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Yield and Storability of Onion (*Allium Cepa L.*) as Affected by Deficit Levels of Irrigation

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Abstract

Bulb yield and storability of onions (cv. N-2-4-1) was studied against deficit irrigation approach 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. Experiment was carried out in Randomized Block Design (RBD) with 27 treatments and two 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. Yields and storage losses are higher with less water stress and reduced with increase in water stress. The highest yield of onion was obtained with a no stress treatment (T1) and it was at par with treatment (T4) which is 20% stress at bulb development stage. Losses due to rotting, sprouting, and physiological weight loss were found higher in irrigated treatments. After six months of storage (from 1st week of May to 1st week of October), the maximum cumulative weight loss (49.09%) was recorded in onions irrigated at maximum stress treatment (T27), while the minimum (38.21%) was recorded in T4 treatment which is 20% stress during bulb development stage.

Keywords: Storability; Onion bulb; Irrigation; Storage losses

Introduction

Onion (*Allium cepa L.*) is one of the important vegetable crops commercially grown in India. India is the second largest producer of onion in the world, next only to China. In India, onion is being grown in an area of 0.83 million hectares with production of 13.57 million tonnes and the productivity is 16.30 t ha-1 which is low. 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. 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. Being a semi-perishable crop, it is subjected to deterioration during storage. Storage loss of onions is caused by rotting, sprouting, and physiological weight loss. Rabbani et al. [1] reported that storage losses in onion could be as high as 66%. Many factors, such as cultivars, bulb maturity, moisture content of the bulb, temperature, relative humidity, etc. are associated with spoilage of onion during storage. Thus, irrigation may have some effect on storability of onion as it helps increase moisture content of bulb. Many authors investigated the effect of irrigation on onion yield, but the literature revealed scanty information about the effect of irrigation on storage of onion. Soujala et al. [2] reported that irrigation had only a minor effect on the storage performance and shelf life of onion. A substantial increase of decomposition in onion during storage with increasing irrigation was reported by Shock et al. [3]. Nandi et al. (2002) reported that growth and yield of onion were significantly affected by irrigation, but not post harvest life. The study was, therefore, undertaken with a view to finding out the effect of irrigation on yield and storability of onion.

Material and Methods

The field experiments to study the effect of deficit irrigation of different quantities in onion (Allium cepa L.) cv. N-2-4-1 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. 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 carried out in Randomized Block Design (RBD) with

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27 treatments and two replications based on different combinations of the quantity of water stress days (no stress- (0.00S), 20% stress- (0.20S) and 40% stress- (0.40S) 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 size of experimental site was 46 m × 40 m and net plot size was 4 m × 4 m. 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.

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

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 (Doorenbos and Kassam, 1979).

Yield and storability of onion

The crop was harvested on 21 April 2013 when about 75-80% of the plants became matured. After harvest, bulbs were kept under a shade for 7 days for curing. Then, for storage studies, 10 kg bulbs from each treatment were taken, divided into 3 equal splits, each representing a replicate and stored on rack at room temperature for 165 days. The observations were done for sprouting, rotting, and total weight loss at 15 days intervals. The rotten bulbs from each treatment were sorted out at the time of recording the data. The temperature and relative humidity of the storage room were also recorded. The collected data on various parameters were statistically analyzed.

Results and Discussion

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

Crop water use

Sr.No	Irrigation Treatment	Number of irrigations	Total depth of irrigation water applied (mm)	
			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

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24	T24	13	378	384
25	T25	13	405	412
26	T26	13	373	379
27	T27	13	358	363

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

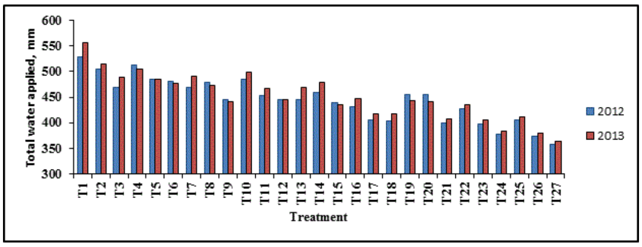

Figure 1: Depth of irrigation water applied in each irrigation treatment.

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 yield data were analyzed statistically for randomized block design. The yields were statistically significant. The mean yields along with CD at 5% are presented in Table 2. These values are shown graphically in Figure 2.

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 2: Oyield for different treatments during 2012 and 2013.

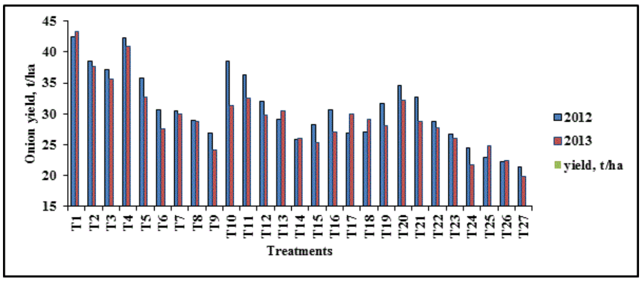

Figure 2: Effect of deficit irrigation treatment of yield of onion crop.

