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Full Length Research Paper

Impact of irrigation and nitrogen levels on bulb yield, nitrogen uptake and water use value of shallot (*Allium cepa var. ascalonicum* Baker)

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A field experiment was carried out at Bahirdar, Northwest Ethiopia, during the dry season of 2009 to evaluate the effects of irrigation levels and nitrogen (N) rates fertilizer on bulb yield, N uptake and water use efficiency (WUE) of shallot. The treatments comprised of three irrigation levels (120, 100, and 50% ET_c) and four N rates (0, 59, 105 and 151 kg N ha^{-1}) which were laid out in a split-plot design using irrigation levels as a main plot and N levels as a subplot with three replications. Data on plant height, number of leaves, WUE, N uptake, bulb number, average bulb diameter, marketable and unmarketable bulb yields were collected and analyzed. The result showed that irrigation and N levels significantly affected all these parameters. The interaction of irrigation and N also highly significantly affected all these parameters except the number of bulbs and N uptake of shallot. The regression equations (TMBY = 5.67 + 0.022Irr + 0.02N and TBY = 3.12 + 0.02109 Irr + 0.0158 N) revealed that an increase in the amount of irrigation by 1 mm can increase marketable and total bulb yield by about 0.022 and 0.0209 t ha^{-1}, respectively and an increase in N by 1 kg ha^{-1} can increase the marketable and total bulb yields by 0.022 and 0.0158 t ha^{-1}, respectively. Application of water at 120% ET_c and fertilized with either 105 or 151 kg N ha^{-1} was the best for maximum marketable (11.64 and 12.03 t ha^{-1}) and total bulb yields (12.91 and 13.3 t ha^{-1}). From WUE point of view, application of water at 100% ET_c and fertilized with 151 kg N ha^{-1} could be the best practice. However, the yield at this interaction level is significantly lower than the maximum yields. The highest total N uptake (37.18 kg ha^{-1}) was obtained at 151 kg N ha^{-1}.

Key words: Irrigation, nitrogen, North-western Ethiopia, bulb, yield, shallot, marketable.

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INTRODUCTION

Shallot *(Allium cepa* var*. ascalonicum* Baker.) is the most important sub-group of the aggrigatum group. Morphologically, except minor differences, it is very similar to common onion (Fritisch and Friesen, 2002). Unlike common onion, which has a large single bulb, it produces clusters of several bulb splits (2 to 20 bulblets) (Currah and Proctor, 1990; Brewster, 1994). Though it is a minor alliaceous crop on global basis, the tropical areas of the world produce and use very large amounts of shallot (Currah and Proctor, 1990). Since it has strong pungency and longer life of stew prepared with it, shallot is preferred to onions for flavoring of the local stew 'wat' to be used in daily meals of many houses in Ethiopia (Kebede, 2003).

Studies on irrigation and nitrogen (N) application indicated that irrigation levels at 120% ET_c and N rates in

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the range of 150 to 200 kg ha^{-1} highly improved the yields of onions (Kumara et al., 2006; Neeraja et al., 1999). In Eastern Ethiopia, it was also observed that shallot yield was increased by about 10 to 15% and more marketable bulbs were obtained by N fertilization in the range of 75 to 150 kg ha^{-1} when it was supplemented with irrigation compared to rainfed shallot crops (Kebede, 2003).

Because of their shallow and unbranched root system, shallot and other alliums are most susceptible compared to many crops in extracting moisture and nutrients (Currah and Proctor, 1990; Brewster, 1994; Kebede, 2003). This makes moisture and N management a key factor in its production. Research gaps have been reported in the fertilizer management, irrigation practices, crop protection and storage quality of shallot (Yohannes, 1987; Hussen, 1997; Yeshi, 2003; ARARI, 2005). Though these problems are prevalent, there is little attempt made to study the effects of N rates in relation to different irrigation levels on shallot in Ethiopia. This study was, therefore, undertaken to study the effects of irrigation levels and rates of N fertilizer on bulb yield, N uptake and water use efficiency (WUE) of shallot.

