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Onion seed production and water productivity under deficit irrigation in Oda Bultum District, West Hararghe Zone, Eastern Ethiopia

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Abstract

In semi-arid areas where agricultural development is highly constrained by water scarcity and its mismanagement, the need to use the available water resources efficiently is important. The aim of the study was to evaluate the effect of different irrigation levels on seed yield, yield components and water productivity of onion. The experiment was carried out on two farmer's field on Midhagdu small scale irrigation scheme at Oda Bultum district, West Hararghe Zone during 2018/19 irrigation season. The experiment was laid out in a randomized complete block design with three replications of five irrigation levels (i.e.100, 90, 80, 70 and 60%) in combination of four growth stages (vegetative, bolting, flowering and seed formation) with non-deficit at all growth stages used as control. The combined result of deficit furrow irrigation techniques indicated that there were significance difference (p<0.05) between onion seed yield and water productivity but no significance difference (p>0.05) were observed on growth parameters. The highest mean seed yield and net return were gained from 20% deficit at vegetative stage with higher benefit-cost ratio indicating better onion seed yield is found with mild water stress and reduced with increase in water stress. Thus, the findings summarized that using deficit irrigation of 20% were economically profitable and saves water than full irrigation at all growth stages.

Keywords: Onion • Growth stages • Water productivity • Seed yield

Introduction

Onion is commonly cultivated in all countries of tropical Africa including Ethiopia. Onion is important in the daily Ethiopian diet and all the plant parts are edible, although the bulbs are widely used as a seasoning or a vegetable in various dishes. It is one of the most economically important horticultural crops in the country. The area under onion is increasing from time to time mainly due to its high profitability per unit area, ease of production and increases in small scale irrigation practices. It is produced both under rain-fed in the “Meher” season and under irrigation during off-season that constitutes much of the area under onion production. During 2018/19 (2011 E.C), the rainy season about 28,185.11 ha of lands were planted and more than 0.263 million tons of bulbs were obtained with an average yield of 9.14 tons/ha [1].

Onion suitably grows in between 500-2400 m.a.s.l. But, the best growing altitude so far known in Ethiopia is between 700-1800 m.a.s.l. Besides altitude which has an indirect bearing on climate, onion production is affected by temperature, rainfall and soil. It is suitably grown under mild seasons without extremes of heat, cold or moderate rainfall. Optimum temperatures of 18.3-23.90°C during day and 10-12°C nights are ideal for onion bulb production. But lower temperature is preferred for seed stalk development. Onion requires deep alluvial and friable or sandy loam soil with a pH limit of 6.0 - 8.0. Onion does not tolerate badly drained soil and also it is moderately sensitive to soil salinity. Onion is the second most produced and important vegetable crop next to potato in eastern part of Ethiopia [2]. The major crops cultivated using irrigation in Western Hararghe zone includes high value crops such as hot pepper, tomato, onion, cabbage, beet root and others [3].

Onion is cultivated both under rain-fed and irrigation in Western Hararghe zone particularly in Gemechis, Guba Qoricha, Anchar, Habro, Oda Bultum and Daro Labu districts. In Gemechis district, for instance, onion is produced in total land area of 218.94 and 431.64 hectares during the main (Meher) and short (Belg) rainy seasons, respectively and the average bulb yield obtained was 6.5 tons per ha which is far less than both from the national and world average yield of 9.14 and 13.4 tons per ha, respectively. This may be due to weak supply and distribution system of vegetable seeds in the region in particular and in Ethiopia in general. There is limited access of improved varieties, seed source and quality as well as their high price [4,5]. The bulk of existing cultivated vegetable seeds are imported, often that are not adapted to the local agro-climate. Similar problem related to seed supply system of vegetables is reported in Eastern part of Ethiopia where less quality seed of onion is imported from other areas (central rift valley for instance) and from abroad through different marketing channels.

A survey conducted, a shown several constraints responsible for low onion yield were water shortage for irrigation, lack improved seed varieties recommended for the area, diseases and pest outbreak, drought and low product price. Among these listed constraints, availability of irrigation water that resulted from absence of adequate surface (rivers, lakes, streams) and ground water resources, low rainfall amount which is characterized by having high spatial and temporal variability (i.e., within and inter-annual variability) in the area is the major one which has to be addressed through efficient utilization of available water resources.

Thus, there is a need to introduce irrigation scheduling based on developmental stage or deficit irrigation; which 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 in those water scarce areas. Water availability and cultural practices may influence not only the interrelationships between onion seed yield and its components but also its quality. Several works have been conducted on onion bulb production through efficient and water saving practices like application of deficit irrigation at different developmental stage but a little information is available on identifying its effects for onion seed production in Ethiopia in general and the study area in particular. It

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is reported that yield and quality of onion seed are greatly affected by soil moisture content during various growth and development stages [6]. It is important to find out the most critical growth stage(s) of onion for quality seed production. Therefore, this study was undertaken to evaluate the effect of deficit irrigation at different growth stages on seed yield, yield components and water productivity of onion for optimum production.

Materials and Methods

Description of study area

The study was conducted in Oda Bultum district of West Hararghe zone. The district is located at longitude and latitude of $08^0$30'0"- $09^0$0'0"N and 40^0 20'0"- 40^0 40'00"E at 404 km east of Addis Ababa, capital city of Ethiopia. The mean annual rain fall is between 900-1,100 mm. It has mean maximum and minimum temperatures of 28°C and 15°C with mean of 20°C. The soil type of the district is characterized sandy loam (Figure 1).

