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Response of drip irrigated onion (*Allium cepa* L.) growth, yield and water productivity under deficit irrigation schedules

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ABSTRACT

Field experiment was conducted to assess the effect of deficit irrigation through drip on onion growth, yield and water productivity in semi arid Maharashtra. The experiment was laid out in Randomized Block Design with nine treatments replicated thrice. The experiment consisted of four treatments with water stress of 60%, 40%, 20% and no stress during entire crop season and four treatments with water stress of 60% during each of the referred growth stages (i.e. initial, development, mid-season and end stages) and 20% stress during remaining period. The growth and yield contributing characters of onion were found decreased with increased water stress. The bulb yield did not differ significantly in treatments with no stress and 20% water stress throughout season and 60% water stress applied during referred growth stage. Drip irrigation with no water stress recorded higher bulb yield (35.5 t/ha) and it was 28.9% high with 42.8% water saving over surface irrigation. Higher water use (375.6 mm) was estimated in no stress treatment while lowest (150.3 mm) was estimated under 60% stress throughout the season. It is concluded that 60% water stress at development stage (21 to 60 DAT) and 20% stress during remaining crop period is advisable irrigation criteria for onion production in semi-arid region.

Keywords: Deficit irrigation, Drip irrigation, Bulb yield, Onion, Water productivity, Water stress

INTRODUCTION

The western part of Maharashtra which is primarily a semi arid region is known for its water scarcity conditions. At present the water for irrigation in this region is becoming scarce and expensive (Shinde *et al*., 2013). The rainfall is low and erratic in these areas. Monsoon variations and over exploited aquifer storage have resulted in shortage of fresh water supplies for agricultural use (Sankar *et al.,* 2008). Due to over exploitation groundwater also has gone to very deep and consequently not available for crop production in many parts (Tripathi *et al.,* 2017). Current use efficiency or productivity of irrigation water is also low that most of future water needs can be met only by increased productivity or efficiency alone. On contrary, the region of western Maharashtra is predominantly known for cultivation of high water requiring crops like sugarcane, banana, etc. However, limited availability of irrigation water and inefficient use of water are the major reasons for low water use efficiency for these crops. The farmer grows such crops due to social and commercial binding but in recent years due to water limiting condition, the farmers of this region especially small holding farmers are now shifting to remunerative vegetable crops like onion with low water requirement (Bhagyawant *et al.,* 2014).

Onion (*Allium cepa* L.) is second most important commercial vegetable crop of India and the country ranks second in onion production with 1.2 million ha cultivation area with total production of 19.7

million tons having productivity as 16.4 t ha^{-1}. Maharashtra is leading onion producing state in country that accounts 39% of total area and 32.5% of national production (Anonymous, 2014). The area under onion in Maharashtra is 0.26 million ha and the onion production is 4.46 million. Onion is mostly grown in western parts of Maharashtra, however, in this region the productivity of onion is low (11.8 t ha^{-1}) mainly due to limiting water conditions.

Onion yield is mostly influenced by irrigation, especially irrigation quantity and method of irrigation plays a vital role (Enciso *et al.*, 2009). Onion is water sensitive crop and excess or deficit water application affects the crop yield drastically. Onion crop does not require similar quantity of water during all stages of its growth. There are specific crop growth periods, which are considered as moisture sensitive periods and shortage of water in these periods may reduce the yield (Patel and Rajput, 2013). Therefore, the extent of water stress during sensitive and non sensitive stages must be determined for efficient irrigation management.

Further, proper irrigation scheduling, including deficit irrigation (DI), can improve crop yield, save irrigation water and increase water productivity if properly practiced (Bekele and Tilahun, 2007). With deficit irrigation (DI), a controlled water stress is imposed on the crop, either during a particular period or throughout the growing season (Begali *et al.,* 2012). However, economical value of crop should not decline. Drip irrigation coupled with deficit irrigation scheduling can prove an efficient method for saving water and improving productivity. However, the deficit irrigation scheduling through drip for onion crop in semi arid condition is not reported yet. The present study was therefore undertaken to study the response of drip irrigated onion (*Allium cepa* L.) growth, yield and water productivity to deficit irrigation schedules.

