refers to the ration of the amount economical crop yield (kg/ha) to the amount of water applied (kg/m3) to the cropped area per season during production. In the current this case, there was no rain fail in both season during the experiment was conducted, due to these the NIR=RAW, due to this WUE and IWUE were equal. In this experiment Water use efficiency (WUE) was estimated as the ratio of marketable onion bulb yield to the total amount of irrigation in depth applied to during the season. According to Michael (1978) WUE was expressed as: WUE=Y/ I = Where: WUE: Water use efficiency (kg/m3) Y: marketable bulb yield of onion (kg/ha) and I: Total net irrigation water applied ($m^3$/ha). The highest and the lowest WUE 6.3 kg ha-1 $m^{-3}$ and 5.2 kg ha-1 $m^{-3}$ were recorded at 80%ASMDL and 120%ASMDL, respectively in 2017/18. where as in 2018/19 highest and the lowest WUE recorded were 6.77 kg ha-1 $m^{-3}$ and kg ha-1 $m^{-3}$ at 80%ASMDL and 160%ASMDL, respectively (Table 7). While the two-year combined analysis result showed that the highest and the lowest WUE 7.06 kg ha-1 $m^{-3}$ and 5.26 kg ha-1 $m^{-3}$ were recorded at 80ASMDL and 160%ASMDL, respectively. These results are in agreement with the statement that crop yield depends on the rate of water use, and that all factors increasing yield and decreasing water used for ET favorably affected WUE (Arnon, 1975). The onion crop was most sensitive to water deficit during the yield formation period and during transplantation. For high yield of good quality, the crop needs a controlled and frequent supply of water throughout the total growing period; however, over irrigation leads to reduced growth and causes spreading of fungal diseases. To achieve large bulb size, high yield and high bulb weight, water deficits, especially during the yield formation period (bulb enlargement) should be avoided. The onion requires frequent, light irrigations which were timed when about 20 percent of available water in the first 0.3 m to 0.5m soil depth has been depleted by the crop. This result agrees with FAO recommendation which state that for high yield, soil water depletion should not exceed 25 percent of available soil water. When much amount of irrigation water per irrigation and for longer interval it causes spreading of diseases such as root rot, mildew, white rot and other fungal diseases. In this experiment, the onion was irrigated from planting upto105 day. Irrigation was discontinued as the crop approaches maturity before 15 days. Because FAO recommended that, irrigation can be discontinued 15 to 25 days before harvest. Proper irrigation scheduling was applying the appropriate amount of water at the correct time.

Table 6: irrigations frequency and irrigation depth of water applied and Effective rainfall for all cropping irrigation seasons

| | | | | | |
|---|---|---|---|---|---|
| | 60% ASMDL | 23 | 0 | 339.18 | 565.30 |
| | 80% ASMDL | 17 | 0 | 362.29 | 603.82 |
| | 100% ASMDL | 14 | 0 | 372.27 | 620.45 |
| | 120% ASMDL | 12 | 0 | 380.63 | 634.38 |
| | 140% ASMDL | 10 | 0 | 370.04 | 616.73 |
| | 160% ASMDL | 9 | 0 | 378.45 | 630.75 |
| | 60% ASMDL | 22 | 0 | 354.33 | 590.55 |
| | 80% ASMDL | 18 | 0 | 382.49 | 637.48 |
| | 100% ASMDL | 15 | 0 | 397.52 | 662.53 |
| | 120% ASMDL | 13 | 0 | 410.93 | 684.88 |
| | 140% ASMDL | 11 | 0 | 405.39 | 675.65 |
| | 160% ASMDL | 10 | 0 | 418.85 | 698.08 |

## Onion yield and yield components

Plat and bulb height were significantly affected by the %ASMDL. The highest and the lowest plant and bulb heights were recorded at 60%SMADL and at 160%ASMDL, respectively in both cropping seasons. When the onion was irrigated very frequent (60%ASMDL) or the irrigated interval very short, the plant height increased. The shortest irrigation interval was important to increase the onion vegetate rather than yield and bulb diameter. Al-Moshileh (2003) reported that frequent irrigation improved plant growth parameters and total yield while marketable yield and the bulb diameter were reduced. It could be due to onions are extremely sensitive to water stress with the most critical time being during bulb swelling. In the two consecutive years, onion bulb weight, bulb diameter and marketable yield (Table 7) were significantly higher in 80%SMADL. The lowest onion marketable yield and the highest unmarketable yield were recorded at 160% SMADL. The highest onion bulb yields of 33611.0 and 36833.3 kg $ha^{-1}$ were produced in 2017/18 and 2018/19 respectively, at treatment 80% SMADL. The lowest unmarketable onion bulb yield was also recorded at 80% SMADL(T2) in the two consecutive years. The lowest marketable onion bulb yield was recorded at treatment 160% SMADL 2277.8 and 8194.4 kg $ha^{-1}$ in 2017/18 and 2018/19 respectively. Yield components and morphological characteristics of onion bulbs were affected by irrigation scheduling (Table 7). The results of Kadayifci *et al*., (2005) had shown that bulb and yield production were highly dependent on amount of water and time of application. Mermoud *et al*., (2005) reported that irrigation frequency had a great impact on the development and yield of the onion crop. However, the two year combined the Analysis of Variance showed that the main effects of ASMDL had very highly significant ($P < 0.0001$) effect on bulb weight, bulb diameter, marketable yield and water productivity. The highest marketable bulb yield and water productivity (35222.2 kg $ha^{-1}$ and 7.06kg/$m^3$) were recorded at (80%ASMDL) and also the lowest unmarketable bulb yield (1513.9 kg/ha) was recorded at the rate of (80%ASMDL) whereas the lowest marketable yield, the lowest water productivity and the highest unmarketable bulb yield (28722.2 kg ha-1, 5.29 kg/m3 and 5236.1 kg/ha) were recorded at (160%ASMDL). While the highest plant height and bulb length (66.33cm and 5.62cm, respectively) were recorded at 60% ASMDL (Table 7).

