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Response of Different Irrigation Levels on Vegetative Parameters of Sweet Cherry Grown in a High Density Planting System

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Authors' contributions

This work was carried out in collaboration between all authors. Author RJ designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Authors WMW and GHR analysed the manuscript. Authors JAW, SAB and NAK modified the manuscript. Authors TRB, SQD, SM and AS checked and managed the literature searches of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted on four year old plants of Sweet cherry cv. Regina grafted on Gisela- 5 rootstock (planted in 2013) at SKUAST-K Shalimar Srinagar Jammu and Kashmir. The period of experiment covers the years from 2016-2018. The experiment consisted of four irrigation

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treatment combinations I_0 (0%), I_1 (50%), I_2 (75%) and I_3 (100%) based on Class A Pan Evaporation percentages (0%, 50%, 75% and 100%) that were applied at four growth stages viz Fruit set stage (T_1), Pit hardening stage (T_2), Fruit growth stage (T_3) and Fruit bud differentiation stage (T_4). The quantity of water required was applied through drip irrigation on daily basis as per crop evapotranspiration. The difference between water levels was 25%. The vegetative parameters such as plant height, plant girth, trunk cross-sectional area (TCSA) and annual shoot extension growth of young dwarf sweet cherry plants cv. Regina on Gisela-5 were investigated in temperate climate. The experiment was laid out in Randomised Block Design with three replications. Maximum average values of vegetative growth parameters were obtained in I_3 treatment followed by I_2. Highest plant height and annual shoot extension growth was recorded at T_1 stage however maximum plant girth was recorded at T_3 stage and highest TCSA was obtained at T_4 stage. Furthermore the highest plant girth was recorded in I_3T_3 combination. Plants treated with 100% and 75% ETc level of irrigation excelled in vegetative growth parameters.

Keywords: Evapotranspiration; irrigation; sweet cherry; gisela; regina and vegetative.

1. INTRODUCTION

Irrigation is one of the major agricultural activities throughout the production season. Its importance increases as climate gets drier [1]. Proper timing of water applications during appropriate periods can increase the yield and quality of most horticultural crops. Rainfall and irrigation promotes significant cherry root access to soil water at shallower depths [2]. The inadequate irrigation levels or disproportionate ratios often cause a reduction in yields and a decrease in fruit quality [3]. Recent advances in agro technology makes it possible to apply irrigation to the root zone only thereby making efficient water utilization. This is especially true with drip irrigation system where only a portion of ground is irrigated. The research intends to review the critical growth stages of water requirement in Sweet Cherry under High Density Plantation that play an important role in determining the overall fruit quality. It is pertinent to mention here that in Kashmir Sweet cherry is mainly grown on Karewas which are totally rain fed with poor water holding capacity. Very meagre amount of rainfall (~700 mm) coupled with its erratic distribution results in deficient water supply at flowering and fruit development stage which causes severe pollination problems, poor fruit set, low productivity and inferior fruit quality that ultimately gets reflected by striking drop in economic well being of farmers and also sweet cherry can't withstand the water stagnation conditions, moreover there is an increasing shift from traditional plantation to High Density Plantation for which water management is most essential.

Cherries need irrigation or adequate soil moisture to ensure good fruit fill. The most critical stages of irrigation in fruit development of cherry is fruit growth stage followed by fruit set and fruit bud differentiation stage. During fruit growth stage, rapid growth takes place through cell expansion that is dependent upon available water. Uneven precipitation can cause plant stress during critical growth periods, which will affect both crop productivity and quality produce. Dehghanisanij et al. [4] reported that there was a high correlation between the length of young branches and canopy volume on one hand and annual amount of irrigation water applied on the other hand in mature cherry trees. Similarly Neilsen et al. [5] while working on interaction of irrigation and soil management on sweet cherry recorded the Larger trunk cross-sectional area (TCSA) and higher yield with High Frequency Irrigation compared with Low Frequency Irrigation in sweet cherry cultivars 'Cristalina' and 'Skeena' on Gisela 6 rootstock.