It is observed from above tables that during 2012 & 2013 the higher yields are observed in treatment T1 (0% water stress throughout growth period) followed by T4, T2, T10, T3,T11, T5, T20, T16,T21, T12, T19, T7, T13, T8, T22, T15, T18, T9, T17, T23, T14, T24, T25, T26 and T27. The onion yield are observed lowest at T27 (40% stress at all stages). The yields of treatments T1, T2 and T4 are at par during 2012 and T1 and T4 are at par during 2013. However the total water applied at treatment T2 is less compared to treatment T1 and T4 in 2012 and the total water applied at treatment T4 is less compared to treatment T1 in 2013. Hence treatment T2 and T4 are the best treatment. But considering the grading of onion bulb the treatment T4 is best treatment which indicates that no water stress during vegetative stage, bulb development stage and 20% water stress at bulb enlargement stage results in statistically significant yield. The yields of treatments T10, T3, T11, T5, T20 and T16 are at par. The yields of treatments T21, T12, T19, T7, T13, T8 and T22 are at par. The yields of treatments T15, T18, T19, T17, T23, 14 and T24 are at par. The yields of treatments T25, T26 and T27 are at par.

The relationship between water stress and crop yield is important for scheduling deficit irrigation. Onion crop yield obtained from different treatments is presented in Table 2. The maximum yield was observed with full irrigation i.e. in treatment T1 (42.52 t/ha) in 2012 and (43.26 t/ha) in 2013. Lowest yield was observed in treatment T27

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(21.35 t/ha) in 2012 and (19.78 t/ha) in 2013.i.e. maintaining the 40% water stress throughout the crop season. In treatment T14, i.e., deficit irrigation of 20% saved only 13.04% of water from full irrigation but reduced the yield significantly by 39.04% in 2012 whereas in 2013 deficit irrigation of 20% saved only 21.58% of water from full irrigation but reduced the yield significantly by 39.73%. Yield obtained in treatment T14, significantly different than T1.The best treatment T4 (20% water deficit during bulb development stage) shows significant yield i.e. 42.36 t/ha in 2012 and 40.91 t/ha in 2013 which is at par to treatment T1 and T2 and significantly different than treatment T14 and T127. The yields of treatmentsT9, T17, T23, and T24 are at par. The 20% water stress throughout growth period of onion crop reduces the yield up to 40% and 40% water stress throughout growth period of onion crop reduces the yield up to 50%.

Effect of irrigation on storage losses

Different kinds of losses of onion under deficit irrigation during storage period have been presented graphically in Figures 3-6. The data pertaining to rotting, sprouting, and total weight loss over 165 days have been presented in Table 3.

Treatment	Rotted onion%	Sprouted onion%	Physiological wt loss%	Total storage loss,%
T1	18.17	5.60	15.23	39.00
T2	16.84	4.70	17.63	39.17
T3	19.62	5.80	16.33	41.75
T4	15.70	5.12	17.39	38.21
T5	19.69	5.82	16.39	41.90
T6	17.63	5.96	19.31	42.90
T7	20.33	5.19	17.73	43.25
T8	20.63	5.07	18.19	43.90
T9	20.74	6.13	17.26	44.12
T10	17.20	4.62	18.18	40.00
T11	16.30	4.76	18.61	39.67
T12	19.86	5.87	16.52	42.25
T13	18.95	5.40	15.96	40.31
T14	19.17	4.89	16.72	40.79
T15	18.67	5.02	19.73	43.42
T16	20.11	5.94	16.73	42.78
T17	16.95	5.53	18.78	41.26
T18	20.63	5.27	17.99	43.89
T19	21.99	5.41	19.39	46.78
T20	17.46	5.10	19.94	42.50
T21	20.78	6.14	17.29	44.21
T22	21.55	5.30	19.00	45.85
T23	21.03	6.79	21.08	48.90
T24	22.51	6.65	18.73	47.89
T25	20.97	5.98	17.67	44.61
T26	22.57	5.63	18.71	46.91
T27	25.17	5.82	18.10	49.09

Table 3: Percentage of rooted, sprouted and physiological weight loss in onion bulbs under deficit different irrigation treatments.

Rotting

The bulbs started rotting after 65 days of storage. Percentage of rotten bulbs of onion was significantly influenced by different levels of irrigation (Figure 3). Losses due to rotting of bulbs of treatments T27 were higher and identical during 165 days of storage period. The lowest rotting was found in treatment (T4). This result corresponds the earlier findings of Shock et al. [3] who reported substantial increase of decomposition of onion during storage with increasing irrigation threshold. The lowest rotting loss in the T4 treatment may be due to the fact that plots did not receive any irrigation that kept the bulbs less succulent and as a result less attacked by bacteria and fungi during storage.

