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Determination of Optimal Irrigation Scheduling for Onion (*Allium cepa L.*) at Assosa District, North West of Ethiopia.

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Abstract

To avoid over or under irrigation, it is important to know how much water is available to the plant, and how efficiently the crop can use it which mean irrigation scheduling. The study was conducted to evaluate the response of Onion to irrigation regime and determination of water use efficiency. The experiment had five treatments which were soil moisture depletion levels, 60% of available soil moisture depletion level, 80% of available soil moisture depletion level, 100% of available soil moisture depletion level, 120% of available soil moisture depletion level and 140% of available soil moisture depletion level and arranged in randomized complete block design. The experiment was tested on Bombay Red onion variety. Soil parameters like bulk density, texture, field capacity and permanent wilting point were analyzed. Climatic data like minimum and maximum temperature and rainfall, wind speed at two meter height, relative humidity and sunshine hours were collected which were inputs to determine reference evapotranspiration. The water requirement of was calculated by taking into consideration the growth periods (initial, development, mid-season and late season) and soil moisture depletion levels. The highest onion bulb yield and water use efficiency were obtained from 60% of available soil moisture depletion level. Irrigation interval of 6 days was required but it is recommended to use irrigation interval depending on growth stages which give an optimum Onion bulb yield and water use efficiency.

Keywords: Assosa, Irrigation scheduling, Onion, Water requirement

1. Introduction

In Ethiopia, although irrigation has been long practiced at different farm levels, there is no efficient and well-managed irrigation water practice (Dessalegn, 1999). According to United Sates Bureau of Reclamation (2005), Irrigation water management is the act of timing and regulating irrigation water applications in a way that will satisfy the water requirement of the crop without the waste of water, soil, plant nutrients, or energy. It means applying water according to crop needs in amounts that can be held in the soil available to crops and at rates consistent with the intake characteristics of the soil and the erosion hazard of the site.

As Kirda (2002) stated that, the amount of water required by plants and the timing of irrigation is governed by prevailing climatic conditions, crop and stage of growth, soil moisture-holding capacity and the extent of root development as determined by crop type, stage of growth, and soil. Lopez (2004)stated that, 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.

Irrigation scheduling is the use of water management strategies to prevent over application of water while minimizing yield loss due to water shortage or drought stress. In water stress sensitive crops such as vegetables grown for their fresh leaves or fruit, growers should schedule irrigations very carefully to avoid losses from over or under watering. To avoid over or under irrigation, it is important to know how much water is available to the plant, and how efficiently the crop can use it which mean irrigation scheduling. There for, this study was conducted to evaluate the response of Onion to irrigation regimeand determination of water use efficiency.

2. Materials and Methods

2.1. Description of the study area

The experiment was conducted for two consecutive years from 2016 to 2017 at Assosa Agricultural Research Center experimental station which was at Gambashirein Assosa district, Benishangul gumuz Regional state, found in the Upper Blue Nile (Abay) River Basin, Ethiopia and located at a distance of about 18km from Assosa to the west direction, the capital city of the region.Assosa town is found at a distance of about 665 km to the North West of Addis Ababa. It is located at $9^0$40’0’’ N -$10^0$23’20’’ N latitude and $34^0$8’20’’ E-$34^0$51’40’’ E longitude at about 1560 meters above sea level (m.a.s.l).