The aim of the present study has been to determine the crop evapotranspiration and effect of different irrigation levels applied at critical growth stages on vegetative growth of sweet cherry under high density plantation through drip irrigation.

2. MATERIALS AND METHODS

Experimental site: This study was carried out in the High Density Experimental Sweet cherry orchard at SKUAST-K, Srinagar (North Kashmir, Jammu and Kashmir), located at an altitude 1588m above sea level on latitude 34° 5' N and longitude 74° 47' E. The period of experiment covers the years from 2016-2018 (Fig. 1). The local climate is temperate with hot and dry, summers and winters cold with snow for almost three months. Meteorological data for the experimental year was measured on a daily basis at the SKUAST-K Agro meteorological

Station (Fig. 2 & Fig. 3). Month wise crop water requirement for cherry at 100% ETc is given in Table 1 which was obtained from Pan Evaporimeter located at the experimental area installed at Agro-metrological station of SKUAST-K Shalimar.

Experimental design and irrigation treatments: The study material consisted of Sweet cherry plants cv Regina (*Prunus cerasus* x *Prunus canescens,*) on Gisela-5 dwarf rootstock. The trees were planted in 2013 spaced 4 x 2 m apart (Fig. 1). The irrigation was applied at four fruit development stages viz T_1 (fruit set), T_2 (pit hardening), T_3 (fruit development) and T_4 (fruit bud differentiation) stages and the amount of irrigation was programmed at I_0 (0%), I_1(50%), I_2 (75%) and I_3 (100%) levels of recorded evapotranspiration as per Class A Pan evaporation. I_0 was used as the control treatment and in this treatment no irrigation was applied at any stage. The amount of irrigation water to be applied on daily basis was calculated from the daily pan evaporation values (Epan) measured in the Class A Pan.

Fig. 1. Experimental high density sweet cherry (cv. Regina on Gisela 5)orchard at SKUAST-Kashmir

Fig. 2. A view of agrometerological station of SKUAST-Kashmir

Fig. 3. USWB CLASS(A) Pan evaporimeter installed at agromet station of SKUAST-Kashmir

Measurements: The quantity of irrigation was estimated by the following FAO methodology as modified by Karmeli and Keller [6]:

$$ETc \text{ or } WR = DE \times KC \times AA \times PC \times AC \div IE$$

Where, ET_C = Crop Evapotranspiration, WR= Water requirement, DE = Daily pan evaporation data or Epan values, KC = Crop coefficient, PC = Pan Coefficient (0.8), AA = Area allotted per plant (m^2), AC = Area shaded by canopy at noon (%), IE = Irrigation efficiency of system (taken as 90%)

Irrigation amount/Water to be applied (litres/tree/day) = ETc – Effective rainfall (Value of KC was taken as given by FAO for cherry during various growth stages, PC was taken as 0.8, however AC was calculated on daily basis).

Vegetative parameters: In order to determine the effects of different irrigation levels at various phonological stages on vegetative growth, the following measurements were taken:

Plant height: Height of each experimental plant was measured with the help of a measuring tape from ground level to the tip of the main leader tape before the commencement and at the end of growing season. The increase in height was calculated by subtracting the initial height from the final height and was expressed in centimetres.

Plant girth: The plant girth of each experimental plant at 30 cm above the graft union was measured with the help of a measuring tape before the commencement and at the end of growing season. The increase in girth was calculated by subtracting the initial girth from the final girth and was expressed in centimetres.

Trunk cross sectional area (TCSA): The Trunk cross sectional area of each experimental plant was taken from the measurements of plant girth and expressed in cm^2 by using the formula as given by Kumar et al. [7]:

$$TCSA = Girth^2 \div 4\pi$$

Shoot extension growth: The shoot extension growth of each experimental plant was obtained by measuring the distance between successive terminal bud scars of the same branch at the end of the growing season and was expressed in cm.