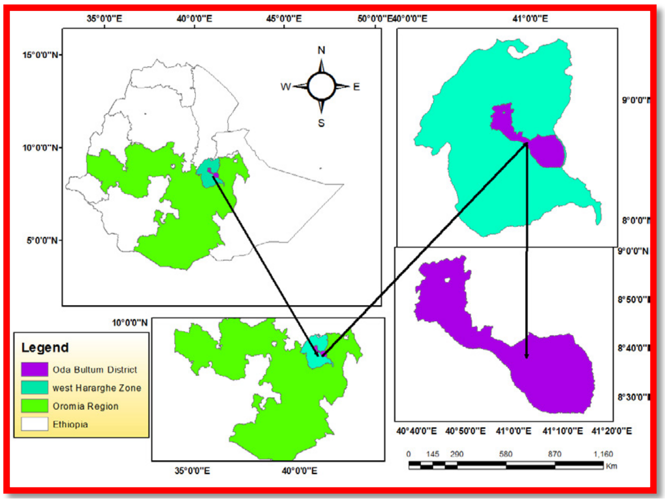

Figure 1: Map of study area.

Experimental design and treatments

The study was conducted starting from October 2018 on two farmer's field at Midhagdu small scale irrigation scheme. Onion variety "**Bombay red**" was used as test crop. Bulb to seed method of seed production was selected for this particular study. The experiment was laid out in a randomized complete block design (RCBD) with three replications of five irrigation levels (i.e., 100% ETc- no water deficit, 90% ETc-10% water deficit, 80% ETc-20% water deficit, 70% ETc-30% water deficit and 60% ETc-40% water deficit) in combination of four growth stages; vegetative (VS), bolting (BS), flowering (FS) and seed formation stages (SFS) in different combinations giving a total of twenty one treatments (Table 1). The experimental plot size of 3 m x 2 m was used with spacing between plots 1 m and blocks 1.5 m in order to avoid water flowing among treatments. This gives a total experimental size of 12 m x 62 m. Bulbs were set upright and at a depth of 2.5 cm. Spacing between plants was 30 cm and between row 40 cm and total plant population in one plot was about 50 plants. Measured amount of water (i.e., according to the treatments) was applied to each plot at required intervals to maintain the soil moisture content in the root zone up to field capacity. The crop was kept weed free by manual hoeing (Table 1).

Estimation of Irrigation Water

The irrigation water was applied to bring the soil moisture content at the root zone to field capacity taking into account the effective root zone depth. Before each irrigation, soil moisture was determined by gravimetric method. Measured amount of water was applied to all treatments. The effective root zone of onion is considered to vary from 30-40 cm (FAO 56) depending on the growth stage. The depth of water was determined using the following equation (eq-1):

$$d_{net} = \sum_{i}^{n} \frac{M_{fci} - M_{bi}}{100} \text{BixDi}$$

Where;

d_{net} = net amount of water to be applied during an irrigation, mm

M_{fci} = field capacity moisture content in the i^{th} layer of the soil, percent

Table 1. Treatment arrangements.

Treatments	Growth stages				Description
	Vegetative stage (VS)	**Bolting stage (BS)**	**Flowering stage (FS)**	**Seed form. stage (SFS)**	
T1	**100%**	100%	100%	100%	No water deficit at any stage
T2	**90%**	100%	100%	100%	10% water deficit at VS
T3	**100%**	90%	100%	100%	10% water deficit at BS
T4	**100%**	100%	90%	100%	10% water deficit at FS
T5	**100%**	100%	100%	90%	10% water deficit at SFS
T6	**80%**	100%	100%	100%	20% water deficit at VS
T7	**100%**	80%	100%	100%	20% water deficit at BS
T8	**100%**	100%	80%	100%	20% water deficit at FS
T9	**100%**	100%	100%	80%	20% water deficit at SFS
T10	**70%**	100%	100%	100%	30% water deficit at VS
T11	**100%**	70%	100%	100%	30% water deficit at BS
T12	**100%**	100%	70%	100%	30% water deficit at FS
T13	**100%**	100%	100%	70%	30% water deficit at SFS
T14	**60%**	100%	100%	100%	40% water deficit at VS
T15	**100%**	60%	100%	100%	40% water deficit at BS
T16	**100%**	100%	60%	100%	40% water deficit at FS
T17	**100%**	100%	100%	60%	40% water deficit at SFS
T18	**90%**	90%	90%	90%	10% water deficit at all stages
T19	**80%**	80%	80%	80%	20% water deficit at all stages
T20	**70%**	70%	70%	70%	30% water deficit at all stages
T21	**60%**	60%	60%	60%	40% water deficit at all stages

M_{bi} =moisture content before irrigation in the i^{th} layer of the soil, per cent

Bi = bulk density of the soil in the i^{th} layer

Di = depth of the i^{th} soil layer, mm, within the root zone, and

n = number of soil layers in the root zone D.

Determination of Effective Rainfall

Effective rainfall is determined using USDA method (FAO, 1984) and is deducted from gross irrigation to supply the remaining irrigation requirement (Eq. 2 & 3).

$$P_{effective} - P_{total}(125 - 0.2 * P_{total})/125 \text{ for } P_{total} < 250 \text{ mm} \quad (2)$$

$$P_{effective} = 125 + (0.1 * P_{total}) \text{ for } P_{total} > 250 \text{ mm} \quad (3)$$

where,

$P_{effective}$ is effective rainfall, mm

P_{total} is total rainfall, mm

Irrigation interval, $I(days) = d_{net}(mm)/ET_{crop}(\frac{mm}{day})$ (4)

Where, **ET_{crop}(mm/day) is** peak evapo-transpiration demand of the crop

Data collection

Soil physical properties such as field capacity**,** permanent wilting point, bulk density **and** soil texture were taken once before commencing the treatment; soil moisture content every 7 days (may adjusted based on Equ-4 above) after commencing the treatments taken at a depth of 20 cm and 40 cm.

