P-ISSN: 2618-0723
E-ISSN: 2618-0731

Extension Journal

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 7; Issue 11; November 2024; Page No. 483-491

Received: 22-10-2024
Accepted: 25-11-2024

Indexed Journal
Peer Reviewed Journal

Onion (*Allium cepa* L.) seed response to drip and fertigation levels

[1]SV Chavan, [2]SB Gadge, [3]MR Patil, [4]BT Patil and [5]SA Pawar

[1-2]Department of Irrigation and Drainage Engineering, Dr. ASCAET, MPKV, Rahuri, Maharashtra, India

[3]Department of Statistics, PGI, MPKV, Rahuri, Maharashtra, India

[4-5]Department of Horticulture, PGI, MPKV, Rahuri, Maharashtra, India

DOI: https://doi.org/10.33545/26180723.2024.v7.i11g.1363

Corresponding Author: SV Chavan

Abstract

A factorial randomized block design with three replications was adopted for field experiment on onion seed crop which was conducted during the period from December 2022 to May 2023 at the All India Coordinated Research Projects on Vegetable Crops, MPKV, Rahuri to check out the economic feasibility along with impacts on onion seed crop growth, yield and yield-contributing characteristics of drip irrigation and fertigation levels in comparison to surface irrigation and to simulate onion seed yield using CROPWAT 8.0 model. The study revealed that cultivating onion seed crop @ 80% PE and 80% water soluble RDF at weekly interval in 11 splits is beneficial for better B:C ratio and WUE under semi-arid conditions. The simulated onion seed yield using CROPWAT 8.0 model revealed comparable results.

Keywords: CROPWAT model, onion seed production, drip irrigation, fertigation, water use efficiency, onion seed yield

Introduction

Onion (*Allium cepa* L.) is an important commercial horticultural crop of India. The country ranks second in onion production, making onion cultivation a critical aspect of Indian agriculture and economy [6]. Onion belongs to the Alliaceae family and is grown for its bulbs, leaves, and seeds. The primary centre of origin for the onion is Central Asia, while an area close to the eastern and Mediterranean regions has emerged as a secondary source [7]. Onions have been shown to have strong antioxidant and anti-inflammatory properties. Onion is used in homeopathic, Unani and ayurvedic medicines. Moreover, more pungent onions are strong antiplatelet and blood thinning agents in human blood which may also contribute to prevention of arteriosclerosis, cardiovascular disease, stroke, diabetes, osteoporosis and heart attack.

Onion seeds are essential for commercial onion production, as they serve as the primary means of propagation [7]. Onion seed production is a significant aspect of the global agricultural sector, with various regions specializing in producing high-quality seeds for both local use and export. India needs around 9400 tons of onion seed annually for covering 11.73 lakh hectares area. Efficient water and nutrient management are essential for maximizing onion seed production while conserving resources and minimizing environmental impacts in achieving high seed yield and quality in onions [8, 9]. Adoption of modern irrigation methods and other improved agricultural technologies for onion seed production can provide opportunities for further expansion of the area [12].

Irrigation practices are crucial for optimizing onion seed production, impacting yield, quality and water use efficiency. Presently area under micro irrigation is around 8.7 million hectares in India and 1.31 million ha across the state of Maharashtra. Drip irrigation, a micro-irrigation technique, delivers water directly to the root zone of reducing water wastage and optimizing water use efficiency. India currently has 3.37 million ha under drip irrigation. Drip irrigation covers 17.09 lakh ha in Maharashtra [5]. Fertigation, the application of fertilizers through irrigation water, allows precise nutrient delivery, promoting balanced plant nutrition and improving crop productivity [12]. Proper fertigation practices are crucial for optimizing onion seed yield, bulb quality, and nutrient use efficiency. Drip irrigation allows for precise control over nutrient application through fertigation, where fertilizers are dissolved in the irrigation water and delivered directly to the plant roots. This targeted nutrient delivery optimizes nutrient uptake and reduces nutrient leaching [22]. The fertilization strategy should be tailored to the specific nutrient requirements of onions, which vary throughout their growth stages [14]. By managing NPK levels effectively, you can enhance the growth, health, and seed production of onions, leading to higher yields and better quality seeds [14, 15]. In addition to NPK, sulphur is also an essential plant nutrient important for onion crop for improving yield and the pungency of onion bulbs [18, 22].

For onions, the precise water application is crucial because the crop is sensitive to both water stress and over-irrigation [12]. Consistent moisture availability promotes better root development, which is crucial for nutrient uptake and plant health. Additionally, reduced water stress helps in preventing quality issues such as splitting and rotting of onion bulbs [12, 20]. On comparison of drip irrigation with conventional furrow irrigation in onion cultivation, drip irrigation increased water use efficiency by up to 50% as compared to furrow irrigation. Drip irrigation can lead to higher yields (25-30%) and improved quality of onions as compared to traditional irrigation methods [11].

In summary, water and fertilizer scheduling are major management variables with drip irrigation systems, but that has not been adequately investigated for drip-irrigated onion seeds in field [12]. Onion seeds are grown in many arid, semi-arid, and sub-humid areas where the availability of water is limited and deficit irrigation is required [24]. In such cases, innovative irrigation strategies that take full benefits of deficit irrigation practices through drip system might result in more effective use of water resources.

