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OPTIMIZATION OF SUBSURFACE DRIP LATERAL DEPTHS AND IRRIGATION LEVELS FOR BEST YIELD RESPONSE OF ONION *(ALLIUM CEPA L.)*

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ABSTRACT

Drip irrigation is being used for growing high value crops as an alternative to traditional flood irrigation. However, high installation cost and short life (due to exposure to atmosphere) are major hindrances in its adoptability. Sub Surface Drip Irrigation (SSDI) is getting popularity for high value crops, as drip lines buried in the soil. However, its efficiency for different crops is still needed to explore. For this purpose, a study was designed to grow onion (*Allium cep L.*) on raised beds and irrigated through surface and subsurface drip irrigation for two years (i.e. 2015-16 and 2016-17). Three irrigations based on 100%, 80% and 60% of crop water requirement were applied with the drip laterals buried at depths of 0, 6, 12, 18 and 24 cm with three replications for each treatment. Dripper discharge of 4 l/s with operating pressure of one kg cm^{-2} was maintained for each irrigation. A significant effect of lateral depth was observed with maximum yield of 13,990 kg ha^{-1} obtained at 12 cm lateral depth, while minimum yield of 9,020 kg ha^{-1} was observed at the lateral depth of 24 cm. It can be concluded that shallow depth vegetables like onion can be grown with maximum irrigation water use efficiency of 57 kg ha^{-1} mm^{-1} using SSDI buried at the depth of 12 cm. Therefore, it is recommended that onion should be grown under SSDI with 12 cm depth and irrigated with 80% of CWR for better crop production and higher drip application efficiency in semi-arid regions.

Keywords: SSDI; lateral depth; irrigation water use efficiency; yield characteristics.

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INTRODUCTION

Water scarcity is a global issue affecting population of the world. It is reported that more than 1.2 billion people directly or indirectly facing problem of water scarcity (GOP, 2015). This water scarcity especially affected the developing countries having low crop water productivity due to old traditional methods (FAO, 2011). Effective management of available water resources is essential for developing countries like Pakistan where population is growing fast at the rate of 1.92% and is projected to reach 320 million by 2050 Chaudhary *et al.,*2015). The available water resources are 184 billion cubic meter (bcm), while per capita water availability has been reduced from 5950 m^3 in 1950 to 1200 m^3 in 2006 and estimated to be reduced to 1000 m^3 against the threshold value of 1800 m^3 (Iqbal *et al.,* 2015). With this increasing population and limiting water resources, ensuring food security is a challenging task. To cope with this issue, one possibility is to improve crop water productivity (i.e. yield per unit applied water) that can be achieved by replacing old conventional irrigation methods (Flood, Basin and Border) with high efficiency irrigation system (HEIS; e.g. drip irrigation), that can increase yield and improve water use efficiency (Dagdelen *et al.,* 2009; Tayel *et al.,* 2008; Mansour *et al.,* 2013; Mansour *et al.,* 2015; Biswas *et al.,*2015; Bhasker *et al.,* 2018).

Irrigation through HEIS is not a new concept and being in used in USA since 1960s. The HEIS provides water at the root zone in the required amount, while maintaining the soil surface dry thus minimizing evaporation from bare soil. Its suitability is higher in sandy and sandy loam soils (Bartolo, 2005), and minimizes weed growth, improves water use efficiency and reduces runoff and contamination of runoff and ground water into surface water bodies (Longo and Spears, 2003). Significant amount of water was saved using HEIS on row crops and it is especially suitable for high value crops and vegetables (Sahin *et al.,* 2015)

In Pakistan, HEIS is getting popularity especially in semi-arid and arid regions due to less irrigation water availability. However, adoptability is relatively lower because of higher installation cost and maintenance issues. During a recent impact assessment campaign carried out by the authors, farmers are quite satisfied with the performance of solar-coupled HEIS for growing high value crops. The maintenance of drip laid on the surface is still a problem that results in reduced life of drip system. Moreover, the drip irrigation system is successful only, if wetted soil pattern matches the crop root zone requirement with proper selection of design parameters, including dripper discharge, number of drippers, irrigation interval and operating pressure (Camp and Lamm, 2003; Detar, 2004). The water uptake by roots of plants increases the drying of soil. It is suggested that dipper discharge should be selected in such way that it may match with rate of water uptake by a plant (Lazarovitch, 2001; Lamm, 2016)