MATERIALS AND METHODS

The experiment was conducted during 2014-15 at experimental farm of Interfaculty Department of Irrigation Water Management, MPKV, Rahuri, Maharashtra, India (19°47′ N and 74°39′ E; altitude 525 m mean sea level). The soil of the experimental site was sandy clay loam with pH 8.1. The values of field capacity, permanent wilting point, available soil moisture, bulk density and electrical conductivity were 33.5%, 14.5%, 19.0%, 1.28 Mg m^{-3} and 0.38 dS m^{-1}, respectively.The soil had low available nitrogen (182 kg ha^{-1}), medium available phosphorus (19 kg ha^{-1}) and high available potassium (224 kg ha^{-1}).

The planting of onion bulb (variety ‘N-2-4-1’) was done on broad bed furrow having 90 cm top width and 120 cm bottom width. On each bed, four rows of onion seedlings were planted at 15 cm spacing. The spacing between two seedlings within a row was 7.5 cm. The recommended fertilizer dose 100:50:50 NPK, kg ha^{-1} was applied to crop as basal dose of phosphorus, potassium and half dose of nitrogen at planting. The remaining half dose of N applied after one month. For these straight fertilizers viz. Urea, SSP (single super phosphate) and MOP (Murate of potash) were used.

The experiment was laid out in Randomized Block Design with nine treatments having three replications. The treatments consisted of 60, 40, 20, and no water stress throughout season (T_1-T_4), 60% water stress at either initial, development, mid or end stages and 20% for rest period (T_5-T_8). The treatment of surface irrigation at 50 mm CPE was added as control (T_9).

The entire growth period of onion was divided into four stages viz. initial stage (0-20 days), development stage (21-60 days), mid season stage (61-90 days) and end stage (91 days onwards). These four growth stages correspond to those defined in FAO 56 (Allen *et al.*, 1998). After transplanting common irrigation was given up to 7 days to all treatments for establishing crop uniformly. The treatments stopped before 15 days of harvesting.

The total water use was estimated for each treatment using a simplified water balance approach.

$$ETc = I + Pe, \text{ (when } I<Pe, I=0) \qquad .....(1)$$

Where, Pe is the effective rainfall (mm); Crop evapotranspiration (ETc) was estimated to schedule irrigations as per FAO recommended pan evaporation method. The irrigation depth (I) for each treatment was calculated as:

$$I = K_{st} \times ET_c \qquad .....(2)$$

$$ET_c = K_c \times ET_0 \qquad .....(3)$$

$$ET_0 = K_p \times CPE, \qquad .....(4)$$

Where, I is Irrigation depth (mm) relative to each treatment; K_{st} is stress coefficient relative to each treatment (Table 1); ET_c is Crop évapotranspiration, mm ; K_c are the standard crop coefficient values of 0.7, 0.7–1.05, 1.05 and 1.05–0.75 at the referred growth stage of onion (FAO-56); K_p is pan

Table 1. Stress coefficient (K_{st}) of treatments relative to various treatments

Sr. No.	Treatment	Growth stage			
		Initial	Development	Mid season	End
1.	T_1	0.4	0.4	0.4	0.4
2.	T_2	0.6	0.6	0.6	0.6
3.	T_3	0.8	0.8	0.8	0.8
4.	T_4	1.0	1.0	1.0	1.0
5.	T_5	0.4	0.8	0.8	0.8
6.	T_6	0.8	0.4	0.8	0.8
7.	T_7	0.8	0.8	0.4	0.8
8.	T_8	0.8	0.8	0.8	0.4
9.	T_9	Surface irrigation at 50 mm CPE			

coefficient, (0.7); CPE is cumulative pan evaporation of two days.

The irrigation water was applied at 2-days interval and volume of water applied through drip system was worked out as:

$$V = I \times Ls \times Es \times Wa/\eta \quad .....(5)$$

Where, V is volume of water (lit/emitter); Ls and Es is lateral and emitter spacing m; W_a is wetted area factor (0.8) and η is emission uniformity of the system (91%). The total water productivity (WP), expressed in kg/ha-mm, was computed as:

$$WP = Y/TWU \quad .....(6)$$

Where, TWU is total water use (mm) and Y is marketable onion bulb yield (kg ha^{-1}).

Drip irrigation system installed to meet out crop water requirement. The Irrigation water pumped by 5 hp electric motor and conveyed through main line of 75 mm PVC pipes after filtering through sand filter. Wire mesh filter also used to avoid clogging of drip holes from physical impurities in irrigation water. From the main, sub mains of 63 mm were drawn and from the sub-main 40 mm manifold were drawn. On manifold, 16 mm LLDPE inline laterals with 4-lph discharge @ 0.5 m spacing were laid at 1.2 m interval. Each lateral irrigate four crop rows on each bed. The operating pressure of drip irrigation system was maintained at 1 kg/cm^2 throughout the study.

