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Yield Response Factor for Onion (Allium Cepa L) Crop Under Deficit Irrigation in Semiarid Tropics of Maharashtra

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ABSTRACT

The present study deals with the study of yield response factor (Ky) for onion crop cultivated under deficit irrigation for Rahuri region (Maharashra). The field experiment was conducted to determine the yield response factor of the onion *(Allium cepa L.)* cv. N-2-4-1 crop under the deficit irrigation approach during summer 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 were monitored throughout the season, while onion bulbs were harvested at the end of season and weighed. Average daily crop water use (crop consumptive use) were estimated from the soil moisture content using the soil moisture depletion method**.** The seasonal yield response factor (Ky) was obtained by relating relative yield decreases to relative crop water use deficit by the regression analysis. The relative yield decreases of the onion crop were proportionally greater with increase in evapotranspiration deficit. It shows the response of yield with respect to the decrease in water consumption. In other words, it explains the decrease in yield caused by the per unit decrease in water consumption. Seasonal crop response factor for onion crop was determined as 1.58, 1.48 and 1.54 during 2012, 2013 and average of both year (2012 &2013) respectively. The yield response factors developed in this study could be used in irrigation design and scheduling for onion in the study area.

Key words: Onion, Deficit Irrigation, Crop Coefficient (Kc), Yield Response Factor (Ky), Crop Water Use.

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. The total area under onion in India is 1064000 ha and the total production is 15118000 MT. India accounts for 26.8 per cent the total area and 19.9 per cent the total production of the world. The average productivity of the world is 19.1 MT/ha while India being the second major onion producing country in the world has a productivity of 14.2 MT/ha (Source FAO Website: March 2012 and Indian Horticulture Database 2011). Maharashtra is the leading onion grower and producer state in the country which accounts 39 per cent of the total area and 32.5 per cent national production followed by Karnataka, Gujarat etc. The area under onion in Maharashtra is 415000 ha and the onion production is 4905000 MT. In India per hectare yield is highest in Gujarat (24.4 MT/ha) followed by Haryana (20.5 MT/ha), Bihar (20.3 MT/ha), Madhya Pradesh (17.5 MT/ha) whereas, in Maharashtra it is 11.8 MT/ ha. (Source FAO Website: March 2012 and Indian Horticulture Database 2011).

Abiotic stresses can directly or indirectly affect the physiological status of an organism by altering its metabolism, growth and development and adversely affect the agricultural productivity

(Bartles and Sunkar 2005, Vibhuti et al 2015, Shahi et al 2015a). Water is the main limiting factor for production of many crops including onion in the arid and semiarid regions. Fresh and dry mass production of crop may reduce due to the adverse effect of water stress (Shahi et al 2015b). When water resources are scarce, deficit irrigation is one way of maximizing water use efficiency (Bekele and Tilahun 2007).Deficit irrigation is the practice of irrigating crops deliberately below their water requirements. Such practice is aimed at minimizing water applied to the crop so as to maximize crop yield per unit of water applied. This may however lower the yield per unit area. Many research works have been carried out to study the consequences of deficit irrigation on onion crop (Olalla et al., 1994; Gorantiwar and Smout.,2003; Pelter et al., 2004; Mermoud et al., 2005; Bekele and Tilahum, 2007; Ouda et al., 2010; and Pejiæ et al., 2011).

A research gap in the region where onion is produced in Maharashtra is the knowledge of water requirement of the onion crop under deficit irrigation. Moreover, the consequences of deficit irrigation regimes are yet to be fully understood. Two key parameters commonly required in determining crop water requirement and predictions of yield-water response to deficit irrigation are crop coefficient (Kc) and yield response factor (Ky). The yield response factor (Ky) is ratio of relative yield reduction to relative evapotranspiration deficit. It is the factor that integrates the weather, crop and soil conditions that make crop yield less than its potential yield in the case of deficit evapotranspiration. The yield response factor Ky is commonly required as input data in some empirical water production functions like (Jensen, 1968) and (Stewart et al., 1977) to predict crop yield response to water.

