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Influence of irrigation levels and phenological stages on yield and quality attributes of sweet cherry cv. Regina

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ABSTRACT

The study was carried out on 4-5 years old plants of sweet cherry cv. Regina grafted on Gisela-5 rootstock to determine the critical stage of specific moisture regime to maximize the yield of quality fruits. During the present study, the irrigation was applied at four different phenological stages (fruit set, pit hardening, fruit growth, and fruit bud differentiation) of sweet cherry through drip irrigation, maintaining the four moisture regimes (control, 50% ETc, 75% ETc and 100% ETc). The highest fruit weight, size, and yield were noted with 100 % (I3) ETc level of irrigation at the fruit growth stage (T3), which was statistically at par with the 75 % Etc level. The highest yield efficiency was recorded under 100 % ETc (I3) irrigation regime at the pit hardening (T2) stage. The highest content of fruit TSS was recorded in 50 % ETc level of irrigation (I1) applied at the fruit growth stage (T3). The highest fruit acidity was observed with 100 % ETc (I3) level of irrigation applied at the fruit bud differentiation stage (T4). The highest value of TSS/acidity was observed in 50 % ETc (I1) irrigation regime applied at the fruit bud differentiation stage (T4). Trees subjected to irrigation at 100 % and 75 % ETc regime during fruit growth (T3) and fruit bud differentiation stage (T4) excelled for yield and quality characteristics over other stages and moisture regimes.

Keywords: *Prunus avium* L., Crop evapotranspiration, Drip irrigation, Fruit growth, Quality, Yield.

INTRODUCTION

Sweet cherry is highly for its nutritional and organoleptic characteristics, besides being highly remunerative crop of temperate zone. The productivity of sweet cherry depends upon the irrigation management at different phenological stages, disease and pest management, nutrition and canopy management. Of these factors, irrigation management during critical phenological stages plays a crucial role in determining the production function. Sweet cherry being a stone fruit, develops very rapidly wherein the II fruit growth stage is highly indistinguishable from the growth stage I and III. As a result, it is not recommendable to apply sub-optimal amounts of water at any stage of fruit growth (Marsal, 9; Rosa *et al*., 15). It has been observed that the complexities in optimizing the irrigation in fruit crops emerge due to difference in tree size, cultivar and fruit developmental stages (Khurshid *et al*., 8). In traditional systems sweet cherry is grown under rain-fed conditions having irrigation during critical phenological stages, resulting in low productivity with poor quality fruits. Keeping in view the scenario of climate change and scarce availability of water, being faced by Indian agriculture these days, it becomes imperative to discourage over and excessive irrigation and hence it is the need of the hour to optimize the irrigation requirement of sweet cherry. Thus the present investigation was undertaken to study the effect of regulated irrigation at various phenological stages in sweet cherry under high density orcharding to optimize the water use under drip system of irrigation.

MATERIALS AND METHODS

The present experiment was carried out during July, 2016-17 to August, 2018 -19 at SKUAST-K, Srinagar situated on latitude 34° 5′ N and longitude 74° 47′ E. The experiment was conducted on 4 -5 years old sweet cherry plants of cv. Regina on Gisela- 5 rootstock spaced at 4m × 2 m spacing. The annual rainfall during the fruiting seasons ranged from 690.40mm to 1229.9mm with annual evaporation rate ranging from of 984.3mm to 1798.9 mm. The amount of water supplied to the trees (Crop Evapotranspiration ETc) under each irrigation regime was calculated from the daily Pan evaporation data which was recorded from USWB Class-A Evaporation Pan. The irrigation was applied through drip system, wherein each tree was provided with two drippers having the discharge capacity of 4 l/h, which were placed at a distance of 25cm from the trunk in opposite direction. Two treatments namely irrigation level (I) and phenological stages (T) each

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at four levels were tested in the present study. The design of the experiment was factorial randomized block design consisting of three replications. Levels of irrigation used were I_0= No irrigation (rainfed), I_1= 50% ETc, I_2 = 75% ETc and I_3 = 100% ETc. Levels of Stages used were T_1 = Fruit set stage (15 April - 5 May), T_2 = Pit hardening stage (6 May - 25 May), T_3 = Fruit growth stage (26 May - 8 June) and T_4 = Fruit bud differentiation stage (1 July - 31 Aug). The measured water applied was calculated using the formula as per Mata *et al.* (10).

$$ETc = \frac{Epan \times Kp \times Kc \times AA \times AC}{IE}$$

Where,

Epan = Pan evaporation (mm); Kc = Crop coefficient; Pc = Pan Coefficient; AA = Area allotted per plant (m2); AC = Area shaded by canopy at noon (%); IE = Irrigation efficiency of system (90%) taken as decimal. Irrigation amount (litres/tree/day) = [ETc-Effective rainfall]. Crop coefficient (Kc) for sweet cherry was taken as given by FAO, during various growth stages.