Soil chemical properties such as pH, CEC, organic carbon, available P & K, total N were determined from composite soil samples taken at two layers (i.e., at 0-20cm & 20-40 cm) before treatment application and at harvest.

Growth parameters and yield components: five plants from middle of each plot were selected randomly at harvest for collection of data on growth, yield components and yield such as plant height (cm), number of flower stalk/plant, length of scape (cm), diameter of scape (cm), diameter of umbel (cm), seed yield per plant (g) and seed yield (kg/ha).

Irrigation schedule and water productivity: amount of irrigation water used for each treatment (mm), time of application (interval) and water productivity (kg/m^3) were taken.

Economic data: all necessary data were taken to determine cost to benefit ratio that help to separate the most economical treatment to be used for further demonstration and scale up.

Soil sampling and analysis

Composite soil samples were collected from three locations of the experimental field at depth of 0-40 cm for soil physico-chemical property analysis. Undisturbed soil samples were collected for bulk density determination using core sampler of volume 98.125 cm^3.

Soil moisture determination

Composite soil samples were taken at 4-7 days interval at depth of 0-40 cm for soil moisture analysis using gravimetric method in order to schedule the irrigation. The collected soil samples were placed in an oven dry at a temperature of 105^{0}C and dried for 24 hrs. Its gravimetric water content was then determined using the expression in Equ. 5 (Cuenca, 1989).

$$\theta dw = \frac{(Wws - Wds)}{Wds} x100 \quad (5)$$

where; Wws= weight of wet soil (g) θdw = water content expressed on weight basis in (%), Wds = weight of dry soil (g)

Determination of soil physical characteristics

Soil texture

The hydrometric method was used for the particle size analysis of the bulk soil samples corresponding to each depth ranges. The textural class of the soil was determined using USDA textural triangle following the procedures indicated by Day.

Bulk density

For the determination of bulk density, undisturbed soil samples were collected and oven dried for 24 hours at a temperature of 105^{0}C to remove the soil moisture to get the dry weight of the soil. It was then computed using the following equation as stated by Michael.

$$\rho b = \frac{Wd}{Vs} \quad (6)$$

where: ρb is the bulk density of the soil in g/cm^3, Wd is the weight of oven dry soil in gram and Vs is the volume of the same soil sample in cm^3 (core volume).

Field capacity and permanent wilting point

The field capacity (FC) and permanent wilting point (PWP) were determined using pressure plate and pressure membrane apparatus, respectively. Soil samples were saturated for one day (24 hours) and a pressure of 1/3 bar and 15 bar were exerted, respectively for FC and PWP, until no water droplets detected.

Determination of soil chemical characteristics

The soil pH was determined by measuring soil solution of 1:2.5 ratios (soil to water) with a pH meter using combination glass electrode as described by Jackson. The percentage of organic carbon (OC) was determined following the wet digestion method as described by Walkley and Black. Organic matter (OM) content was then determined by multiplying OC by 1.724. Electrical conductivity of the irrigation water and the soil was determined using electrical conductivity meter (EC meter).

Depth and discharge measurement

The total amount of water required was diverted to the furrow with calibrated parshal flume having appropriate opening diameter of three inch (3") with a length of 2 m and its appropriate head ranges from 3-33 cm. Water flow to each furrow was controlled by the difference in depth between the water level in the feeder canal and free water level at the outlet at the furrow head. It was calculated as suggested by Michael :

$$Q = 0.1771\, h^{1.55} \quad (7)$$

where; Q = discharge from parshall flume (l/s), h = effective head of Parshall flume causing flow (cm)

The time required to deliver the desired depth of water into each furrow was calculated using the equation recommended by Israelsen (1980).

$$t = \frac{dxwxl}{qx60} \quad (8)$$

Where; d= gross depth of water applied (cm), t= application time (hr), l= furrow length in (m), w= furrow spacing in (m), q= flow rate (l/s)

Flow time measurement

First, the amount of water required for each treatment was calculated, then parshall flume calibrated at different head using stopwatch during each irrigation water application in order to assess the treatment effects. Data on volume of water applied and length of irrigation time was taken during each irrigation events from discharge measuring parshall flume. For each treatment, the water productivity, WP (kg/m^3) was calculated using the following formula as described by Michael

$$Wp\left(\frac{kg}{m3}\right) = \frac{Seed\ yield\,(kg)}{Amount\ of\ water\ used\,(m3)} \quad (9)$$

Data analysis

The means of the above parameters was subjected to analysis of variance (ANOVA) using Gen-stat version 16th computer software. Mean comparison was done by using least significant difference test at 5% significance level.

Results and Discussion

Soil physico-chemical property

Soil physical properties

The bulk density, water content at field capacity (FC) and permanent wilting point (PWP) values is presented in Table 2. The average bulk density values were 1.24 g/cm^3 and 1.18 g/cm^3 for the soil depth 0 - 40 cm on the first and second experimental locations during 2019 respectively, at Midhagdu PA (Table 2). The soil moisture content at field capacity ranged from 39.6 to 40.1% whereas the permanent wilting point values obtained varied between 28 and 29.5% on both locations. These parameters were used to determine irrigation depths which were applied at both locations by using parshall flume.

