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Full Length Research Paper

Effect of Irrigation Depth and Nitrogen Levels on Growth and Bulb Yield of Onion (*Allium cepa* L.) at Algae, Central Rift Valley of Ethiopia

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Abstract
A field experiment was carried out at Algae ATVET College during 2013/14 dry season to determine the effect of irrigation depth and nitrogen levels on growth and bulb yield of onion. The treatments comprised of three irrigation (50, 75 and 100% of crop water requirements (ETc)) and four nitrogen levels (0, 46, 92 and 138 kg ha^{-1})which were laid out in a split-plot design using irrigation as main plot and nitrogen level as subplot with three replications. The irrigation was applied throughout the growth season. Data on plant growth and bulb yield were collected and analyzed. The result showed that irrigation and nitrogen levels significantly affected plant height, leaf number per plant, leaf length, average bulb weight, bulb diameter and length, marketable and unmarketable bulb yield, total biomass and bulbs yield, days to maturity and harvest index per plant, except bulb dry matter, which didn't show significant variation due to application of nitrogen. These parameters, except leaf and bulb length, bulb dry matter, days to maturity and harvest index per plant were also significantly affected by the interaction of irrigation and nitrogen levels. In the present result, application of irrigation water at 100% ETc fertilized with 138 kg N ha^{-1} recorded the highest total bulb yield (36.78t ha^{-1}) and marketable bulb yield (35.62t ha^{-1}), but no significant difference was showed with 92 kg N ha^{-1} with the same irrigation. However, treatment combinations of irrigation at 50 % ETc and no N (control) produced low amount of total bulb yield (19.84 t ha^{-1}) and marketable bulb yield (18.43 t ha^{-1}).Therefore, use of irrigation water at 100% ETc fertilized with 92 kg N ha^{-1} could be the best for maximum bulb yield of Bombay Red onion variety in Algae. However, under conditions that water resources are scarce, the crop can be irrigated using 75% ETc level of irrigation water fertilized with 92 kg ha^{-1} nitrogen.

Keywords: *Bulb yield, Irrigation, Nitrogen*

Introduction

Onion (*Allium cepa* L.) belongs to the genus *Allium* of the family *Alliaceae* and it is bulbous, biennial herb which gives off a distinctive and pungent odor when the tissues are crushed (Rai and Yadav, 2005). Onion is one of the most important crops and used both as a vegetable and spice (Barzegar *et al*., 2008).

Onion (*Allium cepa* L.) is a popular vegetable in Ethiopia and produced in many home gardens and commercially in different parts of the country. Its production is rapidly increasing both under rain-fed condition and irrigation (Fekadu and Dandena, 2006). The area under onion production in the country is increasing from time to time mainly due to its high profitability per unit area and ease of production and increases in small scale irrigation schemes (CSA, 2010). Despite area increase, the average productivity of onion is low and, at present, the national average yield is as low as 10.75 t ha^{-1} as compared to many African countries and the world average yield of 17.30 t ha^{-1}(FAO, 2010) due to lack of information on appropriate nitrogen fertilizers and irrigation regimes (Pathak, 1994), soil physical and chemical characteristics, and disease and pest problems (Abbey and Joyce, 2004). Takele (2004) also reported that soil fertility and water availability are the most serious limiting constraints for crop production in Ethiopia.

Because of their shallow and un-branched root system, onion and other *Alliums* are most susceptible compared to many crops in extracting moisture and nutrients. This makes moisture and nitrogen management a key factor in its production. Hence, they require and often respond well to additional fertilizers and supplemental irrigation (Kebede, 2003). In the study area, irrigation is applied without considering the optimum crop water requirements and application of nitrogen is also based on the national recommendation which does not take cultivar and soil fertility and moisture regimes. As a result, inadequate management of irrigation water and fertilizer was considered to be important limiting factor to onion production in the study area. The reasons behind the improper use of water and nitrogen fertilization are that sufficient information on the simultaneous application of water and nitrogen fertilization is not available in the study area. In view of the existing problem, this study was proposed with the objective to determine the effect of irrigation depth and nitrogen levels on growth and bulb yield of onion.

Materials and methods

Description of the Study area

The experiment was conducted at Algae ATVET College during 2013/2014 dry season. Algae are located 217 km south of Addis Ababa and 32 km west of Bulbula town. It is situated between 7^0 65' N latitude and 38^0 56' E longitudes and at an altitude of 1600 meters above sea level in the agro- ecology of dry plateau of the southern part of the Ethiopian rift valley. Annual rainfall is 800 mm, annual mean minimum and maximum temperatures are 11^0C and 28^0C, respectively.

Materials Used in the Study

Bombay Red onion variety was used for the study as it is dominantly produced at the study area. Mineral nitrogen and phosphorus fertilizers in the form of Urea and TSP, respectively was used.

Experimental Treatments and Design

The experiment consisted of three irrigation [50, 75 and 100% of crop water requirement (ETc)] and four nitrogen levels (0, 46, 92 and 138 kg N ha^{-1}) which were laid out in split plot design using irrigation as main plot and nitrogen level as sub-plot and replicated three times. Full irrigation (100% ETc) implies the amount of irrigation water applied in accordance with the computed crop water requirement with the aid of CROPWAT model software program.

