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Yield and Yield Components of Onion (*Allium cepa* L.) as Affected by Irrigation Scheduling and Nitrogen Fertilization at Hawassa Area Districts in Southern Ethiopia

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ABSTRACT

This study investigated the effects of different Nitrogen (N) levels and irrigation regimes on yield and yield components of Onion (*Allium cepa L.*) at Hawassa area district, southern Ethiopia in 2012. It was a factorial experiment laid out in split plot design with three replications of four irrigation regimes and five N levels. Data on yield and yield components were collected and analyzed. Application of N at different levels and irrigation regime increased total and marketable bulb yield over the unfertilized plot, and their interaction showed a significant effect on the average bulb weight; mean bulb diameter and water productivity of onion. Further increase in N application beyond 100 kg Nha^{-1} and irrigation beyond 75% crop evapo-transpiration ETc did not bring about significant changes. Therefore, 100 kg Nha^{-1} and irrigation at 75% ETc can be tentatively recommended for onion production to the studied area.

Key words: Onion, Nitrogen Level, Irrigation Regime, Bulb Yield and Yield Components.

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INTRODUCTION

Onion (*Allium cepa* L.) is a member of the *Alliaceae* family and is one of the most important vegetables in the world (Gambo et al., 2008). In Ethiopia, onion is produced in many parts of the country by small farmers, private growers and state enterprise (Lemma and Shimelis, 2003). National production of onion is estimated to be over 169.32 thousand metric tons of dry bulb per annum and yield per hectare is 9.6 t (CSA, 2010). Despite onion is rapidly becoming the most popular vegetable among producers and consumers in Ethiopia, the present production level do not meet the demand of the country. Its productivity is also far below the level realized at global level 19.5 t ha^{-1} (FAO, 2010). Several factors are responsible for this discrepancy, among which irrigation and fertilization are the foremost factors (Lemma and Shimelis, 2003; Fekadu and Dandena, 2006).Many experiments have been conducted on onion for optimum N rate fertilization (Kumar et al., 2001; Khan et al., 2002; Lemma and Shimelis, 2003; Abdissa et al., 2011), however, recommendations vary widely. For instance, Lemma and Shimelis (2003) reported that application of 92 kg N ha^{-1} was found adequate for dry bulb production in upper Awash region in Ethiopia, but Abdissa et al. (2011) proved that application of 69 kg N ha^{-1} enhanced the growth and bulb yield of onion in Showa Robit, Ethiopia. Many investigations have been carried out worldwide regarding the effects of irrigation regime on yield of onion (Kebede, 2003; Samson and Ketema, 2007; Pejic et al., 2011). However, most of these studies assessed the effect of reduced water stress (irrespective of appropriate irrigation scheduling to the entire growth stage on bulb yield).Thus, the current field experiment intended to assess the effects of different N levels and irrigation regimes on yield and yield components of onion in the vicinity of Hawassa zuria conditions, southern Ethiopia.

MATERIALS AND METHODS

Description of the Studied Site

These experiments were conducted at farmers' field at Jara Gelelcha in Hawassa Zuria Woreda, Ethiopia during January to June of 2012. The experiments were conducted on sandy soils, which have sandy loam texture with pH value of 8.58. It contains total N of 0.1% and available P of 10.86 mg of P_2O_5 /kg of soil.

Experimental Layout and Data Collection

The experiment comprised a factorial combination of four different furrow irrigation regimes (25, 50, 75 and 100% of crop evapotranspiration) and five different N levels (0, 50, 100, 150 and 200 kg of N ha^{-1}). The experiment was laid out in split plot design with three replications. Irrigation levels were assigned to main plots while N levels to sub plots. The total experiment was, carried out with 40 cm bed including furrow, 20cm between rows on the bed and 10 cm between plants.The variety *Bombay red* of Onion was used as a test variety for the experiment. Seeds were sown at a rate of 3.5-4.0 kg ha^{-1} on 4th January and were transplanted on 18 February, 2012. The recommended rate of P in addition to the N of the treatments were applied at transplanting to all the treatments in the form of di-ammonia phosphate (100 kg ha^{-1}) ,except the unfertilized plot (0 kg of N ha^{-1}) on which tri-super phosphate TSP was used as main source of P. Accounting for the N amount in DAP the remaining N were applied in split bundle application of 50% Urea at transplanting, and the remaining half dose of N was side-dressed 45 days after transplanting.

