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Hetal R Rathod
Department of Vegetable Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

KD Desai
Horticulture polytechnic, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

TR Ahlawat
Department of Fruit Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

VR Naik
ADR, Navsari Agricultural University, Navsari, Gujarat, India

DR Bhanderi
Department of Vegetable Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

VK Parmar
Department of Fruit Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
Hetal R Rathod
Department of Vegetable Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

Effect of irrigation levels, land configurations and growth substances on marketable yield, economics and storage life of onion

Hetal R Rathod, KD Desai, TR Ahlawat, VR Naik, DR Bhanderi and VK Parmar

Abstract
The present investigation was undertaken at Soil and Water Management Research Farm, Navsari Agricultural University, Navsari during the winter (*Rabi*) seasons of 2021-22 and 2022-23 on onion cv. Gujarat Junagadh Red Onion-11 (GJRO-11). The experiment consisting three factors, two main factors viz., deficit irrigation (0.4 ETc, 0.6 ETc and 0.8 ETc), land configuration (raised bed and flat bed) and one sub factor *viz*., foliar spray of growth substances (control, salicylic acid 250 mg l^{-1}, potassium silicate 250 mg l^{-1} and kaolin 50 g l^{-1}). The onion plants exposed to irrigation regime 0.8 ETc yielded significantly the highest marketable bulb yield (39.23, 32.81 and 36.02 t ha^{-1}, respectively) and shelf life (69.17, 73.33 and 71.25 days, respectively) during both the consecutive years and in pooled analysis. Land configurations did not show significant influence on the marketable bulb yield. While, the maximum shelf life (69.17 days and 69.92 days, respectively) was obtained from the raised bed land configuration during first year and in pooled analysis. The highest marketable bulb yield (33.26 t ha^{-1}) was noticed under the treatment receiving foliar spray of potassium silicate 250 mg l^{-1} however, the maximum shelf life (69.78 days) was obtained with foliar spray of salicylic acid @ 250 mg l^{-1}. The economics was calculated based on individual treatment effect and maximum net income of ₹ 2, 42, 682 ha^{-1} and benefit: cost ratio (1.28) was registered by individual effect of 0.8 ETc irrigation level.

Keywords: Deficit irrigation, land configuration, growth substances, shelf life and economics

Introduction

Onion (*Allium cepa* L.) is an important and valuable bulbous vegetable crop belonging to the family Alliaceae and has tremendous economic and dietic importance. Onion is truly a versatile crop due to its wide range of uses from salads to pickles and digestive aids to beauty products. It is an important source of polyphenolic flavonoids, having significant nutritional and medicinal properties (Leskovar *et al*., 2012) [11]. India has a great potential to produce onion throughout the year for local consumption as well as export, depending on irrigation water availability. In Gujarat, it occupies an area of 0.99 lakh hectare with the total production of 24.64 lakh metric tonne with a productivity of 24.79 t/ha (Anonymous, 2022) [5]. It is cultivated in almost all districts of Gujarat and nearby Union Territories.

Water requirement is expected to rise upto the level of 1093 billion cubic meter (BCM) and 1447 BCM by 2025 and 2050, of which 910 and 1072 BCM constituting 83.26% and 74.08%, respectively would alone be required for irrigation purposes (Anonymous, 2011) [4]. About 83% of the fresh water resources in India is currently being used for agriculture, so there is a tremendous pressure on agriculture sector to reduce its share of water and to improve total production by enhancing productivity with increased water use efficiency (Pandey *et al*., 2012; Yaghi *et al*., 2013) [14, 18]. Excessive utilization of irrigation water leads to over exploitation of ground water resources and pollution of the environment (Du *et al*., 2014) [8]. Unpredictable climatic conditions due to global warming have created extreme weather conditions *viz.* erratic rainfall, temperature extremes and soil salinity which is the major constraint for agricultural productivity particularly the vegetable crops.

Onion is a shallow rooted crop, having short and slightly ramified roots with not more than 0.20–0.25 m depth in soil. Therefore, it is sensitive to water stress and require frequent irrigation to achieve good crop yield (Zheng *et al*., 2013) [19]. The sensitivity of plants to water stress varies with species, varieties and physiological stage of the plant. Application of water below the level of full evapotranspiration (deficit irrigation) throughout the cropping season allows crop to sustain some degree of water stress with significant reduction in use of irrigation water having potential to optimize water productivity (Costa *et al*., 2007) [7]. Furthermore, suitability of different land configurations depends on soil type and rainfall pattern. Raised bed and flat bed system is an effective land configuration in onion to improve water use efficiency (Kadari *et al.*, 2019) [9].