Crop establishment and fertilizer application

Bombay Red onion seedlings were raised on a well prepared seedbed following proper management practices to produce healthy seedlings. Seedlings were hardened before transplanting to the main field to enable them withstands the field conditions. The experiment field was ploughed by tractor, levelled and ridge was made manually for planting. Seedlings were carefully transplanted after 45 days to the experimental plots using double rows with spacing of 40cm ridges including 20cm between the double rows and 10cm between plants. Each experimental plot had 2 m length and 2.4m width having an area of 4.8 m^2, with six double rows, and 20 plants per row, total plants were 240 per plot. The distance between subplot, main plots and blocks were 1m and 1.5m and 1.5m, respectively. After transplanting three times full irrigation water were applied at three day intervals before commencement of the irrigation treatments for each plot in order to ensure good plant establishment. Immediately after crop establishment, the respective irrigation treatments were applied to individual plots according to the treatments designed using bucket of known volume.

As per P recommendation made for the onion in the form of TSP and half dose of N rates of each treatment were applied uniformly to all plots during transplanting. The remaining half doses of N rates of each treatment were side-dressed 45 days after transplanting. The source of N was urea fertilizer (46% N). Other than the treatments, uniform field management, disease, insect pest, and weed control and cultivation were performed to all plots as per the recommendation made for the crop.

Irrigation scheduling and crop water requirement

Irrigation scheduling was done using the CROPWAT model software program and adopting the weekly irrigation interval commonly used in the study area. To determine crop water requirements, the reference evapotranspiration (ETo) was calculated by feeding long term (ten years) climatic data that included rainfall, maximum and minimum temperatures, relative humidity, wind speed and sunshine hours collected from Algae meteorological station. Then, crop water requirement was calculated using CROPWAT model from climatic, soil and crop data as inputs. The crop coefficient (Kc), root depth, critical depletion fraction (p), yield response factor (ky) and plant height of onion were adopted from the FAO irrigation and drainage Paper No.56.

The amount of irrigation water applied to each treatment was calculated after estimation of crop water requirement, so the depth of water was obtained using CROPWAT model. The volume of water applied to each plot was then calculated by multiplying the depth of water with the area of the plot (Yenus, 2013) as:

$$V = A * D * 1000$$

Where, V= Volume of water to be applied (lit),

A = Area of the plot (m^2) and D = Depth of application (m)

The calculated volume of water was measured with a bucket of known volume and applied as per the irrigation treatment to each plot manually.

Soil Sampling

For determination of bulk density (BD), moisture content at field capacity (FC) and permanent wilting point (PWP), undisturbed soil samples were collected using core sampler at soil depth of 0-20, 20- 40 and 40- 60 cm from the experimental field before planting. The available water holding capacity of the soil was obtained by subtracting the water content at PWP from that at FC. Composite soil sample was also collected using auger at soil depth 0-20cm from the experimental field to determine various physico -chemical soil properties. All the analysis was made at JIJI Lab Glass P.L.C. soil laboratory in Addis Ababa.

Data Collection

Data on growth parameters and bulb characters were recorded at physiological maturity and harvesting, respectively and expressed as average of ten randomly taken plants in each experimental plots. Maturity and yield data were determined on net plot basis.

Methods of Data Analysis

All the relevant data collected from the experimental plots were subjected to analysis of variances (ANOVA), which was computed using SAS computer soft ware program (Version 9.1) and significant treatment means were compared using least significant difference (LSD) test at $P < 0.05$ probability level.

Results and discussion

Selected Soil Properties

The laboratory analysis revealed that; the experimental site has soil moisture content at field capacity ranged from 41.55% to 46.58%, soil moisture content at permanent wilting point ranged from 21.80% to 24.45% and bulk density of 1.36 to 1.41 g /cm^3.The highest value of total available water content (221.30 mm m^{-1}) was obtained at the depth of 20 - 40 cm whereas lowest value (194.10 mm m^{-1}) was found at the of 40 - 60 cm.

The soil textural class of the experimental site was silty clay loam, having particle size distribution of 14% sand, 57% silt and 29% clay at the depth of 0 - 20 cm. Its reaction is slightly alkaline (pH = 7.87) which was suitable for onion crop production according to Lemma and Shimeles (2003). The soil was medium in total nitrogen (0.14%) and organic carbon (1.61%), low in phosphorus (3.38 mg/kg) and EC (1.24 ds/m) (Landon, 1991), and CEC (19.69 (cmol (+) kg^{-1}).

Phenology and Growth Parameters

Days to maturity

Days to maturity of onion were significantly ($P < 0.01$) affected by the main effects of irrigation and nitrogen treatments, but not significantly affected by the interaction effects of the treatments.

The present result showed that, irrigation at 100% and 75% ETc levels took relatively longer days for onion bulb to mature as compared to the 50% ETc irrigation level. Onion plants with 50% ETc irrigation level reached ten and four days earlier than 100% and 75% ETc irrigation level, respectively (Table 1). This result is in agreement with that of Brewster (1994) who reported that treatments that lacked supplemental irrigation water advanced bulb maturity of onion. Similarly, the finding of Ahmed *et al*. (2008) also showed significant decrease in the number of days to flowering of haricot and faba beans under water stress. This could be due to the fact that plants under stress tend to complete their life cycle, which enables them escape from the unfavourable conditions by ending lifecycle few days earlier than those under normal or high soil moisture conditions, thereby ensuring perpetuation of the species (Al-Suhaibani, 2009).

