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Performance of strawberry grown in open field conditions in relation to differential irrigation scheduling

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Abstract
A two year study was undertaken to examine the effect of differential irrigation (drip and conventional furrow irrigation) on growth, yield, fruit quality and water use efficiency of strawberry grown in open field conditions. The experiment was carried out in a randomized block design in three replicates by growing cv. Chandler variety of strawberry. The experimental treatments included five levels of irrigation *viz*. T_1-drip irrigation at 120 % ETc, T_2-drip irrigation at 100 % ETc, T_3-drip irrigation at 80 % ETc, T_4-drip irrigation at 60 % ETc and T_5-furrow irrigation with 'V' volume of water. The study revealed that the drip irrigation at 120% of ETc gave significantly higher plant height, number of leaves, leaf area, number of runners and fruit yield compared to that obtained with drip irrigation at 80 and 60% of ETc and furrow irrigation. Similarly, the fruit size, fruit weight, TSS, total sugar and reducing sugar were found higher in drip irrigation at 120% of ETc, followed by drip irrigation at 100% ETc. Further, the growth, yield and fruit quality under drip irrigation at 120% of ETc were obtained slightly better compared to that under 100% of ETc. However, the drip irrigation at 100% of ETc confirmed about 16% saving of irrigation water compared to 120% of ETc irrigation treatment. Besides, drip irrigation at 100% ETc recorded 16 to 18%, 16 to 30% and 23% increase in plant height, yield and water use efficiency over furrow irrigation with 'V' volume of water.

Keywords: drip irrigation, yield, water-use efficiency, strawberry

Introduction
Strawberry (*Fragaria* x *ananassa* Duch.) has gained the status of being one of the most important soft fruit of the world. It occupies a significant place in fruit growing since it can be cultivated in plains as well as in hills. In India, it is commercially grown in Maharashtra, Haryana, Punjab, Uttar Pradesh, Jammu and Kashmir, Uttarakhand and Himachal Pradesh. In recent years, the strawberry cultivation in India is gaining momentum and the area is increasing rapidly because of quickest and higher returns as reported in Kachwaya and Chandel (2009) [9]. Strawberry is a shallow rooted plant, thus require more frequent irrigation with less amount of water to maintain optimum soil moisture for quality fruit production.
Availability of irrigation water is the major constraint to crop production in many parts of the world. The advantage of drip irrigation is a significant technological improvement in irrigation system, which helps to combat water scarcity in agriculture. In recent years, the adoption of drip irrigation has gained momentum owing to its positive impact on water saving, productivity and quality of produces in many crops (Panigrahi *et al*; 2012) [12]. The drip system synchronizes the plant water requirement and maintains an optimum soil moisture status around the vicinity of plant roots. Compared to furrow irrigation, drip irrigation provides better water use efficiency as reported in Hoppula and Salo (2007) [6]. The technology holds great potential in water scarce areas having shallow and course textured soils especially, in the Himalayan region. In hilly areas, surface irrigation is not suitable due to undulating topography, shallow and light textured soils with low water holding capacity and availability of meagre water resources. Keeping these points in view, the present investigation was carried out to study the comparative performance of drip and furrow irrigation on growth, yield, fruit quality and water use efficiency and to work out the total irrigation water requirement for strawberry.

Materials and Methods
A field experiment was conducted on strawberry plants of cultivar Chandler planted at 25 cm × 50 cm distance at Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (Himachal Pradesh) located at 30° 51' latitude and 76° 11' E longitude and at an elevation of 1250 meter

above mean sea level during 2010 and 2011. The soil was clay loam with pH 6.3, organic carbon 1.92% and available N, P, K was 368.70 kg/ha, 24.21 kg/ha and 161.0 kg/ha respectively. The annual rainfall of experimental area is about 125-130 cm and major amount of which is received during July-September. The experiment was laid out in Randomized Block Design with five irrigation treatments, *viz*. T_1-drip irrigation at 120 % ETc, T_2-drip irrigation at 100 % ETc, T_3-drip irrigation at 80 % ETc, T_4-drip irrigation at 60 % ETc and T_5-furrow irrigation with 'V' volume of water. Each treatment was replicated five times having 32 plants under each replication. Healthy runners of Chandler variety were planted at a spacing of 25 cm × 50 cm in well prepared beds of 2 m × 2 m size in the last week of September during 2010 and 2011 as the crop was taken as annual crop. The plants were maintained under uniform cultural practices during the period of investigation. Irrigation was based on the evaporation of class 'A' pan evaporimeter and 'V' volume required for irrigation was computed by using equation

