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EFFECT OF PULSE IRRIGATION (DRIP) THROUGH DIFFERENT IRRIGATION LEVELS ON SOIL MOISTURE DISTRIBUTION PATTERN AND YIELD PARAMETERS OF WHITE ONION (*ALLIUM CEPA* L.)

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Abstract

The field experiment was conducted during *rabi* season from 12th November, 2014 to 26th April, 2015 and 23rd November, 2015 to 4th May 2016, on sandy clay loam soil at Instructional Farm of Department of Irrigation and Drainage Engineering, College of Agricultural Engineering and Technology, Dr. BSKKV, Dapoli, India (latitude $17^0 45'$ N and longitude $73^0 10'$ E and altitude of 250 m). The experiment was arranged in twelve treatment combinations with strip plot design as horizontal factor (main treatment) one continuous irrigation (P_1), two pulses (P_2), three pulses (P_3) and four pulses (P_4), while vertical factor (sub treatment) as irrigation levels viz. I_1 (0.80 ET_C), I_2 (1.0 ET_C) and I_3 (1.20 ET_C) treatments. The soil moisture content at 2 hr after irrigation in I_2P_4 treatment combination contours attained semicircular shape. The field capacity moisture (26.0 %) was discerned at 2 hr after irrigation in I_2P_4 treatment combination at 30 cm distance from the emitter across the lateral at 15 cm depth, which might have provided favorable soil-water-air plant relationship during critical growth stages of onion between two emitters at 30 cm distance across the lateral. It was contemplated that average soil moisture content across 30 cm distance from the emitter at 2 hr before and after 2 hr irrigation at 15 cm and 30 cm depth in the treatment combination I_2P_4 provided favorable soil-water-air plant relationship in the entire root zone. The interaction effect revealed that highest mean polar diameter (63.88 mm), geometric mean diameter (59.51 mm), equatorial diameter (63.16 mm), average bulb weight (112.05 g) and yield (38.52 $t.ha^{-1}$) of white onion was found in treatment combination I_2P_4 followed by I_3P_4.

Key words : Pulse irrigation (drip), irrigation scheduling, soil moisture, yield and quality parameters.

Introduction

India has the total geographical area of 328.70 M.ha, out of this cultivable land area is about 182 M.ha, comprising of this net sown area of about 141.40 M.ha. Total gross cropped area is 200.90 M.ha with cropping intensity of 142 per cent. The net sown area works out to be 43 per cent of the total geographical area (Anonymous, 2016a).

In India gross irrigated area during the year 2012-13, 2013-14 and 2015-16 are 91.78 M.ha, 92.25 M.ha and 95.77 M.ha and total cropped area was 195.69 M.ha, 194.14 M.ha and 200.86 M.ha, respectively (Anonymous, 2016 b).

Pulse irrigation (drip) is the concept where the small part of the per day water requirement is given in fraction with a predetermined time of fraction (Dole, 1994). Pulsing irrigation refers to the practice of irrigating for a short period then waiting for another short period, and repeating this on-off cycle until the entire irrigation water is applied (Eric *et al*., 2004). Under pulse irrigation system amount of irrigation water and operation time play a key role in reducing run-off, decreasing percolation of water beneath the root zone and reducing water evaporation after irrigation.

In case of sandy soil under pulse irrigation (drip), horizontal spread of soil moisture is increased than the vertical spread. High irrigation frequency provides desirable conditions for water movement in the soil and uptake by roots (Segal *et al*., 2000). Increased vertical spreading may be undesirable because water moving

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below the active root zone can result in wastage of water, loss of nutrients and ground water pollution. Application of high amount of irrigation water in single irrigation event may result in deep percolation losses in the root zone of growing plants.

Splitting of irrigation depth into six pulses with an interval of fifty minutes increased the yield by 5.78% with 25% of water saving in lettuce crop under sandy soils (Willian *et al*., 2015). Under pulse irrigation (drip) productivity of potato increased from 10.44 $t.ha^{-1}$ in continuous drip irrigation to 15.60 $t.ha^{-1}$ in four pulse irrigation (drip) recording an increase of 49 % yield (Abdelraouf *et al.,* 2012). Average maximum green bean yield was obtained under four pulse irrigation (drip) 4.78 $t.ha^{-1}$ (Mohamed *et al.,* 2012).

White onion crop can be cultivated effectively in South Konkan region comprising of Ratnagiri and Sindhudurg district having predominant lateritic soil. The lateritic soil is having high infiltration rates resulting in increased vertical movement of water (Mane *et al*., 2011). Pulse irrigation (drip) can be used effectively for increasing the horizontal spread in heavy infiltrating soils (Abdelraouf *et al*., 2012).

Materials and Methods

The experiment was conducted at Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The two *rabi* seasons trial of onion were carried, first research trial from 12th November 2014 to 26th April 2015, while second research trial from 23rd November 2015 to 4th May 2016. The experimental site is situated at 17^0 45' 13.1" N latitude and 73^0 10' 47.4" E longitudes and altitude of 174 m. Climatic conditions are humid with average annual rainfall at Dapoli region is 3635 mm (Mandale, 2016). The average minimum and maximum temperatures are 18.5 ^{0}C to 31.0 ^{0}C, respectively. The relative humidity ranges from 55 percent to 99 percent (Gaikwad, 2013).