Fruit yield, yield efficiency and fruit quality attributes were recorded from the selected trees at the time of fruit harvesting. The yield efficiency was calculated by dividing the yield (kg/ tree) from each experimental tree by the respective trunk cross sectional area (cm^2) (Westwood, 17). After harvesting, the fruits were counted in 5 kg samples to determine the average fruit weight using electronic balance. The fruit size was measured using vernier callipers. Moreover, the fruit TSS was recorded with digital hand Refractometer (Erma Make Japan). The titratable acidity of fruit Acidity as % malic acid was estimated as per the method of A.O.A.C. (1). TSS/Acidity ratio was determined by working out the ratio of total soluble solids/acidity of the fruits. The Data were analysed using OPSTAT statistical software.

RESULTS AND DISCUSSION

A significant response of application of different levels of irrigation, applied at various phenological stages on fruit yield was observed (Table 1). Overall, the plants irrigated with 100 % ETc (I_3) level of irrigation showed the highestong yield (6.52 kg/tree) of cherry, however it was similar statistically with 75 % ETc (I_2) level of irrigation, while it was lowest (5.35 kg/tree) in control (I_0). Similarly highest fruit yield (6.36 kg/tree) while irrigated at fruit growth stage (T_3) (Table 1). Higher yield obtained with I_3 and I_2 could be attributed due to higher uptake of water and minerals by the plant resulting in more accumulation of reserves. Interaction effect between the irrigation regimes and the phenological stages revealed that 75% ET and 100% ET (I_3) proved better statistically in respect of fruit yield at phonological stage T_3 (6.71 kg/tree) without showing any significant difference with I_3T_1, I_2T_1 and I_2T_2 combination. These findings are supported by Romero *et al.* (14) who stated that the increase in yield at higher irrigation levels could be due to the significant increase in the rate of photosynthesis that would result in higher canopy volume and carbon gain and carbohydrate accumulation, increasing the necessary reserves for shoot growth and fruiting in the following year. Also the highest values of yield obtained at T_3 stage is because of the fact that the stone fruits are more sensitive at a later stage of season due to their late reproductive bud differentiation and water stress at this stage might result in underdevelopment of primordial flower parts and/or accelerate the emergence of the stamens during bloom, thus decreasing their pollen receptivity. The results are in consonance with Khan *et al*. (7) who reported that yield and yield attributes increased significantly

Table 1. Effect of different irrigation levels at various phenological stages on yield per plant (kg) and yield efficiency (kg/cm^2) of sweet cherry cv. 'Regina' (pooled means for two seasons)

Irrigation	Fruit yield (kg/plant)					Yield efficiency (kg/cm^2)				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
I_0	5.47c	5.25c	5.52b	5.17c	5.35c	0.44a	0.44a	0.43a	0.42a	0.43d
I_1	6.00b	5.71b	6.51a	5.68b	5.98b	0.66a	0.66a	0.63a	0.63a	0.64c
I_2	6.63a	6.42a	6.69a	6.24a	6.50a	0.77a	0.77a	0.71a	0.72a	0.74b
I_3	6.65a	6.44a	6.71a	6.27a	6.52a	0.78a	0.79a	0.77a	0.75a	0.77a
Mean	6.19b	5.95c	6.36a	5.84d		0.66a	0.66a	0.63b	0.63b	
$C.D_{(0.05)}$										
Irrigation (I)			0.13					0.02		
Stage (T)			0.13					0.02		
I × T			0.26					NS		

T1=Fruit set stage (15 April-5May); T2= Pit hardening stage (6 May-25May); T3= Fruit growth stage (26 May-8 June); T4= Fruit bud differentiation stage (1 July-31 August); I_0= 0% ETc; I1= 50% ETc; I2= 75% ETc; I3= 100% ETc.

when irrigation was applied at different phenological stages in almond.

