American-Eurasian J. Agric. & Environ. Sci., 15 (8): 1672-1678, 2015
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2015.15.8.12684

Effect of Deficit Irrigation on Crop Growth, Yield and Quality of Onion under Surface Irrigation

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Abstract: Deficit irrigation is important to increase the efficiency in view of limited water resources for agriculture. It is essential to find the most sensitive stage of crop and influence of deficit irrigation on crop yield. Hence the field experiment was conducted to study the response of yield of onion *(Allium cepa L.)* cv. N-2-4-1 crop under the deficit irrigation approach during rabi seasons of 2012 and 2013 at Instructional Farm of the Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth Rahuri. Experiment was carried out in Randomized Complete Block Design (RCBD) with 27 treatments and 2 replications based on different combinations of the quantity of water stress during different crop growth stages. Water applied per irrigation and soil moisture contents before and after irrigation was monitored throughout the season, while onion bulbs were harvested at the end of season and weighed. The present study shows that the onion yields and field water use efficiency are higher with low water stress and it was reduced with increasing water stress. The 40% deficit water at vegetative stage reduced onion yield 30.16%. The 40% deficit water at bulb development stage reduced onion yield by 29.61% whereas 40% deficit water at bulb enlargement stage reduced onion yield by 15.07%. A deficit irrigation strategy of supplying water at 40% water stress during the 3rd (bulb enlargement, 75 DAT) stage did not reduce the onion yield significantly. The results revealed that water stress imposed early in the growing season at the 1st and 2nd stages reduced the yield significantly. Therefore, adequate irrigation to be provided at the early crop growth stages for realizing high yields. A water deficit imposed late in the season, at the 3rd stage, only marginally affected the yield. Hence vegetative stage and bulb development stage of onion crop are more sensitive stages. The consumptive use of onion crop is 556 mm with no stress.

Key words: Onion · Deficit irrigation · Post harvest attributes · Crop water use

INTRODUCTION

India has the largest irrigation system in the world but its irrigation efficiency has not been more than 40 per cent. Increasing high cost of development of additional water resources make it necessary to use available water more efficiently. Achieving food security is a high priority in many countries including India and agriculture must not only provide food for rising population, but also save water for other uses. The challenge is to develop and supply water saving technology and management methods and, through capacity building enable farming communities to adopt new approaches in irrigated agriculture. To meet the food security, income and nutritional needs of the projected population in 2050, the food production will have to be almost doubled. Thus, judicious use of irrigation water is more important to enhance total production and area under irrigated agriculture [1].

India has the largest area (1.06 mha) under onion (*Allium cepa*) followed by China (0.956 mha) but its average yield of 14.21 t ha-1 (http://faostat.fao.org/) is considerably lower than that of the world average\ of 19.4 t ha-1 (http://nhb.gov.in/). Maharashtra is the leading onion producing state followed by Karnataka, Gujarat etc. In Maharashtra, onion is cultivated in an area of 415000 ha with production of 4905000 MT and the average productivity is 11.8 MT/ha. (Source FAO Website: March 2012 and for Indian Data Indian Horticulture Database 2011) which is low compared to world average.

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Depending upon the critical crop growth stages and soil types, 8 to 10 irrigations are usually given to onion in the Maharashtra state. Availability of irrigation water during rabi and summer seasons is the major limiting factor for onion production. During this season in command area farmers may get only 2 to 3 irrigation and could supplement it with well irrigation. Often the yields of wells are also low and in such cases farmers may not be able to provide 8 to 10 irrigations. If the water is stored in farm pond, only one or two irrigations are possible. Under such circumstances deficit irrigation is inevitable. For deficit irrigation it is necessary to study the response of onion to different water stresses during crop growth period. Therefore the present study was planned to study the response of onion yield to different water stress during important crop growth stages viz. vegetative stage, bulb development stage, bulb enlargement stage etc. The present study was planned to identify optimum management strategies under deficit irrigation on crop growth, yield and quality of onion. The onion crop was exposed to full irrigation and predetermined levels of water stress at different stages of crop growth and throughout the growing season and the resulting growth and yield of crop were monitored.