The crop evapotranspiration (ETc) was estimated using reference evapotranspiration (ETo). The ETo was estimated using climatic data such as; maximum and minimum temperature; relative humidity; sunshine hours and wind speed data obtained from Hawassa weather station for the period 2002 to 2011, according to FAO Penman-Monteith method through the CROPWAT program. Then, ETc of onion was obtained by multiplying ETo with crop coefficient (Kc). The crop coefficient values were adopted from the FAO (2010), and using FAO crop coefficients for onions (0.7 for initial, 1.05 for mid, and 0.75 for end season) as suggested by Allen et al. (1998). The volume of water applied to each plot was then calculated by multiplying the depth of water with the area of the plot (4.48 m^2) as:

$$V = A * d * 1000 \qquad (1)$$

Where V= volume of water to be applied in liter (l), 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 using graduated watering cane as per the irrigation treatments to each plot. Rainfall during the growing season was controlled by plastic cover. For each treatment, the water productivity, WP (kgm^3) was calculated using the following formula as described by Michael (1997),

$$WP = \frac{\text{buld yield}}{\text{water applied}} \qquad (2)$$

(Five plants from each plot were randomly selected for recording growth parameters *such as;* plant height; numbers of leaves per plant; leaf area index and plant biomass). For yield and yield components, the three central double rows were harvested at final harvesting time.

Data Analysis

The means of the above parameters were subjected to analysis of variance (ANOVA) using SAS version 9 computer software. Mean comparison was done by using least significant difference test at 5% probability level. Correlation among the parameters was determined using Pearson's simple correlation coefficient.

RESULTS AND DISCUSSION

Bulb Weight

The interaction effect of irrigation schedule and N level on the average weights of onion bulb was significant ($p \leq 0.05$) (Table 1). Bulb weight of onion initially increased with increase in irrigation frequency and nitrogen level but declined at higher levels of irrigation and N (Table 2). However, both the magnitudes and patterns of increase or decrease were not the same at all N and irrigation levels. Thus, at 100 kg N ha^{-1}, increasing irrigation frequency from 25 to 75% ETc increased mean bulb weight of onion by 19 and 49%, but further increase has no significant effect. Similarly, at 75% ETc, increasing N levels from 50 to 150 kg N ha^{-1} increased mean bulb weight by 48 and 25%, while further increase in N had no significant effect. Similar results were observed at other irrigation and N levels.The interaction results showed that bulb yield of onion is determined by both N levels and irrigation frequency. Bulb weight increased with increasing N level, reaching maximum at higher N rate in combination with increasing reduced water stress level. These results were similar to the findings of Al-Barrak (2006) and Shirazi et al. (2011) in canola and maize, respectively, who found that irrigation and nitrogen in combinations at optimum levels increased economic parts of these crops.

Heavier bulbs of onion at higher N and irrigation combination can be explained by the fact that, at increasing reduced water stress level up to 75% ETc and thereafter, the quantity of applied water at each irrigation time being just sufficient to wet the root zone without causing water leaching, thereby preventing leaching

Table 1. Mean squares of onion as affected by nitrogen and irrigation levels.

Source of variation	DF	BW	BD	MY	TY	WP	HI
Rep (R)	2	115.33^{ns}	0.16^{ns}	1077.7***	824.1***	104.62**	0.006^{ns}
Irrigation (I)	3	1499.11**	8.24***	505.48***	815.8***	85.96**	0.02**
Nitrogen (N)	4	2004.7***	6.64***	190.76***	184.2***	26.33***	0.05***
I*N	12	174.66*	0.57**	17.46^{ns}	11.39^{ns}	5.7**	0.002^{ns}
Rep*I	6	227.39*	0.11^{ns}	8.17^{ns}	22.29^{ns}	13.31***	0.001^{ns}
Error	32	82.14	0.23	10.19	10.46	1.961	0.002

DF = degree of freedom, BW = bulb weight, BD = bulb diameter, MY = marketable yield, TY = total yield, WP = water productivity, HI = harvest index, rep = replication, ns = non-significant at 5% probability level, * = significant at 5% level, ** = significant at 1%, *** = significant at 0.1%.