In order to reduce these concerns, drip lateral buried in the soil normally called as Sub Surface Drip Irrigation (SSDI) system could be an alternative. Researchers (Michelle, 2005; Singh *et al.,* 2006; Lamm *et al.,* 2010; Bagal *et al.,* 2012; Bhasker *et al.,* 2018) obtained better yield of crops sown under SSDI than normal surface drip system. This is possible because of minimum evaporation losses in case of subsurface drip irrigation (Camp 1998; Phene *et al.,*1992). Evett *et al.,* (1995); Mansour *et al.,* (2015) and Biswas *et al.,* (2015) concluded that yield for SSDI was better than the on surface drip due to less evaporation losses and further reported that water saved in subsurface drip irrigation was 5.1cm and 8.1cm by placing lateral at 15 and 30 cm below surface, respectively. Evaporation losses were low for well-watered crops with dry soil as compared to that of wet soil surface as in case of surface drip irrigation (Burt *et al.,*1997). Feasibility of subsurface drip irrigation for more than 30 crops at different depths of drip lateral from 2 to 70 cm was studied by Camp *et al*., (2000). Vegetables like beans, carrot, onion, tomato, peas, sweet corn, potato, cabbage, water melons, broccoli and lettuce were investigated to grow under SSDI system (Lamm and Trooien,2003; Enciso *et al.,*2005). They concluded that the placement and suitability of SSDI was highly variable for different crops and soils. Therefore, site-specific investigation of lateral depth and discharge rate must be carried out before using this system under local conditions. As it is difficult to understand distribution of soil water in SSDI due to unsaturated soil hydraulic properties, which result in low water use efficiency (Ruskin, 2000; Ben *et al.,*2004; Ayars *et al.,* 2015).

As in Pakistan, the farmers are moving towards using HEIS and SSDI system parameters are yet to explore for different vegetables, this pilot study has been carried out to test the influence of different drip lateral depths under altered irrigation levels for onion crop. This research will provide guidelines to use SSDI at proper depths and irrigation levels thus helping farmers to use the system properly with less chances of failure.

MATERIALS AND METHODS

Study area: This study was conducted at Water Management Research Centre (WMRC), University of Agriculture Faisalabad Pakistan (longitude 73.00^o E and latitude 35.23^o N). The experiment was conducted on onion for two consecutive years i.e. 2015-16 and 2016-17. The climate of the experimental area was arid to semi-arid with average rainfall of 300-350 mm and maximum and minimum temperature of 33.7 $^\circ$C and11.8 $^\circ$C respectively. The summer was hot with monsoon rainfall during months of June to August, while winter was cold with very less rainfall caused due to western disturbances. The details of climate prevailed during the study years are provided in the Table 1. The climatic conditions of area were favorable to grow wheat, maize, cotton, sugarcane and vegetables like cucumber, onion, tomato etc. All type of irrigation methods was in practices.

Table 1. Climatic situation prevailed in the study area during the study years 2015-16 and 2016-17.

Month	Average. temperature (° C)		Rel. humidity%		Mean daily Sunshine hours		Rainfall (mm)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Nov	19.6	20.1	61.5	60.1	6.1	6.4	8.8	0
Dec	14.5	16.4	62.5	68.7	7	6.7	0	0
Jan	12.5	12.9	74.4	72	3.5	3.6	13.1	11.5
Feb	16.3	16.8	58.1	53	8.5	6.6	7.8	16.2
Mar	21.2	20.7	59.7	49.5	6.8	7.2	66.7	26.2
Apr	27.2	29.3	34.2	30.6	8.2	9.2	5.6	28.3

Soil Properties and Water Quality: Samples of soil were collected from 10 different locations at 3 different depths i.e. (0-15, 15-30 and 30-45 cm) and analyzed in laboratory of WMRC, University of Agriculture, Faisalabad to test soil texture, bulk density, field capacity and permanent wilting point. Soil texture was analyzed using hydrometer method, described by Moodie *et al.,* (1959), whereas field capacity and permanent wilting point were calculated using pressure membrane apparatus. Bulk density was recorded with core method. It was observed that soil was sandy loam, with bulk density estimated at 1.56 g/cm^3, while field capacity and permanent wilting point were 20.66% and 8.38% respectively. Table 2 shows some physical properties of the soil of the experimental site.

Table 2. Soil physical properties of the study area.

Depth (cm)	Field Capacity percent moisture content (Vol. basis)	Wilting Point percent moisture content (Vol. basis)	Bulk density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	Textural class
0–15	20.196	8.415	1.55	65	22.5	12.5	Sandy Loam
15-30	20.904	8.424	1.56	64.1	22.2	13.2	Sandy Loam
30-45	20.881	8.321	1.57	65	21	14	Sandy Loam

Water quality (both canal and tube well) was within the safer limits as described by Water and Power Development Authority (WAPDA). The irrigation water samples were collected from both the sources i.e. canal and tube well and estimate for EC, pH, residual sodium carbonate (RSC) and sodium absorption ratio (SAR). After collection, all the sample were taken to Water Quality Lab of Irrigation and Drainage Department, University of Agriculture, Faisalabad. The value of pH and EC was determined using pH and EC meter. The SAR was calculated using formula given below after calculating the ratio of Na, Ca and Mg using Flame Atomic Spectrophotometry as:

$$\mathbf{SAR = [Na^{+}] / [(Ca^{2+} Mg^{2+})/2]^{1/2}}$$

Where [Na+], [Ca^{2+}], and [Mg^{2+}] are the concentrations in meq/L of sodium, calcium, and magnesium ions.
RSC was calculated using formula given below as:

$$\mathbf{RSC = (CO_3^{2-} + HCO_3^{-}) – (Ca^{2+} + Mg^{+2})}$$

Where, all concentration is in meq/L.

