Vegetative Growth, Flowering and Fruiting Characteristics in Kiwifruit Cultivars as Influenced by Deficit Irrigation

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Abstract: ***The study was conducted on five cultivars of kiwifruit viz., Allison, Hayward, Abbott, Monty and Bruno to investigate their tolerance under water deficit conditions. Various growth and flowering characteristics were observed under two irrigation treatments, namely standard irrigation (irrigation at 80% FC) and deficit irrigation (irrigation at 60% FC). The cultivar Hayward had highest shoot growth, length of internodes, and leaf area under well irrigated condition. However, when the vines were subjected to DI regime, the reduction in shoot growth, length of internodes and leaf area and increase in leaf yellowing was recorded highest in cultivar Hayward and the least in cultivar Bruno. The DI increased the average leaf thickness in all the cultivars, which was however, noted higher in cultivar Bruno compared to all other cultivars and the least in cultivar Hayward. Furthermore, the DI caused significantly higher reduction in bloom intensity, fruit set, fruit retention and fruit yield in cultivar Hayward and the least in cultivar Bruno. The results of this study suggest cultivar Bruno had better tolerance of to water deficit condition, followed by cultivar Allison while the cultivar Hayward was the most sensitive to water stress.***

Keywords: Kiwifruit, deficit irrigation, shoot growth, leaf area, photosynthetic rate, transpiration rate, leaf yellowing

1. Introduction

Kiwifruit or Chinese gooseberry (*Actinidia deliciousa* Chev.) is a deciduous fruit vine, native to Yangtze valley of south and central China [1] bears pistillate and staminate flowers separately and requires 700-800 chilling hours below 7^{o}C and mild summer with temperature not exceeding 35^{o}C. Approximately, 84 per cent of the world production is contributed by China, Italy, New Zealand and Chile. In India, the area under this fruit is negligible, however, it can be successfully adapted in the mid hills of Himachal Pradesh, Uttarakhand, J &K, Sikkim, Meghalaya, Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura, Nilgiri Hills and Kerala. In Himachal Pradesh, the area under its cultivation is 117 ha with annual production of 555 metric tons [2].

One of the major bottlenecks in the kiwifruit production is high water requirement of its plants due to their vigorous vegetative growth, larger leaf size, vine habit and high humidity in their natural habitat. The water stress in kiwifruit vines decrease shoot growth, causes drooping leaves, browning of the leaves around the edges and complete defoliation with re-growth of new shoots when the stress is continuous [3]. Lack of water can also reduce the amount of blooms, reduce fruit size and cause early fruit drop.

2. Aim and Objectives

Screening of the water deficit tolerant cultivar (s) of kiwifruit for mid-hill conditions of HP. As in kiwifruit, the potential of cultivar(s) to adapt under water scarcity conditions is not much known and therefore, the cultivar(s) were evaluated for their suitability to water stress conditions.

3. Methodology

The experiment was conducted in the experimental orchard of the Department of Fruit Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the years 2011 and 2012. Twenty five-year-old uniform vines of kiwifruit cultivars Allison, Abbott, Monty, Hayward and Bruno planted at 6 x 4 m spacing and trained on T-bar system were selected for this experiment. Twenty vines comprising four plants of each cultivar were selected. Two irrigation treatments viz. irrigation at 80 per cent field capacity and at 60 per cent field capacity (DI) replicated four times were applied under Randomized Block Design (RBD), during the entire growing season. The scheduling of irrigation was done on the basis of soil moisture characteristics curve which was prepared by determining the soil moisture contents retained at different atmospheric pressure using Pressure Plate apparatus [4] by gravimetric method and was expressed on dry weight basis. This helped in calculating the quantity of water required to bring the moisture in soil at field capacity. The quantity of water applied was 198.1 and 396.1 litres at 80 and 60 per cent field capacity levels, respectively. Frequency of irrigation applied under different treatments was calculated by counting the number of days between two consecutive irrigations.

3.1 Soil Moisture Contents

The soil moisture data under irrigation at 80 and 60 per cent field capacity levels were recorded using Aqua Pro Soil Moisture Probe by lowering the probe at 30 and 60 cm depth down the access tubes installed in basins of each experimental vine. The readings were taken at fortnightly intervals during the growing season and average values were expressed in percentage.

3.2 Vegetative Growth

The shoot growth and length of internodes were measured with a measuring tape at the end of growing period. The leaf area was determined by using leaf area meter, Li- COR Model-3100. The leaf thickness was measured with the Digimatic Calliper (Mitutoyo, Japan) and the leaf yellowing was recorded by counting the number of leaves that turned yellow and the total number of leaves on the five selected fruiting arms of each vine and calculated as percentage of total leaves.