Yield efficiency recorded an increase with increased irrigation levels with maximum value of 0.77 kg/cm^2 obtained under 100 % ETc (I_3) level of irrigation. Also the highest yield efficiency was recorded at T_2 stage (0.66 kg/cm^2) which was found to be statistically *at par* with T_1 stage (Table 1). Yield efficiency increased significantly with increased irrigation levels which corresponded well with yield data.

The fruit weight and size of cherry fruit were significantly influenced by the phonological stage and irrigation levels (Table 2). The highest fruit weight (8.80g) was noticed with irrigation at 100 % ET_C (I_3) which was statistically similar with I_2. Furthermore the lowest fruit weight of 5.65 was recorded with 0 % ET_C (I_0) level of irrigation. The highest fruit weight of 7.40g was recorded at T_3 stage which was at par with other stages. Like fruit weight, fruit length and fruit breadth showed an increasing trend on applying higher irrigation regimes. The largest fruit size (length × width) (21.62 mm × 22.94 mm) was observed with 100 % ET_C (I_3) significantly. Similarly, the irrigation at fruit growth stage (I_3) was found best to yield the largest fruits (20.76 mm × 21.70 mm) of Regina cherry, however, it was found statistically similar with T_1 in respect of fruit length. As far as the interaction (I × T) effect is concerned, irrigation at 75% ETc applied at fruit growth stage (I_3 × T_3) proved effective to yield the longest fruits (22.15 × 23.38mm), which was statistically at par with I_2T_3 and I_3T_1. The results are in conformity with Bhandari *et al*. (3). Better performance of sweet cherry in terms of fruit weight and fruit size at higher evaporation replenishment may be the possible reason of better maintenance of internal water balance by the plants The findings are in accordance with Tromp and Wertheim, (16) who reported that the irrigation applied at fruit growth stage increased fruit size and weight due to double sigmoidal growth pattern of sweet cherry, characterised by an initial period of rapid cell division and growth, increasing the fruit growth in terms of fruit weight and fruit size.

The phonological stage of tree and its interaction with irrigation level could result the significant influence on TSS content of cherry fruit (Table 3). The highest TSS content (19.42°B) was contributed by the irrigation at 50% ETc regime (I_1) significantly, while it was lowest in control treatment (18.45°B). All phonological stages proved similar statistically in respect of fruit TSS content (19.34° to 19.72°B), while irrigated at 50% ETc (I_2) stage. Results are in accordance with Blancoa *et al*. (4). The results are in confirmation with Naor (12) and Antunez-Barria (2)

Table 2. Effect of different irrigation levels at various phenological stages on fruit characteristics of sweet cherry cv. 'Regina' (pooled means for two seasons).

Irrigation	Fruit weight (g)					Fruit length (mm)					Fruit breadth (mm)				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
I_0	5.62a	5.55a	5.68a	5.77a	5.65c	18.65c	18.66c	18.69c	18.54c	18.63c	18.57d	19.12c	18.85c	18.53c	18.77d
I_1	6.94a	6.82a	7.02a	6.70a	6.88b	20.46b	19.89b	20.93b	19.85b	20.29b	21.45c	21.14b	21.77b	21.14b	21.37c
I_2	7.96a	7.86a	7.98a	7.80a	7.90a	21.64a	21.13a	21.95a	21.04a	21.44a	22.49b	22.42a	22.83a	22.08a	22.46b
I_3	8.84a	8.75a	8.91a	8.69a	8.80a	21.45a	21.51a	22.15a	21.40a	21.62a	23.09a	22.63a	23.38a	22.67a	22.94a
Mean	7.34a	7.25a	7.40a	7.24a		20.55a	20.26b	20.76a	20.10c		21.40b	21.33c	21.70a	21.10d	
$C.D_{(0.05)}$															
Irrigation (I)			0.16					0.23					0.29		
Stage (T)			NS					0.23					0.29		
I × T)			NS					0.46					0.59		

T1= Fruit set stage (15 pril-5 May); T2= Pit hardening stage (6 May- 25 May); T3 = Fruit growth stage (26 May-8 June); T4= Fruit bud differentiation stage (1 July-31 August); I0= 0% ETc; I1= 50% ETc; I2= 75% ETc; I3= 100% ETc.