The use of practical methods to mitigate moisture stress like chemical treatment is becoming popular, as it increases productivity under moisture stress conditions by reducing transpiration losses. Salicylic acid is a natural signaling molecule, which play an important role in regulating a number of physiological processes in plants. Kaolin is a reflective antitranspirant material, forms thin films of nanoparticles on leaves (Boari *et al*., 2015) [6]. It protects plants against drought stress by reducing transpiration. Potassium silicate increases several physiological activities such as accumulation of photosynthetic pigments and osmoregulation solutes and improves enzyme activity, apart from this, it decreases the malondialdehyde and prevents membrane leakage of onion plant (Khalifa *et al*., 2017) [10].

Materials and Methods

The experiment was implemented in split-plot design with three replications. Experimental treatments included irrigation regimes, land configuration and the application of growth substances *viz*., salicylic acid, potassium nitrate and kaolin. There were three factors studied in this experiment two main factors *viz.,* A) deficit irrigation include three levels (I_1 - 0.4 ETc, I_2 - 0.6 ETc and I_3 - 0.8 Etc) and B) Land configuration include two levels (L_1- Raised bed and L_2- Flat bed) and one sub factor *viz.,* A) foliar spray of growth substances include four levels (S_0 - Control, S_1- Salicylic acid 250 mg l^{-1}, S_2 - Potassium Silicate 250 mg l^{-1} and S_3- Kaolin 50 g l^{-1}). Thus, overall there were twenty four treatment combinations were formed. The replications had a buffer zone of 2 m and 1.2 m was kept between main plots to eliminate influence of lateral water movement and 1m was kept between sub plots. In raised bed treatment, each plot consists of four raised beds including six rows per bed spaced at 10 × 10 cm. In flat bed treatment, each plot consists of twenty four rows spaced at 15 cm and plant to plant distance was kept 10 cm. All plots in the experimental field were irrigated with dripper flow rate of 4 l h^{-1}. Water for each block passed through laterals placed in onion rows. A mini-valve was installed in the lateral to control water flow of the dripper line. The uniformity of emitter water application was checked by recording the time needed for the discharge to fill a vessel of known volume. The average discharge of the emitters was found to be 3.8 l h^{-1} and the uniformity coefficient was more than 90% for all the blocks.

Determination of crop water and irrigation requirement

The crop evapotranspiration (ETc) was estimated by using the value of reference evapotranspiration (ET_0) combined with crop factor (Kc) of onion at different growth stages and the irrigation water requirement was calculated using formula described by Allen *et al*. (2006) [3].

Economics

The input cost of cultivation includes all the operational cost from land preparation to harvesting of crop. The cost that varies between treatments were: cost of irrigation, labour charge of foliar spray, growth substances and market price of produce of different treatments under study. The gross return was calculated based on the bulb yield and price in the market for each treatment under study. Net return was worked out by subtracting the total cost of cultivation from gross realization for each treatment combinations and recorded in rupees per hectare. The benefit cost ratio was also calculated for each treatment combinations under study.

Results and Discussion

Yield Parameters

The result tabulated in Table 1 stated that during both the consecutive years and in pooled analysis, treatment I_3 *i.e.* 0.8 ETc irrigation yielded significantly the highest marketable bulb yield (39.23, 32.81 and 36.02 t ha^{-1}, respectively), but during second year of study (2022-23) it remained at par with I_2 *i.e.* 0.6 ETc irrigation level. Further, the lowest marketable bulb yield (29.61, 26.23 and 27.92 t ha^{-1}, respectively) was recorded with plants exposed to I_1 *i.e.* 0.4 ETc level of irrigation. The trend of marketable yield shows that higher marketable bulbs of onion at higher irrigation levels might be due to the increase in the production of growth measurement, enabling faster synthesis and transportation of photosynthates from source to descend. The increment of marketable yield as the amount of irrigation levels increased was also obtained by Mola (2020) [12], Abouabdillah *et al.* (2022) [2], Tufa *et al.* (2022) [17] and Tehulie *et al.* (2022) [16].