$$V = Ep \times Kc \times Kp \times Wp \times A \times N - Re \times A$$

Where V: volume of water required (liters per irrigation), Ep: mean pan evaporation (mm day^{-1}), Kc: crop factor, Kp: pan factor, Wp: canopy area, A: area of plot (m^2), N: number of days, Re: effective rainfall (Kachwaya *et al*; 2016) [8]. The effective rainfall was calculated by balance sheet method from the actual rainfall received. The pan factor value was 0.70 as suggested for USAD class 'A' pan. The crop factor (Kc) values for different crop stages were computed as per the method of Blaney and Crddle (1950) [2]. The height of ten randomly selected plants per replication was measured with the help of measuring scale from the crown level to the apex of the primary leaf and numbers of leaves in these plants were also counted in the month of May. Fifty fully expanded leaves were collected at random from each plot and leaf area was recorded with LI-COR 3100 leaf area meter. The total number of runners per plot was counted in the month of September and then the number of runners per plant was calculated. After harvest yield and physico-chemical analysis of fruits were done with the standard procedure of AOAC (1980) [1] and Ranganna (1995) [13]. The total water requirement under different irrigation treatments was calculated from the irrigation water applied plus effective rainfall received during the period of study. Water-use efficiency was calculated by dividing the total fruit yield by total water used in cm during the crop growth. The data obtained were statistically analyzed in accordance with the method described by Gomez and Gomez (1984) [5].

Results and Discussion

The vegetative growth parameters were significantly influenced by different irrigation treatments (Table 1). The highest plant height (13.09 cm and 18.56 cm), number of leaves (20.12 and 21.00/plant), leaf area (78.94 cm^2 and 81.77 cm^2) and number of runners (50.51 and 52.00/plant) was recorded in drip irrigation at 120% ETc treatment, which was statistically at par with drip irrigation at 100% ETc treatment, which registered a plant height of 13.06 cm and 18.24 cm, 19.60 and 20.00 leaves/plant, leaf area of 76.34 cm^2 and 80.15 cm^2 and number of runners 48.08 and 51.00/plant during 2010 and 2011 respectively. These drip irrigation treatments were statistically at par with each other but significantly superior to drip irrigation at 80% and 60% ETc and furrow irrigation with 'V' volume of water with respect to growth parameters. The higher vegetative growth under 120% and 100% ETc drip irrigation treatments may attribute to better and continuous availability of water to the plants. These results are in conformity with other researchers (Demir *et al;* 1995, Yuan *et al;* 2004) [4, 16], who obtained significantly higher plant height and more number of leaves with increasing the amount of irrigation water from Ep 0.75 to Ep 1.25 in strawberry. The plants irrigated with less amount of water with drip irrigation at 60% ETc attained less vegetative growth in terms of plant height (7.12 cm and 13.62 cm), number of leaves (10.08 and 12.00/plant), leaf area (52.19 cm^2 and 1254.96 cm^2) and number of runners (36.78 and 39.40/ plant). Similarly, the limited water availability decreased plant growth attributes in Chandler variety of strawberry as reported previously (Kumar *et al;* 2012) [10].

A comparison of different levels of drip irrigation and furrow irrigation indicated highest yield per plant (238.1 g/plant and 240.4 g/plant) and per hectare (15.23 t/ha and 17.30 t/ha) with drip irrigation at 120% ETc, followed by drip irrigation at 100% ETc (228.2 g/plant and 235.5 g/plant) and (13.96 t/ha and 15.51 t/ha), which was significantly higher than plants irrigated with furrow irrigation and drip irrigation at 80 and 60% ETc. The plants irrigated at 120% ETc with drip method showed 29.77 and 16.72% increase in yield during 2010 and 2011 respectively over furrow irrigation method. Similarly, the plants irrigated at 100% ETc registered 26.93 and 14.98% increase in yield over furrow irrigation. The higher yield under drip irrigation at 120% and 100% ETc may be attributed to optimum soil moisture condition owing to frequent, precise and direct application of water in the root zone. The better size and weight of fruits under these irrigation treatments may also accounted for higher total yield in the present study. These results are in accordance with the findings of another author (Yuan *et al;* 2004) [16], who also recorded significant increase in fruit yield of strawberry under higher level of drip irrigation and they attributed it due to optimum soil moisture condition owing to frequent application of water. Similar, results of higher strawberry yield under drip irrigation is reported earlier (Kachwaya *et al*; 2016) [8]. Although in furrow irrigation with 'V' volume the same amount of irrigation water was applied as in case of drip irrigation at 100% ETc, but the yield per plant and total yield/ha was comparatively less. This may be attributed due to the fact that, furrow irrigation not only resulted in wastage of water in deep percolation below root zone, but also sets a chain of undesirable reaction such as leaching of available plant nutrients and poor aeration, consequently resulting in lesser fruit growth and yield.