The experimental design was strip plot and replicated four times. The unit plot size was 27.50 m × 9.70 m having a single bed of 3 m × 1.20 m. Onion seedlings were transplanted in the plots on 15 January 2015 in the first trial and 24 January 2016 in the second trial at the age of six weeks. Plant to plant and row to row spacing were 10 cm and 15 cm, respectively. The soil type of experimental field was sandy clay loam in texture having pH- 6.5, EC- 0.45 $dS.m^{-1}$, bulk density- 1.68 $g.cm^{-3}$, basic infiltration rate- 6.0 $cm.hr^{-1}$, field capacity- 26.0 % and permanent wilting point- 12.5 %. The plots were fertilized with the recommended dose of soluble fertilizer 150- 75- 25 $Kg.ha^{-1}$ N, P_2O_5 and K_2O, respectively. The irrigation water of nine and twelve millimeter had applied immediately for the establishment of seedlings after transplanting during the year 2014-15 and 2015-16, respectively. The soil moisture samples were taken 2 hrs before and 2 hrs after irrigation at fortnightly interval starting from 30 DAT to 75 DAT for all treatment combinations sequentially in all replications. The moisture content was determined by using the gravimetric method. The inline lateral of 16 mm diameter with 4 Lph discharge having 30 cm spacing at 1.0 $Kg.cm^{-2}$ operating pressure was used. The daily water applied for white onion (*Allium cepa* L) under pulse irrigation (drip) was worked out based on Penman-Monteith method (Allen *et al*., 1998). The available discharge and emission uniformity of the drip system were recorded as 3.94 $L.ha^{-1}$ and 96.0% for the year 2015 and 3.96 $L.ha^{-1}$ and 94.50% for the year 2016, respectively. Water application in pulse treatments was imposed on 19th Jan 2015, in first-year trial and 29th Jan 2016 in second-year trial. Water application in pulse treatments terminated on 16th April 2015, in first year trial and 23th April 2016, in second year trial. The onion bulbs were harvested on 2nd May 2015, in the first-year and 9th May 2016, in the 2nd year, respectively. The various periodic biometric observations were recorded on five randomly selected plants of white onion at 20 days interval from 30 DAT to 70 DAT from each plot of treatments. The statistical analysis was done by "analysis of variance" appropriate for the 'strip plot design'.

Results and Discussion

A. Gross depth of water applied

It was contemplated from the Table 1 that total reference evapotranspiration during the crop growth period in year 2014-15 and 2015-16 was 375.0 mm and 387.8 mm, respectively. The crop evapotranspiration (net depth) during the year 2014-15 and 2015-16 was varied from 328.4 mm to 340.4 mm. From the table 1 total water applied under treatment I_1 (0.8 ET_C) varied from 276.8 mm to 289.9 mm in the year 2014-15 and 2015-16, while it was 341.0 mm to 359.8 mm and 406.1 mm to 429.0 mm for irrigation treatments I_2 (1.0 ET_C) and I_3 (1.2 ET_C), respectively.

B. Soil moisture distribution pattern under pulse irrigation (drip)

The soil samples were collected from each treatment combination at the fortnightly interval during both the years (2014-15 and 2015-16). The allowable moisture depletion during growth stages of vegetable crops as suggested by Robert *et al*., 1996) is 20% of total available soil moisture content. This critical 20% depletion of total available soil moisture content was monitored in the evaluation of soil moisture distribution under the treatment combinations. The further discussions of results are more focused on this aspect. In the present case, the field capacity and permanent wilting point moisture content of the soil was 26.01% and 12.50%, respectively. Hence, allowable depletion of 20 % soil moisture was taken as 23.30% of soil moisture content.

The stages of onion crops are initial (0 to 20 days), development (40 days), mid (20 days) and late (10 days) (Allen *et al*., 1998). The bulb enlargement stage is the most sensitive stage during which adequate availability of soil moisture is highly desirable for growth and yield (Michael, 1978). The soil moisture samples were taken 2 hrs before and after irrigation at the fortnightly interval starting from 30 DAT to 75 DAT for all treatment combinations sequentially in all replications. These soil moisture observations coincide with most of the sensitive stages of the onion crop.

a. Average soil moisture content across the lateral through different irrigation levels 2 hr before and 2 hr after irrigation in continuous irrigation (P_1)

The figs. 1 a, 2 a and 3 a, illustrates the contours of soil moisture content at 2 hr before irrigation in I_1, I_2 and I_3 irrigation levels through continuous irrigation (P_1). In case of I_1 irrigation level, soil moisture contours appeared in conical shape showing increasing moisture content towards the bottom of the cone. The 46% depletion of available soil moisture was observed below the emitter at 15 cm depth, while the 34% depletion of available soil moisture was observed below the emitter at 30 cm soil depth. At the same time, 70% depletion was observed at 30 cm distance from the emitter, which might create stress to the second row of onion from the emitter.