3. RESULTS AND DISCUSSION

3.1 Results

Applied irrigation water and evapo-transpiration: Sweet cherry trees were irrigated from 15^{th} of april till 31^{th} august, but the first irrigation was applied during july-august 2016 to record the effect of irrigation applied at fruit bud differentiation stage during the next year. Water requirement (lt/tree/day) for Sweet cherry during 2017 and 2018 is given in Table 1. Highest monthly ETc values for treatment I_3 was estimated as 21.45 lt/tree/day in July and 25.56 lt/tree/day in june during 2017 and 2018 respectively (Table 1). The amounts of applied water per tree in litres was highest in the month of july (624.63) during 2017 and june (729.84) during 2018 (Table 1).

Irrigation and Vegetative growth relations: The differences between irrigation levels (I) as well as the phenological stages (T) were statistically significant ($p<0.05$) for plant height (Table 2), plant girth (Table 3), TCSA (Table 4) and shoot extension growth (Table 5). Also the interaction effect of irrigation levels with that of the phenological stages (IxT) were statistically significant for plant girth (Table 3), however the interaction effect (IxT) for plant height (Table 2), TCSA (Table 4) and shoot extension growth (Table 5) were insignificant.

Plant height of sweet cherry increased significantly with increase in irrigation levels (Table 2). Maximum plant height of 19.16 cm was recorded with highest irrigation level of 100 per cent ET_C (I_3), it was followed by 17.29 cm recorded with 75 per cent ET_C level of irrigation (I_2) however the lowest plant height of 12.69 cm was recorded with 0 per cent ET_C level of irrigation (I_0). Similarly highest plant height increment of 19.45 cm was found at T_1 stage, whereas the lowest (13.33 cm) incremental plant height was recorded at T_4 stage (Table 2).

The data pertaining to plant girth increment (Table 3) revealed that plant girth of sweet cherry increased significantly with irrigation. The highest plant girth (3.22 cm) was recorded with 100 per cent ETc (I_3) level of irrigation over plant girth of 2.54 cm recorded in control trees (I_0). Also the highest plant girth of 3.11 cm was recorded at T_3 phenological stage followed by 3.05 cm at T_4 stage which was statistically at par with T_3 stage (Table 3). The combination I_3T_3 recorded the highest plant girth of 3.43 cm which was statistically at par with I_3T_4 and I_2T_3 (Table 3).

Significant increase in TCSA was noticed during the research with increased irrigation levels, applied at various phonological stages of growth and development (Table 4). Maximum TCSA of 11.92 cm^2 was recorded with highest irrigation level of 100 per cent ETc (I_3) while as the lowest TCSA of 10.66 cm^2 was recorded with 0 per cent ETc level of irrigation (control). Similarly, the maximum TCSA of 11.69 cm^2 was recorded at T_4 phenological stage which was statistically at par with with T_3 stage. However, T_2 stage of growth and development recorded significantly lower TCSA of 10.81 cm^2 (Table 4).

Table 1. Month-wise crop water requirement for cherry during the growing season at 100 per cent ETc by pan evaporation method during 2017 and 2018

Month	2017			2018		
	ETc or Water requirement (lt/tree/day)	Water applied (I_3) (lt/tree)	Total Rainfall (mm)	ETc or Water requirement (lt/tree/day)	Water applied (I_3) (lt/tree)	Total Rainfall (mm)
Apr (15-30)	14.12	156.6	92	12.41	137.55	81
May	16.91	500.81	69	14.40	415.92	50.8
Jun	19.21	503.16	121.9	25.56	729.84	61.6
Jul	21.45	624.63	67.2	22.21	607.99	134.2
Aug	20.72	598.8	38	21.25	565.14	120.6

**Based on 90% irrigation efficiency of drip irrigation method*
The pan co-efficient (Kp) for experimental farm was taken as 0.8

Table 2. Effect of different irrigation levels at various phenological stages on incremental plant height (cm) of Sweet cherry (cv. Regina)