With regard to land configurations, it failed to influence marketable bulb yield significantly during both the experimental years as well as in pooled analysis. Despite of non significant result, the onion bulbs cultivated on raised bed registered greater marketable bulb yield (34.88, 30.07 and 32.47, respectively) than flat bed during all the individual year including pooled analysis. Raised bed land configuration improves soil structure, water use efficiency and provides ideal weather which might be the possible reason for increased marketable yield under raised bed. The current result of this study is in strong agreement with findings of Salari *et al.* (2021) [15].

While, in case of various growth substances, the onion plants receiving foliar spray of potassium silicate 250 mg l^{-1} at 30, 45 and 60 DATP recorded the highest marketable bulb yield (33.26 t ha^{-1}). Potassium silicate improved physiological response of plant leaves by improving the photosynthetic pigments, compatible solute and enzyme activity which thereby results in increased marketable production of the onion bulbs. These results matched with Abd El-Gawad *et al.* (2017) [1].

In the present investigation, all the possible combinations among irrigation levels, land configuration and foliar spray of growth substances were found non significant which indicated that irrigation and growth substances had significantly influenced marketable bulb yield individually irrespective of their interactions.

Table 1: Effect of irrigation levels, land configurations and growth substances on marketable bulb yield (t ha^{-1}) and shelf life (days) of onion

Treatments	Marketable bulb yield (t ha^{-1})			Shelf life (days) till the bulbs loss 20% weight		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Irrigation levels (I)						
I_1: 0.4 ETc	29.61	26.23	27.92	65.58	67.50	66.54
I_2: 0.6ETc	34.60	31.02	32.81	66.50	71.83	69.17
I_3: 0.8ETc	39.23	32.81	36.02	69.17	73.33	71.25
SEm±	1.294	0.720	0.740	0.846	0.759	0.568
CD at 5%	4.08	2.27	2.18	2.66	2.39	1.68
Land configuration (L)						
L_1: Raised bed	34.88	30.07	32.47	69.17	70.67	69.92
L_2: Flat bed	34.08	29.97	32.02	65.00	71.11	68.06
SEm±	1.056	0.588	0.604	0.690	0.620	0.464
CD at 5%	NS	NS	NS	2.18	NS	1.37
Interactions	NS	NS	NS	I × L	NS	Y × L Y × I × L
CV%	18.39	11.75	15.91	6.18	5.24	5.71
Growth substances (S)						
S_0: Control	33.08	29.29	31.18	65.78	69.33	67.56
S_1:Salicylic acid 250 mg l^{-1}	34.74	29.80	32.27	68.22	71.33	69.78
S_2: Potassium Silicate 250 mg l^{-1}	35.89	30.62	33.26	66.11	71.78	68.94
S_3: Kaolin 50 g l^{-1}	34.20	30.36	32.28	68.22	71.11	69.67
SEm±	0.703	0.622	0.469	0.927	0.651	0.566
CD at 5%	NS	NS	1.32	NS	NS	1.60
Interactions	NS	NS	NS	I × L × S	NS	I × L × S
CV%	8.65	8.79	8.73	5.86	3.90	4.93

Table 2: Interaction effect of irrigation levels × land configurations on shelf life (days) till the bulbs loss 20% weight in 2021-22

Land configuration (L)	Shelf life (days) till the bulbs loss 20% weight			
	Irrigation levels (I)			
	I_1	I_2	I_3	Mean
L_1: Raised bed	69.83	68.00	69.67	69.17
L_2: Flat bed	61.33	65.00	68.67	65.00
Mean	65.58	66.50	69.17	
SEm±	1.196			
CD at 5%	3.77			

Table 3: Interaction effect of irrigation levels × land configurations × foliar spray of growth substances on shelf life (days) till the bulbs loss 20% weight in 2021-22 and pooled analysis