In case of I_2 (1.0 ET_C) irrigation level, soil moisture contours appeared in conical shape showing 33 % depletion of available moisture was discerned at 30 cm distance from the emitter at 15 cm depth, which might result less stress on second row of onion from the emitter as compared to I_1 irrigation level. In case of I_3 irrigation level the contours appeared flat showing 27% depletion of available soil moisture content was observed below the emitter at 30 cm depth which might indicated stress on crop below the emitter. At the same time, 46% depletion of total available moisture was observed at 30 cm distance from the emitter at 15 cm depth, which might have caused stress on the second row of onion from the emitter.

In figs. 1 b, 2 b and 3 b depicted the contours of soil moisture 2 hr after irrigation in I_1, I_2 and I_3 irrigation levels through continuous irrigation (P_1). As illustrated in figs. 1 b, 2 b and 3 b, the contours of soil moisture appeared inverse conical shape showing increasing soil moisture in the vertically downward direction in higher water application treatments. In I_1 irrigation level, 26% depletion of available soil moisture was observed below the emitter at 30 cm depth, while 33% depletion of available soil moisture was discerned at 30 cm distance from the emitter at 15 cm depth, which might have imparting stress on the second row of onion crop across the lateral from the emitter. In case of I_2 irrigation level the contours attained inverse conical shape showing increasing downward movement of soil moisture as compared to I_1 irrigation level. In I_2 irrigation level, 27% depletion of available soil moisture was discerned at 15 cm distance from the emitter at 15 cm soil depth, which might have created moisture stress conditions to the second row of crop across the lateral. In case of I_3 irrigation level 7% depletion of available soil moisture was discerned below the emitter at 30 cm depth showing inverse conical shape with the increased vertical movement as compared to I_2 and I_1 irrigation level. The soil moisture of 19% depletion of available soil moisture was observed at 30 cm distance from the emitter at 15 cm depth, which might have provided soil moisture availability for a shorter duration.

b. Average soil moisture content across the lateral through different irrigation levels 2 hr before and 2 hr after irrigation in two pulse irrigation (P_2)

Figs. 4 a, 5 a and 6 a, delineated the contours at 2 hr before irrigation in I_1, I_2 and I_3 irrigation levels through two pulse irrigation (P_2). As depicted in figs. 4 a, 5 a, the moisture contours appeared inverse conical shape showing increasing soil moisture near the surface of the cone. The soil moisture of 41% depletion was observed below the emitter at 25 cm depth, while 56% depletion of available soil moisture was observed at 30 cm distance from the emitter at 15 cm soil depth, which might have created stress on the second row of onion crop across the lateral.

In case of I_2 irrigation level, the 33% depletion of available soil moisture was observed below the emitter at 30 cm depth, while soil moisture of 40% depletion of available moisture was discerned at 30 cm distance from the emitter at 15 cm depth, which was not healthy for good crop growth. In case of I_3 irrigation level, soil moisture of 24% depletion was observed below the emitter and appeared bulb shape. The moisture of 36% depletion was observed at 30 cm distance from the emitter at 15 cm soil depth, which might have created stress for good crop growth.

Figs. 4 b, 5 b and 6 b represented contours at 2 hr after irrigation in I_1, I_2 and I_3 irrigation levels. In case of I_1 irrigation level, soil moisture of 22% depletion of available soil moisture was observed below the emitter at 30 cm depth and appeared in inverse conical shape. The 28% depletion of total available soil moisture was observed at 30 cm distance from the emitter at 15 cm depth in the second row of onion, might have created stress to the crop. In case of I_2 irrigation level soil moisture contours appeared inverse conical shape showing vertical movement more at 30 cm depth below emitter as compared to I_1 irrigation level. The soil moisture of 19% depletion of available soil moisture was observed at 30 cm distance from the emitter at 15 cm depth, which might exert no stress on the second row of onion across the lateral. At the same time, soil moisture of 7% depletion was found below the emitter at 20 cm depth, which might have created availability of soil moisture less than 20% depletion within the root zone of the crop for the longer duration.

In case of I_3 irrigation level, the soil moisture above field capacity (26%) was observed below the emitter at 20 cm soil depth, which might be creating excessive moisture in the root zone below emitter resulting in reduced crop growth. The moisture of 12% depletion of available soil moisture was observed at 30 cm distance from the emitter, while 1% depletion of soil moisture was observed below the emitter showing vertical movement more than I_2 and I_1 irrigation levels.

c. Average soil moisture content across the lateral through different irrigation levels 2 hr before and 2 hr after irrigation in three pulse irrigation (P_3)