Soil chemical properties

The soil pH of the area is determined to be 7.51(slightly alkaline) and is found to be optimum for onion production. The electrical conductivity of the soils (ECe) were 0.87 and 1.7 mmhos/cm, at 25^{0}C which were less than 2 mmhos/cm and the soils are classified as non-saline soil. The soil has medium to high total nitrogen N. The exchangeable sodium measures the amount of soil exchange capacity occupied by sodium and expressed as a percentage which is 0.02% for this area is very low. An ESP>15% indicates that soil sodium will probably limit permeability (Scianna *et al.,* 2007) (Table 3).

Effect of deficit irrigation on growth parameters and onion seed yield

Plant height

Analysis of variance revealed that different irrigation water levels had significant ($p<0.05$) effect on height at both locations (Table 4 and 5). The shortest plant height was recorded when 40% deficit irrigation water was applied throughout all growth stages (65.2 cm) while tallest was recorded at 20% deficit throughout all growth stages (77.27 cm) on the first location (Table 4). The highest plant height (73 cm) on the second location was recorded from full irrigation throughout all growth stages while the shortest was recorded from 30% irrigation water deficit is applied at bolting stage (BS) (Table 5). However, when we see the combined mean, the higher plant heights were recorded when full irrigation water throughout all growth

Table 2. Soil physical properties of the experimental site.

Locations	Depth (cm)	Bulk Density (g/cm³)	FC (%)	PWP (%)	Texture
Midhagdu 1	0-40cm	1.24	40.1	28	Sandy loam
Midhagdu 2	0-40 cm	1.18	39.6	29.5	Silt loam

Table 3. Soil chemical properties of the experimental site.

locations	Depth (cm)	EC (mmhos/cm)	pH	TN (%)	P (mg/kg)	K (mg/kg)	OC (%)	CEC (meq/100g)	Na (meq/100g)
Midhagd 1	0-40	1.7	7.51	0.27	92.4	491	0.59	25.1	0.9
Midhagd 2	0-40	0.87	7.52	0.18	49.6	371.5	0.48	33.5	0.9

Table 4. Growth parameters and seed yield of Onion at Midhagdu scheme 1 during 2018/19.

Trt	PH (cm)	NTPP	NFSPP	LS (cm)	DS (mm)	DU (cm)	SY (kg/ha)
10%Bs	76.20ab	12.47a	12.33a	71.93	3.18	6.3ab	586.4ab
10%Fs	74.00abc	11.20abc	10.40abc	70.07	3.47	6.1ab	662.4ab
10%Sf	69.13abc	11.13abc	10.53abc	65.40	3.65	6.2ab	649.8ab
10%thr	71.47abc	10.13a-d	8.60cd	67.93	3.39	6.0ab	595.8ab
10%Vs	70.00abc	10.73a-d	10.33abc	66.00	3.78	6.0ab	637.2ab
20%Sf	73.47abc	11.00abc	10.67abc	69.33	3.17	5.5b	588.4ab
20%thr	77.53a	11.80abc	11.20abc	71.27	3.77	6.3ab	734.4ab
20%Bs	75.33ab	11.00abc	10.93abc	71.60	3.79	6.2ab	565.3ab
20%Fs	71.33abc	9.40bcd	9.13bcd	64.00	3.68	5.7ab	675.4ab
20%Vs	67.87bc	9.13cd	8.53cd	64.47	3.12	5.8ab	708.7ab
30%Bs	75.47ab	7.73d	7.27d	70.87	3.97	5.8ab	665.1ab
30%Fs	71.47abc	9.93a-d	9.73a-d	67.60	3.44	6.0ab	777.2a
30%Sf	68.20bc	10.20 a-d	9.73a-d	64.27	3.87	6.1ab	778.7a
30%thr	74.80ab	9.93a-d	9.53a-d	70.80	3.62	6.3ab	718.1ab
30%Vs	70.87abc	10.53a-d	10.27a-d	66.87	3.35	5.7ab	663.2ab
40%thr	65.20c	12.33ab	11.87ab	64.80	3.64	6.0ab	490.7b
40%Vs	75.27ab	10.93abc	10.47abc	73.00	3.87	6.1ab	697.2ab
40%Bs	75.67ab	11.6abc	11.20abc	71.40	3.23	6.2ab	574.8ab
40%Fs	69.27abc	9.93a-d	9.47a-d	66.00	3.37	5.7ab	591.6ab
40%Sf	67.60bc	10.67a-d	9.53a-d	63.80	3.23	6.0ab	550.4ab
Nd	73.53abc	9.6 a-d	9.80a-d	69.30	3.66	6.5a	618.6ab
Mean	72.1	10.5	10.1	68.1	3.5	6.0	
LSD(0.05)	8.93**	3.05**	3.06**	9.73(ns)	2.00(ns)	0.93**	246.7**
CV	7.5	17.6	18.4	8.7	37.8	9.4	23.2

SF= seed formation stage, VS= vegetative stage, BS= bolting stage, Thr= equal throughout all stage, FS= flowering stage, Nd= no deficit at all stages, Trt=treatment, PH=plant height, NTPP=No of tillers per plant, NFSPP=No of flower stalk per plant, LS=length of scape, DS=diameter of scape, DU=diameter of umbel, SY=seed yield

Table 5. Growth parameters and seed yield of Onion at Midhagdu scheme 2 during 2018/19.