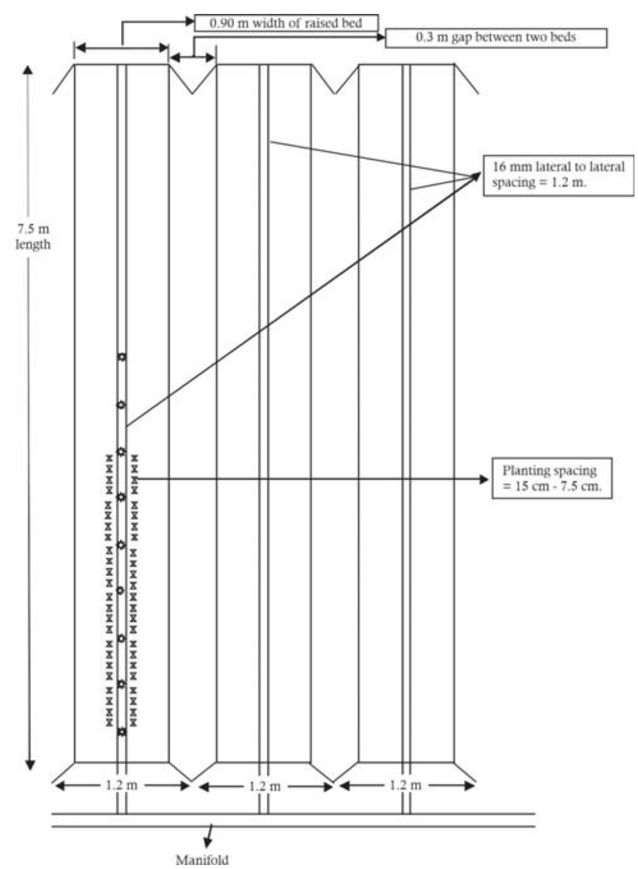

Figure 1. Drip irrigation layout of one experimental plot

RESULTS AND DISCUSSION

Growth attributes

Periodically recorded growth parameters viz. plant height, neck thickness and equatorial diameter registered higher values in drip irrigated treatments. With advancement in age, the height of onion increased up to 90 DAT and then decreased at harvest (Fig.2). This was due to translocation of biomass into bulb. Among drip treatments higher plant height at all growth stages observed in no stress treatment (T_4). The treatment of 60% stress throughout season (T_1) observed with lowest plant height. At all days of observation plant height showed a decreasing trend in treatments which have water stress throughout the growing season as, T_4 (no deficit irrigation) >T_3 (20% deficit irrigation)