Table 2. Interaction effect of irrigation and nitrogen levels on bulb weight (g/bulb) of onion plant.

Treatments	N rate (kg ha^{-1})				
Irrigation level (% ETc)	**0**	**50**	**100**	**150**	**200**
25	42.63	58.31	70.9	71.18	65.91
50	55.77	68.37	84.51	77.76	79.71
75	62.51	71.84	106.3	90.19	85.09
100	60.11	64.66	86.69	110.4	90.19

$LSD_{0.05}$ for comparing two irrigation levels at a single N rate = 21.
$LSD_{0.05}$ for comparing two N rates at a single irrigation level = 15.1.

Table 3. Interaction effects of irrigation and nitrogen on bulb diameter (cm) of onion plant.

Treatments	N rate (kgha^{-1})				
Irrigation level (% ETc)	**0**	**50**	**100**	**150**	**200**
25	3.43	4.03	4.71	4.64	4.64
50	4.52	5.19	5.74	5.36	5.38
75	4.3	5.53	6.16	6.16	6.29
100	4.35	5.22	6.95	7.36	6.2

$LSD_{0.05}$ for comparing two irrigation levels at a single N rate = 0.91$LSD_{0.05}$ for comparing two N rates at a single irrigation level = 0.79.

losses of N as well.In the same scenario, Ramireddy et al.(1982) reported that moisture availability in the root zone, might have increased the mineralization of organic matter leading to increased availability of nitrogen and hence a better utilization of the applied nitrogen and subsequently help various physiological processes in plant growth and finally increase yield and yield components.

Bulb Diameter

Interaction effect of irrigation and nitrogen fertilization on mean bulb diameter of onion was significant (P ≤ 0.01) (Table 1). Mean bulb diameter of onion increased with increasing irrigation regime and N level (Table 3). For instance, at 100% ETc, increasing N level from 50 to 150 kg ha^{-1} increased mean bulb diameter of onion by 33 and 40%, whereas further increase has no significant effect. Similarly, at 100 kg N ha^{-1}, increasing irrigation frequency from 25 to 100% ETc, increased mean bulb diameter by 21, 30 and 47%, respectively. Similar results were observed at other irrigation and N combinations.The interaction results showed that bulb diameter of onion is determined by both N levels and irrigation frequency. The results were in line with the findings of El-Hendawy et al. (2008) and Mansourifar et al. (2011), who reported that optimum combinations of N and irrigation enhanced the formation of maize plant with high economic parts.

Marketable Yield

N level showed a highly significant (P ≤ 0.001) effect on marketable bulb yield of onion (Table 1). The lowest (16.51 t ha^{-1}) and the highest (26.23 t ha^{-1}) marketable bulb yield of onion were obtained for 0 and 100 kg ha^{-1} N, respectively; all the other N treatments performed in between the two levels (Table 4). The effect of irrigation levels on the marketable bulb yield was highly significant

Table 4. Effects of nitrogen and irrigation on harvest index, total yield and marketable bulb yield of onion.

Treatments			Bulb Yield (t ha^{-1})		
			Total	Marketable	Harvest index (%)
N rate (kg ha^{-1})		0	22.01c	16.51c	68c
		50	26.4b	20.80b	72b
		100	31.44a	26.23a	83a
		150	31.04a	24.98a	82a
		200	29.37a	24.72a	80a
	CV%		11.53	14.09	6.69
Irrigation level (% ETc)		25	19c	15.48c	74b
		50	25.13b	20.38b	74b
		75	33.35a	27.13a	80a
		100	34.73a	27.59a	80a
	CV%		16.86	10.21	5.76

at $P \leq 0.001$ (Table 1). The lowest marketable yields (15.48 t ha^{-1}) was recorded at 25% ETc, reaching maximum (27.59 t ha^{-1}) at 100% available soil moisture which however, was statistically identical with marketable bulb yield derived from 75% ETc (Table 4).The results indicated that, marketable bulb yield of onion is influenced by nitrogen and irrigation regime. Marketable yield of onion increased with increasing nitrogen rates up to 100 kg N ha^{-1}. However, further increase in N did not bring significant effect on marketable bulb yield of onion, reductions in marketable bulb yield of onion at N rate beyond 100 kg ha^{-1} may be due to the fact that much higher N can adversely affect marketable bulb yield through the development of physiological disorder such as thick necked bulbs.