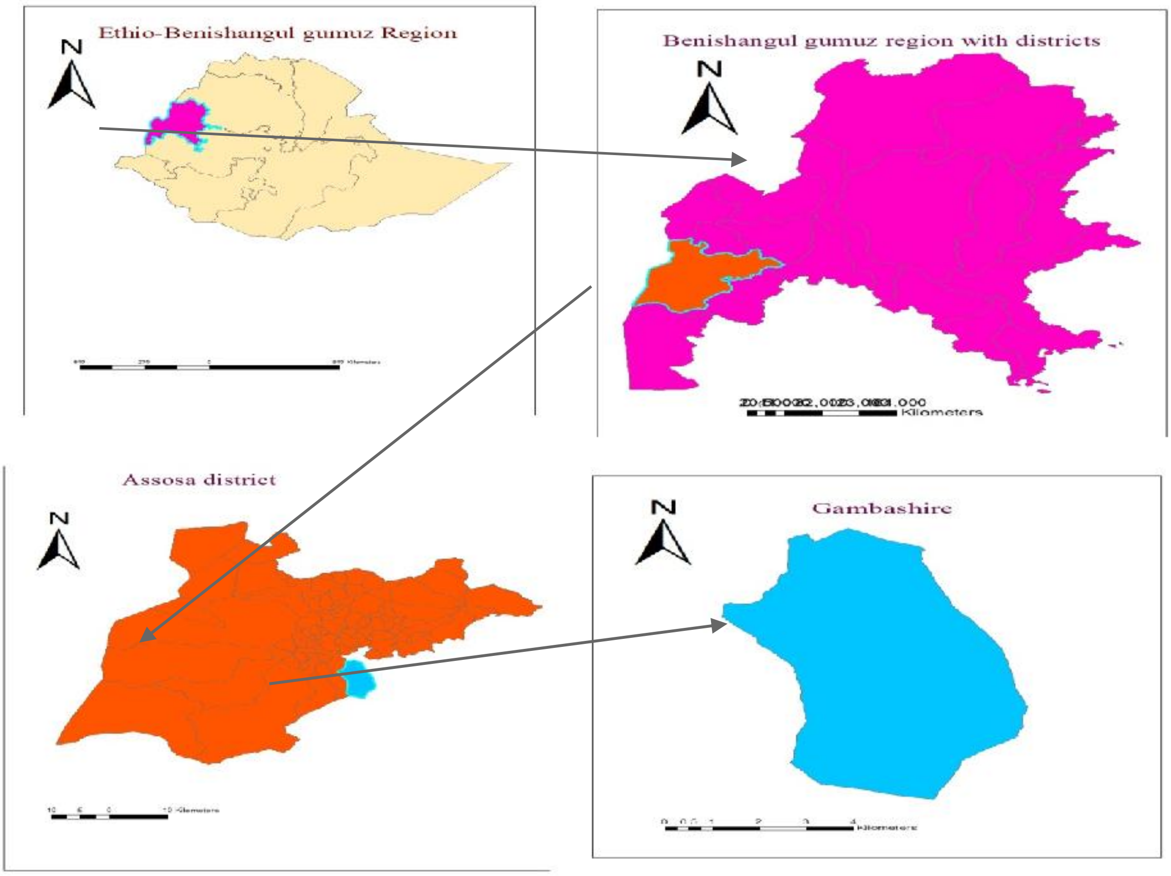

Figure.1: Location map of the study area

The agro-climatic zone of the area is hot to warm moist lowland plain with unimodal rainfall distribution pattern. The rainy season starts at the end of April and lasts at the end of October with maximum rainfall in June, July, August and September. The mean annual minimum and maximum temperatures of the area for the same years were 14.63 and 28.61^{O}C respectively (Moges, M.F., 2019).

2.2. Treatments and experimental design

The experiment had five treatments which were soil moisture depletion levels and arranged in randomized complete block design (RCBD).The experiment was tested on Bombay Red onion variety with experimental plot area of $20m^2$.The space between plots, replications and borders were 1.5m, 2m and 2m respectively. Onion seedling was transplanted on two rows of ridge 40cm spacing and at 10cm spacing between plants and 20cm between plant rows. All agronomic practices were implemented as a time of requirements.

Table 1: Treatment setting for field experiment

Treatments	Descriptions
SMD1	60 % of ASMDL
SMD2	80 % of ASMDL
SMD3	ASMDL according to FAO(33) which is 100%
SMD4	120 % of ASMDL
SMD5	140 % of ASMDL

Where: ASMDL- available soil moisture depletion level, SMD- soil moisture depletion

2.3. Data collection and analysis

2.3.1. Soil data

Soil samples were collected from the experimental field to determine Soil texture, Bulk density (BD), Field capacity (FC) and Permanent wilting point (PWP).Samples were taken up to the maximum root depth which was 60cm. The particle size distributions in the soil profiles were determined using hydrometric method as stated by Stanley and Bernard (1992). Bulk density of the soil was determined using undisturbed soil samples using 4cm height and 4.6cm internal diameter of core sampler. Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in the laboratory with a pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point).