Materials and Methods

Location and Soil of Experimental Plot

A present investigation was conducted at the All India Coordinated Research Projects on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. Geographically, the farm lies at 74° 38' 39" E longitudes and 19° 20' 39" N latitude at 537 m above the mean sea level. The topography of the experimental field was uniform and levelled. The onion variety 'Phule samarth' was sown on 23rd December 2022 @ 60 cm × 20 cm on a raised bed system. The experiment had pan evaporation based three drip irrigation (DI) levels, three fertigation levels and two control treatments.

The physical and chemical properties of soil play an integral role in deciding whether soil is appropriate for crop production or not. The field contained black cotton soil with a moderate organic matter content and "clay" textured. The bulk density, field capacity and permanent wilting point of experimental soil were found to be 1.36 g cm^{-3}, 33.21% and 15.89% respectively. The available moisture in the root zone was 17.32 mm/m. The pH of the soil in the experimental field was 7.73, indicating that it was slightly alkaline. The EC of the soil was 0.14dSm^{-1}. The available N, P, and K were 176, 20, and 526 kg ha^{-1}, respectively.

Climatological Data

Climatic factors viz., temperature (maximum and minimum), relative humidity (maximum and minimum), wind speed, solar radiation and actual sunshine hours were obtained on daily basis from Gramin Krishi Mausam Sewa, MPKV, Rahuri. The maximum temperature varies from 39.6°C to 25.0°C whereas the minimum temperature varies from 25.1°C to 9.1°C. The maximum relative humidity varies from 93% to 37% whereas the minimum relative humidity varies from 65% to 10%. The highest wind speed observed is 3.8 km/hr while the lowest is 0.2 km/hr. The highest pan evaporation is 9.4 mm/day while the lowest value is 3.8 mm/day. The sunshine hour data indicates that the highest sunshine hours is 11.4 hours, while the lowest value is 0.3 hours. The total rainfall received was 70.2 mm with 10 rainy days. The maximum reference evapotranspiration throughout the crop growth period is 5.56 mm day^{-1}, while the minimum value is 1.63 mm day^{-1}. The maximum crop evapotranspiration is 5.03 mm day^{-1} while the minimum value is 1.18 mm day^{-1} throughout the crop growth period.

Experimental setup

Layout of the experimental field

The factorial randomized block design (FRBD) of the field experiment consists of three irrigation levels, three fertigation levels and two controls with three replications. The size of each plot was 3m × 5m. Crop spacing on bed is 60 cm × 20 cm. A 4 m buffer area was provided between two beds to facilitate cultural operations like weeding, spraying, harvesting etc. Drip irrigation system was installed to apply irrigation to the crop.

Treatment details

There are three irrigation levels on the basis of pan evaporation (PE) i.e. I_1: Drip irrigation @ 100% of PE, I_2: Drip irrigation @ 80% of PE and I_3: Drip irrigation @ 60% of PE on alternate day. On the basis of Recommended dose of fertilizer (RDF) 100:50:50:30 NPKS kg/ha there are three fertigation levels i.e. F_1: 100% of RDF, F_2: 80% of RDF and F_3: 60% of RDF at weekly interval. There are two control treatments i.e. Control-1: Drip irrigation @ 80% of ETc with 100% RDF (i.e. recommendation on onion bulb production by MPKV, Rahuri) and Control-2: Surface irrigation @ 50mm CPE with 100% RDF (i.e. traditional method or farmer's practice). There are total 11 treatments out of which 9 are main treatments which are combination of three irrigation regimes and three fertigation levels and 2 are control treatments.

Field operations

The crop was grown using all agronomic practices recommended by the parent agricultural university. Agronomic practices were controlled during field preparation to ensure that soil moisture and the initial nutrient status at the beginning of the season were almost similar. The plant protection measures were undertaken for effective control against the diseases and pests, as and when required. To control the weeds in the experimental plots, two-hand weeding was carried out.

Soil Moisture Studies

Soil moisture content was recorded periodically, 24 hrs after irrigation. Gravimetric method was used for determination of moisture content in the soil. The samples were weighed and kept in the oven for a period of 24 hrs at the temperature of 105 ºC. Oven dry weights of the samples were recorded and then moisture content was calculated by using Eq.,

$$\text{Moisture Content (\%)} = \frac{(\text{Weight of wet sample} - \text{Weight of oven dry sample})}{\text{Weight of oven dry sample}} \times 100$$

The readily available water for the plant in the root zone was estimated using Eq.,

$$\text{Readily available water (\%)} = \text{Available water} \times \text{Maximum allowable depletion}$$

Water requirement

Net irrigation requirement

The crop water requirement was estimated using Eq.

NIR = [(ETc × Irrigation level factor)-Effective Rainfall (mm day^{-1})]

WR = NIR + Effective Rainfall (mm day^{-1})

Where,

NIR = Net irrigation requirement (mm)

WR = Water requirement of crop (mm)

ETc = Crop evapotranspiration (mm day^{-1})

The factor considered as 1.0, 0.8 and 0.6 for respective irrigation levels.