MATERIALS AND METHODS

Experimental site description

The field experiment was conducted at Bahirdar, Northwest Ethiopia, which is found at an altitude of 1802 m above sea level and longitude of 37°25' E and latitude of 11°36' N. The area receives an average annual rainfall of 1418.2 mm (38 years average) with average maximum and minimum temperatures of about 27.6 and 11.85°C, respectively (NMSA, 1998, as cited in CSA, 2001).

Treatments and design

The experiment consist of 3 irrigation levels [50, 100 and 120% of crop water requirement (ET_c)] and 4 N rates (0, 59, 105 and 151 kg ha^{-1}) which were laid out in split-plot design using irrigation levels as a main-plot and N rates as a subplot, replicating three times. The bulbs of local shallot cultivar were planted on each subplots using double rows with spacing of 40 cm between double rows, 20 cm between the rows within the double rows and 20 cm between plants. Each subplot had 8 rows, 15 plants per row, 3 m length and 2.4 m width having an area of 7.2 m^2. The distances between subplots, main plots and blocks were 1, 1.5 and 2 m, respectively.

Agronomic practices

The field was ploughed, leveled and ridges and furrows were made using hoe. On January 10, 2009, shallot bulbs were planted and the recommended rate of phosphorus fertilizer (92 kg ha^{-1} P_2O_5) was applied as triple super phosphate (TSP). Immediately after planting, all the treatments received the full irrigation water requirement (100% ET_c) in order to ensure good sprouting and plant establishment. Then after, irrigation water was applied through furrows to each plot as per the treatments. When the bulbs sprouted, half of the N was applied and the remaining half was side dressed 1 month later. The experimental plots were cultivated and kept free from weeds using hoes.

Data collection

Soil sample

Three undisturbed soil samples were taken using core sampler at 0 to 30 cm and 30 to 60 cm soil depth in the experimental field before planting to determine bulk density (BD), the water content at field capacity (FC) and permanent wilting point (PWP) in the laboratory.

Three soil samples were also taken using augur to a depth of 30 cm soil from the experimental site for the determination of the following soil properties at Gondar Soil Laboratory using the procedures followed by Sahlemedin and Tesfaye (2000): texture (hydrometer method), soil particle density (PD) (Pycnometer method), soil pH (1:2.5 ratio of soil: water suspension), soil organic matter content (OM), total N (Kjeldahl method), available P (Olsen procedure), and cation exchange capacity (CEC).

Soil moisture determination

Irrigation scheduling was done using the CROPWAT computer software program to calculate crop and irrigation water requirements using climatic, soil and crop data as inputs. After estimating the irrigation water requirement, the volume of water to be applied to each plot was calculated as:

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

Where, V = volume of water to be applied (lit), A = area of the plot (7.2 m^2) and d = depth of application (m).

The calculated volume of water was measured with a bucket of known volume (Biswas et al., 2003) and was applied through furrows as per the irrigation treatments to each plot.

For each treatment, the WUE of the crop was calculated as described by Michael (1997):

$$WUE = \frac{\text{Bulb yield}}{ET_c} \qquad (2)$$

Plant tissue analysis and determination of N uptake

Eight plants were randomly taken from each plot at maturity and were separated into tops and bulbs, which were dried under shade. The bulbs were chopped to facilitate drying. The total N content of the samples were analyzed using Kjeldahl method. The N uptake by leaves and bulbs were calculated by multiplying the tissue N concentration with their respective dry weights.

Crop data

Plants in each net plot area were harvested when nearly 80% of the tops had fallen down for yield measurement. Bulb diameter was measured at the widest point (middle portion) of the bulb. Based on this measurement, the yield was categorized into marketable yield (bulbs having a diameter of ≥ 18 mm) and unmarketable yield (bulbs having a diameter of < 18 mm) according to the procedure followed by Kebede (2003).

Eight sample plants were also taken from each plot to determine plant height and number of leaves per plant at the beginning of neck fall-over. Plant height was measured from the ground level to the top of the sample plants. The total number of leaves from the sample plants were also counted and divided by eight to estimate the number of leaves per plant.