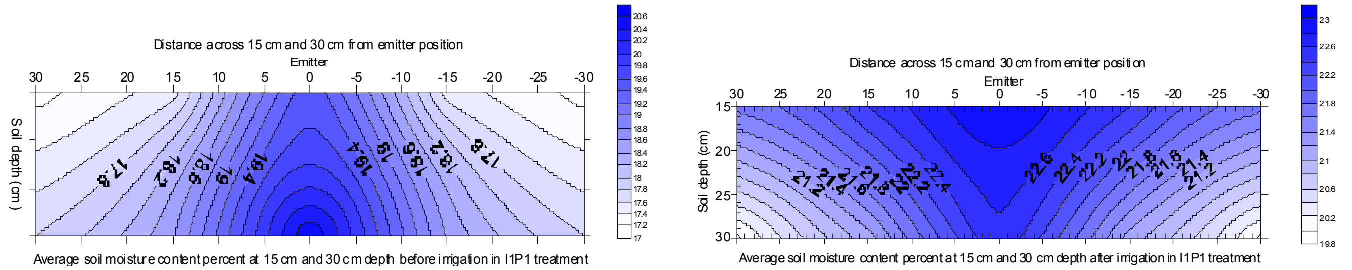
Figs. 7 a, 8 a and 9 a, depicted contours of 2 hr before irrigation in I_1, I_2 and I_3 irrigation levels through three pulse (P_3) irrigation. The soil moisture of 36% depletion of available moisture was observed below emitter at 20 cm depth. At the same time, 50% depletion of available soil moisture was observed at 30 cm distance from the emitter, which might have exerted stress on the second row of onion at 30 cm distance from the emitter. In case of I_2 irrigation level soil moisture of less than 20% depletion was observed below emitter at 20 cm depth and contours appeared in semicircular shape. The moisture of 38% depletion was observed at 30 cm distance from the emitter, which might have created unfavorable conditions to the second row of the onion. In case of I_3 irrigation level, 16% depletion of available soil moisture was observed at 20 cm depth below emitter showing more vertical movement of moisture as compared to I_2 and I_1 irrigation levels. At the same time of 34 % depletion of available soil moisture was observed at 30 cm distance from the emitter, which might have exerted stress-free on the second row of onion from the emitter across 30 cm distance from emitter as compared to I_2 and I_1 irrigation levels.

Figs. 7 b, 8 b and 9 b, represented contours at 2 hr after irrigation in I_1, I_2 and I_3 irrigation levels through three pulse (P_3) irrigation. The 13% depletion of available soil moisture was observed below emitter at 30 cm depth, while less than 20% depletion of available soil moisture was discerned at 22 cm from the emitter. At the same time, soil moisture of 23% depletion of available moisture was observed at 30 cm distance from emitter, which might have created less stress on second row of onion at 30 cm distance from the emitter as compared to I_1 and I_2 irrigation levels. In case of I_2 irrigation level, 6 % depletion of available soil moisture was observed at 30 cm depth below emitter, while contours appeared concave shape below the emitter. The soil moisture of 13 % depletion was observed at 30 cm distance from the emitter at 15 cm depth, which might have created stress-free conditions on the second row of the onion. In case of I_3 irrigation level soil moisture contours appeared in an inverse cone-shaped showing field capacity moisture (26%) at 30 cm depth below emitter within the root zone of the crop, which might have chance in seepage losses below the root zone of the crop.

d. Average soil moisture content across the lateral through different irrigation levels 2 hr before and 2 hr after irrigation in four pulse irrigation (P_4)

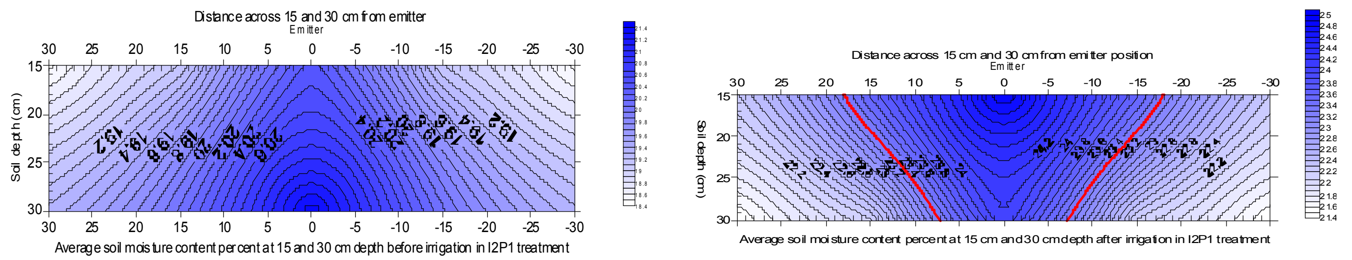
Figs. 10 a, 11 a and 12 a represented contours at 2 hr before irrigation in I_1, I_2 and I_3 irrigation levels through four pulse (P_4) irrigation. The soil moisture contour of 32% depletion was observed below emitter at 30 cm depth, while soil moisture contour of 44% depletion was observed at 30 cm distance from the emitter which might have resulted stress on the second row of onion at 30 cm distance from the emitter. In case of I_2 irrigation level, soil moisture of 17% depletion of total available soil moisture was discerned below the emitter at 30 cm depth. The soil moisture contours appeared in semicircular shape below the emitter at 15 cm and 30 cm depth. The soil moisture was depleted by 12% of available soil moisture at 30 cm distance from the emitter resulting no stress at 30 cm distance from the emitter at the second row of onion.