2.3.2. Reference evapotranspiration

Climatic data like minimum and maximum temperature and rainfall, wind speed at two meter height, relative humidity and sunshine hours were collected from Assosa agricultural research center metrological station which was inputs to determine reference evapotranspiration. Then, reference evapotranspiration was computed using CROPWAT 8.0 model as a measure of evaporative demand of the atmosphere. It has been estimated with the FAO Penman-Monteith equation (FAO, 2009) using the ETo calculator program, using the expression below in equation1

$$ETo = \frac{0.408\Delta(Rn-G)+\gamma(900T+273)u2(es-ea)}{\Delta+\gamma(1+0.34u2)\ (3.5)} \quad (1)$$

Where:

ETo: reference evapotranspiration (mm/day)
Rn: net radiation at the crop surface ($MJ/m^2/day$)
G: soil heat flux density ($MJ/m^2/day$)
T: mean daily air temperature at 2 m height (^oC)
es: saturation vapor pressure (kPa)
ea: actual vapor pressure (kPa)
es - ea: saturation vapor pressure deficit (kPa)
Δ: slope vapor pressure curve ($kPa/^oC$)
γ: psychrometric constant ($kPa/^oC$)

2.3.3. Crop water requirement, irrigation water requirement and irrigation scheduling

The crop water requirement was calculated using CROPWAT 8.0 model which is familiar and easy to manipulate. The water requirement of crop was calculated by taking into consideration the growth periods (initial, development, mid season and late season) and soil moisture depletion levels using CROPWAT 8.0 model. Crop water requirement or ETc can be calculated as:

$$ETc = Kc \times ETo \quad (2)$$

Where:
ETc: crop evapotranspiration/crop water requirement (mm/day),

Kc: crop coefficient, which is a function of crop type and stage of growth
ETo: reference evapotranspiration (mm/day)

The net depth of water required was computed after estimation of total available water. The total available water (TAW) for crop use in the root zone was calculated from field capacity and permanent wilting point using Allen *et al*. (1998) equation 3.

$$TAW = 1000\,\Sigma(\theta FC - \theta PWP) * BD * Zr \quad (3)$$

Where: TAW: volumetric total available water in the root zone (mm/m)
θFC: volumetric moisture content at field capacity (m^3/m^3) and
θPWP: volumetric moisture content at permanent wilting point (m^3/m^3).
BD: bulk density (gm. /cm^3)

$$d_{net} = TAW * P \quad (4)$$

Where:
d_{net}: net depth of water required (mm)
TAW: Total available water
P: water depletion fraction/management allowable depletion (%), for onion (P=0.25).
To calculate irrigation interval, first readily available water or net depth of water required was determined from total available water and management allowable depletion as equation (4).
Therefore, the irrigation interval was calculated as equation 5 below.

$$I = \frac{dnet}{ETc} \quad (5)$$

Where:

I: irrigation interval (days)

The volume of water was applied to the treatment using standardized 3- inch partial flume.

2.3.4. Bulb diameter and yield

The collected dataregarding to bulb diameter, yield and water use efficiency were analyzed using the SAS system for windows 9.0. From that,bulb diameter, yield and water use efficiency data were subjected to analysis of variance to identify the difference between the bulb diameters, yield and water use efficiency of the different treatments applied. Whenever treatment effects were significant, the means were separated using the least significance difference (LSD) procedures.

2.3.5. Water use efficiency

As Tennakoon and Milroy (2003) stated that,cropwater use efficiency is the quantity of crop yieldin kilogram per Hectar produced per unit depth (mm) of water used as indicated in equation 6.

$$CWUE = \frac{Y}{ETc} \quad (6)$$

Where:
CWUE: crop water use efficiency (kg/ha-mm)
Y: yield of crop (kg)
ETc: crop water requirement (mm)

3. Results and Discussion

3.1. Soil data analyzed result

Representative soil samples were taken from the experimental field and analysis in the laboratory and the results were shown in (Table2). The textural class of the soil was clay which means the water holding capacity was high so that low irrigation frequency with increasing the amount of water application was required.The average bulk density of the soil was 1.19 (Table 2) as bulk density indicates the compactness of the soil. Therefore, compactness high means the water holding capacity of the soil is high which decreases the irrigation frequency.