Levels \ Phenological Stages	T_1	T_2	T_3	T_4	Mean
I_0	16.09	13.32	11.74	9.60	12.69d
I_1	19.16	14.84	14.65	13.19	15.44c
I_2	20.51	17.74	16.37	14.53	17.29b
I_3	22.11	20.11	18.44	15.99	19.16a
Mean	19.45a	16.50b	15.30c	13.33d	

C.D. ($p \leq 0.05$) Irrigation levels (I): 0.624; Stages (T): 0.624; I x T: NS
T_1 = Fruit set stage (15April-5May); T_2 = Pit hardening stage (6 May-25May); T_3 = Fruit growth stage (26May-8 june); T_4 = Fruit bud differentiation stage (july-August); I_0 = 0 % ETc; I_1 = 50 % ETc; I_2 = 75 % ETc; I_3 = 100 % Etc
**values followed by the same letter are not significantly different at p< 0.05.*

Table 3. Effect of different irrigation levels at various phenological stages on increase in plant girth (cm) of Sweet cherry cv. Regina

Levels \ Phenological Stages	T_1	T_2	T_3	T_4	Mean
I_0	2.47	2.27	2.73	2.69	2.54d
I_1	2.52	2.40	3.01	2.98	2.74c
I_2	2.7	2.65	3.27a	3.19	2.59b
I_3	3.08	2.98	3.43a	3.38a	3.22a
Mean	2.69b	2.59c	3.11a	3.05a	

C.D. ($p \leq 0.05$) Irrigation levels (I): 0.105; Stages (T): 0.105; I x T: 0.210

*T_1 = Fruit set stage (15April-5May); T_2 = Pit hardening stage (6 May-25May); T_3 = Fruit growth stage (26May-8 june); T_4 = Fruit bud differentiation stage (July-August); I_0 = 0 % ETc; I_1 = 50 % ETc; I_2 = 75 % ETc; I_3 = 100 % Etc *values followed by the same letter are not significantly different at p< 0.05.*

Table 4. Effect of different irrigation levels at various phenological stages on TCSA (cm^2) of Sweet cherry cv. Regina

Levels \ Phenological Stages	T_1	T_2	T_3	T_4	Mean
I_0	10.29	10.22	11.09	11.03	10.66d
I_1	10.65	10.50	11.62	11.46	11.08c
I_2	10.99	10.90	12.13	11.94	11.49b
I_3	11.73	11.54	12.07	12.33	11.92a
Mean	10.92b	10.81c	11.73a	11.69a	

C.D. ($p \leq 0.05$) Irrigation levels (I): 0.202; Stages (T): 0.202; I x T: NS

*T_1 = Fruit set stage (15April-5May); T_2 = Pit hardening stage (6 May-25May); T_3 = Fruit growth stage (26May-8 june); T_4 = Fruit bud differentiation stage (july-August); I_0 = 0 % ETc; I_1 = 50 % ETc; I_2 = 75 % ETc; I_3 = 100 % Etc *values followed by the same letter are not significantly different at p< 0.05.*

Table 5. Effect of different irrigation levels at various phenological stages on Shoot extension growth (cm) of Sweet cherry cv. Regina

Levels \ Phenological Stages	T_1	T_2	T_3	T_4	Mean
I_0	38.00	36.66	35.16	34.33	36.04b
I_1	50.50	49.00	48.33	47.88	48.91a
I_2	51.33	49.16	48.50	48.00	49.25a
I_3	52.00	50.33	49.33	48.66	50.08a
Mean	47.95a	46.29a	45.33b	44.70c	

C.D. ($p \leq 0.05$) Irrigation levels (I): 2.05; Satges (T): 2.05; I x T: NS

T_1 = Fruit set stage (15April-5May); T_2 = Pit hardening stage (6 May-25May); T_3 = Fruit growth stage (26May-8 june); T_4 = Fruit bud differentiation stage (july-August);