Days to maturity was also significantly delayed (100 days) by the application of nitrogen at the level of 138 kg N ha^{-1}, followed by 92 kg ha^{-1} N level; while plants from unfertilized plots matured earliest (94 days). However, no significant difference was observed between unfertilized plot and those received 46 kg N ha^{-1} plots. Generally, plants grown under higher nitrogen rates tended to delay maturity (Table 1). The result indicates that the prolonged time required by the plants to reach maturity at higher rates of nitrogen fertilizers may be due to enhanced cell division and stimulation of vegetative growth which, as a result, delayed maturity of the plants. The current observation is in line with Sørensen and Grevsen (2001) and Kebede (2003) who reported that higher nitrogen levels resulted in excessive vegetative growth and delayed maturity. This result also supported by Ojala *et al.* (1990) who reported that the application of higher nitrogen levels to potato promoted excessive vegetative growth and delayed maturity.

Plant height

From the analysis, highly significant difference ($P < 0.01$) in plant height was observed due to main effects of irrigation and nitrogen levels as well as their interaction effects.

Based on the result, longest plant height (57.63 cm) was recorded at 100% ETc irrigation depth fertilized with 138 kg ha^{-1} N level, but no significant difference was observed with those fertilized at 92 kg ha^{-1} N level with the same irrigation levels. On the other hand, the shortest plant height (40.56cm) was recorded from unfertilized onions at the 50% ETc irrigation level with no nitrogen. At 75% ETc irrigation level, longest (50.80 cm) and shortest (47.56 cm) plant height were recorded at nitrogen rates of 92 kg ha^{-1} and 0 kg ha^{-1}, respectively. However, no significant differences were observed among unfertilized plot and 46 kg ha^{-1}, 46 and 138 kg ha^{-1}, and 92 and 138 kg ha^{-1} N levels (Table 2). The increase in plant height with increases in nitrogen and irrigation water could be mainly due to better availability of soil moisture and sufficient up take of nutrient (N) which has enhancing effects on the vegetative growth of plants by increasing cell division and elongation. The increasing plant height with adequate depth of irrigation application also indicate the favorable effect of water in maintaining the turgor pressure of the cell which is the major prerequisite for growth (Vaux and Pruit,1983). On the contrary, shortening of plant height under soil moisture stress may be due to stomata closure and reduced CO_2 and nutrient uptake by the plants and, hence, photosynthesis and other biochemical process are hampered, affecting plant growth (El-Noemani *et al.,* 2009).

This finding is in agreement with the finding of Yenus (2013) who reported that highest and lowest plant height of shallot resulted from interaction of 151 kg N ha^{-1} with 1.2 ETc and 0 kg ha^{-1} with 0.5 ETc irrigation levels, respectively. Neeraja *et. al*., (1999) also observed that the interaction of higher level of irrigation (1.2 IW: CPE) and nitrogen (200 kg ha^{-1}) resulted in maximum plant height. The present result was also in agreement with the work of Al-Moshileh (2007) who reported that with increasing soil water supply, plant growth parameters (plant height) were significantly increased. Similarly, Biswas *et al.* (2003) reported that onion bulbs of irrigated treatments were bigger whereas plants grown without supplemental irrigation were significantly shorter. Kumar *et al*.(2007a) also reported that irrigation had significant effect on plant height; which subsequently influenced the crop yield.

Table -1. Main effects of irrigation depth and nitrogen levels on days to maturity, leaf length, bulb length, Bulb dry matter (%) and Harvest index of onion grown at Algae

Treatment	Day to maturity	Leaf length(cm)	Bulb length(cm)	Bulb dry matter (%)	Harvest index
Irrigation levels					
50% Etc	92.00^{c}	36.00^{c}	4.05^{b}	12.45^{b}	0.76^{b}
75% Etc	96.41^{b}	40.60^{b}	4.10^{b}	13.10^{a}	0.77^{b}
100% Etc	102.83^{a}	46.75^{a}	4.67^{a}	13.13^{a}	0.81^{a}
LSD (0.05)	**1.57**	**1.06**	**0.25**	**0.45**	**0.03**
Nitrogen (kg ha^{-1})					
0	94.44^{c}	39.27^{c}	4.05^{b}	13.22	0.73^{b}
46	95.66^{c}	40.88^{b}	4.28^{ab}	12.78	0.78^{a}
92	98.00^{b}	42.11^{ab}	4.46^{a}	12.84	0.80^{a}
138	100.22^{a}	42.21^{a}	4.31^{ab}	12.73	0.80^{a}
LSD (0.05)	**1.81**	**1.22**	**0.28**	**ns**	**0.04**
CV (%)	**1.88**	**3.01**	**6.82**	**4.13**	**5.43**

Means followed by the same letter are not statistically different from each other at 5% level of significant

Table - 2. Interaction effects of irrigation depth and nitrogen levels on plant height (cm) and leaf number per plant of onion grown at Algae

Irrigation Levels	Plant height (cm)				Leaf number per plant			
	Nitrogen levels (kg ha^{-1})				Nitrogen levels (kg ha^{-1})			
	0	46	92	138	0	46	92	138
50% ETc	40.56^{h}	44.66^{g}	47.33^{ef}	46.03^{fg}	5.50^{f}	5.73^{f}	6.23^{ef}	5.46^{f}
75% ETc	47.56^{ef}	48.63^{de}	50.80^{c}	49.70^{cd}	6.80^{de}	6.86^{cde}	7.86^{b}	6.70^{de}
100% ETc	51.20^{c}	53.56^{b}	56.20^{a}	57.63^{a}	7.33^{bcd}	7.73^{bc}	8.80^{a}	9.36^{a}
LSD (0.05) = 1.77		**CV (%) = 1.72**			**LSD (0.05) = 0.87**		**CV (%) = 7.49**	

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant.