Gross depth of irrigation

The gross depth of irrigation was estimated by using Eq.

$$d_{gross} = \frac{NIR}{\eta a}$$

Where,

d_{gross} = Gross depth of irrigation (mm)

NIR = Net irrigation depth (mm)

ηa = Field application efficiency (%)

Field application efficiency is considered as 95% for drip irrigation.

Time of operation

The operating time for the drip irrigation system was calculated by using Eq.

$$T = \frac{\text{Amount of water to be applied (lit)}}{\text{Discharge of emitter(lit } hrs^{-1})}$$

Where,

T = Time of application (hrs)

In treatment control-2 i.e. Surface irrigation @50mm CPE, 7cm depth of water was applied. Irrigation was stopped 15 days before the harvesting for maturity. Volume of water applied was computed by using Eq. 3.9:

$$V = \frac{D \times L \times W}{\eta a} \quad (3.9)$$

Where,

V = Volume of water applied, (lit)

D = Depth of water, (mm)

L = Length of plot, (m)

W = Width of plot, (m)

ηa = Field application efficiency, (%)

Field application efficiency considered as 65% for surface furrow irrigation system.

Experimental Biometric observation

For recording various biometric observations, three plants were randomly selected from each treatment. For easy identification, the selected plants were tagged with the help of ribbon. The growth characters i.e. number of umbels per plant and average diameter of umbel were recorded for three observational plants from each plot. The yield contributing character i.e. number of seeds per umbel were recorded for three observational plants of each plot and recorded on mean pant basis. The seed yield per plot was recorded for each plot separately.

The water use efficiency was measured in terms of field water use efficiency (FWUE) and crop water use efficiency (CWUE). The FWUE was determined from the onion seed yield and the gross depth of water applied including application losses while the CWUE was determined from the onion seed yield and the net depth of water applied.

Yield Prediction

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO. The program allows the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data, the development of irrigation schedules for different management conditions and also the calculation of water supply for varying crop patterns. Data such as reference evapotranspiration, rainfall, crop and soil as well as irrigation and rainfall data are input for calculation of water and irrigation requirements.

The effect of water stress on yield is quantified by relating the relative yield decrease to the relative evapotranspiration deficit with an empirical field response function,

$$\frac{Y}{Ym-1} = Ky\left(1 - \frac{ETa}{ETm}\right) \quad (3.30)$$

Where,

Ky = Crop yield response factor

Y and Ya = Expected and maximum crop yields, resp.

ETa and ETm = Actual and maximum evapotranspiration, resp.

The yield of onion seed crop was used to validate the yield reduction extracted from the CROPWAT model.

Results and Discussion

Soil Moisture Studies

A higher level of irrigation treatment results in better soil moisture distribution near to the point of application. The interpretation of the soil moisture wetting pattern indicates that the soil that irrigation level influences the soil moisture distribution varies both vertically and horizontally from the point of application. The readily available water content was estimated based on field capacity and permanent wilting point values of the soil. Table 1 represents, the distribution of readily available water curve surrounding the point of application. From Table 1 it is clear that, the decrease in irrigation levels reduces the readily available water curve in the soil, around the point of application. Higher irrigation level recorded wider readily available water curve which is beneficial for crop. As crop grows beyond 90 DAS, the decrease in the readily available water curve was observed due to higher utilization of water by the crops from its root zone.

Table 1: Distribution of readily available moisture curve around the emitter

Irrigation Regimes	Readily Available Moisture Curve Around The Emitter (Cm)							
	30 Das		60 Das		90 Das		120 Das	
	Vertical Distance	Horizontal Distance	Vertical Distance	Horizontal Distance	Vertical Distance	Horizontal Distance	Vertical Distance	Horizontal Distance
I_1	55	45	65	55	60	50	55	45
I_2	50	30	55	50	45	40	40	35
I_3	45	15	50	35	35	25	30	20
Control-1	50	45	65	50	55	35	50	30
Control-2	60	50	70	55	60	45	60	45

Growth contributing character

The number of umbels per plant showed a significant interaction effect between the two factors i.e. irrigation and fertigation and the control treatments. Lower levels of irrigation and fertigation resulted in lesser umbel production. The irrigation regime I_1 produced maximum number of umbels per plant (3.57, 6.28 & 6.00) while minimum number of umbels per plant was recorded in regime I_3 (1.47, 4.17 & 3.81) also for the fertigation level F_1 recorded more number of umbels per plant (3.10, 6.04 & 5.74) whereas less number of umbels per plant was observed under F_3 (1.99, 4.54 & 4.27) during crop growth period.