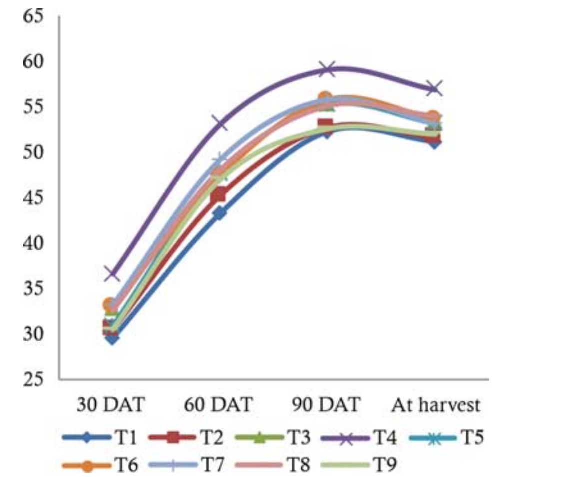

Figure 2. Plant height (cm) of onion by different treatments

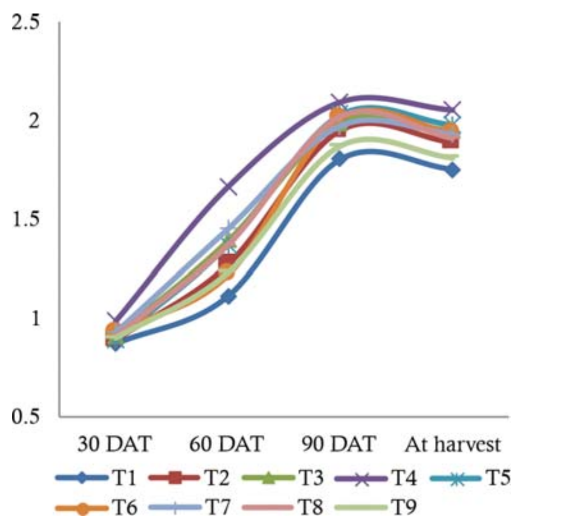

Figure 3. Neck thickness (cm) of onion bulb by different treatments

>T_2 (40% deficit irrigation) >T_1 (60% deficit irrigation). Kanton *et al*. (2003) reported that application of full irrigation water in onion caused taller plants. Among different treatments stress at any of onion growth stages the height of T_5, T_6, T_7, and T_8 at harvest were at par with each other. The plant height for T_6, 60% stressed during development stage, had significantly smaller than the non-stressed T_4, at 60 DAT but later on it was improved, thus indicating ability to recover from water stress at this stage. Results agree with findings of other researchers, for example, Channagoudar *et al*. (2004).

The neck thickness of onion bulbs also increased upto 90 DAT and thereafter slightly shrank at harvest (Fig.3). At harvest, it was higher in no stress treatment T_4 (2.05 cm) followed by T_5 (1.98 cm). Among different treatments where 60% water stress was given at different growth stages, neck thickness was found at par. However, better neck thickness was found in T_5 at 90 DAT and at harvest (2.03 and 1.98 cm, respectively). The treatment $T_{6,}$ T_7 and T_8 i.e. stress at development, mid-season and end stage also resulted in closer values of neck thickness may be because of less effect of stress during these stages. The findings of present study were in accordance with Metwally (2011).

The equatorial diameter of onion bulb showed similar trend as that of plant height and neck thickness (Fig.4). The equatorial diameter was significantly influenced by irrigation quantity at all the observations except at 60 DAT. The higher diameter noticed with T_4 at harvest. However, it was at par with T_3, T_5 and T_8. The lowest equatorial diameter was observed in T_1 due to low moisture availability for crop growth.

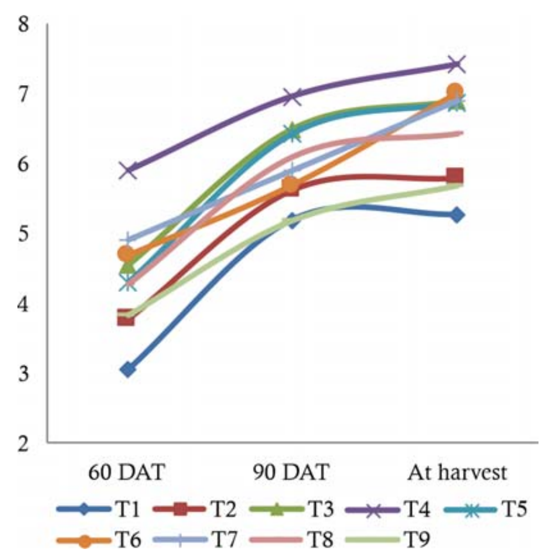

Figure 4. Equatorial diameter (cm) of onion bulb by different treatments

Yield contributing characters

Higher dry matter was noticed in no stress treatment (T_4), whereas, significantly small values noticed in T_1 and T_2 (Fig.5). High dry matter of plant in T_4 was observed because of adequate water application throughout the season and *vice versa*. The bulb dry matter weight at harvest was more in T_7 (60% stress at mid stage). However, it was on par with T_5, T_6 and T_8. Earlier Martin de Santa, Olalla *et al.* (2004) have also reported similar trend of results.

The onion bulb weight was influenced significantly under different treatments at harvest

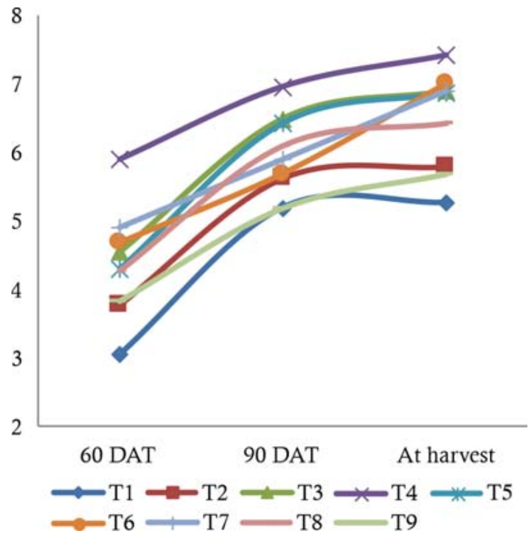

Figure 5. Dry matter (g) of onion bulb by different treatments

(Table 3). The maximum weight obtained in T_4 (no stress) as 85.3 g which was significantly higher over all other treatments. The lowest weight (53.6 g) recorded in T_1 (60% water stress). Significant lower values of bulb weight in T_1 and T_2 observed because of considerable water stress in these treatments. The treatments T_6 and T_7 had on par bulb weight. The low weight of bulb in T_8 shows that inducing stress at end stage starts early translocation process, which results in low weight of bulb (Zheng *et al.,* 2013).