Leaf number

The leaf number of onion plants was significantly affected ($P < 0.01$) by irrigation depth and application of nitrogen fertilizer as well by their interaction ($P < 0.05$). The study revealed that, interaction effects of irrigation at 100% ETc irrigation depth and nitrogen fertilization at 138 kg ha^{-1} resulted highest number of onion leaves (9 leaves per plant); while the least number (5 leaves per plant) was recorded in plots received 50% ETc irrigation level and not fertilized with N. The leaf number per plant was significantly improved at treatment combinations of 100% ETc irrigation level fertilized with 92 or 138 kg ha^{-1}nitrogen levels, which were about 20% or 28%, respectively compared to plants that didn't receive nitrogen fertilization. In general, onion plant leaf formation responded to nitrogen fertilization with availability of soil moisture (Table 2).

This result seems closely related to that of Neeraja *et al.* (1999) who obtained more number of leaves per plant of onion by the interaction effects of 1.2 IW: CPE irrigation level and nitrogen rate of 200 kg ha^{-1}. Similarly, Yenus (2013) found that highest and few number of leaves per plant of shallot from interaction of 151 kg N ha^{-1} with 1.0 ETc and 0 kg ha^{-1} with 0.5 ETc irrigation levels, respectively. Biswas *et al.* (2003) also reported that onion bulbs of irrigated treatments gave highest leaves number per plant than the non irrigated one, whereas onion grown without supplemental irrigation gave lower number of leaves. The higher leaf number per plant resulted from application of 100% ETc irrigation depth is due to the irrigation effect that facilitates nutrient availability and photosynthesis for undisrupted growth of the plant, similarly the reduced number of leaves per plant at 0.5 ETc of irrigation level or depth may be attributed to effects of water stress on cell expansion (Abbey and Joyce, 2004). This indicated that when plants respond to water stress by closing their stomata to slow down water loss by transpiration, gas exchange within the leaf is limited, consequently, photosynthesis and growth will slow down (Curah and Proctor, 1990). The result also in agreement with the findings of Wien (1997) who found that leaf number had a linear correlation with the availability of soil moisture.

Leaf length

Leaf length of onion plants was significantly ($P < 0.01$) affected by the main effects of irrigation and nitrogen treatments. However, it was not significantly affected by the interaction effect of those treatments. This study indicated that, highly significant differences were observed among the irrigation treatments in such a way that the 100% ETc irrigation depth gave the longest (46.75 cm) onion leaves; while the shortest leaf length (36 cm) was obtained under 50% ETc irrigation level. In general, leaf length increased with increasing irrigation level, as the plant does not experience moisture stress at any growth and development (Table 1).

The result supported by observation of Bagali (2012) who reported longer leaves at 100% crop water requirement compared to treatments of deficit irrigation. Water deficit leads to retarded plant growth as it results in closure of stomata and interfere with photosynthesis ability and nutrient uptake of plants and consequently, reducing cell division and growth and thus resulting in stunting of leaves. During water deficit, stomata close to conserve water, limiting carbon dioxide availability and decrease in photosynthesis. This means that carbon assimilation is reduced and therefore the rate of leaf growth is reduced. It has been demonstrated that the decrease in available water under moisture stress first affects leaf expansion and then stomata conductance and gas exchange (Sadras and Milory, 1996). Similarly, Smith (2011) quoted that the rate of transpiration, photosynthesis and growth are lowered by even mild water stresses.

Application of 138 kg N ha^{-1} gave significantly longer leaf length (42.21 cm) than the lower doses (0 and 46 kg ha^{-1}) whereas with 92 kg ha^{-1} N treatment did not show significant difference. Also no significant difference was recorded among the 46 and 92 kg ha^{-1} N levels. In general, leaf length tended to show an increasing trend as nitrogen increases (Table 1). The leaf length response to nitrogen fertilizer is in agreement with Jilani *et al*. (2004) who reported that higher rates of nitrogen resulted in longer leaves of onion. Similarly, Kebede (2003) reported that too much nitrogen promoted excessive vegetative growth (leaf length) in onion plant. The positive effect of N on leaf length may be due to the role it plays on chlorophyll, enzymes and proteins synthesis essential for vegetative growth (Halvin *et al.,* 2002) and also due to its enhancing effect on efficient uptake and utilization of phosphorus and other nutrients (Gustfson, 2010).

Yield Related and Bulb Yield Parameters

Bulb length

Irrigation and nitrogen treatments significantly affected the onion bulb length, but not their interaction ($P > 0.05$). The result indicated that, at 50% ETc irrigation level, the bulb length was significantly reduced, but no significant difference was observed with 75% ETc irrigation level. Compared to the 50 and 75% ETc irrigation treatments, 100% ETc irrigation level produced 15% and 14% longer bulbs, respectively (Table 1). This indicates that the 50% ETc irrigation level might have reduced transpiration and photosynthesis and assimilate available for growth of the crop, which thus caused to produce small bulbs. This result is in line with that of Olalla *et al.* (2004) who observed smaller sized bulbs in mild water-stressed onion plants. Similarly, Neeraja *et al*. (1999) reported that higher level of irrigation 1.2 IW: CPE resulted in maximum bulb length.