All the results concluded that both canal and ground water were within the standard limits and fit for irrigation. Both canal and ground water were used for irrigation depending upon availability of canal water. The results are presented in Table 3 and water standards recommended by WAPDA, Pakistan are given in footnote of the table.

Table 3. Chemical analysis of water (canal and groundwater) used for irrigation.

Parameter	Canal water				Ground water			
	R1	R2	R3	Average	R1	R2	R3	Average
pH	7.2	7.12	7.22	7.18	7.65	7.88	7.34	7.6
EC(dS/m)	1.14	1.15	1.11	1.13	1.54	1.47	1.43	1.48
SAR(meq/L)	3.7	3.6	3.7	3.67	4.1	4.3	3.9	4.1
RSC(meq/L)	1.67	1.66	1.62	1.65	1.63	1.67	1.66	1.65

Irrigation water quality standards (WAPDA, Pakistan)
Ph= 7-8.5 (Acceptable range),
RSC(meq/L) = if < 2.5 (Good), if range between 2.5-5(Marginal), if > 5 consider (Bad)
SAR(meq/L) = if < 10 (Good), if range between 10-18 (Marginal), if > 18 consider (Bad)
EC(ds/m) = if < 1.5 (Good), if range between 1.5-2.7(Marginal), if > 2.7 consider (Bad)

Experimental layout: The experiment was conducted on 2100 m^2 with drip laterals installed at 61 cm wide raised-beds. The experimental design was Randomized Complete Block Design (RCBD) with 5 treatments and 3 replications. Five treatments (T_O, T_1, T_2, T_3, T_4) referred to drip laterals depths i.e on surface, 6 cm, 12 cm, 18 cm and 24 cm below ground surface with three replications of 100%, 80% and 60% of crop water requirement was studied. The detail of experimental treatments is presented in table 4. For the purpose of seedlings, initially onion (**Variety: Phulkara**) seeds was sown in the seedbeds for time period of 4-8 weeks before transplanting in the field. The land was ploughed 2-3 times, after which the field was levelled and ready to transfer the seedlings to the field. For both the years **i.e. 2015-16 and 2016-17,** seedling was transplanted in the field during the last week of November with four rows sown on the raised beds, two at each side of drip laterals at a distance of 10 and 23 cm maintained plant to plant distance of 10 cm apart as shown in Fig 1. Field demonstration and data collection is also shown in Fig 2.

Table 4. Details of experimental treatments.

Treatments	Depth of drip buried at different depth (cm)	Level of irrigation (%)
T_0	0 (surface)	100
T_1	6 (Subsurface)	100
T_2	12(Subsurface)	100
T_3	18(Subsurface)	100
T_4	24(Subsurface)	100
$0.8T_0$	0 (surface)	80
$0.8T_1$	6(Subsurface)	80
$0.8T_2$	12(Subsurface)	80
$0.8T_3$	18(Subsurface)	80
$0.8T_4$	24(Subsurface)	80
$0.6T_0$	0 (surface)	60
$0.6T_1$	6(Subsurface)	60
$0.6T_2$	12(Subsurface)	60
$0.6T_3$	18(Subsurface)	60
$0.6T_4$	24(Subsurface)	60