Trt	PH (cm)	NTPP	NFSPP	LS (cm)	DS (mm)	DU (cm)	SY (kg/ha)
10%Bs	68.01a-c	10.13	9.33	63.57a-c	1.54ab	5.64bc	782.4ab
10%Fs	72.13a	9.27	8.33	67.88ab	1.49b	5.54bc	677.9ab
10%Sf	67.60 a-c	8.87	7.60	63.86a-c	1.52ab	5.70abc	848.1ab
10%thr	70.20a-c	11.47	10.80	65.87a-c	1.65ab	6.10ab	701.4ab
10%Vs	68.00a-c	9.40	8.20	64.30a-c	1.57ab	5.86abc	577.7ab
20%Sf	69.13a-c	9.60	8.73	65.60a-c	1.48b	5.97abc	943.6a
20%thr	69.27a-c	8.60	7.80	65.63a-c	1.67ab	5.50bc	597.1ab
20%Bs	70.90a-c	9.33	8.80	66.63a-c	1.63ab	6.29a	696.3ab
20%Fs	65.00c	8.33	8.00	61.07c	1.54ab	5.40c	843.7ab
20%Vs	66.07bc	9.67	9.13	62.08bc	1.52ab	5.72abc	849.3ab
30%Bs	64.87c	10.07	8.53	61.48bc	1.44b	5.41c	821.5ab
30%Fs	70.07a-c	11.00	10.20	66.27a-c	1.72ab	5.82abc	602.9ab
30%Sf	70.87a-c	11.07	10.20	66.87a-c	1.54ab	5.76abc	661.4ab
30%thr	68.33a-c	11.33	10.53	64.47a-c	1.56ab	5.75abc	638.9ab
30%Vs	66.97bc	9.73	8.73	63.00a-c	1.66ab	5.92abc	770.6ab
40%thr	69.47a-c	8.33	7.73	66.07a-c	1.54ab	5.83abc	676.7ab
40%Vs	68.13a-c	9.33	8.40	63.53a-c	1.57ab	5.64bc	754.8ab
40%Bs	68.57a-c	9.67	9.07	63.97a-c	1.51ab	5.76abc	891ab
40%Fs	66.87bc	9.93	9.27	62.53a-c	1.84a	5.67abc	918.9a
40%Sf	70.87a-c	10.93	10.67	66.87a-c	1.58ab	5.86abc	645.9ab
Nd	73.67a	9.00	8.73	68.93a	1.59ab	6.00abc	541.8b
LSD(0.05)	6.43**	3.15(ns)	3.4(ns)	6.57**	0.33*	0.64*	372.3**
CV (%)	5.70	19.60	22.90	6.10	12.80	6.70	30.7

N.B. keys for abbreviations are the same as in Table 4

stages, 20% water deficit at BS and 10% water deficit at flowering stage (FS) were applied. The shortest plant height (66.97 cm) was recorded when 20% water deficit was applied at vegetative stage (VS) (Table 6). The result agrees with that applying 40% water deficits throughout the growth stages of onion reduced plant height. The shortest plant height was due to water stress exerted when the crop needs more water. Also, the result obtained agrees with the finding of who reported reduced plant height of onion due to water deficit at vegetative and bulb formation stages. The increasing of plant height with adequate soil moisture application is related to role of water in maintaining the turgor pressure of the plant cells which is the main reason for enhancing plant growth. In contrast, the shortening of plant height under mild soil moisture stress may be associated with the closure of stomata to conserve soil moisture evaporation, thus leads to reduced uptake of CO_2 and nutrient. Therefore, photosynthesis and other biochemical reactions are hindered, eventually affecting plant growth.

Number of tiller per plant

The different levels of irrigation water application at different onion growth stages showed significant effect on number of tillers per plant (Table 4 and 6). The application of different irrigation water levels showed that higher numbers of tillers per plant were recorded when 10% and 40% water deficit are applied at BS. The lower tiller number were recorded at 40% deficit throughout growth stage, 20% deficit at FS and 30% deficit at BS on both locations (Table 4 and 5). Different irrigation water levels shown significance difference ($p<0.05$) between 10 BS, 30 BS and 20 VS on number of tillers per plant parameters (Table 4) while no significance difference ($p>0.05$) between irrigation water levels on the second location (Table 5).

Number of flower stalk per plant

The combined mean of both locations statistical analysis result indicated that number of flower stalk per plant was significantly ($p<0.05$) affected by the deficit irrigation levels at different growth stages.

Number of flower stalk per plant is summation of number of tillers forming flower including mother stalk. This is important parameters affecting seed yield positively, if it effectively bears a seed. As shown in the Table 4 and 5 the highest number of flower stalk per plant was found from treatments of 10% irrigation water deficit at all growth stages except when irrigated with 10% water deficit throughout on first location while on the second location 30% throughout growth stage.

Length and diameter of scape

There was no significance difference ($p>0.05$) between irrigation water regimes on length and diameter of scape. The highest length of scape was found on 20% Bs, 10%Fs and no deficit at all growth stage while the lowest was found on 40% Fs and 30% Vs (Table 5). This shows length of scape reduced with increase water stress. While highest diameter of scape was found on 20% thr and 40% Vs and the lowest was found on 20% Vs and 20% Sf. The combined mean of length of scape and diameter of scape ranges from 64.27 cm to 69.12 cm and 2.32 cm to 2.72 cm respectively.

Diameter of Umbel

The diameter of umbel is important growth parameters contributing to seed yield. The irrigation water regimes had no significant difference ($p>0.05$) on umbel diameter, which was ranged from 5.5 to 6.25 cm with mean of 5.8 cm (Table 5). These values are similar with studies of Kumar *et al.* (2014). The highest combined mean of umbel diameter was recorded from no deficit at all growth stage (100%) and 20% Bs with similar values of 6.25 cm while the lowest was obtained from 20% Fs with values of 5.55 cm (Table 5).