Table 2: Number of umbels per plant as impacted by different irrigation and fertigation levels at different growth stages

Treatments	No of Umbels per Bulb				Treatments	No of Umbels per Bulb		
	60 DAS	90 DAS	At Harvest			60 DAS	90 DAS	At Harvest
A. Irrigation regimes (I)					**A. Irrigation regimes (I)**			
I1 : 100% PE	3.57	6.28	6.00		I1 : 100% PE	3.57	6.28	6.00
I2 : 80% PE	2.67	5.40	5.13		I2 : 80% PE	2.67	5.40	5.13
I3 : 60% PE	1.47	4.17	3.81		I3 : 60% PE	1.47	4.17	3.81
S.E.M±	0.08	0.11	0.11		S.E.M±	0.09	0.12	0.11
C.D. AT 5%	0.23	0.30	0.33		C.D. at 5%	0.25	0.36	0.33
B. Fertigation regimes (F)					**B. Fertigation regimes (F)**			
F1 : 100% RDF	3.10	6.04	5.74		F1 : 100% RDF	3.10	6.04	5.74
F2 : 80% RDF	2.62	5.28	4.93		F2 : 80% RDF	2.62	5.28	4.93
F3 : 60% RDF	1.99	4.54	4.27		F3 : 60% RDF	1.99	4.54	4.27
S.E.M±	0.08	0.11	0.11		S.E.M±	0.09	0.12	0.11
C.D. at 5%	0.23	0.30	0.33		C.D. at 5%	0.25	0.36	0.33
C. Interaction (I × F)					**C. Interaction (I × F)**			
I1F1	4.00	7.00	6.75		I1F1	4.00	7.00	6.75
I1F2	3.74	6.66	6.28		I1F2	3.74	6.66	6.28
I1F3	2.96	5.19	4.98		I1F3	2.96	5.19	4.98
I2F1	3.56	6.49	6.15		I2F1	3.56	6.49	6.15
I2F2	2.67	5.06	4.85		I2F2	2.67	5.06	4.85
I2F3	1.78	4.66	4.38		I2F3	1.78	4.66	4.38
I3F1	1.74	4.62	4.33		I3F1	1.74	4.62	4.33
I3F2	1.44	4.11	3.67		I3F2	1.44	4.11	3.67
I3F3	1.22	3.78	3.44		I3F3	1.22	3.78	3.44
S.E.M±	0.14	0.18	0.20		S.E.M±	0.15	0.22	0.20
C.D. at 5%	0.40	0.52	0.57		C.D. at 5%	0.43	0.62	0.57
D. Control					**D. Control**			
Control-1	3.67	6.48	6.18		Control-2	2.08	4.75	4.48
G. Treated × Control					**G. Treated × Control**			
S.E.M±	0.15	0.19	0.21		S.E.M±	0.16	0.23	0.21
C.D. at 5%	0.42	0.55	0.60		C.D. at 5%	0.45	0.65	0.60
General Mean	2.64	5.39	5.04		General Mean	2.52	5.23	4.93
CV (%)	9.30	5.97	6.91		CV (%)	10.06	7.05	6.84

The umbel diameter showed a significant interaction effect between the two factors i.e. irrigation and fertigation and the control treatments at 60 and 90 DAS, while non-significant at harvest. Lower levels of irrigation and fertigation resulted in smaller umbel diameter. The irrigation regime I_1 produced highest diameter of umbel (4.55, 8.25 & 8.75) while smallest diameter (2.23, 4.96 & 5.72) was observed under regime I_3 and for fertigation level F_1 recorded highest diameter of umbel (3.96, 7.61 & 8.12) whereas smallest diameter (2.82, 5.74 & 6.61) was observed under F_3 during the crop growth period.

Table 3: Umbel diameter as affected by different irrigation and fertigation levels at different growth stages

Treatments	Umbel Diameter				Treatments	Umbel Diameter		
	60 DAS	90 DAS	At Harvest			60 DAS	90 DAS	At Harvest
A. Irrigation regimes (I)					**A. Irrigation regimes (I)**			
I1 : 100% PE	4.55	8.25	8.75		I1 : 100% PE	4.55	8.25	8.75
I2 : 80% PE	3.54	7.09	7.68		I2 : 80% PE	3.54	7.09	7.68
I3 : 60% PE	2.23	4.96	5.72		I3 : 60% PE	2.23	4.88	5.72
S.E.M±	0.14	0.13	0.12		S.E.M±	0.13	0.14	0.12
C.D. at 5%	0.39	0.39	0.34		C.D. at 5%	0.37	0.40	0.35
B. Fertigation levels (F)					**B. Fertigation levels (F)**			
F1 : 100% RDF	3.96	7.61	8.12		F1 : 100% RDF	3.96	7.61	8.12
F2 : 80% RDF	3.55	6.96	7.41		F2 : 80% RDF	3.55	6.96	7.41
F3 :60% RDF	2.82	5.74	6.61		F3 : 60% RDF	2.82	5.66	6.61
S.E.M±	0.14	0.13	0.12		S.E.M±	0.13	0.14	0.12
C.D. at 5%	0.39	0.39	0.34		C.D. at 5%	0.37	0.40	0.35
C. Interaction (I × F)					**C. Interaction (I × F)**			
I1F1	5.00	8.80	9.24		I1F1	5.00	8.80	9.24
I1F2	4.75	8.41	8.94		I1F2	4.75	8.41	8.94
I1F3	3.91	7.53	8.07		I1F3	3.91	7.53	8.07
I2F1	4.50	8.10	8.72		I2F1	4.50	8.10	8.72
I2F2	3.67	6.97	7.51		I2F2	3.67	6.97	7.51
I2F3	2.46	6.21	6.81		I2F3	2.46	6.21	6.81
I3F1	2.38	5.92	6.40		I3F1	2.38	5.92	6.40
I3F2	2.22	5.49	5.79		I3F2	2.22	5.49	5.79
I3F3	2.09	3.48	4.96		I3F3	2.09	3.48	4.96
S.E.M±	0.24	0.23	0.20		S.E.M±	0.22	0.24	0.21
C.D. at 5%	0.68	0.67	NS		C.D. at 5%	0.65	0.70	NS
D. Control					**D. Control**			
Control-1	4.31	8.12	8.64		Control-2	2.90	6.19	6.56
G. Treated × Control					**G. Treated × Control**			
S.E.M±	0.25	0.25	0.21		S.E.M±	0.24	0.25	0.22
C.D. at 5%	0.72	0.71	0.62		C.D. at 5%	0.68	0.73	0.65
General Mean	3.53	6.86	7.47		General Mean	3.39	6.69	7.30
CV (%)	11.89	5.97	4.76		CV (%)	11.30	6.21	5.00