In order to determine the yield response factor of onion crop for Rahuri region (Maharashtra) the present study was carried out by raising the onion crop under different regimes of deficit irrigation approach. It is anticipated that the information generated in this study will be useful for developing crop water requirements for irrigated onion under deficit irrigation regimes and for the overall improvement of irrigation water management for onion in the study area.

MATERIALS AND METHODS

The field experiment to determine the yield response factor of the onion *(Allium cepa L.)* cv. N-2-4-1 crop under the deficit irrigation approach was conducted during summer season of 2012 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 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 thetreatments 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 46m x 40m and net plot size 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.

$$d=\sum_{i=1}^{n} \frac{(FC-MC)}{100} \text{xBDxD} \quad ...(1)$$

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.

The yield response factor was computed using the Doorenbos and Kassam (1979) equation re-arranged as,

$$1-\frac{\text{Ya}}{\text{Ym}}=\text{Ky}(1-\frac{\text{ETa}}{\text{ETm}}) \quad ...(2)$$

Where

Ya = actual yield (t/ha),

Ym = maximum yield (t/ha),

Eta = actual evapotranspiration (mm)

ETm = maximum evapotranspiration (mm).

Ky = yield response factor of onion to deficit irrigation.

The values of yield response factor, Ky, was estimated by the regression analysis.

RESULTS AND DISCUSSION

Crop water use

Number of irrigations and gross depth of irrigation water applied to each treatment are given in Table1.

Onion yield as influenced by water stress

The mean pooled onion yield for two two season 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 Table2.

It is observed from above table that the higher yields are observed in trématent T1 (0% stress at vegetative stage,bulb development stage and bulb enlargement stage) followed by T4, T3, T10, T11, T5, T20, T21, T12, T19, T6, T16, T7, T13, T8, T22, T15, T18, T9, T17, T18, T23, T14, T24, T25, T26 and T27. The onion yields are lowest for T27 (40% stress at vegetative stage, bulb development stage and bulb enlargement stage). However, the yields of treatments T1 and T4, T2, T3 and T10 are at par. The yields of treatments T5, T11, and T20 are at par. The yields of treatments T6, T7 and T16 are at par. The yields of treatments T8, T13, T15 and T22 are at par. The yields of treatments T15, T8, T14, and T22 are at par. The yields of treatmentsT9, T17, T23 and T24 are at par. Statistically shows that the vegetative stage of the onion crop with no water stress gives higher onion yield at C.D.5%.Thus, the onion yields are higher with less water stress and reduce with increase in water stress.

Yield response factor (Ky)

Table 3, 4 and 5 shows the relative decreases in seasonal crop water use and bulb yield for 2012, 2013 season and average of two seasons. Yield response factor (Ky) indicates a linear relationship between the decrease in relative water consumption and the decrease in relative yield. It shows the response of yield with respect to the decrease in water consumption. In other words, it explains the decrease in yield caused by the per

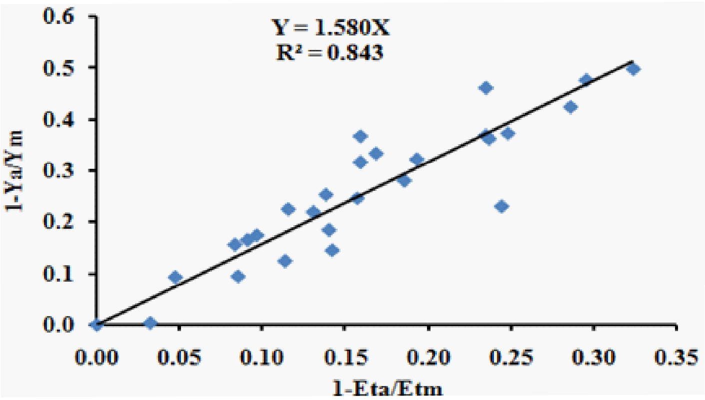

Fig.1: The relation between reduction in relative onion yield to reduction in relative evapotranspiration (2012)