Seed yield per plant (g) and seed yield (kg/ha)

The analysis of variance result shows that there were significant yield difference at ($P<0.05$) between deficit irrigation on seed yield (kg/ha). There is significant difference between treatments of deficit irrigation 30%Sf and 40% thr on first location and 20%Sf and Nd on second location (Table 3 and 4). As observed from Table 3 and 4, the highest yield obtained from 30%Sf (778 kg/ha) and 20% Sf (943.6kg/ha) while the lowest yield obtained from 40% deficit throughout growth stage (490.7 kg/ha) and no deficit at all stage (100%) by (541.8kg/ha) on Midhagdu 1 and Midhagdu 2 respectively (Table 3 and 4). As shown from this result high water stress and high amount of

Table 6. Combined mean of growth parameters and seed yield of Onion of two locations.

Trt	PH (cm)	NTPP	NFSPP	LS (cm)	DS (mm)	DU (cm)	SY (kg/ha)
10%Bs	72.11abc	11.30a	10.83a	67.75a-c	2.36	5.97ab	684.40
10%Fs	73.07ab	10.24ab	9.37ab	68.98a	2.48	5.82ab	670.15
10%Sf	68.37bcd	10.00ab	9.07ab	64.63a-c	2.59	5.95ab	748.95
10%thr	70.84a-d	10.80ab	9.70ab	66.90a-c	2.52	6.05ab	648.60
10%Vs	69.00a-d	10.07ab	9.27ab	65.15a-c	2.68	5.93ab	607.45
20%Sf	71.30a-d	10.30ab	9.70ab	67.47a-c	2.33	5.74ab	766.00
20%thr	72.40abc	10.20ab	9.50ab	68.45ab	2.72	5.90ab	665.75
20%Bs	73.12ab	10.17ab	9.87ab	69.12a	2.71	6.25a	630.80
20%Fs	68.17bcd	8.87b	8.57ab	62.54c	2.61	5.55b	759.55
20%Vs	66.97d	9.40ab	8.83ab	63.28bc	2.32	5.76ab	779.00
30%Bs	70.17a-d	8.90ab	7.90b	66.18a-c	2.71	5.6b	743.30
30%Fs	70.77a-d	10.47ab	9.97ab	66.94a-c	2.58	5.91ab	690.05
30%Sf	69.54a-d	10.64ab	9.97ab	65.57a-c	2.71	5.93ab	720.05
30%thr	71.57a-d	10.63ab	10.03ab	67.64a-c	2.59	6.03ab	678.50
30%Vs	68.92a-d	10.13ab	9.50ab	64.94a-c	2.51	5.81ab	716.90
40%thr	67.34cd	10.33ab	9.80ab	65.44a-c	2.59	5.92ab	583.70
40%Vs	72.70ab	10.13ab	9.44ab	68.27ab	2.72	5.87ab	726.00
40%Bs	72.12abc	10.64ab	10.14ab	67.69a-c	2.37	5.98ab	732.90
40%Fs	68.07bcd	9.93ab	9.37ab	64.27a-c	2.61	5.69ab	755.25
40%Sf	69.24a-d	10.80ab	10.10ab	65.34a-c	2.41	5.93ab	598.15
Nd	73.60a	9.30ab	9.27ab	69.12a	2.63	6.25a	580.20
Mean	70.4	10.2	9.5	66.5	2.6	5.9	689.8
LSD(0.05)	5.11	2.41	2.52	5.45	1.16(ns)	0.60	237.83(ns)
CV (%)	4.40	14.40	16.0	5.00	25.30	6.10	20.90

water application affects the seed yield. There is significance difference between treatment 30% deficit applied at seed formation stage (30%sf) and 40% deficit applied throughout growth stage (40% thr) as well as between 20% deficit applied at Seed formation stage (20%Sf) and no water deficit at all stage (100%). As observed from the Table 3 and 4 onion seed yield is affected at 10%Vs, 40% thr and Nd at both locations.

The average seed yield per plant ranged from 6.9 to 9.4 g with an average of 8.2 g. The highest seed yield per plant (9.4 g) and (9.2 g) were obtained from 20%Vs and 20% Sf respectively. While the lowest seed yield per plants were found on no deficit irrigation at all stages and 40% throughout all growth stage with values of 6.95 g and 7 g respectively. From the results it is clear that flowering stage of onion seed production may be considered critical. However, the role played by each of the yield contributing factors is actually the result of complex interactions with all the others and, as such, is difficult to interpret.

ANOVA shows that there is no significance difference between the growth parameters and yield components when we see both locations combined mean (Table 6). The highest mean of yield from two locations were recorded on 20% Vs, 20%Fs, 20%Sf and 10% Sf while the lowest mean yield was recorded from Nd, 40% thr and 40% Sf. This shows that the optimum seed yield were obtained on 20% on all growth stages except on bolting stage only, while high water stress and no deficit throughout growth stages affects yield of onion negatively on Oda Bultum district. Thus, the onion yields are higher with less water stress and reduced with increase in water stress except on no deficit at all growth stage. This result agreed with Bhagyawant *et.al* (2015) which reported the 20% deficit irrigation did not reduce the onion yield significantly (Figure 2).