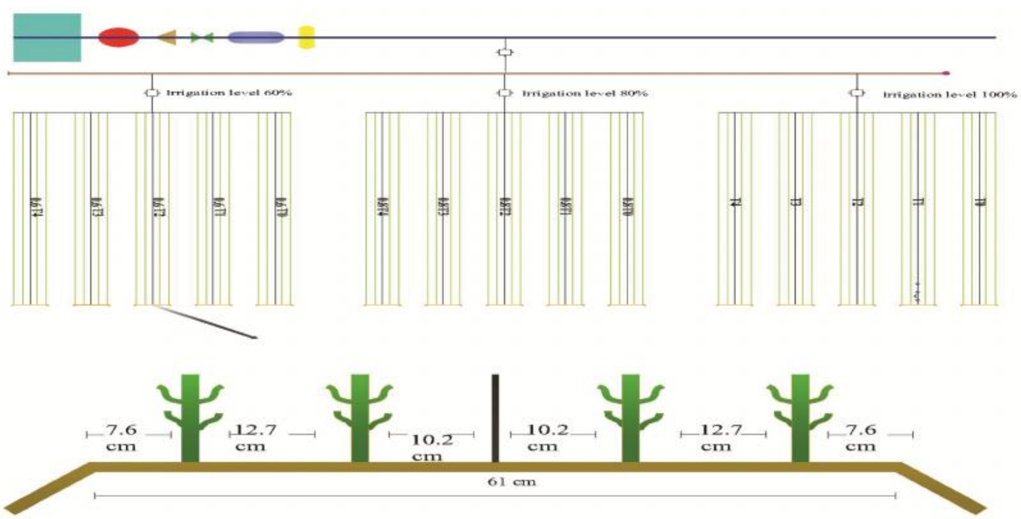

Figure 1. Layout of experiment with schematic geometry of laterals buried in raised bed

Figure 2. Field demonstration and data collection of onion crop

Drip Operating Parameters

Dripper discharge uniformity: Dripper application uniformity was evaluated using 60 drippers selected randomly. The uniformity of water application for the dripper discharge was analyzed in terms of coefficient of variation (CV), statistical uniformity (SU) and distribution uniformity (DU) using equation (1), (2), and (3) respectively as suggested by Patel and Rajput, (2008) and Chauhdary *et al.,* (2015). Five micro-irrigation uniformity classifications were used to evaluate the performance of SSDI, which ranged from acceptable to unacceptable (ASAE, 1996a, b).

$$CV = \left(\frac{s}{q}\right) \quad (1)$$

$$DU = \left(\frac{q_{lq}}{q}\right) \times 100 \quad (2)$$

$$SU = \left(1 - \frac{s}{q}\right) \times 100 \quad (3)$$

where 's' is the standard deviation of drippers discharge (l hr^{-1}), 'q' is mean dripper flow rate (l hr^{-1}), and 'q_{lq}' is mean of lowest one-fourth of drippers discharge (l hr^{-1})

Operating Pressure: Operating pressure is the important parameter controlling overall performance of the system and help in providing required amount of water to the root zone without excessive percolation, seepage and evaporation. Two operating pressure i.e. (1 kg cm^{-2} bar and 2 kg cm^{-2}) were investigated to verify the efficiency of the drip system. The field conditions were developed in the lab providing opening in the vessels filled with soil at 0 cm, 6 cm, 12 cm, 18 cm and 24 cm referred as treatments T_0, T_1, T_2, T_3, T_4, respectively. For these five vessels, system was operated for two selected operating pressures i.e. 1 kg cm^{-2} bar and 2 kg cm^{-2} for 30 minutes daily for 30 days during the month of October and the dimension of cavity formation on soil surface was observed. In this way best operating pressure was selected to avoid over or under irrigation.

Evaporation losses: Evaporation losses in the SSDI were estimated to check water use efficiency as suggested by (Singh, 2004; Patel and Rajput, 2008). The same setup (section 2.4.2) was used to determine evaporation losses. After selection of 1 kg cm^{-2}operating pressure, the system was operated for 30 minutes daily for the month of October. Weight of the vessels used to collect water was taken before and after operating the system at 1 kg cm^{-2}. The difference was calculated as evaporation loss.

Estimation of irrigation water requirement: Crop water requirement was calculated using class-A pan and crop coefficient for each growing stage of onion that was estimated at 0.7, 0.9, 1.05 and 0.75 at initial, development, bulb formation and bulb maturity stage, respectively (Allen *et al.*, 1998). From first stage to last stage, the crop water requirement ranges between 0.1 to 6.6 mm day^{-1} and 0.1 to 6.11 mm day^{-1} for the years 2015-16 and 2016-17, respectively. To apply exact amount of water required for each treatment, control valves were used. Total crop water requirement for different treatments varied between 38 cm to 22 cm for two growing seasons. Crop water requirement for different growth stages during the two growing seasons is shown in Fig 3.