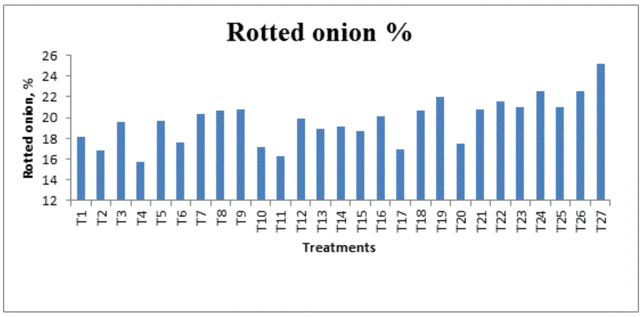

Figure 3: Rotten loss of onion during storage.

Sprouting

Sprouting behavior of onion under different irrigation levels has been shown in Figure 4. The bulbs started sprouting after 80 days of storage. Sprouting was significantly higher after 165days of storage in the onions of treatment T23 and T24.The lowest sprouting was observed in non-irrigated treatment T10 during the entire storage period. The higher percentage of sprouting in the treatments that received higher number of irrigation may be due to slightly higher moisture content in the bulbs of these treatments. Thompson et al. [4] reported that the onion bulbs are naturally dormant at maturity and the length of this dormant period varies with the cultivar and conditions under which the bulbs were grown and stored. Salunkhe and Desai [5] described sprouting as a normal physiological change in stored bulbs that develops reproductive shoots in the second year. Irrigation, thus, has little effect on sprouting.

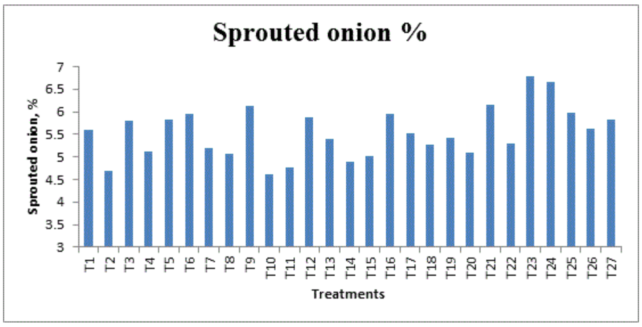

Figure 4: Sprouting loss of onion during storage.

Physiological weight loss

Physiological loss in weight for onion bulb was measured during the storage period of 165 days in 2013 indicated that it increased with the increases in water stress from 0% stress to 40% stress up to 75 days of storage (Figure 6). Thereafter, PLW increased at faster rate in all treatment. But Physiological loss in weight in T27 (40% deficit) treatment was much higher than other treatment. The water stress treatment recorded higher physiological loss in weight during storage than no stress treatment. While in latter part of storage, i.e., 75 days onward, higher PLW was recorded in 40% stress (T27) and minimum at 0% stress. At 75 days of storage, PLW was recorded minimum 11.03% to maximum 19.50%, in all treatment, which increased to 38.21% and 49.09% after 165 days of storage for all treatments. The total Physiological loss in weight was minimum in treatment T4 and Physiological loss in weight was maximum in treatment T27. Results have shown that PLW (%) increased with the decrease in irrigation from 0% stress to 40% stress during the storage period of onion bulbs. Physiological loss in weight was maximum in treatment T27 due to spoilage of bulbs .The result indicated that crop grown under 40% stress has experienced water stress and hence it was forced to early maturity. Thus, it resulted into development of either immature or partial matured bulbs, which started rotting during storage at an early date in rainy season.

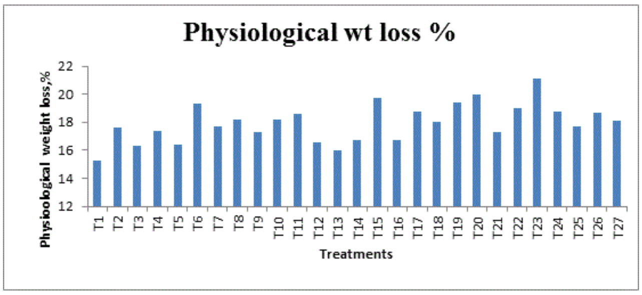

Figure 5: Physiological weight loss loss of onion during storage.

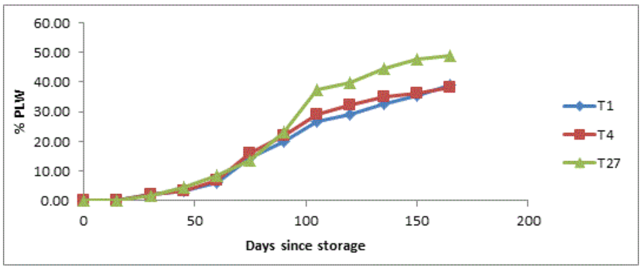

Figure 6: Total weight loss of onion during storage.

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. The storage losses of onion were found to increase gradually with decrease in irrigation from 0% stress to 40% stress during the storage period of onion.

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