The data presented in Table 1 indicates that drip irrigation significantly increased fruit size and weight as compared to furrow method of irrigation during both the years of study (Plate 1). The maximum fruit length (35.09 mm and 36.20 mm), breadth (26.51 mm and 27.22 mm) and fruit weight (12.15 g and 13.21 g) was observed in drip irrigation at 120% ETc treatment closely followed in drip irrigation at 100% ETc. These treatments were statistically at par with each other but significantly superior to drip irrigation at 60% ETc and furrow irrigation with respect to fruit size and weight during 2010 and 2011 respectively. The higher fruit size and weight under 120 and 100% ETc drip irrigation treatments may be attributed to optimum soil moisture content maintained by frequent irrigations and better nutrients availability during the entire growth period. These results are in line with the findings of another researcher (Yuan *et al;* 2004) [16], who found that the size and weight of strawberry fruit increased with the increase in amount of irrigation water from Ep 0.75 to Ep 1.25. Also a significant increase in strawberry fruit size and weight under drip irrigation with 'V' volume of water has been noticed previously (Sharma *et al*; 2005) [14]. The minimum fruit length (31.30 mm and 30.12 mm), breadth (21.78 mm and 20.12 mm) and fruit weight (9.65 g and 10.00 g) was observed in drip irrigation at 60% ETc treatment during 2010 and 2011 respectively. The fruit growth is directly related to the availability of soil moisture, therefore, due to low availability of soil moisture during entire growing season under 60% ETc drip irrigation the fruits failed to attain normal size and weight as reported in Hsiao (1973) [7]. These results are in conformity to the findings of another study (Kumar *et al;* 2012) [10], which recorded better fruit size and weight of strawberry at 1.0 IW/CPE ratio irrigation levels than at 0.6 IW/CPE ratio of irrigation.

The data presented in Table 2 indicates that drip irrigation significantly increased total soluble solids, total and reducing sugar as compared to furrow method of irrigation during both the years of study. The maximum TSS (8.40ºB and 8.64ºB), total sugar (6.79% and 6.82%) and reducing sugar (5.70% and 5.86%) was observed in drip irrigation at 120% ETc treatment during 2010 and 2011 respectively. The increase in TSS, total sugar and reducing sugar might be attributed to more synthesis of metabolites, degradation of carbohydrates and formation of more organic acid due to high soil moisture as reported in Nijjar and Chopra (1972)[11]. These results are in consonance with that obtained in a previous study (Kumar *et al;* 2012) [10], which reported that TSS and sugars in strawberry fruits increased in drip irrigation at 1.0 IW/CPE irrigation level.

However, in contrast, one previously conducted study reported increased TSS and sugars under water stress conditions (Terry *et al*; 2007) [15]. The minimum TSS (7.20ºB and 7.22ºB), total sugar (5.84% and 5.95%) and reducing sugar (4.11% and 4.24%) was observed in drip irrigation at 60% ETc treatment during 2010 and 2011 respectively. Lower TSS, total and reducing sugar in this treatment can be explained on the basis of decreased fruit size and consequently less synthesis of carbohydrates and other metabolites and their translocation to the fruit tissue. These findings are in agreement with Chauhan and Chandel (2010)[3], who reported that TSS and sugar content decreased under 0.6 'V' volume of water irrigation treatment as compared to 1.0 'V' volume of water level of irrigation in kiwifruit.

The result revealed that highest water use efficiency (0.67 t ha^{-1} and 0.95 t ha^{-1}) during 2010 and 2011, respectively was observed under treatment 60% ETc drip irrigation treatment. The minimum water use efficiency (0.48 t ha^{-1} and 0.63 t ha^{-1}) was recorded in furrow irrigation with 'V' volume of water treatment, during the year 2010 and 2011, respectively. These results are in line with the results of another study (Sharma *et al*; 2005) [14], which reported that drip irrigation registered much higher water use efficiency as compared to surface irrigation. Also, the drip irrigation registers much higher water use efficiency as compared to surface irrigation in strawberry (Kumar *et al*; 2012) [11].