Irrigation water use

The reference evapotranspiration (ET_0) increased from initial to development stage and then decreased at mid stage (Table 2). The amount of irrigation among treatments differed with duration of each growth stage and stress coefficient of respective treatments. The irrigation water applied to onion under different irrigation treatments ranged between 139.6-600 mm.

The effective rainfall also differed among treatments and it was more in surface irrigation treatment (Table 3). The crop evapotranspiration (ET_c) or water use followed the same trend as of ET_0 that increased up to development stage. However, it decreased at mid stage due to short duration even though value of crop coefficient at this stage was high. The crop ET_c then further decrease at end stage because of decline in crop coefficient value nevertheless, climatic parameters were high, at this stage.

Table 2. Duration, reference evapotranspiration (ET) and Irrigation depth applied (mm) at each growth stages for all treatments

Stages	Duration (days)	ET_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Initial	0-20	71.0	19.9	29.8	39.7	49.7	19.9	39.7	39.7	39.7	150
Development	21-60	141.7	50.3	75.4	100.5	125.7	100.5	50.3	100.5	100.5	200
Mid-season	61-90	114.8	37.6	57.4	79.0	100.9	79.0	79.0	37.6	79.0	150
End	91 onwards	91.7	31.9	47.9	63.8	79.8	63.8	63.8	63.8	31.9	100
Total	112	419.2	139.6	210.4	283.1	356.0	263.2	232.8	241.7	251.2	600

Table 3. Yield, irrigation water, effective rainfall, water use (ET_c) and water productivity of onion as influenced by different water stress through drip

Treat.	Average weight of bulb (g)	Bulb yield (t/ha)	I (mm)	Effective rainfall (mm)	ET_c (mm)	WP (kg/ha-mm)	Water saving (%) over T_9	% increase in yield over T_9
T_1	53.6	23.86	139.6	10.6	150.3	158.8	72.9	0
T_2	60.6	24.86	210.4	15.0	225.4	110.3	61.6	0
T_3	72.8	30.41	283.1	17.4	300.5	101.2	49.7	10.4
T_4	85.3	35.5	356.0	19.6	375.6	94.5	37.8	28.9
T_5	69.8	30.38	263.2	17.4	280.6	108.3	52.5	10.3
T_6	76.1	31.11	232.8	17.4	250.3	124.3	56.3	12.9
T_7	79.4	31.62	241.7	10.6	252.3	125.3	56.5	14.8
T_8	65.1	29.01	251.2	17.4	268.6	108.0	55.6	5.3
T_9	58.1	27.55	700	44.4	744.40	37.0	—	0
	5.5	6.2						

The total water use (ET_c) in T_1 –T_4 treatments varied between 150.3-644.4 mm, whereas, in T_5 –T_8 treatments it ranged between 250.3-280.6 mm. Among different treatments in which water stress applied during any growth stage of onion, more water used in T_5 (280.6 mm) followed by T_6 (250.3 mm). For the treatment of surface irrigation (T_9-) the total water use was (644.4 mm) which almost 1.7 times higher than T_4. This emphasized efficient water utilization under drip as compared to surface method. These results are in close confinement with Zheng *et al.* (2012).

Bulb yield and water productivity

The onion bulb yield increased by 5-28.9% in drip irrigated treatments over surface irrigation treatment (Table 3). The no stress treatment comes out with 41.8% water saving as compared to surface irrigation method, which advised to adopt drip irrigation system in semi-arid regions. Among drip irrigated treatment, higher bulb yield (35.5 t ha^{-1}) obtained in no stress treatment and decreased with increase in water stress. However, yields of most of the treatments did not differ significantly except T_1 (23.9) and T_2 (24.9). This may be because of earlier maturity occurred in water-stressed conditions (T_1 and T_2) when compared with other treatments due to accelerated plant growth in response to water stress.

The yield in treatments T_7 and T_6 improved slightly over other treatments where 60% water stress induced at growth stage i.e. T_5 and T_8. The better yield of T_7 and T_6 may be attributed to the fact that water stress at development and mid stage not affected the yield significantly. This indicates that the onion plants have the ability to develop the bulbs with reduced water. Earlier, Bhatt *et al.* (2006) reported that bulbs are part of the root system, and therefore their growth when plants are water stressed is a consequence of their surviving strategy for developing the root system and creating water reserves in the bulb.