Table 4: Number of seeds per umbel as impacted by different irrigation and fertigation levels after harvest

Treatments	No of Seeds per Umbel		Treatments	No of Seeds per Umbel
	After Harvest			After Harvest
A. Irrigation regimes (I)			**A. Irrigation regimes (I)**	
I_1 : 100% PE	783.59		I_1 : 100% PE	783.59
I_2 : 80% PE	662.04		I_2 : 80% PE	662.04
I_3 : 60% PE	458.59		I_3 : 60% PE	458.59
S.E.M±	10.26		S.E.M±	9.26
C.D. at 5%	29.55		C.D. at 5%	26.69
B. Fertigation levels (F)			**B. Fertigation levels (F)**	
F_1 : 100% RDF	726.48		F_1 : 100% RDF	726.48
F_2 : 80% RDF	623.00		F_2 : 80% RDF	623.00
F_3 : 60% RDF	554.74		F_3 : 60% RDF	554.74
S.E.M±	10.26		S.E.M±	9.26
C.D. at 5%	29.55		C.D. at 5%	26.69
C. Interaction (I × F)			**C. Interaction (I × F)**	
I1F1	822.11		I1F1	822.11
I1F2	798.00		I1F2	798.00
I1F3	730.67		I1F3	730.67
I2F1	808.11		I2F1	808.11
I2F2	644.22		I2F2	644.22
I2F3	533.78		I2F3	533.78
I3F1	549.22		I3F1	549.22
I3F2	426.78		I3F2	426.78
I3F3	399.78		I3F3	399.78
S.E.M±	17.77		S.E.M±	16.05
C.D. at 5%	51.18		C.D. at 5%	46.22
D. Control			**D. Control**	
Control-1	778.19		Control-2	550.34
G. Interaction (Treated × Control)			**G. Interaction (Treated × Control)**	
S.E.M±	18.73		S.E.M±	16.91
C.D. at 5%	53.95		C.D. at 5%	48.72
General Mean	649.09		General Mean	626.30
CV (%)	4.85		CV (%)	4.38

Yield and Yield-contributing character

The study assessed the impact of different irrigation and fertigation levels on the number of seeds per umbel after harvest. The number of seeds per umbel showed a significant interaction effect between the two factors i.e. irrigation and fertigation and the control treatments. Lower levels of irrigation and fertigation resulted in lowest number of seeds per umbel. The irrigation regime I_1 produced highest number of seeds per umbel (783.59) while lowest (458.59) was recorded in I_3 and for the fertigation level F_1 was recorded highest number of seeds (726.48) whereas lowest (554.74) was observed under F_3, after harvest.

The study highlights the importance of both irrigation and fertigation in achieving optimal onion seed yield. The onion seed yield showed a non-significant interaction between the two factors i.e. irrigation and fertigation and with Control-1 treatment. The yield recorded under I_1 regime (838.22 kg/ha) is at par (778.70 kg/ha) with I_2. The lowest yield was recorded under I_3 regime (632.24 kg/ha). The reduction in yield with decreasing irrigation levels indicates that lower water availability negatively affects onion seed productivity. Similar to irrigation, fertigation levels also had a notable impact on seed yield. The seed yield (806.54 kg/ha) at F_1 is at par (742.50 kg/ha) with F_2. The lowest seed yield (696.13 kg/ha) was recorded under F_3. Reduced fertigation levels resulted in lower yields, reflecting the critical role of adequate nutrient supply for onion seed development.