The total available water holding capacity of the soil (TAW) was determined after the determination of Field capacity and permanent wilting point of the soil. The average field capacity and permanent wilting point of the soil was 35.85% and 20.03% respectively. As indicated in (Table 2) the total available water was 112.15mm.

Table 2: Soil data analysis result of the experimental field

Soil depth (cm)	Textural class	BD (gm/cm^3	FC (%)	PWP (%)	TAW (mm)
0-30	clay	1.12	36.12	19.93	54.4
30-60	clay	1.25	35.52	20.12	57.75
Average and Total for TAW		1.19	35.82	20.03	112.15

Where: BD- bulk density, FC- field capacity, PWP- permanent wilting point, TAW- total available water

3.2. Reference evapotranspiration

The reference evapotranspiration of the experimental season was calculated and the result is shown in (Figure 2).The result was increased from December to February and decreased at the month of March and increased at April. The highest reference evapotranspiration was recorded at the month of April and the lowest evapotranspiration was recorded at the month of December.The lowest and the highest value have great contribution to decrease and increase the crop water requirement respectively. As shown in (Figure 2), there was no effective rainfall from December to March but increase after the month of March. As the effective rain fall contribution is low, the requirement of irrigation water is increased.

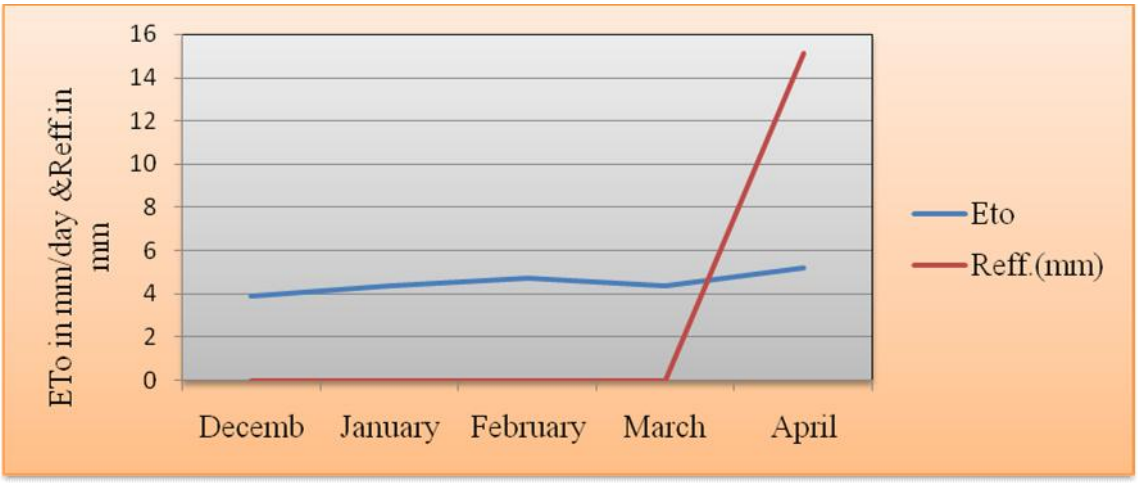

Figure.2: Reference evapotranspiration and effective rain fall during experimental season

3.3. Crop water requirement, irrigation water requirement and scheduling

The crop requires optimum amount of water with the appropriate time to give the expected yield.The seasonal water requirement was 610.4mm and irrigation requirement was 507.8mm.The time of application of water was varying depending on the soil moisture depletion levels. The irrigation intervals were 3 to 4 days, 5 to 6 days, 8 days and 9 days for initial, developmental, mid-season and late season stages respectively. Therefore, the average irrigation interval was 6 days throughout the growing season but it is better to use irrigation intervals according to growing stages to get an optimum crop yield.

3.4. Onion bulb diameter and yield

The highest bulb diameter was obtained at 60%, 100% and 140% of available soil moisture depletion levels and the lowest was at 80% and 120% of available soil moisture depletion levels. However, statistically the bulb diameter was indicated that there was no significance difference at ($P<0.05$) between soil moisture depletion levels what ever increasing and decreasing the amount of depletion levels as indicated in (Table 3).