MATERIALS AND METHODS

The field experiments were conducted during rabi season of 2012 and 2013 at Instructional Farm of the Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth Rahuri. To investigate the effect of deficit irrigation of different quantities in onion *(Allium cepa L.)* cv. N-2-4-1. Climatically the region falls under the semi-arid and sub-tropical zone with average annual rainfall of 555.5 mm. The distribution of rain is uneven and is distributed over 15 to 37 rainy days. The annual mean maximum and minimum temperature ranges between 21.2°C to 41.8°C and 3.0°C to 24.6°C, respectively. The annual mean pan evaporation ranges from 2.3 to 14.9 mm/day. Experiment was laid out in Randomized Complete Block Design (RCBD) with 27 treatments and two replications based on different combinations of the quantity of water stress days (no stress- (0.00S), 20% stress- (0.20S i.e. 20% stress of no stress treatment) and 40% stress- (0.40S i.e. 40% stress of no stress treatment) during different crop growth stages vegetative Stage (VS) – up to 50 days, bulb development stage (BDS) - 50 to 75 days and bulb enlargement stage (BES) – 75 to 100.The different combinations of the treatments are:

T1. VS-0.00S, BDS-0.00S, BES-0.00S,
T2. VS-0.00S, BDS-0.00S, BES-0.20S
T3. VS-0.00S, BDS-0.00S, BES-0.40S,
T4. VS-0.00S, BDS-0.20S, BES-0.00S
T5. VS-0.00S, BDS-0.20S, BES-0.20S,
T6 VS-0.00S,BDS-0.20S,BES-0.40S
T7. VS-0.00S, BDS-0.40S, BES-0.00S,
T8. VS-0.00S, BDS-0.40S, BES-0.20S
T9. VS-0.00S, BDS-0.40S, BES-0.40S,
T10. VS-0.20S, BDS-0.00S, BES-0.00S
T11. VS-0.20S,BDS-0.00S,BES-0.20S,
T12. VS-0.20S,BDS-0.00S,BES-0.40S
T13. VS-0.20S,BDS-0.20S,BES-0.00S,
T14. VS-0.20S,BDS-0.20S,BES-0.20S
T15. VS-0.20S,BDS-0.20S,BES-0.40S,
T16. VS-0.20S,BDS-0.40S,BES-0.00S
T17. VS-0.20S,BDS-0.40S,BES-0.20S,
T18. VS-0.20S,BDS-0.40S,BES-0.40S
T19. VS-0.40S,BDS-0.00S,BES-0.00S,
T20 VS-0.40S,BDS-0.00S,BES-0.20S
T21. VS-0.40S,BDS-0.00S,BES-0.40S,
T22. VS-0.40S,BDS-0.20S,BES-0.00S
T23. VS-0.40S,BDS-0.20S,BES-0.20S,
T24. VS-0.40S,BDS-0.20S,BES-0.40S
T25. VS-0.40S,BDS-0.40S,BES-0.00S,
T26. VS-0.40S,BDS-0.40S,BES-0.20S
T27. VS-0.40S,BDS-0.40S,BES-0.40S

The 27 treatments were replicated two times, making a total of 54 plots and two additional plots were worked for onion root study. The gross area of experimental site was 46m x 40m and net plot area was 4m x 4m.The blocks were separated by a distance of 2 m., while the basins in each block were separated by a distance of 1.5 m which serves as buffer to minimize lateral movement of water from one basin to another. The irrigations were scheduled at every growth stage of onion crop. The quantities of water were applied according to the treatments. There was no rainfall during period of experimentation. The depth of water to be applied during each irrigation was calculated according to the following formula.

$$d = \sum_{i=1}^{n} \frac{(FC - MC)}{100} \text{ x BD x D}$$

where
FC = Field capacity,%
MC = Moisture content at the time of irrigation,%
BD = Bulk density of soil, g/cc
D = effective root zone depth, cm

Irrigations were scheduled at every growth stage of onion crop as per stress underlined in each treatment. The stress was estimated from the moisture content stress in the rootzone. The depths of irrigation water were applied according to the treatments. Irrigation was stopped before 25 days of harvesting [2].

Yield Contributing Characters

Plant Height: Plant height was measured in each treatment by using a meter scale at a 15-day interval.

Average Weight of Onion Bulb: The average weight of each onion bulb was recorded from the five observation plants immediately after harvest. For estimation of bulb weight, 1 m x 1 m area was earmarked from the center of the field. With the help of total weight and number of harvested bulbs, mean bulb weight was determined.