Table 1

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

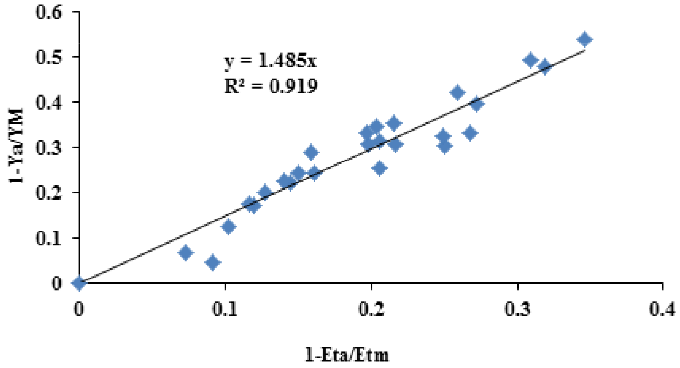

Fig. 2: The relation between reduction in relative onion yield to reduction in relative evapotranspiration (2013)

Table. 2: Mean onin yield for different treatments during 2012 and 2013.

Sr. No.	Treatment	2012 Mean yield (kg/ha)	2012 Decrease in yield (%)	2012 Mean yield (%)	2013 Mean yield (kg/ha	2013 Decrease in yield (%)	2013 Mean yield (%)
1	T1	42.52	-	100.00	43.26	-	100.00
2	T2	38.55	9.32	90.67	37.66	12.93	87.06
3	T3	37.22	12.46	87.53	35.61	17.68	82.31
4	T4	42.36	0.36	99.63	40.91	5.42	94.57
5	T5	35.85	15.67	84.32	32.73	24.35	75.65
6	T6	30.69	27.79	72.20	27.56	36.28	63.71
7	T7	30.41	28.48	71.51	29.96	30.75	69.25
8	T8	28.91	32.00	67.99	28.78	33.47	66.52
9	T9	26.90	36.73	63.26	24.14	44.19	55.80
10	T10	38.49	9.43	90.52	31.28	27.69	72.30
11	T11	36.32	14.55	85.44	32.48	24.91	75.08
12	T12	32.05	24.62	75.37	29.81	31.09	68.90
13	T13	29.05	31.67	68.32	30.50	29.48	70.51
14	T14	25.92	39.02	60.97	26.07	39.73	60.27
15	T15	28.32	33.37	66.62	25.39	41.30	58.69
16	T16	30.57	28.09	71.90	26.98	37.63	62.36
17	T17	26.83	36.88	63.11	29.893	30.90	69.09
18	T18	27.12	36.22	63.77	29.06	32.82	67.17
19	T19	31.74	25.34	74.65	28.12	34.99	65.00
20	T20	34.64	18.51	81.48	32.12	25.74	74.25
21	T21	32.71	23.06	76.93	28.75	33.53	66.46
22	T22	28.81	32.24	67.75	27.76	35.81	64.18
23	T23	26.66	37.28	62.71	25.97	39.96	60.03
24	T24	24.47	42.44	57.55	21.75	49.71	50.28
25	T25	22.9	46.14	53.85	24.86	42.52	57.47
26	T26	22.27	47.61	52.38	22.44	48.12	51.87
27	T27	21.35	49.78	50.21	19.78	54.27	45.72
CD at 5%			4.298			2.440	