The highest bulb yield was 139.58Qt/ha which was obtained at 60% of available soil moisture depletion level and this was in lined with Yemane *et al*. (2019) findings in which the highest onion bulb yield was obtained from 60% of available soil moisture depletion level. The lowest was 112.50Qt/ha which was obtained from 100% of available soil moisture depletion level (Table 3).

Table 3: Statistical analysis results of bulb diameter, bulb yield and water use efficiency

TRT	BD (cm)	YLD (Qt/ha)	WUE (kg/ha-mm)
SMD1	49.797[a]	139.58[a]	45.813[a]
SMD2	44.907[b]	122.92[a]	30.257[b]
SMD3	48.027[a]	112.50[a]	22.154[cb]
SMD4	43.603[b]	120.83[a]	19.830[c]
SMD5	48.340[a]	127.08[a]	17.876[c]
Sig(P<0.05)	NS	0.619	NS
CV (%)	3.511	16.613	16.956

Where; TRT: treatment, BD: bulb diameter, YLD: bulb yield, NS: non-significant, CV: coefficient of variation, WUE: water use efficiency

3.5. Water Use Efficiency

As shown in (Figure3) when the soil moisture depletion levels were increased, the water use efficiency was decreased. The highest water use efficiency was 45.81kg/ha-mm which was obtained at 60% of available soil moisture depletion level and the lowest was 17.87kg/ha-mm obtained at 140% of available soil moisture depletion level. The lowest water use efficiency was obtained from 120% and 140% of available soil moisture depletion levels without significance difference.

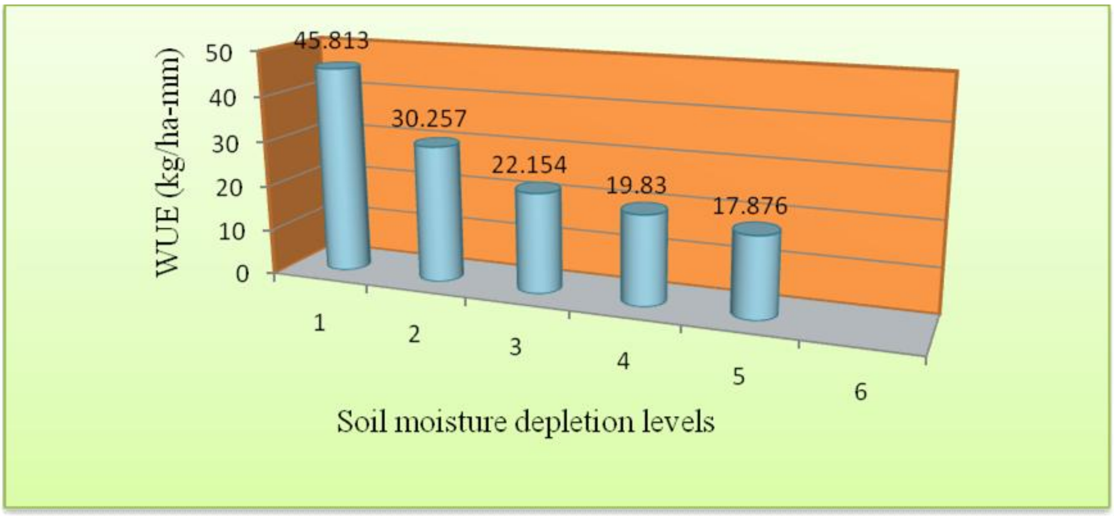

Figure.3: Effect of soil moisture depletion levels on water use efficiency

4. Conclusion

The highest bulb diameter was obtained from 60%, 100% and 140% of available soil moisture depletion levels without significance difference among these treatments. The highest onion bulb yield and water use efficiency were obtained from 60% of available soil moisture depletion level. Irrigation requirement of onion was 507.8mm and an irrigation interval of 6 dayswas required but it is recommended to use irrigation interval depending on growth stages which give an optimum Onion bulb yield and water use efficiency.

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