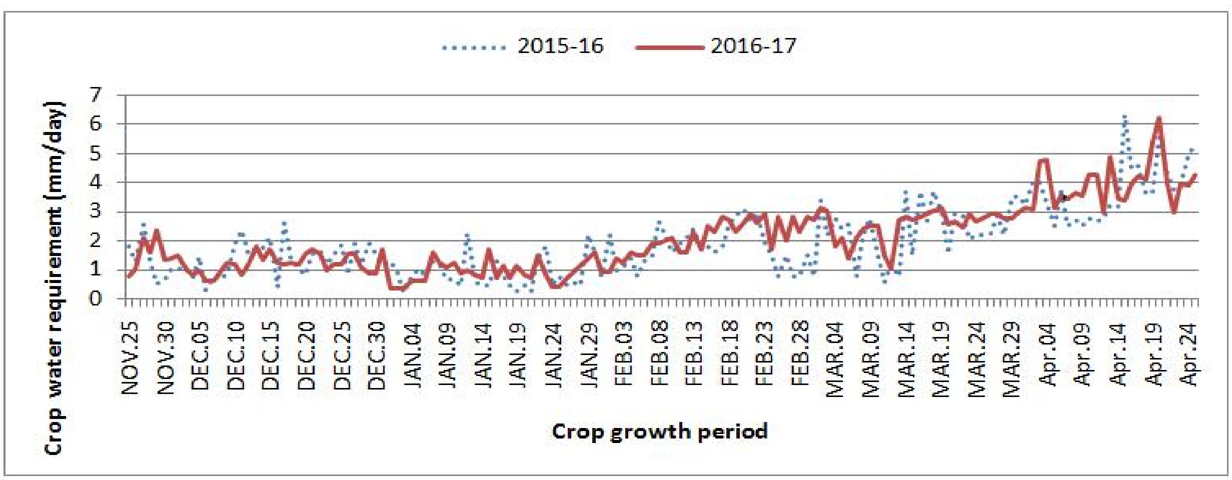

Figure 3. Crop water requirement of onion during the growing season of 2015-16 and 2016-17.

Nutrient application: The nutritional requirement of onion was 100 kg ha^{-1} potassium (P), 150 kg ha^{-1} nitrogen (N)and 80 kg ha^{-1} phosphorous (K). For proper application of N, P and K, Urea, phosphoric acid and muriate potash were used, respectively. After 15 days of transplanting, fertigation was started on weekly basis with irrigation. For precautionary measures, fertilizer was filtered to remove any foreign material and it was poured directly into the main drip system.

Onion yield: The onion was uprooted after 155 days of sowing (for both the years), during the last week of April (i.e 22/04/2016 and 27/04/2017). The crop was dried for three days and bulbs were separated. Statistical analyses on yield of different treatments were carried out using standard analysis of variance (ANOVA) to test the significance of the treatments. Least significant difference (LSD) test was used for comparison between the treatments' mean at 5% probability level.

Irrigation water use efficiency: The water use efficiency is a ratio between outputs i.e. crop yield obtained to the input i.e. total water applied. The water used efficiency was calculated using Eq.4,

$$\text{Irrigation water use efficiency} = \frac{Y}{T.I.W.P} \quad (4)$$

(where Y= Yield (kg ha^{-1}), T.I.W.P =Total Irrigation Water Applied (mm))

RESULTS AND DISCUSSION

Efficiency of drip system: The SSDI system installed for the experiment operated at 1 kg cm^{-2} pressure for all the treatments for two growing seasons i.e 2015-16 and 2016-17. The performance of the system was tested for two years was found good with CV estimated at 0.052 and 0.058, respectively. Patel and Rajput (2008) stated that CV value between 0.05-0.066 indicated efficient performance of drip system. Similarly, DU and SU were more than 90%, during the two growing seasons and marked as efficient as suggested by Patel and Rajput, 2008. Chauhdary *et al.,* (2015) also reported that the drip system with DU and SU greater than 90% and 91% respectively indicated an efficient performance of the installed drip system. Operating pressure was tested to check the performance of the system and 1 kg cm^{-2} was finally selected on the basis of less cavity formation in SSDI, as more cavities were observed for operating pressure of 1 kg cm^{-2}, while dripper discharge was adjusted at 4 l h^{-1}.

The evaporative losses were measured for all the five treatments. It depicted that the evaporation loss decreases with increase in depth of drip lateral. It was observed that evaporation loss for treatments T_0, T_1, T_2, T_4 and T_4 were 14.8%, 9.22%, 6.33%, 4.56% and 2.45%, respectively (Fig 4). results were also reported by(Meshkat *et al.,* 2000) and Patel and Rajput, 2008).