Table 1. Soil physical properties at Bahirdar experimental site before planting.

Soil depth (cm)	BD ($gm\ cm^{-3}$)	PD ($gm\ cm^{-3}$)	Porosity (%)	FC (%)	PWP (%)	TAW ($mm\ m^{-1}$)	Particle size distribution (%)			Textural class
							Sand	Silt	Clay	
0-30	1.26	2.66	52.3	37.5	24	170.1	15	31	54	Clay
31-60	1.28	-	-	36.6	23.2	171.5	14	28	58	Clay

BD = Bulk density, PD = Particle density, FC = Field capacity, PWP = Permanent wilting pont, TAW = Total available water. Infiltration rate = 40 mm/day.

Table 2. Soil chemical properties at Bahirdar experimental site before planting.

Total N (%)	OM (%)	AV. P (ppm)	CEC (cmol+/kg)	pH	EC (ms/cm)
0.2	3.51	15.58	22.05	6.1	0.08

CEC = Cation exchange capacity, OM = Organic matter, Av. P = Available phosphorus, EC = Electric conductivity.

Table 3. Soil total N (%) after harvest as affected by irrigation and nitrogen levels at Bahirdar experimental site.

N rates	50% ET_c	100% ET_c	120% ET_c	Mean
0	0.08	0.13	0.11	0.11
59	0.15	0.17	0.15	0.16
105	0.18	0.19	0.17	0.18
151	0.19	0.2	0.21	0.2
Mean	0.15	0.17	0.16	

Statistical analysis

The relevant data collected from the experimental plots were subjected to analysis of variance (ANOVA), which was computed using the MSTAT computer software program. When the treatment effects were significant, mean differences were separated following least significant difference (LSD) test.

RESULTS

Soil properties

The laboratory analysis revealed that the soil textural class of the experimental area is clay, having 1.26 to 1.8 gm cm^{-3} BD, 2.66 $gmcm^{-3}$ PD, 52% total porosity and total available water content of 170 mm m^{-1} in the soil (Table 1). Its reaction is slightly acidic (pH = 6.1). The study area is low in total soil N (0.2%) and medium in P level (15.58 ppm). It has also low OM (3.5%) and EC (0.08 ms cm^{-1}). After harvest the mean N content of the soil increased as the applied N levels increased, while it was slightly higher at irrigation of 100% ET_C > 120% ET_C > 50% ET_C (Table 2).

Yield related parameters

Highly significant difference ($P < 0.01$) in plant height, number of leaves and average bulb diameter were observed due to irrigation and N levels as well as their interaction effects. Irrigation and N levels, but not their interaction, significantly affected ($p < 0.05$) the number of shallot bulbs (Table 3).

The longest plants (37.27 cm) were produced by application of irrigation water at 120% ET_C and fertilized with 151 kg N ha^{-1}, while the shortest plants (19.93 cm) were produced under irrigation level of 50% ET_C on the unfertilized plot (Table 4).

The numbers of leaves per plant were significantly improved at treatment combinations of 100% ET_C with 151 kg N ha^{-1} and 120% ET_C fertilized with 105 or 151 kg N ha^{-1}. In the 50% ET_C level, N application significantly improved the number of leaves per plant at 151 kg N ha^{-1} and no significant difference among the other N levels was recorded. At 100% ET_C treatment, increasing the N levels up to 151 kg N ha^{-1} showed significant increase in leaf number per plant. In the 120% ET_C level, increasing the N level up to 105 kg N ha^{-1} significantly increased the number of leaves per plant, but further increment of N level to 151 kg N ha^{-1} did not statistically increase the leaf number (Table 4).

Under all the three irrigation levels, increasing the N rate up to 151 kg ha^{-1} significantly increased the average bulb diameters of shallot. The widest average bulb diameter (30.28 mm) was observed under irrigation

Table 4. Effects of irrigation and N levels on plant height, number of leaves per plant and average bulb diameter at Bahirdar experimental site.