In irrigation level I_3 the contours appeared in



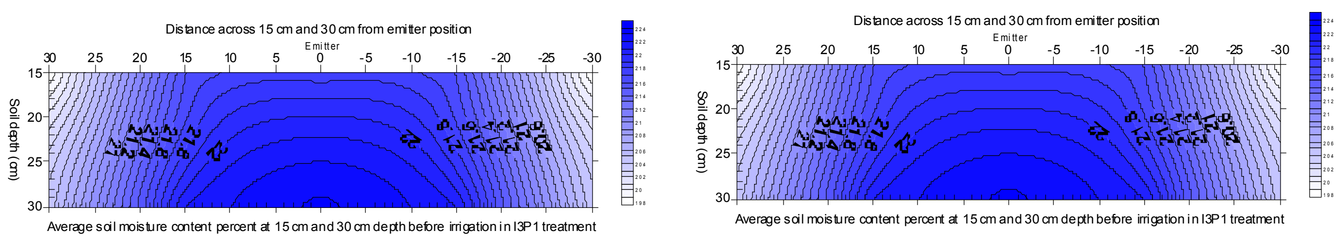
a 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 1 : Average soil moisture content across the lateral in $I_1 P_1$ treatment combination



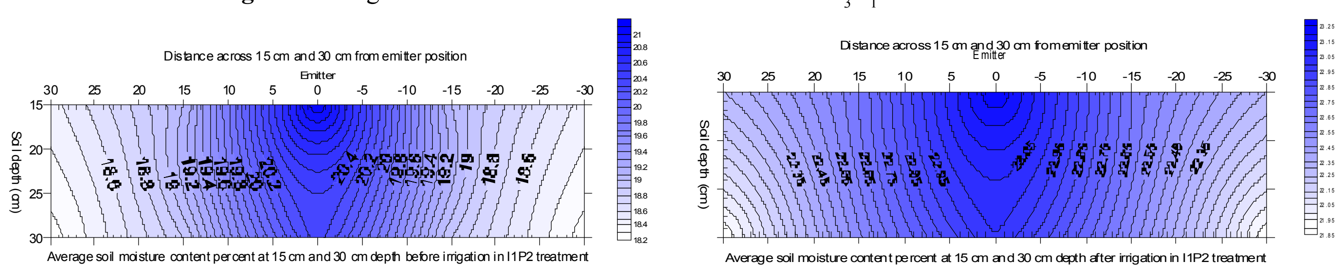
a 2- hr before next irrigation **b. 2 -hr after irrigation**

Fig. 2 : Average soil moisture content across the lateral in $I_2 P_1$ treatment combination.



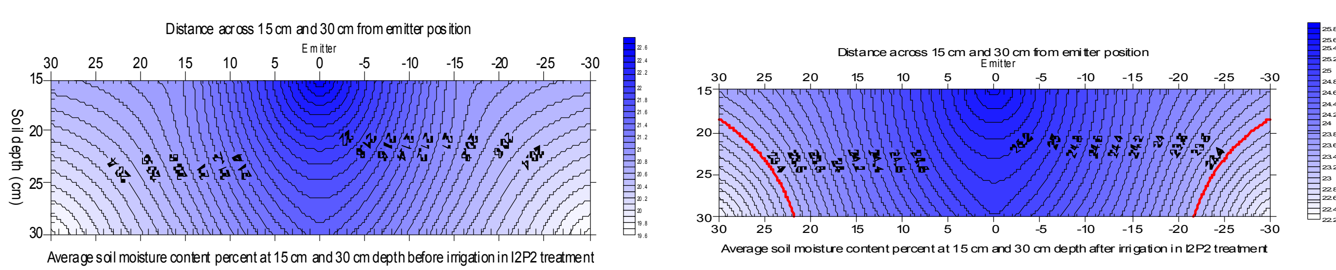
a. 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 3 : Average soil moisture content across the lateral in $I_3 P_1$ treatment combination.



a. 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 4 : Average soil moisture content across the lateral in $I_1 P_2$ treatment combination.



a. 2 - hr before next irrigation b. 2 **-hr after irrigation**

Fig. 5 : Average soil moisture content across the lateral in $I_2 P_2$ treatment combination.