Bulb Size: 5 kg sample of onion bulbs was taken randomly from a heap of each treatment. The diameter of the bulbs of the five sample plants from representative area of each treatment was measured with the help of Vernier Calliper along the three co-ordinates i.e. X, Y and Z. The mean polar diameter, mean equatorial diameter and geometric mean diameter of bulbs of onion were calculated using following relationship.

$$\text{Mean Polar Diameter} = \frac{(A+B)}{2} \quad (1)$$

where

A = Diameter along X-axis, mm.

B = diameter along Y-axis, mm.

$$\text{Mean Equatorial diameter} = C \quad (2)$$

where,

C = diameter along Z-axis, mm

$$D = (A \times B \times C)^{1/3} \quad (3)$$

where

D = Geometric Mean diameter of bulb, mm.

Total soluble solids (TSS): Total soluble solids of onion crop under various regimes after harvest of onion bulb were estimated with hand refractometer (0–50, ERMA, Japan).

Specific Gravity: Specific gravity of onion bulb was estimated by water displacement method (Mohsenin, 1970).

Moisture Content: Moisture content of onion bulb was estimated before storage.

Statistical Analysis: The experiments were laid out in randomized complete block design (RCBD) with 27 treatments and 2 replication. The data obtained from the experimentation were analyzed for individual year and pooled for 2 years. Analysis of variance (ANOVA) was carried out using 'F' test. Least significant difference (LSD) method was used to determine whether differences existed between certain comparisons. The probability level for determination of significance was 0.05.

RESULTS AND DISCUSSION

Number of irrigations and gross depth of irrigation water applied are given in Table 1. These values are shown graphically in Fig. 1.

Crop Water Use

Onion Yield as Influenced by Water Stress: The mean pooled onion yield for two seasons for all the treatments are given in Table 2.The yields were statistically significant. The mean yields along with CD at 5% are presented in Table 2. These values are shown graphically in Fig 2.

It was observed from the pooled analysis of yields obtained in 2012 and 2013 and presented in Table 2, that the maximum yields are obtained in no stress treatment T1 (43.08 t/ha), followed by T4, T2, T3, T5, T11, T20, T10, T12, T13, T7, T21, T17, T19, T8, T18, T6, T22, T16, T23, T15, T14, T9, T25, T24, T26 and T27. The significant differences were found in treatments with S.E. of 0.729 and C.D. of 2.070 at 5%. The yields of treatments T1 (43.08 t/ha) and T4 (41.27 t/ha) are at par with each other. These treatments are significantly superior with other treatments. However treatment T4 is subjected to 20% stress at bulb development stage which results in 10% less water compared to T1.Hence as T4 needs less water compared to T1 and the yields of both the treatments are at par, for maximization of yield treatment T4 is considered as the best treatment.

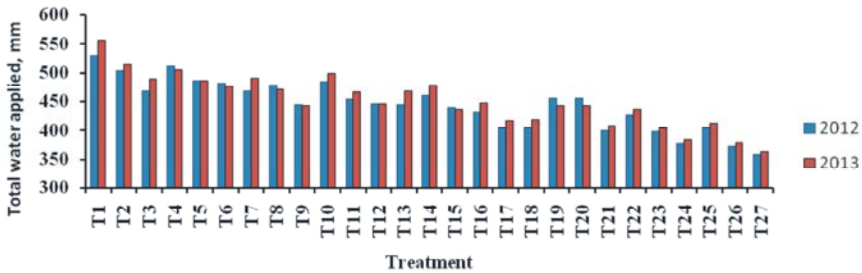

Fig. 1: Depth of irrigation water applied in each irrigation treatment

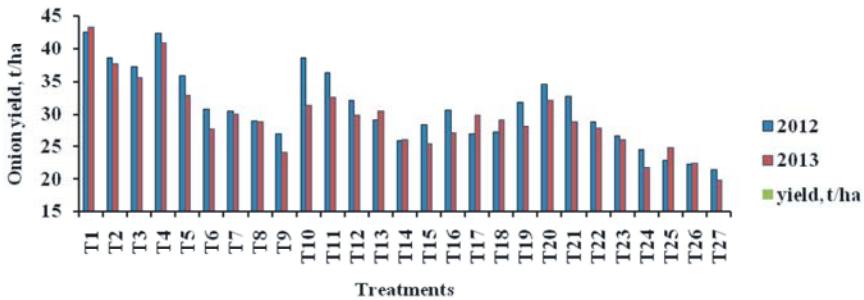

Fig. 2: Effect of deficit irrigation treatment of yield of onion crop

Table 1: Number of irrigations and gross depth of irrigation water applied in each treatment during 2012 and 2013