N levels (kg ha^{-1})	Plant height (cm)				Number of leaves per plant				Bulb diameter (mm)			
	Irrigation levels				Irrigation levels				Irrigation levels			
	50% ET_c	100% ET_c	120% ET_c	Mean	50% ET_c	100% ET_c	120% ET_c	Mean	50% ET_c	100% ET_c	120% ET_c	Mean
0	19.93^{f}	30.60^{d}	31.43^{d}	27.32^{d}	15.40^{h}	25.07^{f}	26.47^{e}	22.31^{d}	17.02^{i}	27.59^{e}	28.15^{d}	24.25^{d}
59	250%0^{f}	33.73^{c}	35.73^{b}	29.99^{c}	15.30^{h}	28.67^{c}	27.53^{d}	23.83^{c}	19.13^{h}	28.48^{d}	29.23^{c}	25.61^{c}
105	20.93^{f}	34.67^{c}	36.26^{b}	30.62^{b}	15.80^{h}	29.67^{b}	30.00^{ab}	25.16^{b}	19.85^{g}	29.12^{c}	29.62^{bc}	26.2^{b}
151	23.33^{e}	36.20^{b}	37.27^{a}	32.27^{a}	17.70^{g}	30.80^{a}	350%3^{a}	26.34^{a}	20.4^{f}	29.97^{ab}	30.28^{a}	26.86^{a}
Mean	21.17^{c}	33.80^{b}	35.18^{a}		16.05^{b}	28.55^{a}	28.63^{a}		19.1^{b}	28.77^{a}	29.32^{a}	
LSD ($P < 0.05$)		I** 0.50	N** 0.58	I × N** 1.00	LSD ($p < 0.05$)	I** 0.66	N** 0.48	I × N** 0.83	LSD ($p < 0.05$)	I** 0.7	N** 0.31	I × N** 0.54
CV (%) = 1.95					CV (%) = 1.98				CV (%) = 1.18%			

Values followed by the same letter are statistically the same at 5% significant level.

level of 120% ET_C and 151 kg N ha^{-1}, which produce statistically the same bulb diameter with that of 100% ET_C and 151 kg ha^{-1} (Table 4).

Significantly higher numbers of bulbs were produced by application of irrigation water at 120% ET_C compared to that of 50% ET_C, while the 100% ET_C level resulted intermediate value between the two. Similarly, significantly high numbers of bulbs were produced at 151 kg N ha^{-1} compared to that of the unfertilized treatment and 59 kg N ha^{-1}, while the 105 kg N ha^{-1} gave intermediate value (Table 4).

Bulb yield

The marketable, unmarketable and total bulb yields were highly significantly affected ($p < 0.01$) due to the variation in irrigation and N application levels as well as their interaction effects (Table 5).

Significantly, the highest (11.64 and 12.03) and the lowest (1.50 t ha^{-1} and 1.57 t ha^{-1}) marketable bulb yields were observed in 120% ET_C fertilized with 105 or 151 kg N ha^{-1} and at 50% ET_C with unfertilized treatment or 59 kg N ha^{-1}, respectively. At 50% ET_C, application of 105 or 151 kg N ha^{-1} treatments exhibited significant increment of marketable bulb yield compared to the unfertilized and 59 kg N ha^{-1}, which are statistically the same. Under 100% ET_C level, the marketable bulb yield considerably increased as the N level increased to the highest level (151 kg N ha^{-1}). In 120% ET_C level, increasing the N rate up to 105 kg ha^{-1} significantly increased the marketable bulb yield, which was at par with that of 151 kg N ha^{-1}.

The highest unmarketable bulb yields (1.85 and 1.82 t ha^{-1}) were produced by irrigation application at 50% ET_C fertilized with 105 or 151 Kg N ha^{-1}. Under 50% ET_C treatment, 59 kg N ha^{-1} produced statistically the same unmarketable bulb yield as that of the control, but the yield was significantly increased as the N level further increased to 105 kg N ha^{-1}, which produced similar yield with that of 151 kg N ha^{-1}. However, under higher irrigation levels (100 and 120% ET_C), increasing the N rates did not significantly improve the unmarketable bulb yields.