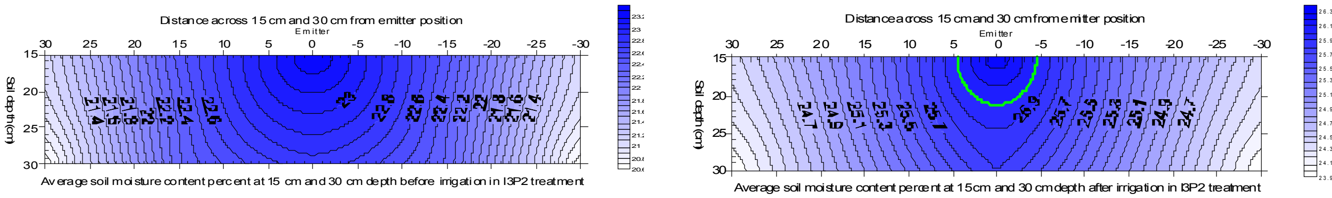
Table 1 : Month wise gross depth and seasonal depth applied for white onion under different irrigation treatments.

Irrigation levels	Season	January*	January**	February	March	April#	Seasonal ET_O/ ET_C/ Gross depth (mm)
ET_O	2015	12.1	41.5	109.8	134.3	77.3	375.0
ET_C		9.0	29.1	85.5	129.2	75.4	327.7
I_1 (0.8 ET_C)		9.0	23.2	71.2	111.1	62.8	276.8
I_2 (1.0 ET_C)		9.0	30.3	89.1	134.6	78.5	341.0
I_3 (1.2 ET_C)		9.0	36.3	106.9	161.5	92.9	406.1
ET_O	2016	17.1	7.1	108.9	141.9	112.6	387.6
ET_C		12.0	7.5	79.7	130.7	110.6	340.5
I_1 (0.8 ET_C)		12.0	6.0	67.5	110.6	93.7	289.8
I_2 (1.0 ET_C)		12.0	7.9	84.3	138.4	117.3	359.8
I_3 (1.2 ET_C)		12.0	9.5	101.1	165.9	140.5	429.0

* General irrigation for establishment of the crop from 15th January to 18th January, 2015 and from 24th January to 29th January, 2016
** Pulse treatments were imposed on 19th Jan 2015 and 29th Jan 2016.
\# Water application terminated on 16th April 2015 and 23th April 2016.

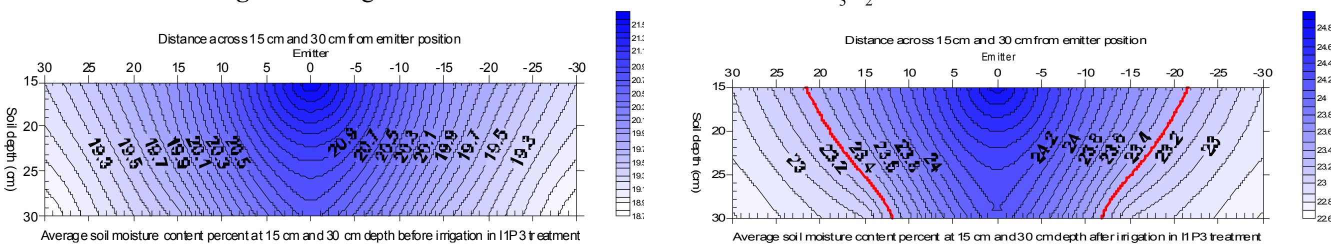
Table 2 : Individual and interaction effect of yield parameters of white onion (Pooled).

Pulse/ irrigation treatments	Mean polar diameter (mm)	Geometric mean diameter (mm)	Equatorial diameter (mm)	Average bulb weight (g)	Yield ton per (hectare)	TSS (Brix)
Continuous (P_1)	49.12	46.90	48.07	68.92	27.26	7.11
Two (P_2)	53.09	49.53	50.52	83.22	28.89	7.80
Three (P_3)	57.10	54.53	55.55	98.97	33.64	9.14
Four (P_4)	61.30	58.41	60.86	107.38	36.50	9.81
S.E.	0.86	0.43	0.40	1.27	0.91	0.15
C.D. at 5 %	2.56	1.27	1.19	3.76	2.70	0.44
I_1 (0.8) ET_C	51.80	49.41	50.92	77.94	29.30	7.55
I2 (1.0) ET_C	57.07	53.38	54.79	94.96	32.27	8.82
I3 (1.2) ET_C	56.59	54.24	55.53	95.97	33.15	9.03
S.E.(m)±	0.93	0.67	0.33	0.78	0.25	0.15
C.D. at 5 %	2.86	2.05	1.03	2.39	0.78	0.46
Interactions						
I_1P_1	46.84	44.30	45.49	57.07	25.24	6.65
I_1P_2	48.80	46.56	47.26	65.13	26.26	6.81
I_1P_3	53.68	51.40	53.67	88.82	31.99	8.33
I_1P_4	57.87	55.37	57.27	100.75	33.71	8.44
I_2P_1	49.70	47.89	48.94	71.81	27.25	7.23
I_2P_2	56.44	50.50	51.16	88.64	29.64	7.90
I_2P_3	58.25	55.64	55.91	107.32	33.66	9.70
I_2P_4	63.88	59.51	63.16	112.05	38.52	10.44
I_3P_1	50.82	48.52	49.77	77.88	29.29	7.47
I_3P_2	54.02	51.53	53.13	95.90	30.76	8.70
I_3P_3	59.38	56.56	57.09	100.77	35.28	9.40
I_3P_4	62.14	60.35	62.15	109.34	37.26	10.56
S.E.(m)±	0.71	0.71	0.74	2.19	0.81	0.10
C.D. at 5 %	2.04	NS	NS	NS	NS	0.28