Growth substances (S)	Shelf life (days) till the bulbs loss 20% weight													
	2021-22							Pooled analysis						
	L_1			L_2			Mean	L_1			L_2			Mean
	I_1	I_2	I_3	I_1	I_2	I_3		I_1	I_2	I_3	I_1	I_2	I_3	
S_0: Control	70.67	61.33	68.00	58.67	69.33	66.67	65.78	68.00	66.67	69.33	62.00	70.00	69.33	67.56
S_1:Salicylic acid 250 mg l^{-1}	68.00	73.33	69.33	62.67	64.00	72.00	68.22	67.33	74.00	70.67	66.00	68.00	72.67	69.78
S_2: Potassium Silicate 250 mg l^{-1}	68.67	66.67	70.67	60.00	62.67	68.00	66.11	68.33	69.33	73.33	64.00	67.33	71.33	68.94
S_3: Kaolin 50 g l^{-1}	72.00	70.67	70.67	64.00	64.00	68.00	68.22	69.33	70.67	72.00	67.33	67.33	71.33	69.67
Mean	69.83	68.00	69.67	61.33	65.00	68.67		68.25	70.17	71.33	64.83	68.17	71.17	
S.Em±	2.270							1.387						
CD at 5%	6.52							3.91						

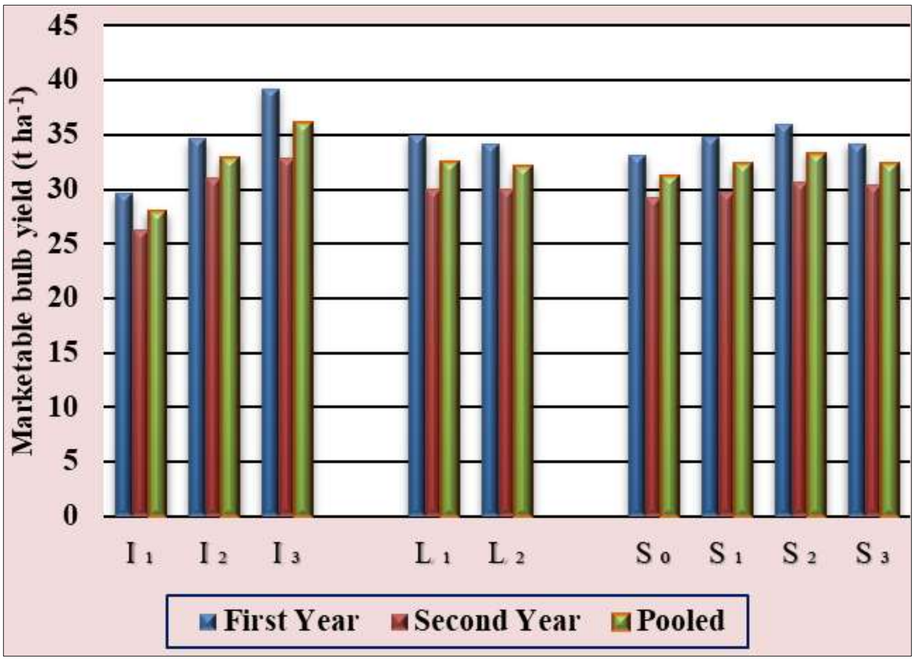

Fig 1: Effect of irrigation levels, land configurations and growth substances on marketable bulb yield (t ha^{-1}) of onion