3.3 Flowering and Fruiting

The bloom intensity was calculated as number of flower per fruiting arm over cross sectional area of fruiting arm multiplied by hundred. The fruit set was calculated as number of fruit set on the fruiting arm over total number of flowers present on the fruiting arm multiplied by hundred. The per cent fruit retention was also calculated as number of fruits retained on the fruiting arm over total number of fruit set on the fruiting arm multiplied by hundred.

3.4 Fruit Yield

The total yield of kiwifruit under different treatments was determined on the basis of total weight of fruits harvested from the vine under each treatment and average yield per vine was calculated and was expressed in kilogram per vine. On the basis of weight, the fruits were classified into four grades viz; A (>70g), B (50-70g), C (<40-50g) and D(<40g) and the yield of different grades was expressed in percentage of the total yield.

3.5 Leaf Transpiration and Photosynthetic Rate

The transpiration rate and photosynthetic rate of kiwifruit leaves were recorded when the soil moisture content under respective treatments reached the required tension (i.e. 80% and 60% FC). Ten mature leaves from each experimental vine were selected randomly from all over the vine periphery. The observations were taken using LI-COR 6200 Portable Photosynthetic System during active growth periods between 9:00 to 11:00 AM.

4. Results and Discussion

During the study, the soil moisture contents were greatly affected by deficit irrigation treatment and soil depth (Figures 1, 2 & 3). The decrease level of soil moisture content under deficit irrigation regime in different fruit crops has also been documented earlier [5,6]. Average soil moisture content was lower at 60cm soil depth compared to 30cm depth irrespective of time, cultivars and irrigation treatments indicating greater root activity and moisture extraction or water losses due to leaching from the lower soil profile. In kiwifruit, distribution of root depends upon irrigation practice, and soil type, however, these tend to grow laterally and downward from the crown [7]. In general, the peak water use period (Tables 1, 2 & 3) coincided with active growth period of vines during summer months.

Table 1: Effect of different irrigation levels on shoot growth and length of internodes of kiwifruit cultivars

Cultivars	Shoot length (cm)		Length of internodes (cm)	
	SI	DI	SI	DI
Allison	290.8	282.3	8.37	8.22
Hayward	294.8	249.1	10.56	8.78
Abbott	287.8	273.3	7.73	7.5
Monty	275.5	264.5	6.76	6.59
Bruno	280.9	274.5	7.15	7.07
$CD_{0.05}$				
I	0.6		0.02	
C	1.0		0.04	
I x C	1.4		0.05	

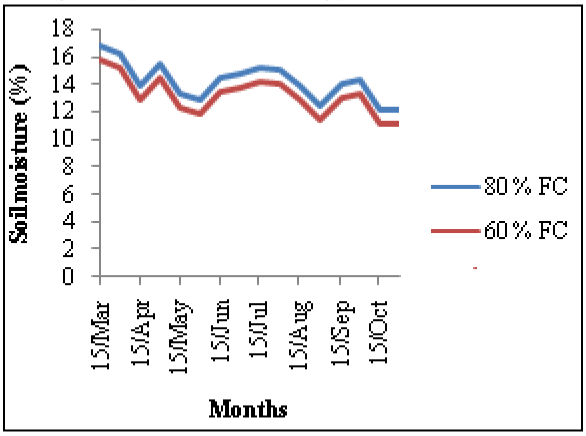

Figure 1 (a)

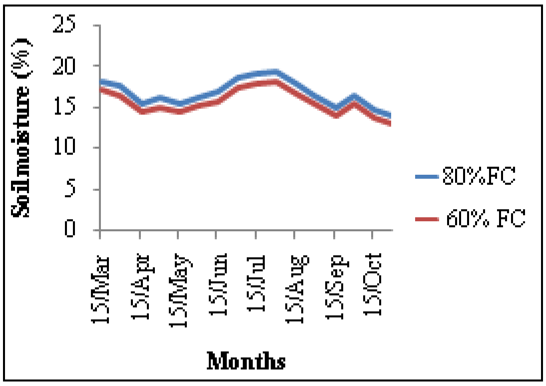

Figure 1 (b)

Figure 1 Average soil moisture content (%) of five cultivars of kiwifruit under two irrigation levels at 30 cm soil depth (a) and at 60 cm soil depth (b) during the year 2011

However, increased irrigation intervals under the both irrigation regime irrespective of cultivar in the month of August clearly indicate low consumption of soil moisture during this period. In the study, the per cent reduction in soil moisture content due to deficit irrigation was found to be higher under "Hayward" and lower under "Bruno" cultivar (Fig. 3). The greater depletion in soil moisture content under "Hayward" can be attributed to higher leaf transpiration rate (Table 4) in this cultivar. The differences in soil moisture contents under different cultivars however, did not affect the number of irrigations applied, which remained constant among the cultivars under the respective irrigation regime, during both the years. The reduction in transpiration and photosynthetic rate was observed under DI treatment among all five cultivars, the reduction in transpiration rate was highest in cultivar "Bruno" and the least in "Hayward" whereas the reduction in photosynthetic rate was found to be highest in "Hayward" and the least in "Bruno"(Figure 3).