			Total depth of irrigation water applied (mm)	
Sr.No	Irrigation treatment	Number of irrigations	2012	20013
1	T1	13	529	556
2	T2	13	504	515
3	T3	13	469	489
4	T4	13	512	505
5	T5	13	485	485
6	T6	13	481	476
7	T7	13	468	491
8	T8	13	478	472
9	T9	13	445	442
10	T10	13	484	499
11	T11	13	454	467
12	T12	13	446	446
13	T13	13	445	468
14	T14	13	460	478
15	T15	13	440	436
16	T16	13	431	447
17	T17	13	405	417
18	T18	13	404	418
19	T19	13	456	443
20	T20	13	455	442
21	T21	13	400	407
22	T22	13	427	436
23	T23	13	398	405
24	T24	13	378	384
25	T25	13	405	412
26	T26	13	373	379
27	T27	13	358	363

Table 2: Yields of onion in 2012 and 2013 and pooled yield for different treatments

Sr. No.	Treatments	Yield, t/ha 2012	2013	Pooled
1	T1	42.52	43.26	43.08
2	T2	38.55	37.66	37.88
3	T3	37.22	35.61	36.00
4	T4	42.36	40.91	41.27
5	T5	35.85	32.73	33.49
6	T6	30.69	27.56	28.33
7	T7	30.41	29.96	30.07
8	T8	28.91	28.78	28.81
9	T9	26.90	24.14	24.82
10	T10	32.49	31.28	31.47
11	T11	36.32	32.48	33.42
12	T12	32.05	29.81	30.36
13	T13	29.05	30.50	30.15
14	T14	25.92	26.07	26.04
15	T15	28.32	25.39	26.11
16	T16	30.57	26.98	27.86
17	T17	26.83	29.89	29.15
18	T18	27.12	29.06	28.59
19	T19	31.74	28.12	29.01
20	T20	34.64	32.12	32.74
21	T21	32.71	28.75	29.72
22	T22	28.81	27.76	28.02
23	T23	26.66	25.97	26.14
24	T24	24.47	21.75	22.42
25	T25	22.9	24.86	24.39
26	T26	22.27	22.44	22.40
27	T27	21.35	19.78	20.16
S.E.±		1.478	0.839	0.729
C.D. at 5%		4.298	2.440	2.070

Table 3: Post harvest quality of onion plant and bulb influenced by different deficit irrigation treatments

Sr. No.	Treatment	Plant height, (cm)	Mean bulb weight, (g)	Specific gravity	Total soluble solid (%)	Moisture content (%)
1	T1	66.06	74.09	0.98	12.04	86.95
2	T2	63.45	72.34	0.97	12.63	86.86
3	T3	60.58	73.1	0.97	12.15	86.35
4	T4	62.6	73.76	0.98	12.85	87.52
5	T5	59.87	71.6	0.96	12.81	86.96
6	T6	58.52	71.87	0.97	12.74	87.14
7	T7	55.74	72.14	0.96	12.7	86.21
8	T8	53.13	68.97	0.97	13.07	86.63
9	T9	52.64	69.15	0.96	13.15	86.05
10	T10	51.93	71.28	0.97	12.91	86.03
11	T11	50.67	67.3	0.97	12.86	85.38
12	T12	51.58	67.11	0.96	12.98	86.15
13	T13	50.87	67.8	0.96	13.27	86.09
14	T14	49.88	65.48	0.97	12.78	86.42
15	T15	48.88	66.00	0.96	13.12	65.99
16	T16	46.02	65.12	0.96	13.29	85.37
17	T17	45.38	64.21	0.95	13.27	85.45
18	T18	45.65	64.47	0.95	12.99	85.97
19	T19	47.53	65.62	0.97	12.77	86.52
20	T20	48.7	65.24	0.97	13.24	86.91
21	T21	45.33	63.84	0.95	12.36	85.29
22	T22	44.27	64.61	0.96	13.14	86.46
23	T23	43.82	63.66	0.95	12.29	85.23
24	T24	43.2	63.08	0.95	13.18	85.19
25	T25	44.54	63.05	0.96	13.4	85.93
26	T26	42.97	62.06	0.95	13.31	84.82
27	T27	41.39	62.13	0.95	62.13	84.44
CD at 5%		2.164	1.137	1.06E-02	0.616	0.980