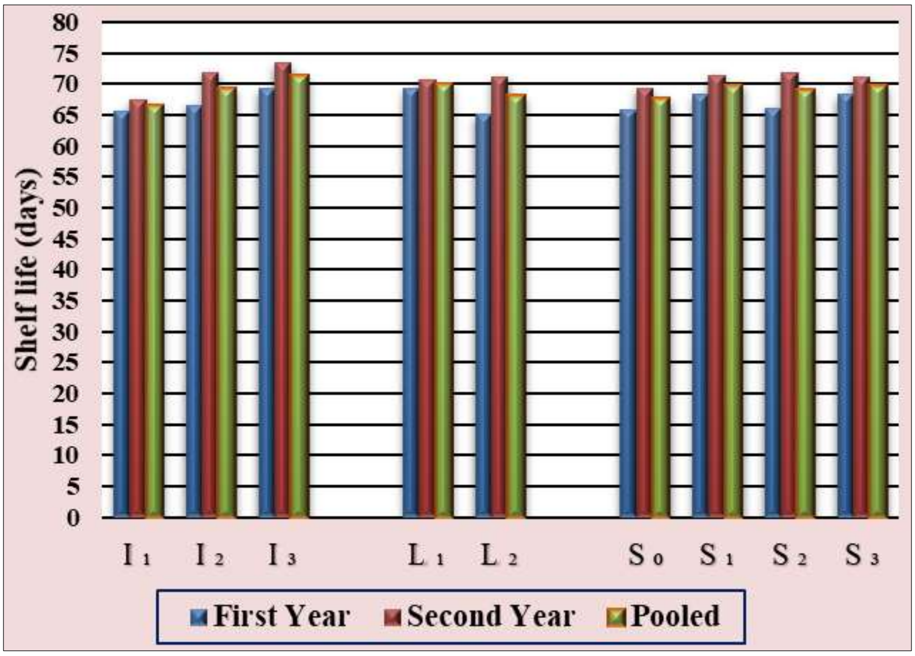

Fig 2: Effect of irrigation levels, land configurations and growth substances on shelf life (days) of onion

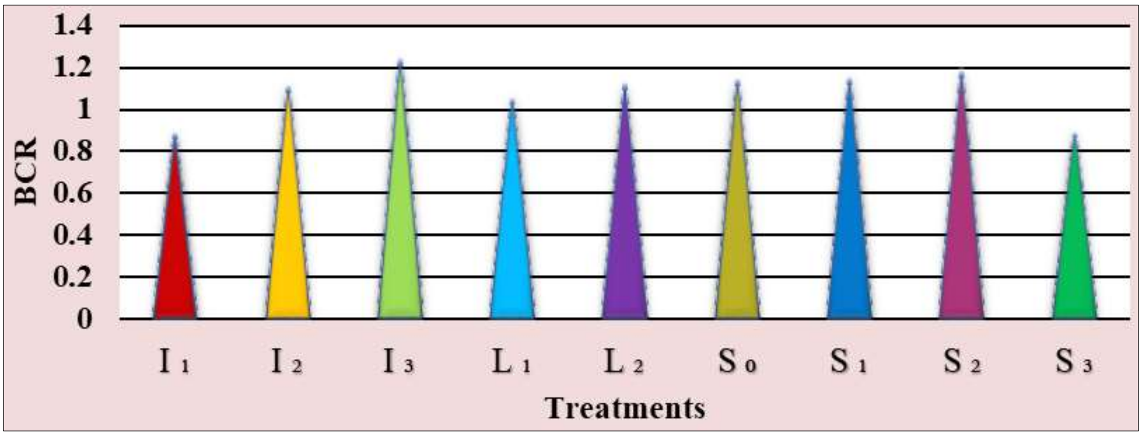

Fig 3: Effect of irrigation levels, land configurations and growth substances on economics of onion cultivation (₹ ha^{-1})

Table 4: Effect of irrigation levels, land configurations and growth substances on economics of onion cultivation (₹ ha^{-1})

Treatments	Marketable yield per hectare (t)	Fixed cost (₹ ha^{-1})	Variable cost (₹ ha^{-1})	Cost A (₹ ha^{-1})	Cost B (₹ ha^{-1})	Cost C (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	BCR
I_1	27.92	84,095	69,065	1,53,160	20,940	1,74,100	3,35,040	1,60,940	0.92
I_2	32.81	84,092	74,678	1,58,773	24,608	1,83,381	3,93,720	2,10,340	1.15
I_3	36.02	84,092	78,448	1,62,543	27,015	1,89,558	4,32,240	2,42,682	1.28
L_1	32.47	84,092	78,056	1,62,151	24,353	1,86,504	3,89,640	2,03,137	1.09
L_2	32.02	84,092	70,061	1,54,156	24,015	1,78,171	3,84,240	2,06,069	1.16
S_0	31.18	84,092	63,894	1,47,989	23,385	1,71,374	3,74,160	2,02,786	1.18
S_1	32.27	84,092	68,264	1,52,359	24,203	1,76,562	3,87,240	2,10,679	1.19
S_2	33.26	84,092	71,138	1,55,233	24,945	1,80,178	3,99,120	2,18,942	1.22
S_3	32.28	84,092	92,950	1,77,045	24,210	2,01,255	3,87,360	1,86,105	0.92

Shelf life

The shelf life of onion bulbs was significantly influenced by different levels of irrigation during both the years (2021-22 and 2022-23) of investigation including pooled analysis. The onion plants cultivated under irrigation level 0.8 ETc recorded significantly the higher shelf life (69.17, 73.33 and 71.25 days, respectively) which was found at par with 0.6 ETc irrigation level during second year of study. Furthermore, the lowest shelf life (65.58, 67.50 and 66.54 days, respectively) was observed in 0.4 ETc irrigation level (Table 1).