I_0 = 0 % ETc; I_1 = 50 % ETc; I_2 = 75 % ETc; I_3 = 100 % ETc

**values followed by the same letter are not significantly different at p< 0.05.*

Annual shoot extension growth of sweet cherry was positively influenced with different levels of irrigation, applied at various phenological stages (Table 5). The maximum annual shoot extension growth of sweet cherry (50.08 cm) was recorded with 100 per cent ETc (I_3) level of irrigation which was found to be statistically at par with 75 (I_2) and 50 (I_1) per cent ETc level of irrigation whereas 0 per cent ETc (I_0) level of irrigation registered lowest (36.04) shoot extension growth. Similarly the annual shoot extension growth of sweet cherry showed a significant difference at various phenological stages of growth and development. Maximum annual shoot extension growth of 47.95 cm was recorded for T_1 stage which was statistically at par with T_2 stage (Table 5).

3.2 Discussion

Response of sweet cherry to various irrigation levels with respect to vegetative parameters at various phonological stages showed a positive effect with an increase in irrigation levels this may be due to the availability of sufficient moisture for continued growth which probably lead to a greater development of the overall tree canopy. Applied irrigation water based on daily pan evaporation data or Epan values were in agreement with the results reported by Abrisqueta et al. [8], but not in agreement with results of study conducted by Dehghanisanij et al. [4]. This disagreement could be based on different climate conditions .The differences may also be attributed to different type and age of fruit trees. Many researchers reported that vegetative growth significantly increased as the irrigation water applied in different stone fruit trees Burak and Senih [9], Osman et al. [10] and Dehghanisanij et al. [4]. Also the regulated deficit irrigation applied at stage II as well as combined regulated irrigation at stage II and postharvest stage reduced length of the shoots (>75 cm) inside the canopy in clingstone peaches (Sotiropoulos,) [11]. The higher values of vegetative parameters obtained at higher irrigation levels are also in consonance with the results of Cigdem et al. [12] who worked on effects of different irrigation levels on the vegetative growth, flower bud formation and fruit quality of sweet cherry in western part of Turkey and reported that the increase in vegetative parameters showed a parallelism with the increase in the water application levels. In the present study, the relation between vegetative growth and applied irrigation water for I_3 was in agreement with findings of those researches. Also the maximum growth was recorded at cell division and expansion stage as the cell expansion is most sensitive to water deficit during growing season. The results are in uniformity with Candogen and Yazgan, [13]. Stino et al. [14] also reported the higher values of all quality parameters with increase in irrigation in pear. The amount of water available for cell expansion is therefore an important factor regulating the vegetative growth of plants. The present findings are also in agreement with those of Hutmacher et al. [15], who observed reduced trunk growth in almond due to deficit irrigation. Li [16] reported that deficit irrigation during fruit development and post-harvest in peach trees significantly reduced vegetative growth. The greater trunk girth obtained under present study with availability of water might be due to higher absorption of water and nutrient from soil, better translocation of assimilates and production of hormones from roots and better unloading through phloem.

4. CONCLUSION

All the vegetative growth parameters of sweet cherry cv. Regina increased with higher water application levels. Significantly highest plant height of 19.16 cm was recorded with highest irrigation level of 100 per cent ET_C (I_3). Plant girth increment obtained in I_3T_3 (3.43 cm) combination was the highest compared to all other combinations. Highest TCSA (11.92 cm^2) was obtained with highest irrigation level (I_3) at T_2 stage. The maximum annual shoot extension growth of 50.08 cm and 47.95 cm was recorded with 100 per cent ETc (I_3) and T_1 phenological stage respectively. The reason for maximum vegetative growth at higher irrigation levels may be due to adaptation ability of young plants to the root zone and plant characteristics such as shallow root development and dwarf rootstock. Irrigation treatment I_3 and I_2 may be recommended as optimum irrigation treatment for irrigation of Regina on Gisela-5 young sweet cherry trees in the temperate conditions. On the other hand, these irrigation treatments must be re-considered in different conditions and I_3 irrigation level should be verified with yield parameters.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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