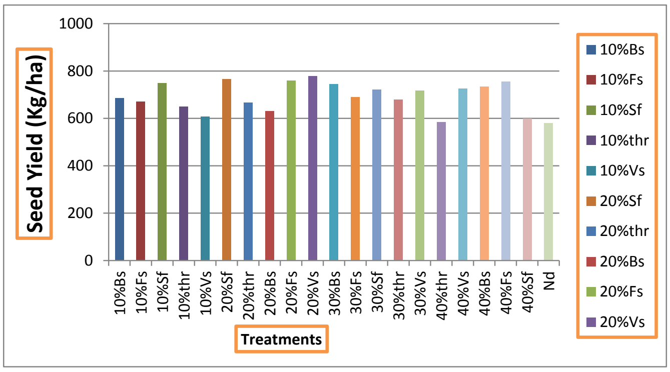

Figure 2: Graph of seed yield in kg/ha.

Effect of deficit irrigation on water productivity

The seasonal water used (mm), total irrigation water applied (m^3/ha) and water productivity are explained on Table 7, 8 and 9). The total seasonal water used ranges from 187.53 mm/season to 312.63 mm/season from 40% irrigation water deficit throughout all growth stages and no water deficit at all growth stages, respectively on the first location (Table 7). The highest water productivity was found on 30% and 20% water deficit at all growth stages with values of 0.328 kg/m^3 and 0.294 kg/m^3, respectively while the lowest was found at 10% water deficit at bolting stage and when full irrigation is applied throughout all growth stages with values of 0.193 and 0.198 kg/m^3 (Table 7). The water productivity ranges from 0.193 kg/m^3 to 0.406kg/m^3 on both locations. The highest water productivity was found on 20% deficit seed formation stage and 40% deficit throughout all growth stage with values of 0.359 and 0.406 kg/m^3. The highest yield of seed also found on 20% deficit seed formation stage (Table 9). When we see the mean of water productivity on both locations the highest water productivity was found from 30% thr (0.33kg/m^3) and 40% thr (0.33kg/m^3) while the lowest found from full irrigation at all growth stage (0.2kg/m3). This shows the increase in the water stress the higher water productivity found (Table 8). The result agrees with (Ayana, 2019) the water productivity increased with decreasing water supply.

Cost Benefit Analysis

The result shows that highest yield and returns were gained from 20%

Table 7. Mean seasonal consumptive water use and productivity on the Midhagdu scheme 1.

Trt	Total seasonal water used (mm)	Total irrigation water applied (m^3/ha)	Onion Seed yield (kg/ha)	Water productivity (kg/m^3)
10%Bs	303.63	3036.30	586.4	0.193
10%Fs	305.16	3051.60	662.4	0.217
10%Sf	303.60	3036.00	649.8	0.214
10%thr	281.32	2813.20	595.8	0.212
10%Vs	306.83	3068.30	637.2	0.208
20% Sf	294.53	2945.30	588.4	0.200
20%thr	250.05	2500.50	734.4	0.294
20%Bs	294.63	2946.30	565.3	0.192
20%Fs	297.75	2977.50	675.4	0.227
20%Vs	301.03	3010.30	708.7	0.235
30%Bs	285.63	2856.30	665.1	0.233
30%Fs	290.33	2903.30	777.2	0.268
30%Sf	285.47	2854.70	778.7	0.273
30%thr	218.77	2187.70	718.1	0.328
30%Vs	295.23	2952.30	663.2	0.225
40% thr	187.53	1875.30	490.7	0.262
40% Vs	289.43	2894.30	697.2	0.241
40%Bs	276.63	2766.30	574.8	0.208
40%Fs	282.93	2829.30	591.6	0.209
40%Sf	276.43	2764.30	550.4	0.199
Nd	312.63	3126.30	618.6	0.198
LSD(0.05)	Ns	Ns	**246.7****	**0.16**
Cv (%)	-	-	**23.2**	**29.9**

SF= seed formation stage, VS= vegetative stage, BS= bolting stage, Thr= equal at all stage, FS= flowering stage, Nd= no deficit at all stages

Table 8. Mean seasonal consumptive water use and productivity of Midhagdu scheme 2.

Trt	Total seasonal water used(mm)	Total irrigation water applied(m^3/ha)	Onion Seed yield (kg/ha)	Water productivity (kg/m^3)
10%Bs	270.17	2701.7	782.4	0.290
10%Fs	270.33	2703.3	677.9	0.251
10%Sf	270.02	2700.2	848.1	0.314
10%thr	249.69	2496.9	701.4	0.281
10%Vs	271.67	2716.7	577.7	0.213
20%Sf	262.61	2626.1	943.6	0.359
20% thr	221.95	2219.5	597.1	0.269
20%Bs	262.83	2628.3	696.3	0.265
20%Fs	263.17	2631.7	843.7	0.321
20%Vs	265.83	2658.3	849.3	0.319
30%Bs	255.50	2555.0	821.5	0.322
30%Fs	256.00	2560.0	602.9	0.236
30%Sf	255.20	2552.0	661.4	0.259
30%thr	194.20	1942.0	638.9	0.329
30%Vs	260.00	2600.0	770.6	0.296
40% thr	166.47	1664.7	676.7	0.406
40% Vs	254.17	2541.7	754.8	0.297
40%Bs	248.17	2481.7	891	0.359
40%Fs	248.83	2488.3	918.9	0.369
40%Sf	247.80	2478.0	645.9	0.261
Nd	277.50	2775.0	541.8	0.195
LSD(0.05)	Ns	Ns	372.3**	0.09*
Cv(%)	-	-	30.7	22.1

SF= seed formation stage, VS= vegetative stage, BS= bolting stage, Thr= equal at all stage, FS= flowering stage, Nd= no deficit at all stages

Table 9. Mean seasonal consumptive water use and productivity.