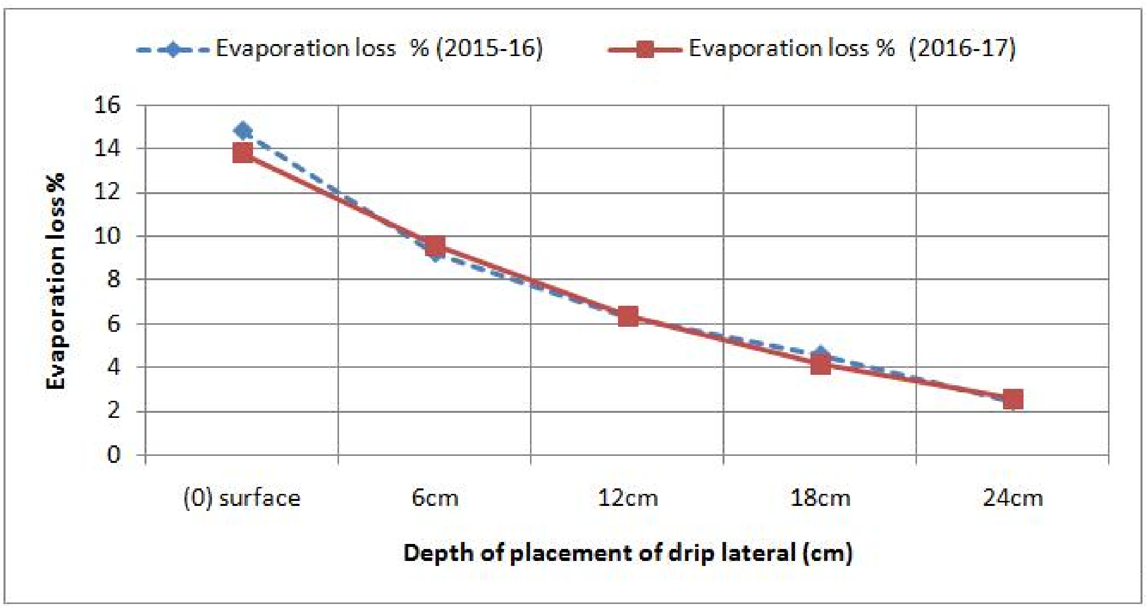

Figure 4. Percentage evaporation loss at different depths of drip laterals

Yield (kg ha^{-1}) and irrigation water use efficiency (kg ha^{-1} mm^{-1}): Yield was found highly significant for different treatments (i,e different depths of drip lateral) under different irrigation levels (Table 5).The significantly higher yield of onion was found in treatment T_2 measured as13990 kg ha^{-1} while minimum was observed in case of treatment T_4 i.e. 9.02 t ha^{-1}. It was observed that the onion yield varied for different treatments under different irrigation levels i.e. (100%, 80%, 60% of crop water requirement).

The overall onion yield for treatments T_0, T_1, T_2, T_3 and T_4 was measured as12850 to 10610, 14100 to 11410, 15860 to 11420, 12470 to 8550 kg ha^{-1} and 9920 to 7280 kg ha^{-1} respectively. Similarly, comparison of the treatments showed that maximum yield was found under T_2 as 13990 t ha^{-1}, followed by T_1 and T_0 as 12820 kg ha^{-}

[1] and 11790 kg ha^{-1} respectively while minimum yield was found under T_4 as 9020 kg ha^{-1}. Similar findings were also reported by Kadayifci *et al.,* (2005) and Patel and Rajput (2008). The different irrigation level 100%, 80% and 60%, also significantly affected the yield as shown in Table 5. It was observed that as compared to treatment T_0, 20% water was saved under treatment $0.80T_0$ with onion yield decreased by 7%, but for $0.60T_0$ amount of water saved was 40% with yield decreased by 16%. Similarly, it was also observed that as compared to treatment T_1, 20% water was saved under treatment $0.80T_1$with onion yield decreased by 8%, but for $0.60T_1$, amount of water saved was 40% with yield decreased by 19%.

For treatment T_2, 20% water was saved under treatment $0.80T_2$ with onion yield decreased by 8%, but for $0.60T_2$, amount of water saved was 40% with yield decreased by 25%. Further for treatment T_3, 20% water was saved in treatment $0.80T_3$ with onion yield decreased by19%, but for $0.60T_3$, amount of water saved was 40% with yield decreased by 31%. Dagdelen *et al.,(*2006); Karlberg *et al.,* (2012); Anjum *et al.,* (2014); and Satyendra *et al.,* (2007) also reported that water stress levels had significant affect on the vegetable yields. Effect of different depth of drip laterals under different irrigation levels on yield (kg ha^{-1}) for the growing seasons 2015-2016 and 2016-2017 is presented in Fig 5.

Table 5. Effect of different irrigation levels and depth of drip laterals on yield (kg ha^{-1}).