On the contrary of this finding, application of 120 kg N ha^{-1} gave highest marketable bulb yield of onion (Jilani et al., 2004). Marketable bulb yield was lowest at 25% ETc; it increased with increase in depth of application reaching maximum at 100% ETc (Table 3). Higher marketable bulbs of onion at higher irrigation levels might be due to the increase in the formation of growth measurements causing faster synthesis and transportation of photosynthtates from source to sinks. The current findings are in agreement with those of Al-Jamal et al. (2000) who reported that highest graded bulb yield of 43.74 and 55.1 t ha^{-1} were obtained with irrigation at 80 and 100% ETc, respectively.

Total Bulb Yield

Nitrogen had a highly significant effect ($P \leq 0.001$) on total bulb yield of onion per hectare (Table 1). The lowest (22.01 t ha^{-1}) total bulb yield of onion was recorded at 0 kg N ha^{-1} while the highest (31.44 t ha^{-1}) was recorded at 100 kg N ha$^{–1}$ followed by 150 and 200 kg N ha$^{–1}$ with 31.04 and 29.37 t ha^{-1}, respectively (Table 4). Irrigation levels had a highly significant effect on the total bulb yield of onion ($P < 0.001$, Table 1). The lowest (19 t ha^{-1}) total bulb yield of onion was obtained at irrigation level of 25% ETc, while the highest (34.73 t ha^{-1}) was obtained at irrigation level of 100% ETc followed by 75% ETc (Table 4).The data presented, above showed that total bulb yield of onion is influenced by nitrogen and irrigation regime. Total bulb yield of onion increased with increase in nitrogen rates up to 100 kg N ha^{-1}. However, further increase in N application beyond 100 kg N ha$^{–1}$ had no effect on total bulb yield of onion. The increase in total bulb yield of onion with increase in nitrogen levels up to 100 kg N ha^{-1}may be attributed to the fact that nitrogen supply increased the rate of metabolism where more carbohydrate is synthesized which increases bulb size and weight of onion and thus increases total bulb yield of onion.

These results were in close conformity with Khan et al*.* (2007) who reported that the total bulb yield was highest with 100 kg nitrogen per hectare. Total bulb yield of onion also increased with increase in irrigation frequency up to 100% ETc. This result clearly indicates that an increased photosynthetic area in response to moisture availability had substantially contributed to enhance onion productivity that could be through the production of more assimilates. This result is in conformity with many authors (Pejic et al., 2011; Enciso et al., 2009; Kandil et al., 2011) working with onion.

Harvest Index (HI)

Nitrogen levels had a highly significant effect ($P < 0.001$) on harvest index of onion plantTable 1. The lowest harvest index (68%) was recorded at 0 N kg ha^{-1}, reaching a maximum (83%) at 100 kg N ha^{-1} which was statistically at par with harvest index at 150 and 200 kg N ha^{-1} (Table 4). The harvest index of onion plant was highly ($P \leq 0.01$) affected by irrigation treatmentsTable 1. The lowest (74%) harvest index of onion was observed for each of the 25 and 50% ETc treatments; harvest index increased with irrigation level, reaching a maximum

Table 5. Depth of application (mm) under different irrigation treatments.

Irrigation level (% ETc)	Net irrigation (mm)	Gross irrigation (mm)
25	126.6	158.2
50	217.2	271.5
75	358.5	448.1
100	421.1	526.3

Table 6. Interaction effect of irrigation and nitrogen on water productivity (kgm^3) of onion plant.

Treatments	N rate (kg ha^{-1})				
Irrigation level (% ETc)	0	50	100	150	200
25	7.82	9.33	12.83	15.12	14.93
50	7.12	8.37	11.18	10.14	9.44
75	6.33	7.5	7.99	8.04	7.34
100	5.3	6.55	7.46	6.96	6.7

$LSD_{0.05}$ for comparing two irrigation levels at a single N rate = 4.1.
$LSD_{0.05}$ for comparing two N rates at a single irrigation level = 2.3.

at 100% ETc (Table 4). Means within a column followed by same letter (s) are not significantly different at P $\leq$ 0.05. Interaction effects of nitrogen and irrigation levels harvest index of onion was not significant (Table 1).