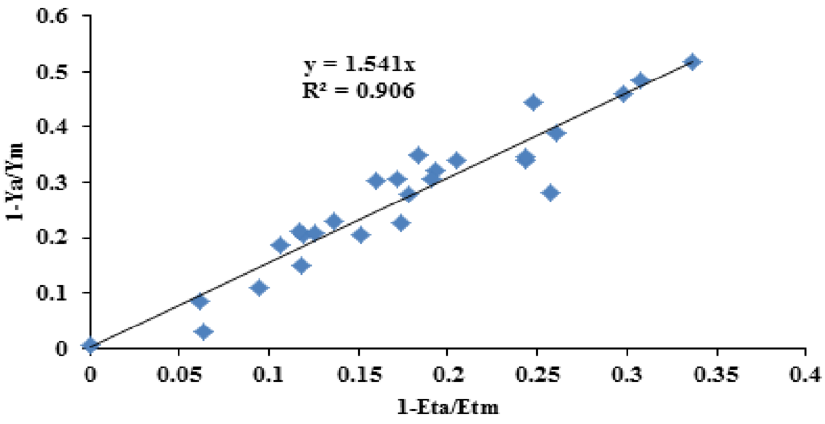

Fig. 3: The relation between reduction in relative onion yield to reduction in relative evapotranspiration (average).

Table 3: Relationship between the decrease in relative water use and decrease in relative yield for onion during 2012 season.

Treatment	ETa	ETm	Ya	Ym	1-ETa/ETm	1-Ya/Ym
T1	529	529	42.518	42.518	0	0
T2	504	529	38.554	42.518	0.047	0.093
T3	469	529	37.218	42.518	0.113	0.124
T4	512	529	42.364	42.518	0.032	0.003
T5	485	529	35.855	42.518	0.083	0.156
T6	481	529	35.48	42.518	0.090	0.165
T7	468	529	32.942	42.518	0.115	0.225
T8	478	529	35.087	42.518	0.096	0.174
T9	445	529	26.901	42.518	0.158	0.367
T10	484	529	38.49	42.518	0.085	0.094
T11	454	529	36.328	42.518	0.141	0.145
T12	446	529	32.049	42.518	0.156	0.246
T13	445	529	29.049	42.518	0.158	0.316
T14	460	529	33.181	42.518	0.130	0.219
T15	440	529	28.327	42.518	0.168	0.333
T16	431	529	30.574	42.518	0.185	0.280
T17	405	529	26.833	42.518	0.234	0.368
T18	404	529	27.115	42.518	0.236	0.362
T19	456	529	31.742	42.518	0.137	0.253
T20	455	529	34.645	42.518	0.139	0.185
T21	400	529	32.71	42.518	0.243	0.230
T22	427	529	28.807	42.518	0.192	0.322
T23	398	529	26.664	42.518	0.247	0.372
T24	378	529	24.471	42.518	0.285	0.424
T25	405	529	22.899	42.518	0.234	0.461
T26	373	529	22.273	42.518	0.294	0.476
T27	358	529	21.349	42.518	0.324	0.497

unit decrease in water consumption. Hence the regression analysis was used to find the value of Ky.

Crop yield response factor (Ky) indicates a linear relationship between the decrease in relative water consumption and the decrease in relative yield. It shows the response of yield with respect to the decrease in water consumption. In other words, it explains the decrease in yield caused by the per unit decrease in water consumption.

The moisture content observations during 2012 and 2013 were recorded before irrigation, after irrigation and during irrigation period for all the treatments for the purpose of computing the actual evapotranspiration. The treatment T1 was treatment without water stress and hence actual evapotranspiration of treatment T1 was considered as maximum crop evapotranspiration. The maximum crop evapotranspiration during 2012 and 2013 and average of 2012 and 2013 were computed. These are 529, 556 and 543 mm for 2012, 2013 and average of 2012 and 2013 respectively. The treatments T2 to T27 were treatments with some stress. The values of actual evapotranspiration along with maximum onion evapotranspiration are presented in Tables 3,4 and 5. These tables show the relative decreases in seasonal crop water use and bulb yield for onion crop during 2012 and 2013 seasons and average of two seasons

The relationship between relative yield reduction and relative evapotranspiration deficit for

Table. 4: Relationship between the decrease in relative water use and decrease in relative yield for onion during 2013 season.