Treatments (Depth of drip laterals)	Irrigation Levels			
	100%	80%	60%	Mean
T_0	12850±0.00bcd	11890±530de	10620±110efg	11790±360C
T_1	14110±60bc	12950±540bcd	11410±490d-g	12820±440B
T_2	15870±120a	14530±830ab	11580±140def	13990±680A
T_3	12470±100cd	10050±130fgh	8520±80hi	10350±580D
T_4	9920±30fgh	9820±20gh	7330±270i	9020±430E
Mean	13040±520A	11850±510B	9890±460C	

*T_0= o cm (surface drip irrigation), T_1= 6 cm (depth of drip lateral below soil surface), T_2= 12 cm (depth of drip lateral below soil surface), T_3= 18 cm (depth of drip lateral below soil surface), T_4= 24 cm (depth of drip lateral soil surface)

*Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

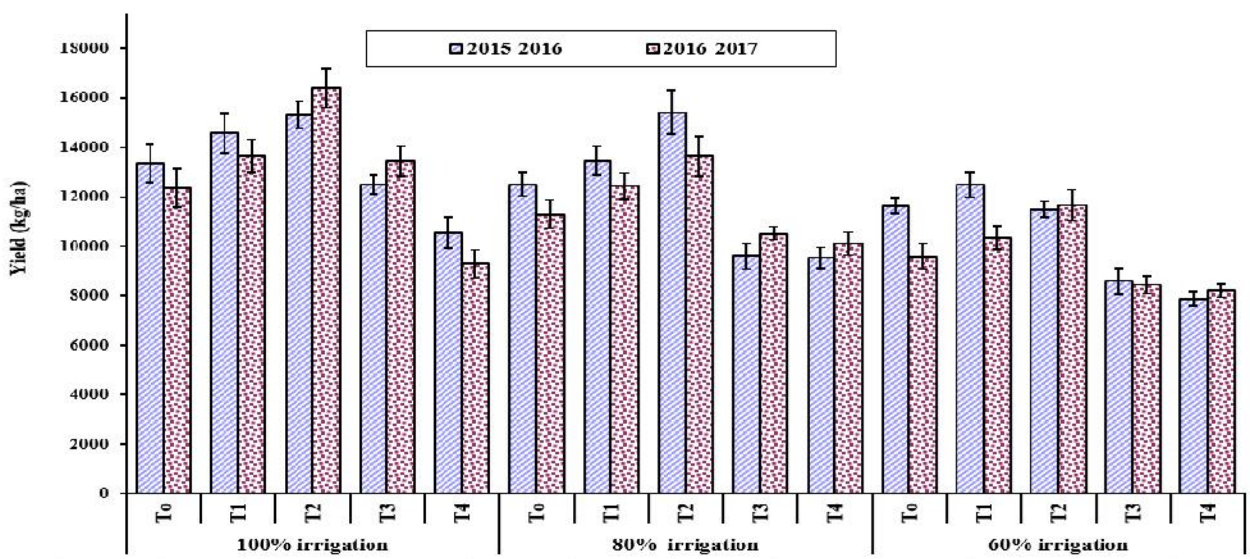

Figure 5. Effect of different depth of drip laterals under different irrigation levels on yield (kg ha-1) for both the years i.e. (2015-16 and 2016-17).

Application of 40% less amount of water as per crop water requirement decreased the yield for different treatments. It can be concluded that onion was very sensitive to stress at different growth stages. Onion yield showed a linearly relationship with the application of water. Similar findings had also been reported by Kadayifci *et al.,* (2005) and Patel and Rajput (2008). It was also observed that yield obtained in SSDI was significantly higher than the surface irrigation method (Satyendra *et al.,*2007; Enciso *et al.,* 2015 and Shock *et* *al.,* 2013). The deficit irrigation of 40%, has shown decreased onion yield due to placement of the drip lateral at 24 cm decreased the lateral movement of water in the soil, so outer plant row was unable to receive water up to the field capacity. For the treatment T_2, best yield was observed due to proper lateral water movement and less evaporation. The lateral depth at 10-12 cm depth can be consider as best suitable depth for onion that was also suggested by (Singh *et al.,* 2005).

Drip lateral placed at 12 cm depth with 40% deficit irrigation estimated maximum irrigation water used efficiency of 52 and 49 (kg ha^{-1} mm^{-1}) for growing seasons 2015-16 and 2016-17 respectively Table 6. Total depth of irrigation water was 325 mm, 270 mm and 225 mm for 100%, 80% and 60% irrigation levels under different depths of drip laterals. These were also supported by the studies of Kadayifci *et al.,* (2005) and Patel and Rajput (2008) for onion crop under subsurface drip irrigation. The overall IWUE for different depth of drip lateral for treatments T_0, T_1, T_2, T_3 and T_4 was 55, 48, 46, 37 and 35 (kg ha^{-1} mm^{-1}) respectively. For different irrigation level maximum IWUE was observed at 60% irrigation level as 47 (kg ha^{-1} mm^{-1}) and minimum IWUE was observed for 100% irrigation level as 41 (kg ha^{-1} mm^{-1}). Effect of different depth of drip laterals under different irrigation levels on irrigation water use efficiency (kg ha^{-1} mm^{-1}) for both the years i.e. (2015-16 and 2016-17) is presented in Fig 6. It is concluded that in water constrict condition 20% water deficit can be considered best in accordance with Satyendra *et al.,* (2007); Mehment *et al.,* (2004); Juan *et al.,(*2015); Aurora *et al,* (2005); Dagdelen *et al.,* (2007) and Ana *et al.,* (2005) that subsurface improves irrigation water use efficiency.