The results indicated that water and nitrogen supply hadmuch influence on harvest index of onion. Increasing N application up to 100 kg ha^{-1} increased the harvest index of onion plant. But further increase up to 200 kg N ha^{-1}did not bring significant effect in the harvest index of onion, the observed improvement in harvest index of onion plant in response to N fertilization up to 100 kg ha^{-1} could be attributed to an increased dry matter partitioning to the bulbs with advanced maturity. These results are in conformity with results obtained by Abdissa et al. (2011), who reported that there was a significant and consistent increase in harvest index of onion with increasing levels of nitrogen up to 138 kg N ha^{-1}.

The same source also reported that N improved harvest index in onion by increasing both bulb dry weight and total biomass yield).Harvest index also increased with increase in irrigation level up to 100% ETc. As observed in the current finding, highest harvest index of onion as a result of moisture availability were attributed to the fact that water supply promote plant growth and development through enhancement of extra dry matter production and partitioning of carbohydrates to economic sinks This result is in agreement with the results of Gholinezhad et al. (2009) who obtained higher harvest index of sunflower with wetter treatments.

Seasonal Water Consumptive Use Demand

The lowest (158.2 mm) gross irrigation in the season was observed at 25% ETc; reaching maximum (526.3 mm) at 100% ETc (Table 5).Yields of onion were lowest at lowest water application in the season, increased with increasing reduced water stress level, reaching maximum at 0 depletion level. In the current study, seasonal ETc of onion at Hawassa area, southern Ethiopia ranged from 448.1 to 526.3 mm for bulb yield of 33.35 to 34.73 t ha^{-1}. Similar results were reported by Doorenbos and Kassam (1986) who reported that onion yields of 35 to 45 t ha^{-1} could be obtained with 350 to 550 mm of water using furrow irrigation. They advised that soil water depletion should not be allowed to drop below 25% of available water for optimum yield.

Water productivity

Interaction effect between irrigation and N fertilizer treatments had significantly (P ≤ 0.01) influence on water productivity of onion (Table 1). Both irrigation and N application have positive effect on total bulb yield increments. The water productivity, however, decreased with increasing depth of irrigations, whereas N application significantly increased water productivity at all irrigation levels (Table 6). Thus at 50 kg N ha^{-1}, increasing irrigation frequency from 25 to 100% ETc decreased water productivity of onion by 10, 19 and 30%, Meanwhile, at 25% ETc, increasing N levels from 50 to 150 kg N ha^{-1} increased water productivity of onion by 37 and 62%, but further increase of N did not bring significant effect. Similar results were also observed at other irrigation and N combination.From the current study, it was observed that water productivity of onion plant is influenced by both irrigation regime and nitrogen level.

The results of the present study are in harmony to the findings of Tayel et al. (2010) who found maximum water productivity of garlic plant at N-irrigation combination of

50% ETc + 285 kg N ha^{-1}. These results are also in a close agreement with Kebede (2003) Samson and Ketema (2007) who reported that when irrigation water becomes a limiting factor, yield losses due to reduced soil moisture could be compensated for by water use efficiency.

CONCLUSION

The effects of N and irrigation levels were assessed by examining their effects on yield and yield components of onion. The result of current study revealed that N had a significant effect on harvest index, marketable bulb yield and total bulb yield. Marketable and total bulb yield of onion increased with increase in nitrogen rates up to 100 kg N ha^{-1}. However, in all cases further increase in N application beyond 100 kg N ha^{-1} did not bring significant effect. Similarly, wetter irrigation treatments such as 75 and 100% ETc resulted in maximum values of all parameters tested. For instance, total and marketable bulb yield of onion were increased by 75%, in response to the applications of irrigation at 75% ETc; thereafter treatments varied non-significantly. Therefore, N level of 100 kg ha^{-1} and irrigation given at 75% ETc sounds economical and can be tentatively recommended for onion production to the studied area. Since this finding is one season research at one location; further research across more locations and years is of paramount importance.

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