A significant difference in onion bulb length was also observed between the fertilizer treatments where 92 kg ha^{-1} N application resulted in 9% increment in bulb length compared to those from untreated control plots that resulted in the shortest bulb length (4.05 cm). However, bulb length in plants that received the different nitrogen levels didn't vary statistically (Table 1). The result agreed with observation of Mozumder *et al.* (2007) who reported that bulb length significantly increased with the increases of nitrogen fertilizer up to 150 kg ha^{-1}. The bulb length was higher with the application of nitrogen dose, may be due to higher synthesis of carbohydrates in the leaf and their translocation to the bulb, which comparatively helped in the increased length of onion bulbs (Reddy and Reddy, 2005).

Bulb diameter

The main effects of irrigation and nitrogen treatments as well as their interaction had significant effects on the bulb diameter of onion.The largest onion bulbs (5.16 cm diameter) were recorded at the 100% ETc irrigation level fertilized with 92 kg ha^{-1} N, but with no significant difference from those fertilized at 46 and 138 kg ha^{-1} N levels and received same amount of irrigation water. On the other hand, the smallest bulb diameter (3.33 cm) was recorded from plants treated with 50% ETc irrigation level with no nitrogen application. In 75% ETc irrigation level, increase in application of nitrogen up to 92 kg ha^{-1} significantly increased the diameter of onion bulbs; while further increase of nitrogen did not significantly alter bulb diameter. Also no significant differences in onion bulb diameter were recorded among treatments of 0 and 46 kg ha^{-1}, and 46 and 138 kg ha^{-1} N levels with the same irrigation level. Likewise, at 100% ETc irrigation level, increasing nitrogen from 0 to 92 kg ha^{-1} increased bulb diameter; further increasing nitrogen up to 138 kg ha^{-1} decline the bulb diameter by 4%, but no significant difference was shown among nitrogen treatments (Table 3).

The present result on bulb diameter of onion is in agreement with the findings of Kumar *et al*.(2007b) who reported that irrigation at 1.20 Ep and fertigation at 200 kg N ha^{-1} resulted in the highest bulb size. Similarly, Neeraja *et al.* (1999) reported that higher level of irrigation 1.2 IW: CPE and 200 kg N ha^{-1} and their interaction resulted in maximum bulb diameter which is in line with the present result. Yenus (2013) also reported that, largest and smallest bulb diameter resulted from interaction of 151 kg N ha^{-1} with 1.2 ETc and 0 kg ha^{-1} with 0.5 ETc irrigation levels, respectively.

Table -3. Interaction effects of irrigation and nitrogen levels on bulb diameter (cm) and average bulb weight (g) of onion grown at Algae

Irrigation Levels	Bulb diameter (cm)				Average bulb weight (g)			
	Nitrogen levels (kg ha^{-1})				Nitrogen levels (kg ha^{-1})			
	0	46	92	138	0	46	92	138
50% ETc	3.33^{h}	3.96^{g}	4.16^{fg}	4.33^{def}	29.50^{f}	36.11^{f}	6.86^{e}	49.34^{de}
75% ETc	4.13^{fg}	4.23^{efg}	5.13^{a}	4.53^{cde}	47.73^{e}	56.62^{d}	76.68^{b}	50.41^{de}
100% ETc	4.67^{bcd}	4.86^{abc}	5.16^{a}	4.93^{ab}	65.15^{c}	77.33^{b}	81.10^{b}	93.60^{a}
LSD (0.05) = = 0.35		**CV (%) = 4.38**			**LSD (0.05) = 7. 58**	**CV (%) = 8.11**		

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant.

Average bulb weight

The average bulb weight of onion was significantly affected ($P < 0.01$) by the main effects of irrigation and nitrogen treatments as well as by their interaction effects. The highest average bulb weight (93.6g) was recorded from plots that received 138 kg N ha^{-1} fertilization with 100% ETc irrigation treatment combinations; while the least average bulb weight (29.50g) was obtained from non-fertilized plots irrigated at 50% ETc. At 75% ETc irrigation level, plots fertilized with 92 kg ha^{-1} N produced the highest average bulb weight followed by 46 kg ha^{-1} N level while the lowest average bulb weight was produced by unfertilized treatments, which were at par with those fertilized with 138 kg ha^{-1} N. Under 100% ETc irrigation level, the unfertilized plot notably reduced the average bulb weight compared to the three nitrogen levels; the average bulb weights increased up to nitrogen level of 138 kg ha^{-1}, but 46 and 92 kg ha^{-1} N levels showed no significant difference on the average bulb weight of onion (Table 3). In general, mean bulb weight of onion responded to nitrogen and this improved with increased level of irrigation water applied. The increment in bulb weight due to increase in irrigation and nitrogen levels might be due to the growth of taller plants with higher number of leaves causing better synthesis and transportation of assimilates from source to sinks (Biswas *et al.*, 2003).

In agreement with the present result, Neeraja *et al*. (1999) and Kumar *et al.* (2007b) reported that interaction of higher level of irrigation 1.2 IW: CPE and 200 kg N ha^{-1} resulted in maximum bulb weight of onion. Similarly, Abdulaziz (2003) reported average bulb weight of onion was significantly increased at 120% ETc irrigation levels. Hassan (2007) also reported that largest average bulb weight was obtained with 90 kg N ha^{-1}. Similarly, Nasreen *et al*. (2007) indicated that high nitrogen level increased the bulb weight of onion.