The highest total bulb yields (12.91 and 13.30 t ha^{-1}) were obtained at irrigation level of 120% ET_C fertilized at 151 kg N ha^{-1} or 105 kg N ha^{-1}. Under 120% ET_C, the total yield statistically increased as the N level increased up to 105 kg N ha^{-1}. However, no significant difference was found between 105 and 151 kg N ha^{-1}. At 120% ET_C treatment, increasing the N level significantly increased the total bulb yield with the highest yield at 151 kg N ha^{-1} followed by the other N level in descending order. In 50% ET_C level, the unfertilized and 59 kg N ha^{-1} produced statistically the same yield, while further increase of N application increased the total bulb yield (Table 5).

WUE of shallot

Irrigation and application of N levels and their interaction had a high significant influence ($p < 0.01$) on WUE of shallot. The best WUE

Table 5. Effects of irrigation and N levels on bulb yield of shallot.

N levels	Marketable bulb yield (t ha^{-1})				Unmarketable bulb yield (t ha^{-1})				Total bulb yield (t ha^{-1})			
	Irrigation levels			Mean	Irrigation levels			Mean	Irrigation levels			Mean
	50% ET_c	100% ET_c	120% ET_c		50% ET_c	100% ET_c	120% ET_c		50% ET_c	100% ET_c	120% ET_c	
0	1.50^h	8.64^f	9.46^e	6.53^d	1.82^b	0.73^d	1.13^c	1.23^c	3.31^h	9.37^e	1.57^d	7.75^d
59	1.57^h	9.26^e	10.95^c	7.26^c	1.85^b	0.91^d	1.21^c	1.32^b	3.42^h	10.17^d	12.16^b	8.58^c
105	2.13^g	10.47^d	11.64^a	8.08^{ab}	2.27^a	0.85^d	1.27^c	1.46^a	4.40^g	11.32^c	12.91^a	9.54^b
151	2.47^g	11.21^b	12.03^a	8.58^a	2.45^a	0.75^d	1.28^c	1.49^a	4.92^f	11.98^b	13.30^a	10.07^a
Mean	1.92^c	9.90^b	11.02^a		2.10^a	0.81^c	1.22^b		4.01^c	10.71^b	12.24^a	
LSD(P<0.05)	Irr**	N**	I × N**		Irr**	N**	I × N**		Irr**	N**	I × N**	
	0.29	0.24	0.61		0.26	0.1	0.19		0.38	0.26	0.52	
CV (%) =				3.25				7.93				3.35

(2.73 kg m^{-3}) of shallot was obtained from 100% ET_c by 151 kg N ha^{-1} treatment. In 50% ET_c level, the WUE was notably increased at 151 kg N ha^{-1} followed by 105 kg N ha^{-1} application, compared to the unfertilized plot and 59 kg N ha^{-1}, which are at par. Under 100% ET_c level, increasing the N level significantly increased WUE. At 120% ET_c level, the WUE was appreciably improved with N application of 105 or 151 kg N ha^{-1} followed by 59 kg N ha^{-1}, while the WUE in the unfertilized plot was significantly reduced (Table 6).

Nitrogen concentration and its uptake by the plant

Irrigation did not significantly influence the total N concentration of shallot. On the other hand, N application significantly ($p < 0.01$) affected the N concentration in bulbs but not in leaves. On the other hand, the N uptake by leaves, bulbs and by the whole plant showed significant variation ($p < 0.01$) due to irrigation and N levels. Compared to the unfertilized plots, the fertilized plots significantly increased the N content by bulbs and the whole plant (Table 7).