Land configuration did not show significant effect on physiological loss in weight (%) due but the result presented in Table 1 indicated that the maximum shelf life (69.17 days and 69.92 days, respectively) was obtained from the raised bed land configuration during first year of experimentation as well as in pooled analysis which is in accordance with Kaur *et al.* (2017) [20].

The maximum shelf life (69.78 days) was obtained with foliar spray of salicylic acid @ 250 mg l^{-1} and found at par with S_3 and S_2. However, the result was remained unaffected in both the individual years of experimentation (Table 1)

The significant variation was found due to the combined effect of I × L during first year of study in respect of shelf life. The highest shelf life (69.83 days) was obtained from I_1L_1treatment combination *i.e.* 0.4ETc irrigation level + raised bed and it was at par with I_3L_1, $I_3L_2$and I_2L_1 (Table 2).

An interaction between irrigation levels, land configuration and growth substances (I × L × S) was found significant in first experimental year and in pooled analysis (Table 3). The combination of 0.6 ETc irrigation level + raised bed + foliar spray of salicylic acid @ 250 mg l^{-1} ($I_2L_1S_1$) recorded significantly the maximum shelf life (73.33 days and 74.00 days, respectively) during experimental year 2021-22 and pooled analysis and was found at par with treatment combinations $I_3L_1S_0$,$I_3L_1S_1$, $I_3L_1S_2$, $I_3L_1S_3$, $I_3L_2S_2$, $I_3L_2S_3$, $I_2L_1S_3$, $I_2L_2S_0$, $I_1L_1S_0$, $I_1L_1S_1$, $I_1L_1S_2$ and $I_1L_1S_3$ during first year of experimentation but in case of pooled analysis treatment combinations $I_3L_1S_2$, $I_3L_2S_1$, $I_3L_1S_3$, $I_3L_2S_2$, $I_3L_2S_3$, $I_2L_1S_3$and $I_3L_1S_1$ was found at par.

Economics

The adoption of any innovation among farmers depends upon its economic feasibility in financial terms. After completion of two consecutive years of experimentation, the economics was worked out to find the best and economical levels of deficit irrigation, land configurations and growth substances. Result regarding economic analysis for different treatment combinations are presented in Table 4 and depicted in Figure 3. Cost A, Cost B and Cost C were used to calculate economics together with gross income, net income and BCR.

In the present experiment, the interaction of different irrigation levels, land configurations and foliar spray of growth substances did not reflected significant effect on marketable yield of onion bulbs. Therefore, the economics was calculated based on individual treatment effect. The result revealed that the maximum net income of ₹ 2, 42, 682 ha^{-1} and benefit: cost ration (1.28) was registered by individual effect of I_3 treatment *i.e.* 0.8 ETc irrigation level followed by individual effect of foliar spray of potassium silicate @ 250 mg l^{-1} at 30, 45 and 60 DATP. Thus, irrigation level 0.8 ETc proved to be economical for production of onion under limited water condition with additional benefit of 20% irrigation water saving. In the current investigation, the net income increased with increasing irrigation level from 0.4 ETc to 0.8 ETc which might be due to improved bulb size thereby increased yield as well as reduced production of small sized unmarketable onion bulbs in 0.8 ETc irrigation level. These findings are in agreement with those of Kadari *et al.* (2019) [9] and Nawaz *et al*. (2017) [13].

Conclusion

The data of two consecutive years of experimentation, showed non significant interaction among various deficit irrigation levels, land configuration and growth substances on marketable yield of onion crop production. Therefore, the economics was calculated based on individual treatment effect. The result revealed that the maximum net income of ₹ 2, 42, 682 ha^{-1} and benefit: cost ratio (1.28) was registered by individual effect of I_3 treatment *i.e.* 0.8 ETc irrigation level which proved to be economical for production of onion under limited water condition with additional benefit of 20% irrigation water saving.

Future Scope

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Conflict of Interest

None

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