Treatment	ETa	ETm	Ya	Ym	1-ETa/ETm	1-Ya/Ym
T1	556	556	43	43	0	0
T2	515	556	40	43	0.073	0.070
T3	489	556	36	43	0.120	0.172
T4	505	556	41	43	0.091	0.048
T5	485	556	34	43	0.127	0.202
T6	476	556	33	43	0.145	0.222
T7	491	556	35	43	0.117	0.177
T8	472	556	33	43	0.151	0.243
T9	442	556	29	43	0.205	0.315
T10	499	556	38	43	0.103	0.126
T11	467	556	32	43	0.161	0.245
T12	446	556	30	43	0.198	0.307
T13	467	556	31	43	0.159	0.290
T14	478	556	33	43	0.141	0.224
T15	436	556	30	43	0.216	0.310
T16	447	556	29	43	0.197	0.334
T17	417	556	30	43	0.251	0.305
T18	418	556	29	43	0.249	0.324
T19	443	556	28	43	0.204	0.346
T20	442	556	32	43	0.206	0.253
T21	407	556	29	43	0.268	0.331
T22	436	556	28	43	0.215	0.354
T23	405	556	26	43	0.272	0.396
T24	384	556	22	43	0.309	0.494
T25	412	556	25	43	0.259	0.422
T26	379	556	22	43	0.319	0.478
T27	363	556	20	43	0.347	0.540

Table 5: Average relationship between the decrease in relative water use and decrease in relative yield for onion during 2012 and 2013 season.

Treatment	ETa	ETm	Ya	Ym	1-ETa/ETm	1-Ya/Ym
T1	543	543	43	43	0.001	0.006
T2	510	543	39	43	0.062	0.087
T3	479	543	37	43	0.118	0.149
T4	509	543	42	43	0.064	0.031
T5	485	543	35	43	0.107	0.188
T6	479	543	34	43	0.119	0.204
T7	480	543	34	43	0.117	0.210
T8	475	543	34	43	0.125	0.208
T9	444	543	28	43	0.183	0.350
T10	492	543	38	43	0.095	0.111
T11	461	543	34	43	0.152	0.205
T12	446	543	31	43	0.179	0.279
T13	456	543	30	43	0.160	0.302
T14	469	543	33	43	0.136	0.230
T15	438	543	29	43	0.193	0.322
T16	439	543	30	43	0.192	0.307
T17	411	543	28	43	0.243	0.339
T18	411	543	28	43	0.243	0.348
T19	450	543	30	43	0.172	0.305
T20	449	543	33	43	0.174	0.225
T21	404	543	31	43	0.257	0.282
T22	432	543	28	43	0.205	0.339
T23	402	543	26	43	0.261	0.388
T24	381	543	23	43	0.298	0.460
T25	409	543	24	43	0.248	0.443
T26	376	543	22	43	0.308	0.485
T27	361	543	21	43	0.336	0.519

onion yield is shown in Figures 1, 2 and 3. The yield response factor (Ky) for onion in 2012, 2013 and average of 2012 & 2013 by regression analysis was found to be 1.58, 1.48 and 1.54 for whole growing season. Result obtained was in agreement with those reported by Doorenbos and Kassam (1986). They reported that seasonal yield response factor (Ky) value of 1.50 for onion during the whole growing season. Generally, higher Ky values indicate that the crop will have a greater yield loss when the crop water requirements are not met. This result indicated a high impact of soil-water stress treatment on the onion yield. Therefore, water management of onion is extremely important at all stages of plant growth.

CONCLUSION

1. The results indicated a high impact of soil-water stress treatments on the onions yield.
2. The crop water use of the onion crop decreased with increase in irrigation deficit.
3. The yield response factor (Ky) for onion in semi arid tropics of Maharashtra was found to be 1.54 for whole growing season.

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