Table 3. Effect of different irrigation levels at various phenological stages on fruit quality of sweet cherry cv. 'Regina'((pooled means for two seasons).

Irrigation	Fruit TSS (°B)					Fruit acidity (%)					TSS/acidity ratio (%)				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
I_0	18.61b	18.28b	18.51b	18.39b	18.45	0.34a	0.35a	0.32a	0.37a	0.34a	49.42b	53.35b	54.82b	58.43b	54.01
I_1	19.37a	19.51a	19.72a	19.34a	19.42a	0.22a	0.24a	0.18a	0.30a	0.23a	66.20a	82.57a	87.11a	91.55a	81.85a
I_2	17.44c	17.54b	17.58c	17.45c	17.50c	0.62a	0.39a	0.35a	0.41a	0.37	43.17c	45.35c	48.28c	50.15c	46.74c
I_3	17.46c	17.35b	17.38c	17.40c	17.40cd	0.42a	0.43a	0.40a	0.49a	0.44a	35.22d	40.24d	41.90d	43.09d	40.11d
Mean	18.22a	18.17a	18.29a	18.15a		0.33a	0.35a	0.31a	0.39a		48.50d	55.37c	58.03b	60.80a	
$C.D_{(0.05)}$															
Irrigation (I)			0.36					NS					2.22		
Stage (T)			NS					0.14					2.22		
I × T			0.72					NS					4.43		

T1= Fruit set stage (15 April-5 May); T2= Pit hardening stage (6 May-25 May); T3= Fruit growth stage (26 May- 8 June); T4= Fruit bud differentiation stage (1 July- 31 August); I0 = 0% ETc; I1 = 50% ETc; I2 = 75% ETc; I3 = 100% ETc.

who suggested the availability of reduced fruit water content for osmotic adjustment or an increased dry matter accumulation at lower irrigation levels in sweet cherry resulting in higher fruit TSS.

The content of fruit acid could be significantly influenced only by the level of irrigation (Table 3) The highest fruit acid content (0.44 %) was observed with 100 % ETc (I_3) level of irrigation which was statistically at par with I_2 and I_0 irrigation levels, and the lowest (0.23 %) was recorded with 50 % ETc (I_1) level of irrigation. The decreased fruit acidity at lower irrigation regimes can be possibly attributed due to high sugar concentration under water stress conditions. The results are in accordance with the findings of Mills *et al.* (11).

Various irrigation levels and phonological stages of tree growth significantly influenced the TSS: acid ratio of Regina cherry fruits (Table 3). The highest value of TSS/acid ratio (81.85 was recorded when 50 % ETc (I_1),regime of irrigation was used and lowest TSS/acid ratio (40.11) was recorded with 100% ETc level of irrigation (I_3). Also the highestTSS:acid ratio (60.80) was contributed by T_4 phenological stage. Of the various interactions (I × T), the irrigation at 50% ETc irrigation at T_4 stage showed the highest TSS:acid ratio (I_1T_4: 91.55%) statistically. The increase in TSS content under reduced moisture conditions can be explained in light of the fact that an increased conversion of starch to sugars takes place at water stress conditions thereby increasing the fruit TSS levels or could be the concentration effect due to the reduced cell water content in the fruits. Furthermore high TSS and low acidity recorded at fruit growth stage were in conformity with the findings of Garcia-Montiel *et al.* (5). During the process of ripening, fruit become much sweeter due to the increased sugar concentrations while acids, predominantly malic acid, remain relatively constant.

Furthermore Water use efficiency (WUE) under different irrigation regimes was also determined and it was recorded that WUE (yield per unit water) decreased with increase in the amount of water applied in sweet cherry. The maximum value of 5.75 kg/m^3 was recorded with 50 ETc (I_1) level of irrigation and the lowest value of 3.70 kg/m^{3}was obtained with 100 per cent ETc (I_3) level of irrigation (Fig 1). The results were in uniformity with Ishtiyaq, A. (6). The significantly lower water use efficiency at higher evaporation replenishment may have been caused by greater transpiration of trees which did not undergo any water stress. Under dry conditions, irrigation upto 50 per cent ETc resulted in markedly higher water use efficiency, probably due to increased rate of leaf net CO_2 assimilation and low net transpiration rate (Palma and Novello, 13).