Table 5: Onion seed yield as influenced by different irrigation and fertigation levels after harvest

Treatments	Yield (kg/ha)		Treatments	Yield (kg/ha)
	After Harvest			After Harvest
A. Irrigation regimes (I)			**A. Irrigation regimes (I)**	
I_1 : 100% PE	834.22		I_1 : 100% PE	838.67
I_2 : 80% PE	778.70		I_2 : 80% PE	778.70
I_3 : 60% PE	632.24		I_3 : 60% PE	632.24
S.E.M±	24.38		S.E.M±	26.60
C.D. at 5%	70.24		C.D. at 5%	76.63
B. Fertigation levels (F)			**B. Fertigation levels (F)**	
F_1 : 100% RDF	806.54		F_1 : 100% RDF	806.54
F_2 : 80% RDF	742.50		F_2 : 80% RDF	742.50
F_3 : 60% RDF	696.13		F_3 : 60% RDF	700.57
S.E.M±	24.38		S.E.M±	26.60
C.D. at 5%	70.24		C.D. at 5%	76.63
C. Interaction (I × F)			**C. Interaction (I × F)**	
I1F1	897.22		I1F1	897.22
I1F2	820.67		I1F2	820.67
I1F3	784.78		I1F3	798.11
I2F1	847.07		I2F1	847.07
I2F2	769.30		I2F2	769.30
I2F3	719.74		I2F3	719.74
I3F1	675.31		I3F1	675.31
I3F2	637.54		I3F2	637.54
I3F3	583.87		I3F3	583.87
S.E.M±	42.23		S.E.M±	46.08
C.D. at 5%	NS		C.D. at 5%	NS
D. Control			**D. Control**	
Control-1	780.28		Control-2	495.49
G. Interaction (Treated × Control)			**G. Interaction (Treated × Control)**	
S.E.M±	44.52		S.E.M±	48.57
C.D. at 5%	NS		C.D. at 5%	139.91
General Mean	751.58		General Mean	715.43
CV (%)	9.77		CV (%)	10.64

Water Use Efficiency

The FWUE increases with decrease in irrigation levels and decreases with decrease in fertigation levels whereas, the CWUE decreases with decrease in both irrigation and fertigation levels. Among irrigation levels, the highest FWUE (14.36 kg/ha cm) was observed under I_3 at par (13.76 kg/ha cm) with I_2 while I_1 had lowest FWUE (12.06 kg/ha cm). Among fertigation levels, the highest FWUE (14.42 kg/ha cm) was observed under F_1 at par (13.31 kg/ha cm) with F_2 while F_3 had lowest FWUE (12.44 kg/ha cm). Among irrigation levels, the highest CWUE (21.31 kg/ha cm) was observed under I_1 at par (19.89 kg/ha cm) with I_2 while I_3 had lowest CWUE (16.15 kg/ha cm). Among fertigation levels, the highest CWUE (20.60 kg/ha cm) was observed under F_1 at par (18.97 kg/ha cm) with F_2 while F_3 had lowest CWUE (12.44 kg/ha cm).

Benefit cost ratio

The B:C ratio is non-significantly affected by interaction effect between irrigation and fertigation treatments when compared with Control-1. However, was significant when compared with Control-2. Treatment I_1 provided B:C ratio (3.50) at par (3.27) with I_2. Whereas, I_3 has lowest B:C ratio (2.66), suggesting that insufficient water supply negatively impacts crop yield and profitability. Among fertigation levels, F_1 provided the B:C ratio (3.38) at par (3.12) with F_2 while lowest (2.94) was recorded in F_3.

Table 6: Water use efficiencies of onion seed crop under different irrigation and fertigation

Treatments	FWUE	CWUE		Treatments	FWUE	CWUE
A. Irrigation regimes (I)				**A. Irrigation regimes (I)**		
I_1 : 100% PE	12.06	21.31		I_1 : 100% PE	12.06	21.31
I_2 : 80% PE	13.76	19.89		I_2 : 80% PE	13.76	19.89
I_3 : 60% PE	14.36	16.15		I_3 : 60% PE	14.36	16.15
S.E.M±	0.43	0.62		S.E.M±	0.42	0.64
C.D. at 5%	1.24	1.79		C.D. at 5%	1.21	1.85
B. Fertigation levels (F)				**B. Fertigation levels (F)**		
F_1 : 100% RDF	14.42	20.60		F_1 : 100% RDF	14.42	20.60
F_2 : 80% RDF	13.31	18.97		F_2 : 80% RDF	13.31	18.97
F_3 : 60% RDF	12.44	17.78		F_3 : 60% RDF	12.44	17.78
S.E.M±	0.43	0.62		S.E.M±	0.42	0.64
C.D. at 5%	1.24	1.79		C.D. at 5%	1.21	1.85
C. Interaction (I × F)				**C. Interaction (I × F)**		
I1F1	12.97	22.92		I1F1	12.97	22.92
I1F2	11.86	20.96		I1F2	11.86	20.96
I1F3	11.35	20.05		I1F3	11.35	20.05
I2F1	14.97	21.64		I2F1	14.97	21.64
I2F2	13.59	19.65		I2F2	13.59	19.65
I2F3	12.72	18.38		I2F3	12.72	18.38
I3F1	15.34	17.25		I3F1	15.34	17.25
I3F2	14.48	16.28		I3F2	14.48	16.28
I3F3	13.26	14.91		I3F3	13.26	14.91
S.E.M±	0.75	1.08		S.E.M±	0.73	1.11
C.D. at 5%	NS	NS		C.D. at 5%	NS	NS
D. Control				**D. Control**		
Control-1	18.12	19.93		Control-2	2.42	10.36
E. Interaction (Treated × Control)				**E. Interaction (Treated × Control)**		
S.E.M±	0.79	1.14		S.E.M±	0.76	1.17
C.D. at 5%	NS	3.27		C.D. at 5%	2.20	3.38
General Mean	13.50	18.24		General Mean	12.29	18.24
CV (%)	9.67	9.76		CV (%)	9.38	10.07