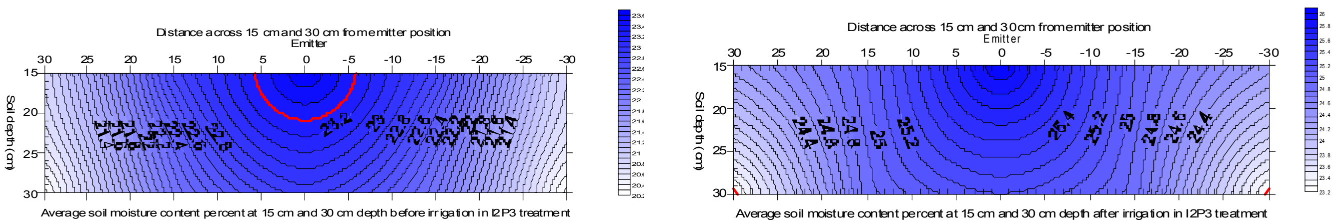
a. 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 6 : Average soil moisture content across the lateral in I_3P_2 treatment combination.



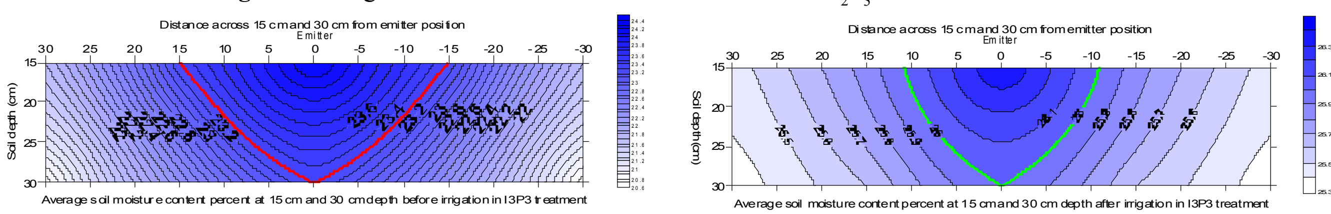
a. 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 7 : Average soil moisture content across the lateral in I_1P_3 treatment combination.



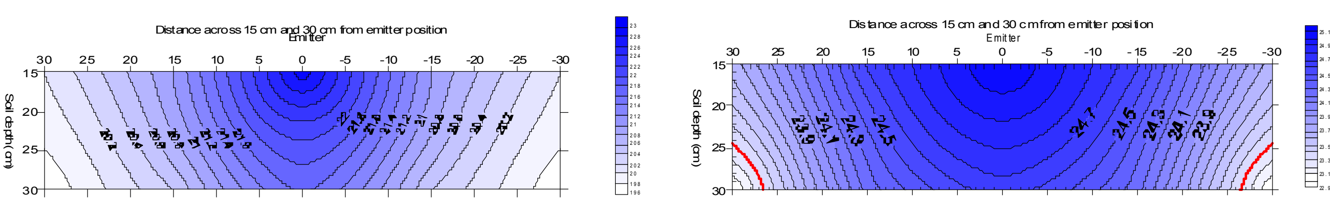
a 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 8 : Average soil moisture content across the lateral in I_2P_3 treatment combination.



a 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 9 : Average soil moisture content across the lateral in I_3P_3 treatment combination.

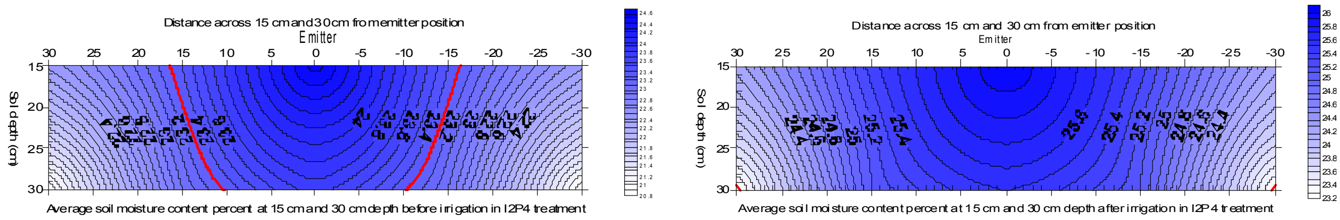


a 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 10 : Average soil moisture content across the lateral in I_1P_4 treatment combination.