Irrigation at 50% ET_c level significantly reduced the amount of N taken up by the leaves and bulbs (Table 7). However, the N uptake at 100 and 120% ET_c had no variation. N uptake by leaves was significantly reduced in the unfertilized plot compared to the N treated plots, which exhibited no significant variation between them. The lowest mean N uptake values by leaves (3.01 kg ha^{-1}) and bulbs (12.03 kg ha^{-1}) were recorded in plants from the unfertilized plots, while bulbs took the highest amounts of N (32.43 kg ha^{-1}) from plots applied with 105 kg N ha^{-1} (Table 7). Generally, the highest (37.18 kg N ha^{-1}) and the lowest (19.73 kg N ha^{-1}) mean total N uptake by the whole plant were recorded at the 151 kg N ha^{-1} and unfertilized treatment, respectively (Table 7).

DISCUSSION

The result showed that higher irrigation and N levels are required to increase yield related parameters of shallot such as plant height, number of leaves, number and size of bulbs. The progress of average bulb diameter with the rise up of N and irrigation levels implies the contribution of this parameter for the increase in yield of large sized bulbs, which have high market demand. Neeraja et al. (1999) also found that the interactions of higher levels of irrigation [120% irrigation water to cumulative pan evaporation (IW:CPE)] and N (200 kg ha^{-1}) resulted in maximum plant height, more number of leaves per plant and maximum diameter of onion bulbs. Similarly, other reports stated that onion crops require plenty of water to maximize its vegetative growth, which is comparatively more sensitive to water stress compared to many other deep rooted crops (Curah and Proctor, 1990; Brewster, 1994).

The present result demonstrates that the shallot bulbs produced under moisture shortage and low amount of N in the soil are small in size and low in yield, whereas higher irrigation and N levels notably increased the yield of large sized (marketable) bulbs at the expense of small sized (unmarketable) bulb yield. Generally, the

Table 6. Effects of irrigation and nitrogen levels on irrigation WUE (kg m^{-3}).

N rate (kg ha^{-1})	irrigation levels			Mean
	50% ET_c	100% ET_c	120% ET_c	
0	1.51^{g}	2.13^{e}	2.00^{f}	1.88^{d}
59	1.55^{g}	2.31^{d}	2.31^{d}	2.06^{c}
105	2.00^{f}	2.58^{b}	2.45^{c}	2.34^{b}
151	2.24^{de}	2.73^{a}	2.52^{bc}	2.5^{a}
Mean	1.83^{c}	2.44^{a}	2.32^{b}	
LSD (P < 0.05)		Irr**	N**	I × N**
		0.07	0.07	0.12
CV (%)		3.25		

Values followed by the same letter are statistically the same at 5% significant level.

Table 7. Effects of irrigation and N levels on number of bulbs, N concentration and N uptake.

Treatment	N uptake by leaves (kg ha^{-1})	N uptake by bulbs (kg ha^{-1})	Total N uptake (kg ha^{-1})	Bulb N conc. (%)	Leaf N conc. (%)	Total N conc. (%)	Number of bulbs per plant
Irrigation levels							
50% ET_c	2.01^{b}	12.03^{b}	14.03^{b}	1.58	1.13	2.71	7.15^{b}
100% ET_c	5.09^{a}	30.46^{a}	35.55^{a}	1.68	1.41	3.10	8.72^{ab}
120% ET_c	5.04^{a}	35.6^{a}	40.63^{a}	1.77	1.35	3.12	10.14^{a}
LSD (P < 0.05)	1.58	8.63	9.35	Ns	ns	ns	1.80
Nitrogen levels (kg ha^{-1})							
0	3.01^{b}	16.65^{c}	19.66^{c}	1.33^{b}	1.22	2.55^{b}	7.98^{b}
59	4.11^{a}	26.71^{b}	30.81^{b}	1.76^{a}	1.34	3.10^{a}	8.38^{b}
105	4.25^{a}	28.31^{ab}	32.56^{b}	1.73^{a}	1.32	3.04^{a}	8.80^{ab}
151	4.75^{a}	32.43^{a}	37.18^{a}	1.89^{a}	1.31	3.20^{a}	9.50^{a}
LSD (P < 0.05)	0.858	4.53	4.53	0.06	ns	0.13	0.9
CV (%)	27.19	17.75	15.59	15.13	23.37	12.31	11.99

Values followed by the same letter are statistically the same at 5% significant level.