Table 6. Effect of different irrigation levels and depth of drip laterals on irrigation water use efficiency (kg ha^{-1} mm^{-1}).

Treatments (Depth of drip laterals)	Irrigation Levels			
	100%	80%	60%	Mean
T_0	42.5±1.3	44.3±1.8	52.5±1.5	46.4±1.7B
T_1	44.3±1.9	49.7±0.7	51.3±0.9	48.4±1.2B
T_2	50.7±1.2	58.2±1.5	59.5±3.1	56.1±1.7A
T_3	38.0±2.1	35.8±1.7	38.0±4.0	37.3±1.4C
T_4	31.8±1.2	34.7±0.7	36.3±3.3	34.3±1.2C
Mean	41.5±1.8C	44.5±2.4B	47.5±2.6A	

*T_o= o cm (surface drip irrigation), T_1= 6 cm (depth of drip lateral below soil surface), T_2= 12 cm (depth of drip lateral below soil surface),T_3= 18 cm (depth of drip lateral below soil surface), T_4= 24 cm (depth of drip lateral soil surface)

*Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

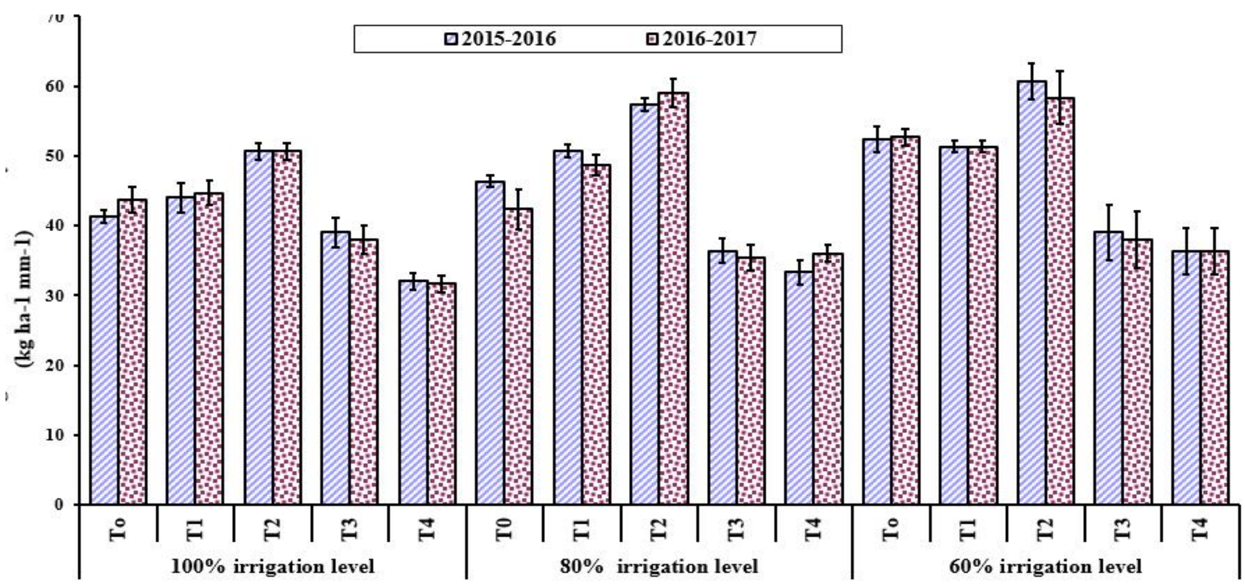

Figure 6. Effect of different depth of drip laterals under different irrigation levels on irrigation water use efficiency (kg ha^{-1} mm^{-1}) for both the years i.e. (2015-16 and 2016-17)

Conclusions: The operating pressure of 1.0 kg cm^{-2} with dripper discharge of 4.0 l hr^{-1} was adjusted as a best option to operate the drip system because it did not lead to more cavity formation. The coefficients of variance for drippers flow rate were 0.052 and 0.058 during 2015-16 and 2016-17, respectively. It is concluded that if the depth of lateral is more than 18cm, then it will not provide sufficient soil moisture available for plant. A significant effect of lateral depth was observed with maximum yield of 13990 kg ha^{-1} was obtained at 12 cm lateral depth, while minimum yield of 9002 kg ha^{-1} was observed with lateral depth of 24 cm. It is concluded that in water restricted condition, 20% water deficit can be consider as best for higher crop yield and irrigation water use efficiency.

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