Trt	Total seasonal water used (mm)	Total irrigation water applied (m^3/ha)	Onion Seed yield (kg/ha)	Water productivity (kg/m^3)
10%Bs	286.90	2869.00	684.40	0.24
10%Fs	287.75	2877.45	670.15	0.23
10%Sf	286.81	2868.10	748.95	0.26
10%thr	265.51	2655.05	648.60	0.25
10%Vs	289.25	2892.50	607.45	0.21
20% Sf	278.57	2785.70	766.00	0.28
20%thr	236.00	2360.00	665.75	0.28
20%Bs	278.73	2787.30	630.80	0.23
20%Fs	280.46	2804.60	759.55	0.27
20%Vs	283.43	2834.30	779.00	0.28
30%Bs	270.57	2705.65	743.30	0.28
30%Fs	273.17	2731.65	690.05	0.25
30%Sf	270.34	2703.35	720.05	0.27
30%thr	206.49	2064.85	678.50	0.33
30%Vs	277.62	2776.15	716.90	0.26
40% thr	177.00	1770.00	583.70	0.33
40% Vs	271.80	2718.00	726.00	0.27
40%Bs	262.40	2624.00	732.90	0.28
40%Fs	265.88	2658.80	755.25	0.29
40%Sf	262.12	2621.15	598.15	0.23
Nd	295.07	2950.65	580.20	0.20
LSD(0.05)			309.50	0.12*
CV (%)			26.95	26

Table 10. Partial budget analysis.

Trt	Total cost (ETB/ha)	Total seed yield (kg/ha)	Total return	Net income (Birr)	B/C
10%Bs	31391	1368.8	273760	242369	7.7
10%Fs	31427.6	1340.3	268060	236632.4	7.5
10%Sf	31383.4	1497.9	299580	268196.6	8.5
10%thr	30518	1297.2	259440	228922	7.5
10%Vs	31482.6	1214.9	242980	211497.4	6.7
20% Sf	31014.2	1532	306400	275385.8	8.9
20%thr	29293.6	1331.5	266300	237006.4	8.1
20%Bs	31040	1261.6	252320	221280	7.1
20%Fs	31099.8	1519.1	303820	272720.2	8.8
20%Vs	31237.2	1558	311600	280362.8	9
30%Bs	30677	1486.6	297320	266643	8.7
30%Fs	30778.4	1380.1	276020	245241.6	8
30%Sf	30662	1440.1	288020	257358	8.4
30%thr	28068.8	1357	271400	243331.2	8.7
30%Vs	30962.4	1433.8	286760	255797.6	8.3
40% thr	26842.5	1167.4	233480	206637.5	7.7
40% Vs	30711.7	1452	290400	259688.3	8.5
40%Bs	30331.8	1465.8	293160	262828.2	8.7
40%Fs	30465.8	1510.5	302100	271634.2	8.9
40%Sf	30314.6	1196.3	239260	208945.4	6.9
ND	33060	1122	224400	191340	5.8

deficit at vegetative stage (vs), flower stage(Fs) and seed formation stage (S). The 20% deficit irrigation level at vegetative stage gave a net income of 280,362.8 Birr/ha (Two hundred thousand and three hundred sixty two birr) and highest cost benefit ratio of 9. Thus, the findings summarized that using deficit irrigation of 20% were economically profitable and saves water than no deficit at all growth stage at study area.

Conclusion and Recommendation

In western Hararghe, where this study was done is affected by constraints of water scarcity, less irrigation availability, lack of improved seed of onion and low rain fall. So, this study on deficit irrigation improves water productivity, irrigation water management and onion seed production resulting in water saving by maintaining soil moisture content below optimum level throughout growth season. The onion seed yields and field water productivity are higher with less water stress and reduced with increase in water stress. From this study, it is recommended that 20% deficit irrigation shows the highest onion seed yield. As well as the findings summarized that using deficit irrigation of 20% were economically profitable and saves more water than no deficit at all growth stage at study area and in similar irrigation available agro ecology.

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References

1. CSA (Central Statistical Agency). "Agricultural Sample Survey Report on Area and Production of Major Crops during Meher Season (2018/19 (2011 E.C.)" *Statistical Bulletin No* (2019).
2. Bezabih Emana, Hadera Gebremedin. 2007 "Constraints and opportunities of horticulture production and marketing in eastern Ethiopia. Dry Lands Coordination Group" *DCG Report* (2007): 91.
3. Gamachu Ayala, Beyisa Muleta and Tadele Geremu. "Assessment of Status of Irrigation Practice and Utilization in Western Hararghe Zone, Oromia, Ethiopia" *journal of Civil and Environmental Research* (2018).
4. Getachew Tabor and Mohammed Yesuf. "Mapping the Current Knowledge of Carrot Cultivation in Ethiopia" *Technical Report Submitted to Carrot Aid, Charlottenlund, Denmark* (2012).
5. Amsalu Ayana, Victor Afari-Sefa, Bezabih Emana, Fekadu F. Dinssa and TesfayeBalemi et al. 2014 "Analysis of Vegetable Seed Systems and Implications for Vegetable Development in the Humid Tropics of Ethiopia" *International Journal of Agriculture and Forestry* (2014)4: 325-337.
6. Dilip Kumar Roy, Sujit Kumar Biswas, AbdurRazzaqueAkanda, KhokanKumerSarker and AbedaKhatun. "Effect of Irrigation at Different Growth Stages on Yield, Water Productivity and Seed Production of Onion (*Allium cepa* L. CV BARI Piaz-1)" *American Journal ofAgriculture and Forestry (2014)*2: 256-261

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