Table 7: Cost Economics of onion seed crop influenced by different treatments

Treatments	Gross Monetary Return (GMR) (Rs.)	Net Income (Rs.)	B :C Ratio		Treatments	Gross Monetary Return (GMR) (Rs.)	Net Income (Rs.)	B : C Ratio
A. Irrigation regimes (I)					**A. Irrigation regimes (I)**			
I_1 : 100% PE	667379	476944	3.50		I_1 : 100% PE	667379	476944	3.50
I_2 : 80% PE	622963	432655	3.27		I_2 : 80% PE	622963	432655	3.27
I_3 : 60% PE	505791	315609	2.66		I_3 : 60% PE	505791	315609	2.66
S.E.M±	19506	19506	0.10		S.E.M±	20102	20102	0.11
C.D. at 5%	56191	56191	0.30		C.D. at 5%	57908	57908	0.31
B. Fertigation levels (F)					**B. Fertigation levels (F)**			
F_1 : 100% RDF	645230	454141	3.38		F_1 : 100% RDF	645230	454141	3.38
F_2 : 80% RDF	594000	403691	3.12		F_2 : 80% RDF	594000	403691	3.12
F_3 : 60% RDF	556904	367375	2.94		F_3 : 60% RDF	556904	367375	2.94
S.E.M±	19506	19506	0.10		S.E.M±	20102	20102	0.11
C.D. at 5%	56191	56191	0.30		C.D. at 5%	57908	57908	0.31
C. Interaction (I × F)					**C. Interaction (I × F)**			
I1F1	717779	526564	3.75		I1F1	717779	526564	3.75
I1F2	656534	466100	3.45		I1F2	656534	466100	3.45
I1F3	627823	438168	3.31		I1F3	627823	438168	3.31
I2F1	677660	486571	3.55		I2F1	677660	486571	3.55
I2F2	615437	425129	3.23		I2F2	615437	425129	3.23
I2F3	575793	386264	3.04		I2F3	575793	386264	3.04
I3F1	540251	349288	2.83		I3F1	540251	349288	2.83
I3F2	510028	319846	2.68		I3F2	510028	319846	2.68
I3F3	467095	277692	2.47		I3F3	467095	277692	2.47
S.E.M±	33786	33786	0.18		S.E.M±	34818	34818	0.19
C.D. at 5%	NS	NS	NS		C.D. at 5%	NS	NS	NS
D. Control					**D. Control**			
Control-1	624227	433273	3.27		Control-2	324395	172219	2.13
E. Interaction (Treated × Control)					**E. Interaction (Treated × Control)**			
S.E.M±	35613.35	35613.4	0.19		S.E.M±	36701.54	36701.5	0.20
C.D. at 5%	NS	NS	NS		C.D. at 5%	105724.6	10572.6	0.57
General Mean	601262.7	410889	3.16		General Mean	571279.5	384784	3.04
CV (%)	9.77	14.33	9.79		CV (%)	10.07	14.77	10.29

Comparison of actual yield reduction and CROPWAT simulation

The yield reductions are expressed as percentages of the yield obtained under optimal irrigation level I_1 i.e. Drip Irrigation @ 100% PE. Control-2 shows maximum yield reduction both in actual (41.0%) and CROPWAT 8.0 simulation (33.4%). From Table 3.8 it is cleared that, results obtained from CROPWAT 8.0 were found near to actual results. Figure 4.26 shows close correlation between actual and simulated yield. Therefore, CROPWAT 8.0 model is useful to simulate the onion seed yield under local conditions.

Table 8: Comparison of actual and CROPWAT simulated yield for onion seed crop

Treatments	Actual		Cropwat	
	Yield (kg ha^{-1})	Yield Reduction (%)	Yield (kg ha^{-1})	Yield Reduction (%)
I_1	839	0.0	839	0.0
I_2	779	7.1	796	5.1
I_3	632	24.7	660	21.3
Control-1	780	7.0	799	4.8
Control-2	495	41.0	559	33.4

Conclusion

In conclusion, the study revealed that cultivating onion seed crop @ 80% PE and 80% water soluble RDF at weekly interval in 11 splits is beneficial for better B:C ratio and water use efficiency under semi-arid conditions of Rahuri, District Ahmednagar. If the crop coefficient values for the onion seed crop are available, drip fertigation at 80% ETc and 100% RDF is recommended for economical use of available water. The simulated onion seed yield using CROPWAT 8.0 model revealed comparable results. The actual yield reduction of 24.7% in treatment DI @ 60% PE was comparable with yield reduction 21.3% using CROPWAT 8.0. Thus, the CROPWAT 8.0 Model can be used to predict the onion seed yield under semi-arid region of Maharashtra.