Total biomass yield

The total biomass yield of onion which is the sum of all above and underground biomass was highly influenced by irrigation and nitrogen treatments. Their interaction had also highly significant ($P < 0.01$) effect on total biomass yield of onion.

From this result, 100% ETc irrigation level combined with fertilization at 138 kg N ha^{-1}, followed by same level of irrigation combined with 92 kg ha^{-1} N fertilization gave the highest total biomass yield with no significant variation among them. Under 50% ETc irrigation level, the total biomass yield showed significant increase at nitrogen fertilization level of 92 kg ha^{-1} while the other nitrogen levels didn't show variation from non-fertilized plot. Similarly, at 75% ETc irrigation level, highest total biomass yield was recorded with nitrogen fertilizer level of 92 kg ha^{-1}, but no significant difference was showed between unfertilized plot and the remaining nitrogen levels. On the other hand, at the 100% ETc irrigation level, increasing the nitrogen level significantly increased the total biomass yield with the highest yield (45.63 t ha^{-1}) at 138 kg ha^{-1}. However, no significant difference among 46 and 92 kg ha^{-1}, and 92 and 138 kg ha^{-1}nitrogen levels with the same irrigation levels (Table 4).

This result is consistent with findings of Neeraja *et al.* (1999) who reported that the interaction of higher level of irrigation 1.2 IW: CPE and 200 kg N ha^{-1}resulted in maximum biomass yield. Water shortage reduces biomass yield through its influence up on any one of the yield components or their combination. Hence, the response of total biomass yield to high amounts of water and nitrogen application could be attributed to the improvement of water to nutrients availability to the plant root and its enhancing effect on crop's biological function, which improves the growth of the crop (Abdulaziz, 2003).

Subedi *et al.* (2002) also found that total biomass of onion was significantly reduced at low irrigation level. Similarly, Kumar *et al*.(2007a) and Enciso *et. al*., (2009) found that irrigation highly affected the total onion yield, yield components and morphological characteristics of onion bulbs. The reason for lowest total biomass yield at 0.5 ETc may be because of plants response of closing their stomata under water stress to slow down water loss by transpiration; consequently, gas exchange within the leaf is limited and photosynthesis and growth will slow down (Curah and Proctor, 1990). Moreover, the shallow root system of onion leads to less access to reserve water for the root and thus limit growth of the plant (Brewster, 1994).

The response to nitrogen fertilization is also in agreement with results of Neeraja *et al*. (1999) who reported that application of nitrogen fertilizer at the rate of 150 kg ha^{-1} increased biological yield of onion. The increase in biomass yield in response to the increased N application may be ascribed to the predominant role that N plays in enhancing the physiological function of plants through promoting leaf expansion, photosynthesis, and resulting dry matter accumulation (Balasubramaniyan and Planiappan, 2001). Similarly, this result is consistent with that of El-Tsntawy and El-Beik (2009) who reported that highest total biomass yield of onion at higher dose of nitrogen.

Table -4. Interaction effects of irrigation and nitrogen levels on total biomass yield (t ha^{-1}) and marketable bulb yield (t ha^{-1}) of onion grown at Algae

Irrigation Levels	Total biomass yield (t ha^{-1})				Marketable bulb yield (t ha^{-1})			
	Nitrogen levels (kg ha^{-1})				Nitrogen levels (kg ha^{-1})			
	0	46	92	138	0	46	92	138
50% ETc	20.58 ^{f}	23.29^{ef}	26.97^{e}	24.19^{ef}	18.43^{f}	20.65^{def}	22.68^{de}	20.15^{ef}
75% ETc	31.77^{d}	34.04^{d}	36.3^{cd}	32.65^{d}	23.03^{d}	27.43^{c}	28.48^{bc}	26.71^{c}
100% ETc	34.29^{d}	39.23^{bc}	42.51^{ab}	45.63^{a}	26.99^{c}	30.98^{b}	34.18^{a}	35.62^{a}
LSD (0.05) = 4.64		**CV (%) = 5.35**			**LSD (0.05) = 2.74**		**CV (%) = 4.95**	

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant.

Marketable bulb yield

Marketable bulb yield of onion was significantly affected ($P < 0.01$) by the irrigation and nitrogen levels. Similarly, highly significant interaction effect of irrigation and nitrogen was observed on the marketable bulb yield of onion. Under 50% ETc irrigation level, marketable bulb yield increased by about 23% at 92 kg ha^{-1} nitrogen compared to lowest yield (18.43t ha^{-1}) recorded from unfertilized plots; further increase of nitrogen to 138 kg ha^{-1} did not significantly show variation, rather it showed a drop by about 11% and leveled off with yields from control plots and those fertilized at 46 kg ha^{-1}nitrogen. At 75% ETc irrigation level, the highest marketable bulb yield (28.48 t ha^{-1}) was produced at 92 kg ha^{-1} N level while the lowest marketable bulb yield (23.03 t ha^{-1}) was obtained from unfertilized plot. However, no significant difference was showed among yields at 46, 92 and 138 kg ha^{-1} N levels, which were at par. In 100% ETc irrigation level, the unfertilized plot notably reduced the yield of marketable bulb as compared to the three nitrogen levels, which were at par. Similarly, the highest marketable bulb yield (35.62t ha^{-1}) was recorded at 100% ETc irrigation level combined with 138 kg ha^{-1} nitrogen, which however, didn't vary from 92 kg ha^{-1} N (Table 4). From the present result it can be deduced that higher irrigation and nitrogen levels help to increase the vegetative growth of the plant which has improved average assimilate available for storage and increased average bulb weight that gave an advantage to increase the marketable bulb yield.