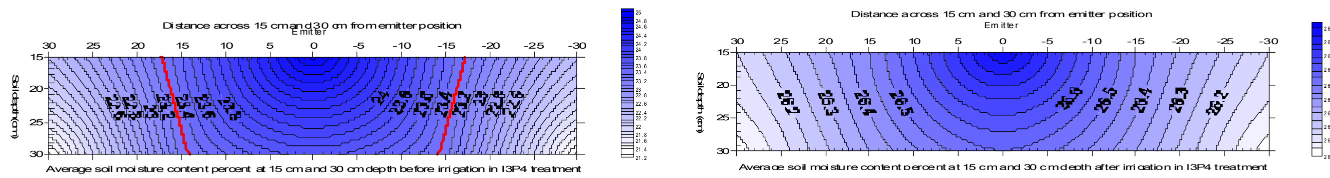
semicircular shape showing 18% depletion of available soil moisture observed below emitter at 30 cm depth. The moisture of 27% depletion was discerned at 30 cm distance from the emitter, which might have exerted some stress on the second row of onion from the emitter.

In Figs. 10 b, 11 b and 12 b delineated soil moisture contours at 2 hr before irrigation through four pulse irrigation (P_4). In case of I_1 irrigation level, the contours took semicircular shape, showing increasing soil moisture content upwardly at 15 cm depth. In case of I_1 irrigation level 10% depletion was observed at 30 cm



a 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 11 : Average soil moisture content across the lateral in I_2P_4 treatment combination.



a 2 - hr before next irrigation **b. 2 -hr after irrigation**

Fig. 12 : Average soil moisture content across the lateral in I_3P_4 treatment combination.

Note: Legends indicates 20% depletion of total available soil moisture content Indicates field capacity of soil moisture content.

C. Yield observations

The data in table 2 revels that influencing irrigation levels through different pulse treatment P_2 (two pulse), P_3 (three pulse) and P_4 (four pulse) treatments and continuous irrigation (P_1) increased significantly the yield parameters like bulb diameter, average bulb weight and yield of white onion. The highest mean polar diameter (61.30 mm), geometric mean diameter (58.41 mm), equatorial diameter (60.86 mm), average bulb weight (107.38 g) and yield (36.50 t.ha^{-1}) of white onion was found in P_4 (four pulse treatment), respectively.

The data in the table 2 revels that influencing irrigation levels I_1 (0.8 ET_C), I_2 (1.0 ET_C) and I_3 (1.2 ET_C) significantly increased the yield parameters like bulb diameter, average bulb weight and yield of white onion. The highest geometric mean diameter (54.24 mm), equatorial diameter (55.53 mm), average bulb weight (95.97 g) and yield (33.15 t.ha^{-1}) of white onion was found in I_3 (1.2 ET_C), except mean polar diameter (57.07 mm) in I_2 (1.0 ET_C) irrigation levels, respectively. Similar effect of irrigation on size of onion bulb was also observed by Martin de Santa Olalla *et al.* (2004). Increase in the bulb yield is mainly attributed to positive association between yield and yield contributing parameters like bulb weight and size in terms of equatorial and polar diameter of the bulb. The shorter interval of irrigation ensures optimum growth of the crop by assuring balanced water and nutrient supply throughout the crop growth period. Similar result for bulb yield was reported by Quadir *et al*. (2005). It can be evident from the table 2 that among the different treatment combination I_2P_4 (four pulse treatment (P_4) with I_2 (1.0 ET_C) irrigation levels) treatment combination was found significantly superior over I_1P_1 irrigation levels) and at par with I_3P_4. The interaction effect revealed that highest mean polar diameter (63.88 mm), geometric mean diameter (59.51 mm), equatorial diameter (63.16 mm), average bulb weight (112.05 g) and yield (38.52 ton.ha^{-1}) of white onion was found in treatment combination I_2P_4 followed by I_3P_4. These results corroborated by findings of Zin El-Abedin (2006), Feng-Xin, *et al.* (2000), Beenson (1992).

It can be seen from the table 2 that the quality attributes of white onion like total soluble solid increases with increased from continuous drip irrigation P_1 (7.11 Brix^0) to four pulse drip irrigation P_4 (9.81 BrixÚ). In case of irrigation levels total soluble solids (TSS) of onion bulb increased with increase from 0.8 to 1.2 ET_C irrigation levels. The highest TSS at 1.2 ET_C (9.03 BrixÚ) probably due to fulfillment of optimum demand of crop for moisture and their proper utilization. This corresponds to earlier finding of Vagen and Slimestad, (2008). From pooled data effect of interaction inferred maximum T.S.S was found 10.56 (°Brix) in treatment combination I_3P_4, which was significantly more than other treatment combination.

Conclusion

The soil moisture content at 2 hr after irrigation in I_2P_4 treatment combination contours attained semicircular shape. The field capacity moisture (26.0%) was discerned at 2 hr after irrigation in I_2P_4 treatment combination at 30 cm distance from the emitter across the lateral at 15 cm depth, which might have provided favorable soil-water-air plant relationship during critical growth stages of onion between two emitters at 30 cm distance across the lateral. It was contemplated that average soil moisture content across 30 cm distance from the emitter at 2 hr before and after 2 hr irrigation at 15 cm and 30 cm depth in the treatment combination I_2P_4 provided favorable soil-water-air plant relationship in the entire root zone.

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