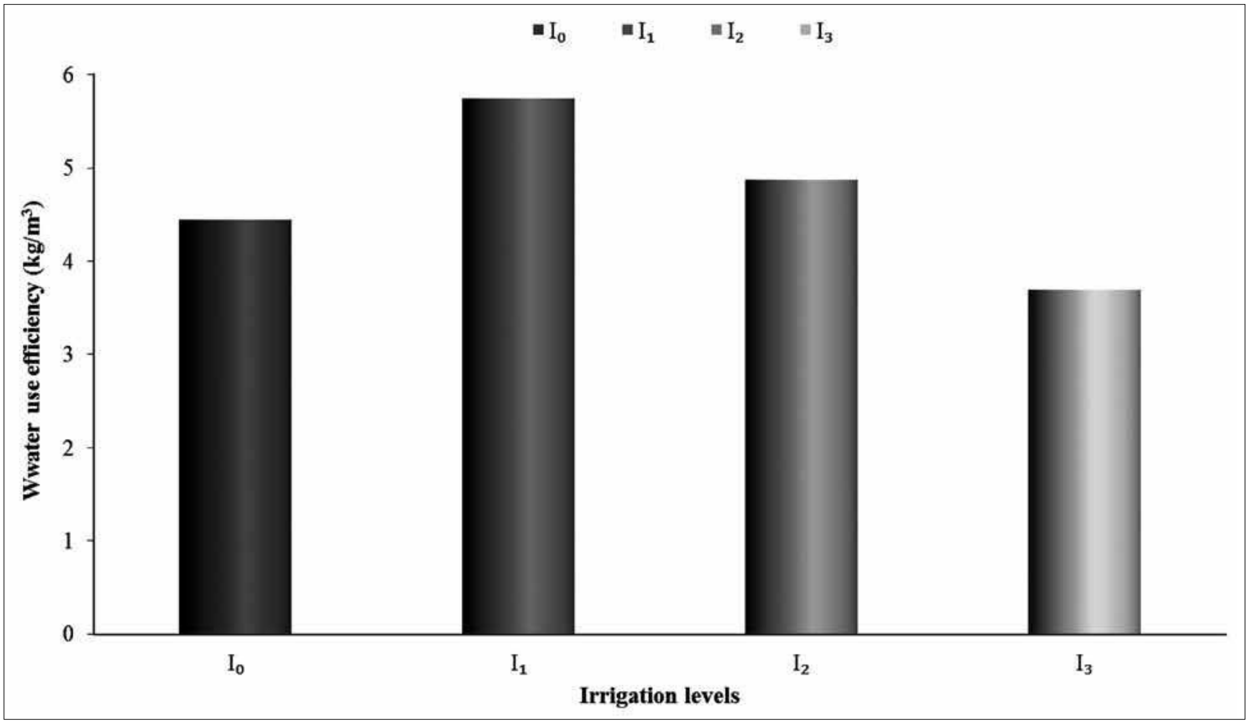

Fig. 1: Effect of irrigation levels on water use efficiency (kg/m^3) of sweet cherry cv. Regina

Management of irrigation for HDP is the most influential factor for yield and quality. To obtain higher yield and better quality fruits in sweet cherry, water management conditions must be improved by applying irrigation at critical phenological stages particularly at fruit growth and fruit set stages. Two irrigation regimes 100% and 75% ETc showed superiority with yield and quality characters. Water use efficiency of sweet cherry decreased with the increase in irrigation level. Highest water use efficiency was recorded in plants receiving 50% ETc followed by 75 and 0 per cent ET_C levels of irrigation. Moreover the average water requirement (L/tree/day) in sweet cherry came out to be 92.41 litres . and the average water requirement for producing 1 kg (L/tree/day) of sweet cherry came out to be 14.21.

AUTHORS' CONTRIBUTION

Conceptualization of research (RJ, WMW); Designing of the experiments (GHR, RJ); Contribution of experimental materials (WMW); Execution of field/lab experiments and data collection (RJ); Analysis of data and interpretation (RJ, GHR, NAG); Preparation of the manuscript (RJ, NAG).

DECLARATION

The authors declare that there is no conflict of interest.

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