The present result agrees with the general principle that the response of crop to fertilizers is generally higher under irrigated conditions than non irrigated one (Michael, 1978). The increment in marketable bulb yield due to application of nitrogen and irrigation water could be attributed to the increment in vegetative growth and increased production of assimilate, which is associated with increment in leaf area index, bulb diameter and average bulb weight (Neeraja *et al*., 1999). Yenus (2013) found that highest and lowest marketable bulb yield of shallot from interaction of 151 kg N ha^{-1} with 1.2 ETc and 0 kg ha^{-1} with 0.5 ETc irrigation levels, respectively. Kumara *et al*. (2007b) also reported that the percentage of B-grade (commercially important) bulbs were considerably higher at irrigation level of 1.20 Ep and fertigation of 200 kg N ha^{-1} interaction.

Unmarketable bulb yield

The analysis of variance indicated that unmarketable bulb yield of onion was significantly ($P < 0.01$) affected by irrigation and nitrogen alone and by their interaction. Based on the result, highest unmarketable bulb yield (2.62 t ha^{-1}) was recorded with 50% ETc irrigation level combined with fertilization at 92 kg ha^{-1} followed 138 kg ha^{-1} N level, with no statistical difference among them. Similarly, under 75% ETc irrigation level, nitrogen application at 138 kg ha^{-1} produced the highest unmarketable bulb yield followed by that of 92 kg ha^{-1} N level; while the lowest yield of unmarketable bulb yield was obtained in unfertilized plots. However, no significant difference was observed among 0 and 46 kg ha^{-1} as well as among 92 and 138 kg ha^{-1} N levels with the same irrigation depth. In 100% ETc irrigation level, the unfertilized plot notably produced low yield of unmarketable bulb (0.77 t ha^{-1}) compared to the three nitrogen levels. In general, the yield of unmarketable bulbs was significantly increased as nitrogen level increased up to 138 kg ha^{-1} N level and irrigation dropped from 100% to 50% ETc irrigation levels (Table 5). From present result, increasing N fertilizer with increasing water deficit had a positive relationship with the production of high yield of under size bulbs. This might be due to low availability and utilization of N nutrient which is needed for foliage growth and photosynthesis activity that contribute to bulb growth and developments.

The result revealed that, yield of very small bulbs increased with deficit irrigation. Stressed onion plants may bulb too early, produce small-sized bulbs and bulb splits and, thus, produce high amount of unmarketable yield (Kebede, 2003). This could be due to low rate of transpiration caused by stomata closer under moisture stress condition which brought about reduced photosynthesis and poor bulb growth and developments. Corresponding to this, Martin *et al*. (2004), Olalla *et al*. (2004) and Zayton (2007) reported that plots which received the lowest volumes of water during the development and ripening stages produced higher percentage of small size bulbs.

Table-5. Interaction effects of irrigation and nitrogen levels on unmarketable bulb yield (t ha^{-1}) and total bulb yield (t ha^{-1}) of onion grown at Algae.

Irrigation Levels	Unmarketable bulb yield (t ha^{-1})				Total bulb yield (t ha^{-1})			
	Nitrogen levels (kg ha^{-1})				Nitrogen levels (kg ha^{-1})			
	0	46	92	138	0	46	92	138
50% ETc	1.41^{c}	2.18^{b}	2.62^{a}	2.51^{a}	19.84^{g}	22.82^{ef}	25.30^{ed}	22.66^{f}
75% ETc	0.95^{efg}	1.08^{ef}	1.36^{cd}	1.48^{c}	23.98^{ef}	28.78^{c}	29.84^{bc}	27.86^{cd}
100% ETc	0.77^{g}	0.88^{fg}	1.09^{ef}	1.16^{de}	27.76^{cd}	31.86^{b}	35.27^{a}	36.78^{a}
LSD (0.05) = 0. 20		**CV (%) = 8.71**			**LSD (0.05) = 2.63**		**CV (%) = 4.45**	

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant.

Total bulb yield

The total bulb yield which is the sum of unmarketable and marketable bulb yield was highly influenced by irrigation and nitrogen treatments. A highly significant difference ($P < 0.01$) in total bulb yield was also observed due to the effect of irrigation by nitrogen interaction.

Generally, application increased level of nitrogen produced higher total bulb yields with increased level of irrigation depth. The highest total bulb yield (36.78t ha^{-1}) was recorded under 100% ETc irrigation level combined with application of 138 kg ha^{-1} N while the lowest value (19.84t ha^{-1}) was obtained from application of 50% ETc irrigation level with no N fertilizer. Under 75% ETc irrigation depth, the highest and lowest total bulb yields were recorded at 92 kg ha^{-1}nitrogen and unfertilized plots, respectively; however, no significant difference was recorded among 46, 92 and 138 kg ha^{-1} N treatments. In the 100 % ETc irrigation level, N application at 92kg ha^{-1} and 138 kg ha^{-1} improved total bulb yield by about 27% and 32%, respectively compared to that of unfertilized plot, but the two (92 and 138 kg ha^{-1}) had no significant difference with the same irrigation levels (Table 5). The high total bulb yield produced due to N application and higher irrigation water depth might be because of increased photosynthetic area of the plant (height of plants and number of leaves) which increased the amount of assimilate that could be partitioned to the storage organs (increased bulb diameter and mean bulb weight) which consequently increased the total bulb yield.