References

1. Abdelkhalik A, Nuria PS, Nájera I, Domene MÁ, Baixauli C, Pascual B. Regulated deficit irrigation as a water-saving strategy for onion cultivation in Mediterranean conditions. Agronomy. 2019;9:521.
2. Abdelkhalik A, Nuria PS, Nájera I, Domene MÁ, Baixauli C, Pascual B. Effect of deficit irrigation on the productive response of drip-irrigated onion (*Allium cepa* L.) in Mediterranean conditions. The Horticulture Journal. 2019;88(4):488-498.
3. Abebe N, Kebede E, Derese Y, Robi F, Nanesa K. Determination of crop coefficients and water requirement of onion by using lysimeter at Werer, Middle Awash Valley of Ethiopia. Int J Res Stud Agric Sci. 2021;7(3):14-21.
4. Agbemabiese YK, Shaibu AG, Gbedzi VD. Validation of AquaCrop for different irrigation regimes of onion (*Allium cepa*) in Bontanga irrigation scheme. Int J Irrig Agric Dev. 2017;1(1).
5. Anonymous. Department of Agriculture and Farmer Welfare; c2015.
6. Anonymous. Government of India, Agriculture Statistics at a Glance, Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare; c2017.
7. Anonymous. Area and productivity of onion. www.indiastat.com; c2020a.
8. Anonymous. FAOSTAT Database. Food and Agriculture Organization of the United Nations. 2020b.
9. Anonymous. Onion and garlic research. Indian Council of Agricultural Research-Directorate of Onion and Garlic Research; c2021.
10. Bhagyawant RG, Gorantiwar SD, Dahiwalkar SD. Yield response factor for onion (*Allium cepa* L) crop under deficit irrigation in semiarid tropics of Maharashtra. Curr Agric Res J. 2015;3(2):128-136.
11. Bhasker P, Singh RK, Gupta RC, Sharma HP, Gupta PK. Effect of drip irrigation on growth and yield of onion (*Allium cepa* L.). J Spices Aromatic Crops. 2018;27(1):32-37.
12. Dingre SK, Pawar DD. Response of drip irrigated onion (*Allium cepa* L.) growth, yield and water productivity under deficit irrigation schedules. J Nat Res Conserv Manag. 2020;1(1):69-75.
13. Dingre SK, Pawar DD, Kadam KG. Productivity, water use and quality of onion (*Allium cepa*) seed production under different irrigation scheduling through drip. Indian J Agronomy. 2012;57(2):186-190.
14. Dingre SK, Pawar DD, Kale KD, Kadam MM. Onion seed productivity, nutrient use, and quality response to drip fertigation in semi-arid India. J Plant Nutr. 2016;39(10):1391-1403.
15. Jilani MS, Faridullah, Waseem K, Khan MS, Kiran M, Nadim MA, *et al*. Optimization of NPK combination for seed production of onion (*Allium cepa*) crop. Pure Appl Biol. 2019;8(2):1736-1743.
16. Khokhar K. Mineral nutrient management for onion bulb crops-A review. J Hortic Sci Biotechnol. 2019;94(6):703-717.
17. Kumari G. Effect of different NPK levels and intervals of fertigation on growth and yield of onion (*Allium cepa* L.) in the central dry zone of Karnataka. The Pharma Innovation Journal. 2022;11(3):2266-2269.
18. Manna D, Santra P, Maity TK, Basu AK. Quality seed production of onion (*Allium cepa* L.) cv. Sukhsagar as influenced by bulb size and date of planting. Agric Res Technol Open Access J. 2016;2(3):102-110.
19. Massaranduba WDM, Filho RRG, Brito MEB, Carvalho CMD, Araújo RR, Oliveira THS. Production and yield of onion under different water and nutrition managements. Rev Caatinga. 2022;35(2):402-411.
20. Mishra S, Pyasi SK, Awasthi MK, Shrivastava RN. Improving water efficiency and crop yield of drip irrigated onions through the application of deficit irrigation, mulching, and fertigation. The Pharma Innovation Journal. 2023; 12(10): 2368-2371.
21. Patel N, Rajput TBS. Effect of deficit irrigation on growth, yield and quality of onion in subsurface irrigation. Int J Plant Production. 2013;7(3):417-436.
22. Roy DK, Biswas SK, Akanda AR, Sarker KK, Khatun A. Effect of irrigation at different growth stages on yield, water productivity and seed production of onion (*Allium cepa* L. CV BARI piaz-1). Am J Agric For. 2014;2(6):256-261.
23. Sankar V, Thangasamy A, Lawande KE. Effect of drip irrigation on onion (*Allium cepa* L.) seed production

under Western Maharashtra conditions. Int J Trop Agric. 2015;33(2):589-602.
24. Satpute ST, Singh M, Khanna M, Singh AK, Ahmad T. Response of drip irrigated onion crop to irrigation intervals and fertigation strategies. Indian J Hortic. 2013;70(2):293-299.
25. Sujeewa RM, Mikunthan T, Sayanthan S, Thushyanthi Y, Piraphaharan M. Effect of deficit irrigation on growth and yield of red onion (*Allium cepa*) in drip irrigation system. Scholars J Agric Vet Sci. 2020;7(7):144-150.
26. Yihunie D. A single onion crop water requirement and irrigation schedule validation by the integration of Arc GIS Tool and CROPWAT 8.0 model: Case study in Fogera, Libokemkem, and Dera districts, Amhara region, Ethiopia. J Curr Res Food Sci. 2022;3(1):10-16.