Table 7: Year wise parameters affected by %ASMDL

| Treatments | PH (cm) | SC (no) | BW (gr) | BD (cm) | BH (cm) | MY (kg/ha) | UMY (kg/ha) | WEU (kg/m3) |
|---|---|---|---|---|---|---|---|---|
| (a) 1st Year (2017/18) parameters affected by %ASMDL | | | | | | | | |
| 60% ASMDL | 61.20$^{a}$ | 860 | 100.44$^{b}$ | 6.00$^{b}$ | 5.23 | 31583.3$^{b}$ | 1416.6$^{b}$ | 5.86$^{b}$ |
| 80% ASMDL | 58.96$^{ab}$ | 853 | 115.36$^{a}$ | 6.61$^{a}$ | 5.29 | 33611$^{a}$ | 555.5$^{d}$ | 6.3$^{a}$ |
| 100% ASMDL | 58.73$^{abc}$ | 865.6 | 100.87$^{b}$ | 5.9$^{b}$ | 5.18 | 30138.9$^{c}$ | 1250.0$^{b}$ | 5.46$^{cd}$ |
| 120% ASMDL | 55.86$^{bdc}$ | 880 | 100.71$^{b}$ | 6.00$^{b}$ | 5.1 | 29472.2$^{c}$ | 1222.2$^{b}$ | 5.2$^{e}$ |
| 140% ASMDL | 54.86$^{dc}$ | 872 | 102.58$^{b}$ | 6.02$^{b}$ | 5.05 | 29944.4$^{c}$ | 944.4$^{c}$ | 5.5$^{c}$ |
| 160% ASMDL | 53.26$^{d}$ | 829 | 89.38$^{c}$ | 5.88$^{b}$ | 4.84 | 29500$^{c}$ | 2277.8$^{a}$ | 5.26$^{de}$ |
| LSD (5%) | 3.92 | ns | 5.11 | 0.156 | Ns | 1294 | 272.59 | 0.23 |
| CV | 3.77 | 5.67 | 2.76 | 1.41 | 4.43 | 2.31 | 11.72 | 2.23 |
| (b) 2$^{nd}$ Year (2018/19) parameters affected by %ASMDL | | | | | | | | |
| 60% ASMDL | 71.46$^{a}$ | 890.67 | 111.73$^{ab}$ | 5.73$^{c}$ | 6.00$^{a}$ | 31500.00$^{b}$ | 6750.0$^{b}$ | 5.933$^{b}$ |
| 80% ASMDL | 63.66$^{b}$ | 867.00 | 131.93$^{a}$ | 7.36$^{a}$ | 5.70$^{ab}$ | 36833.30$^{a}$ | 2472.2$^{e}$ | 6.77$^{a}$ |
| 100% ASMDL | 60.73$^{b}$ | 829.00 | 106.37$^{abc}$ | 6.10$^{b}$ | 5.33$^{bc}$ | | | |

## Conclusions and Recommendation

Irrigation water management is the most critical constraint for the development of irrigation agriculture. Hence, effective use of available water with optimal irrigation scheduling has a significant implication on irrigated agriculture. Based on this study, onion need to be cultivated under 80%ASMDL at shorter period irrigation interval. The maximum plant height, and bulb height 66.33cm, and 5.62cm, respectively were obtained at 60% ASMDL. The highest marketable bulb yield (35222.2 kg $ha^{-1}$) and the lowest unmarketable bulb yield (1513.9 kg $ha^{-1}$) were obtained from 80 % ASMDL. The lowest marketable bulb yield (28722.2 kg $ha^{-1}$) and the highest unmarketable bulb yield (5236.1kg $ha^{-1}$) were obtained from 160 % available soil moisture depletion level. The highest water use efficiency (7.06 kg/$m^3$) was obtained at 80% ASMDL whereas the minimum water use efficiency (5.29 kg/$m^3$) was recorded at 160% ASMDL. Generally, the application of different %ASMDL responds differently for the productivity of onion. From the two years combined result 80% ASMDL gave the maximum marketable bulb yield and water use efficiency advantage. Therefore, based on the findings of the current experiment, it is recommended that using 80%ASMDL for furrow irrigation system for onion to be grown in areas around Fogera and similar agroecology as best options to increase yield and water use efficiency for the production of onion.

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