improvement of the marketable bulb yield with increase in the N rate was at higher order under the two higher irrigation levels (100 and 120% ET_C) than under shortage of water. In agreement to the present observation, studies on onion and potato also indicated that higher irrigation (120% ET_O) and N levels (150 to 200 kg ha^{-1}) resulted in maximum yields (Kumara et al., 2006; Mayer and Marcum, 1998; Neeraja et al., 1999). Michael (1978) also noted that response of fertilizers is a higher order under irrigated conditions than under non-irrigated conditions. The result showed that the increase in total bulb yield with increase in irrigation and N levels is mainly due to the increase in large sized (marketable) bulbs. The response of bulb yield to high amounts of water and N application could be attributed to the improvement of water to availability of nutrients to the plant root, which improves the growth of the crop (Abdulaziz, 2003). Such effect may increase photosynthetic area of the plant (height of plants and number of leaves) which increases the amount of assimilate that could be partitioned to the storage organs (larger bulbs) that could consequently increase large sized (marketable) bulb yield. In addition, the regression equations (TMBY = 5.67 + 0.022Irr + 0.02N and TBY = 3.12 + 0.021Irr + 0.016N) revealed that an increase in the amount of irrigation by 1mm and N application by 1 kg ha^{-1}, within the range of the present treatments, can increase the marketable and total bulb yield of shallot by 0.022 and 0.020 t ha^{-1}, and 0.021 and 0.016 t ha^{-1}, respectively. In this study, 83 and 97.7% of the variation in marketable (R^2 = 0.83) and total bulb yields (R^2 = 0.977) of shallot were due to both N and irrigation treatments.

The increment of WUE at 100% ET_C by 151 kg N ha^{-1} treatment could be because the increase in yield (nominator) produced by higher N level is more than the corresponding increase in water consumption (denominator) (Michael, 1978). Conversely, plants which grow in a soil that contains a relatively small quantity of nutrients grow slower and transpire more water per gram of tissue produced than those growing where the plant nutrients are in abundance (Foth, 1990). Michael (1978) also noted that nutrient and irrigation management practices can increase WUE by increasing crop yield. Other studies indicated that WUE was significantly reduced due to water stress in onion plants (Al-jemal and Sammis, 2001; Abbey and Joyce, 2004), while in another observation, it was increased with increased in the amounts of applied water up to 120% ET_c (Abdulaziz, 2003). Moreover, Bandyopadhyay et al. (2003) reported that irrigation level of 120% IW: CPE improved WUE of onion than 0.9 and 0.6 IW:CPE, respectively. In contrast, Samson and Ketema (2007) reported that deficit irrigations (50 and 75% ET_c) increased the WUE of onion.

The N uptake of shallot in this experiment was higher at higher irrigation and N levels. Increasing the N rate improved more the N uptake by the bulbs than by leaves. Kebede (2003) also observed that the N uptake by shallot bulbs significantly responded to the application of N. The study on potato by Mayer and Marcum (1998) indicated that the total tuber N content increased as the amount of applied water increased. Brewster (1994) also explained that for N to be available to growing crops, the soil moisture must be sufficient to allow nitrates to move to the roots. However, in dry soil optimal quantities of N may not enter to the plant, indicating that N utilization is influenced by soil moisture status during the growing season.

Conclusion

This study showed that higher irrigation (120% ET_c) and N levels (105 to 151 kg N ha^{-1}) are required for shallot crop to produce large sized bulb (marketable) yields at the expense of small sized (unmarketable) bulbs. From the result, it can be concluded that application of irrigation water at 120% ET_c and fertilizing with 105 kg N ha^{-1} is best management practice for shallot production in the study area. Though the best WUE of shallot was obtained from 100% ET_c and fertilized with 151 kg N ha^{-1}, the bulb yield produced at this interaction level was significantly lower than the maximum yield. The highest total N uptake by the whole plant (37.18 kg N ha^{-1}) which was recorded at the 151 kg N ha^{-1} contributes to obtain highest bulb yield at this rate.

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