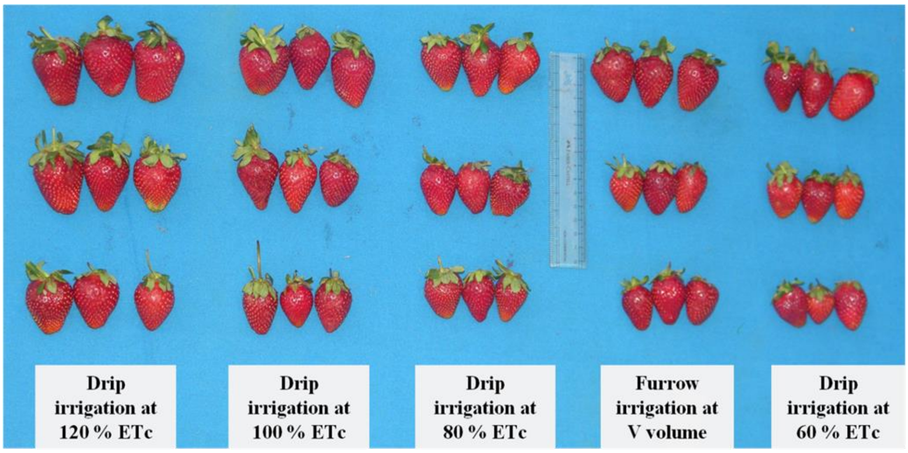

Plate 1. Effect of drip and furrow irrigation treatments on fruit size of strawberry

Table 1: Effect of drip and furrow irrigation treatments on vegetative growth, fruit yield, fruit size and weight of strawberry cv. Chandler

Treatments		Plant height (cm)		Number of leaves/plant		Leaf area (cm^2)		Number of runners /plant		Yield/plant (g)		Yield t/ha		Fruit length (mm)		Fruit breadth (mm)		Fruit weight (g)	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	(Drip irrigation at 120% ETc)	13.09	18.56	20.12	21.00	78.94	81.77	50.51	52.00	238.1	240.4	15.23	17.30	35.09	36.20	26.51	27.22	12.15	13.21
T_2	(Drip irrigation at 100% ETc)	13.06	18.24	19.60	20.00	76.34	80.15	48.08	51.00	228.2	235.5	13.96	15.51	34.20	35.46	25.23	26.24	11.86	12.98
T_3	(Drip irrigation at 80% ETc)	9.11	15.24	12.12	15.00	67.22	70.89	42.38	48.00	169.4	208.4	10.84	15.00	32.94	33.20	23.48	24.12	10.33	11.32
T_4	(Drip irrigation at 60% ETc)	7.12	13.62	10.08	12.00	52.19	54.96	36.78	39.40	140.8	180.8	09.01	13.01	31.30	30.12	21.78	20.12	9.65	10.00
T_5	(Furrow irrigation with 'V' volume of water)	10.96	15.22	12.14	14.00	73.30	75.83	47.60	46.60	167.2	200.2	10.70	14.41	32.00	32.76	22.94	23.12	10.58	11.00
$CD_{0.05}$		1.74	0.76	0.86	1.86	2.91	1.62	5.16	2.58	10.20	7.28	0.17	0.47	0.72	0.78	1.16	1.11	0.79	0.65

Table 2: Effect of drip and furrow irrigation treatments on TSS, total and reducing sugar, irrigation water requirement and water use efficiency (WUE) of strawberry cv. Chandler

Treatments		TSS (ºB)		Total sugar (%)		Reducing sugar (%)		Irrigation water applied (cm)		Effective rainfall (cm)		Water use efficiency (t ha^{-1} cm)	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	(Drip irrigation at 120% ETc)	8.40	8.64	6.79	6.82	5.70	5.86	26.71	27.37	24.04	17.97	0.57	0.64
T_2	(Drip irrigation at 100% ETc)	8.20	8.36	6.50	6.75	5.22	5.45	22.26	22.81	24.04	17.97	0.62	0.67
T_3	(Drip irrigation at 80% ETc)	7.72	7.92	6.19	6.45	5.04	5.10	17.80	18.24	28.79	20.58	0.60	0.82
T_4	(Drip irrigation at 60% ETc)	7.20	7.22	5.84	5.95	4.11	4.24	13.35	13.68	32.44	23.24	0.67	0.95
T_5	(Furrow irrigation with 'V' volume of water)	7.70	7.82	5.92	5.98	4.72	4.94	22.26	22.81	24.04	17.97	0.48	0.63
$CD_{0.05}$		0.44	0.35	0.24	0.27	0.02	0.19						

Conclusions
The drip irrigation (at 100% and 120% of ETc) significantly increased growth, yield and quality of strawberry fruits in comparison to furrow irrigation with 'V' volume of water. Further, the drip irrigation at 100% of ETc saved about 16% of irrigation water compared to 120% of ETc irrigation treatment. Moreover, on average, drip irrigation at 100% ETc confirmed about 17%, 23% and 23% increase in plant height, yield and water use efficiency compared to conventional furrow irrigation.

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