In agreement with the present result, Neeraja *et al*. (1999) obtained that the interaction of irrigation level of 1.2 IW: CPE by nitrogen rates of 150 or 200 kg ha^{-1} resulted in maximum bulb yield. Similarly, Yenus (2013) obtained highest and lowest total bulb yield of shallot from interaction of 151 kg N ha^{-1} with 1.2 ETc and 0 kg ha^{-1} with 0.5 ETc irrigation levels, respectively. Mayer and Marcum (1998) also showed that maximum yield of potato was obtained at 1.10 to 1.2 ETc applied water and application of 168 to 224 kg N ha^{-1}.

The increment in onion total bulb yield might be attributed to large size of onion bulb due to application of high nitrogen dose; this is because nitrogen encourages cell elongation, above ground vegetative growth and imparts dark green color of leaves which is important for more assimilate production and partition that favors onion bulb growth (Brady, 1985). The increased total bulb yield by applying combination of high N and full (no deficit) irrigation could be mainly due to better N uptake and performance of vegetative growth like plant height, number of leaves and leaf length which increase photosynthetic capacity of the plant, which in turn improved bulb weight that contributed to increment in total bulb yield.

Harvest index

Analysis of variance indicated that harvest index was significantly influenced by the main effect of irrigation and nitrogen treatments. However, their interaction had no significant effect on harvest index of onion.

Irrigation level at 50% ETc statistically decreased the harvest index, compared with 75% ETc and 100% ETc of irrigation water. On the other hand, at 100% ETc irrigation level, highest value (0.81) of harvest index of onion was recorded; while the lowest value (0.76) was obtained from 50% ETC irrigation water, however no significant difference among 50 and 75% ETc irrigation levels (Table 1). The result in response to irrigation regime was similar to that of Yenus (2013) who reported that increasing the amount of irrigation statistically increased the harvest index of shallot in North West Ethiopia.

Except unfertilized plots, in all level of nitrogen treatments, harvest index showed no significant difference. However, the harvest index showed an increased trend as nitrogen increased from 0 to 138 kg ha^{-1} levels (Table 1). The result was similar with that of Abdissa (2008) who observed that harvest index of onion increased with increase of nitrogen up to 115 kg ha^{-1} compared to the untreated control. This could be attributed to improved photosynthetic capacity of plants and movement of assimilates from the leaves to the bulbs during the growing period.

Bulb dry matter content

Irrigation level significantly affected ($P < 0.01$) the bulb dry matter of onion bulb. However, nitrogen and its interaction with irrigation level had no significant effect on this parameter.

Compared to the 75% and 100% ETc irrigation depth, which didn't show variation statistically; mean bulb dry matter content at 50% ETc irrigation depth decreased by about 5%. On the other hand, nitrogen application tended to reduce the dry matter content of onion bulbs although the values were not statistically different from those of unfertilized crops (Table 1).

In agreement with the present result, Al-Kaisi and Broner (2005) reported that water stress at any growth stage of onions results in dry matter yield reduction, which could possibly be due limitation in assimilate production and accumulation in bulbs under stress conditions. Kumar *et al*.(2007b) reported that irrigation at 1.20 Ep (highest water supply) produced higher dry matter yield. On the contrary, Olalla *et al*. (2004) reported that the dry matter yield was not affected by the volume of water intake (with volumes ranging from 603.1 to 772.0 mm) in drip irrigation system. Similarly, Kebede (2003) observed that moisture stress had no significant effect on bulb dry matter content of shallot, but it tended to be high in plants stressed at the late stage of growth.

In line with dry matter accumulation response to N application in this result, Maier *et al.* (1990) reported that dry matter of onion bulbs was not affected by nitrogen application. This result indicates that nitrogen fertilizer at lower rate would result in bulb with proportional dry matter content of onion. Patricia and Bansal (1999) also reported that nitrogen application had no effect on potato tuber dry matter. However, Sørensen and Grevsen (2001) reported that excessive nitrogen resulted in a vigorous vegetative growth and reduced dry matter contents of onion bulbs.

Summary and Conclusion

Onion (*Allium cepa* L.) is a widely recognized cash crop, successfully produced under rain fed as well as irrigated conditions in different parts of Ethiopia. The area under onion production in the country is increasing from time to time. Despite area increases, the productivity of the crop is much lower due to different problems. However, lake of information and adoption of appropriate fertilizer rates and irrigation regimes are among the major problems that cause low productivity of onion. This research was undertaken to study the effect of irrigation depth and nitrogen levels on growth and bulb yield of onion at Algae.

Therefore, the study showed that that, highest yield of marketable and total bulb yield of Bombay Red onion variety were obtained at 100% ETc irrigation depth fertilized with 138 kg ha^{-1} N levels, but no significant difference with 92 kg N ha^{-1} at the same irrigation levels or depths. Therefore, it can be concluded that, at Algae area under no limitation of soil moisture, yield of Bombay Red onion variety could be improved substantially through irrigating 100% ETc irrigation amount with 92 kg ha^{-1} of nitrogen fertilizers. However, under conditions that water resources are scarce, it can be recommended that Bombay Red onion variety can be irrigated with 75% ETc irrigation amount fertilized with 92 kg N ha^{-1}.

Since this experiment is a one-year study in a single environment, further research over locations and years is warranted to confirm the present results.

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