Water productivity (WP) relative to drip irrigated treatment revealed that treatment T_1 with the smallest irrigation depth and smaller yield has the greatest WP values while the smallest WP correspond to the non-stressed T_4. The surface irrigation treatment T_9 had lesser WP as 42.8 kg/ha-mm. Thus, water productivity in drip was more than double than surface irrigation strongly recommends to adopt drip system under limiting water conditions.

CONCLUSION

The frequent application of water in small quantity through drip proved beneficial for all growth and yield characters of onion as compared to surface irrigation method. The increase in water stress decreased the growth and yield of onion. Drip irrigation with no water stress throughout the season, (T_4), gave more growth and yield attributes of onion. However, it was at par with all other treatments except 60% and 40% water stress throughout season and surface irrigation. The 60% stress at any of the growth stages of onion did not influence bulb yield significantly. However, based on low water use, the treatment T_6 is considered better than other treatments. The advisable irrigation strategy is 60% water stress at development stage (21 to 60 DAT) and 20% stress during remaining crop period.

Conflict of Interest

The authors declare that they have no competing interests.

REFERENCES

Anonymous (2014). Annual Report of National Horticultural Research and Development Foundation, Nashik (Maharashtra), 48-49.

Allen, R.G., Pareira, L.S., Dirk, R. and Smith, M. (1998). Crop-evapotranspiration-Guidelines for computing crop water requirements, FAO - 56, Rome Italy. pp. 102-106.

Bagali, N., Patil, H.B., Guled, M.B. and Patil, R.V. (2012). Effect of scheduling of drip irrigation on growth, yield and water use efficiency of onion (*Allium cepa* L.). *Karnataka J. Agric. Sci.*, 25(1), 116-119.

Bekele, S. and Tilahun, K. (2007). Regulated deficit irrigation scheduling of onion in a semi arid region of Ethiopia. *Agric. Water Manag*., 89, 148-152.

Bhatt, R.M., Srinivasa Rao, N.K. and Veere Gowda, R. (2006). Response of bulb onion to water stress: photosynthesis, stomatal conductance and osmotic adjustment. *Indian J. Horticulture*, 63(3), 270-280.

Channagoudar, R.F. and Janawade, A.D. (2004). Effects of different levels of irrigation and sulphur on growth, yield and quality of onion (*Allium cepa* L.). *Karnataka J. Agric. Sci.*, 19(3), 489-492.

Bhagyawant, R., Gorantiwar, S. and Dahiwalkar, S. (2015). Yield response factor for onion (*Allium cepa* L.) crop under deficit irrigation in semiarid tropics of Maharashtra. *Current Agriculture Research Journal*, 3, 128-136.

Enciso, J., Wiedenfeld, B., Jifon, J. and Nelson, S. (2009). Onion yield and quality response to two irrigation scheduling strategies. *Scientia Horticulturae*, 120(3), 301-305.

Kanton, R.A.L., Abbey, L. and Gbene, R.H. (2003). Irrigation schedule affects onion (*Allium cepa* L.) growth, development, and yield. *J. Veg. Crop Prod.*, 9(1), 3-11.

Metwally, A.K. (2011). Effect of water supply on vegetative growth and yield characteristics in onion (*Allium cepa* L.). *Austral. J. Basic Appl. Sci.*, 5(12), 3016-3023.

Patel, N. and Rajput, T.B.S. (2013). Effect of deficit irrigation on growth, yield and quality of onion in subsurface irrigation. *International J. Plant Production*, 7(3), 417-436.

Sankar, V., Lawande, K.E. and Tripathi, P.C. (2008). Effect of micro irrigation on growth, yield and water-use efficiency of onion (*Allium cepa* L.) under western Maharashtra conditions. *Indian J. Agric. Sci.*, 78(7), 584-588.

Tripathi, P.C., Sankar, V. and Lawande, K.E. (2017). Micro irrigation in onion (*Allium cepa* L.) and garlic (*A. sativum*) - A review. *Current Horticulture*, 5(1), 3-14.

Zheng, J., Huang, G. and Wang, J. (2013). Effects of water deficits on growth, yield and water productivity of drip-irrigated onion (*Allium cepa* L.) in an arid region of Northwest China. *Irrig. Sci.*, 31, 995-1008.