It is observed from Table 2 that the yields obtained in no stress for all growth stages i.e. treatment T1, 20% water stress for all stages i.e. treatment T14 and 40% water stress for all stages i.e. treatment T27 were 43.08 t/ha, 26.04 t/ha and 20.16 t/ha, respectively. Statistically treatment T1 is superior compared to treatments T14 and T27. Hence when uniform stress is to be given, no stress treatment is the best treatment. The yields of treatments T14 and T27 are at par with each other. However treatment T27 needs 23% less water compared to T14. Hence in case of water scarcity where uniform stress is to be given, treatment T27 providing 40% stress during all stages is to be preferred compared to 20% stress during all stages.

Data presented in Table 3 it is observed that the plant height was vary in the treatments T1 to T27.The minimum plant height was 41.39 cm in treatment T27, whereas the maximum plant height was observed to be 66.06 cm in treatment T1. In best treatment T4 plant height was observed to be 62.60 cm. In the treatment T27 i.e. 40% water deficits all through the crop season, plant height was reduced. A significant decrease in bulb weight with the increase in water stress from 0% (74.09 g) stress to 40% stress (62.13 g) was observed. Weight was highest at T1 (0% stress) treatment. In general, weight was reduced significantly with decreasing applied irrigation, which may be due to water shortage. Onion plant experienced water stress during latter part of growing period, i.e., bulb development under irrigation regimes of 40% stress and produced smaller sized bulbs. The statistically mean pooled analysis shows the significant effect in bulb weight during both seasons. Specific gravity of onion bulbs decreased progressively with the increase in water stress from 0% stress to 40% stress. There was significant reduction in specific gravity from 0% to 40% stress. The maximum specific gravity (0.98) was recorded at T1 treatment (0% stress) of irrigation and the minimum was recorded at 40% stress (0.95). Although, irrigation influenced the specific gravity of onion bulbs significantly. Total soluble solids of onion was increased with increasing water stress from 0% water stress to 40% water stress TSS at 0% water stress to 40% water stress was statistically significant. Moisture content of onion bulb was decreased with increasing water stress from 0% to 40% stress. The statistically mean pooled analysis shows the significant effect of moisture content in onion bulb.

DISCUSSION

Effect of Stress on Onion Yield: The onion yields for all the treatments were analysed statistically for randomized complete block design and found that the yields were statistically significant. It was observed that higher yields are obtained in treatment T1 (no stress at vegetative, bulb development and bulb enlargement stage) and minimum yields are obtained in T27 (40% stress at vegetative, bulb development and bulb enlargement stage). Thus, the onion yields are higher with less water stress and reduced with increase in water stress. It was observed from yield data that vegetative stage is more sensitive stage followed by bulb development and bulb enlargement stage. The dry matter yield for all the treatments were analysed statistically for randomized complete block design and found that yields were statistically significant. In case of good quality grading yield, it was observed that they are higher with less water stress and reduce with increase in water stress. The yield for no stress treatment i.e. T1 is at par with T4. But treatment T4 required 10% less water compared to T1. Hence treatment T4 is considered as the best treatment.

Post Harvest Attributes of Onion Bulb under Deficit Irrigation Treatments: Our results indicated that plant height varied in the treatments T1 to T27. A significant decrease in plant height was observed with the increase in water stress. Weight was highest at T1 (0% stress) treatment. In general, weight reduced significantly with the decrease in irrigation, which may be due to water shortage. Specific gravity of onion bulbs decreased progressively with the increase in water stress from 0% stress to 40% stress. There was significant reduction in specific gravity from 0% to 40% stress. Total soluble solids of onion increased with the increase in water stress from 0% water stress to 40% water stress. TSS of no stress treatment is significantly more compared to maximum stress treatment. Moisture content of onion bulb decreased with increase in water stress.

CONCLUSION

The onion yields and field water use efficiency are higher with less water stress and reduced with increase in water stress. A deficit irrigation strategy of supplying 20% deficit water during the bulb development stage did not reduce the onion yield significantly. Our study indicated that onion crop should be irrigated at 20% water deficit during bulb development stage which is most appropriate for growing onion with better postharvest attributes.

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