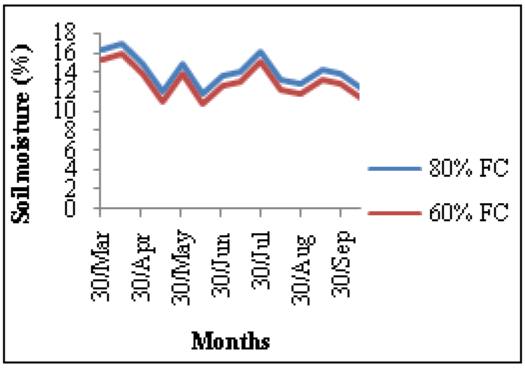

Figure 2 (a)

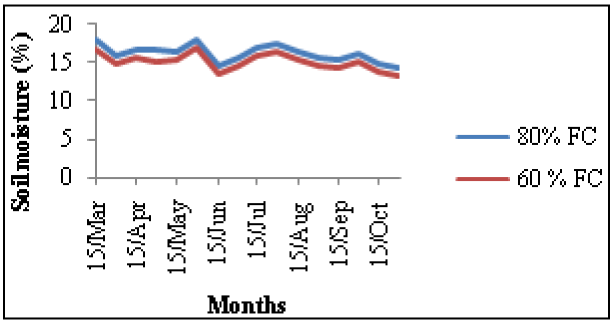

Figure 2 (b)

Figure 2 Average soil moisture content (%) of five cultivars of kiwifruit under two irrigation levels at 30 cm soil depth (a) and at 60 cm soil depth (b) during the year 2012

In the study, the shoot length, length of internodes and leaf area decreased significantly in vines subjected to DI regime (Figure 4 a) whereas, the leaf thickness and leaf yellowing were increased significantly with DI treatment over the well irrigated control (Table 2 & Figure 4 b). The

Table 2: Effect of different irrigation levels on leaf area, leaf thickness and leaf yellowing of kiwifruit cultivars

Cultivars	Leaf area (cm^2)		Leaf thickness (mm)		Leaf yellowing (%)	
	SI	DI	SI	DI	SI	DI
Allison	156.9	153.8	0.413	0.422	22.8	33.5
Hayward	158.0	156.1	0.415	0.416	29.1	44.3
Abbott	156.7	154.3	0.437	0.442	12.8	19.8
Monty	154.2	151.6	0.445	0.451	16.5	23.5
Bruno	157.1	153.2	0.397	0.418	20.9	28.1
$CD_{0.05}$						
I	0.1		0.003		0.4	
C	0.1		0.004		0.6	
I x C	0.2		0.006		0.8	

Plant growth performance is limited by availability of soil water and photosynthetic carbon products [8]. Under the water stress, cell expansion slows down or ceases, and plant growth is retarded [9].

During the present study, the bloom intensity, fruit set and fruit retention decreased under deficit irrigation in all the cultivars; however the reduction in these parameters were more marked in cultivar Hayward and the least in cultivar Bruno (Table 3 & Figure 5). Similar results were also reported by Lamp *et al.* [10] and Shubiao *et al.* [11], who reported the reduction in bloom intensity due to water stress in almond and olive, respectively and Liu *et al.* [12] observed decreased fruit set in Macadamia under deficit irrigation regime. Suitable environment during the period of

Table 3: Effect of different irrigation levels on bloom intensity, fruit set and fruit retention of kiwifruit cultivars

Cultivars	Bloom intensity (%)		Fruit set (%)		Fruit retention (%)	
	SI	DI	SI	DI	SI	DI
Allison	0.65	0.63	86.1	80.4	84.9	72.5
Hayward	0.61	0.57	85.2	72.6	80.8	54.3
Abbott	0.64	0.61	85.6	77.2	79.4	56.6
Monty	0.66	0.65	85.0	77.7	77.1	59.3
Bruno	0.68	0.66	85.3	81.1	75.0	67.0
$CD_{0.05}$						
I	0.01		0.1		0.1	
C	0.01		0.2		0.2	
I x C	0.01		0.3		0.3	

Table 4: Effect of different irrigation levels on total and A and B grade fruit yield of kiwifruit cultivars

Cultivars	Total yield (Kg/vine)		"A" Grade fruit yield (%)		"B" Grade fruit yield (%)	
	SI	DI	SI	DI	SI	DI
Allison	66.5	62.7	27.3	22.0	37.5	32.7
Hayward	49.0	36.9	61.2	44.4	10.3	4.3
Abbott	61.5	50.9	34.3	26.4	32.2	24.5
Monty	43.5	38.4	23.0	18.3	27.4	20.9
Bruno	64.5	63.4	57.1	55.1	29.1	28.4
$CD_{0.05}$						
I	0.3		0.2		0.2	
C	0.5		0.4		0.3	
I x C	0.8		0.5		0.5	

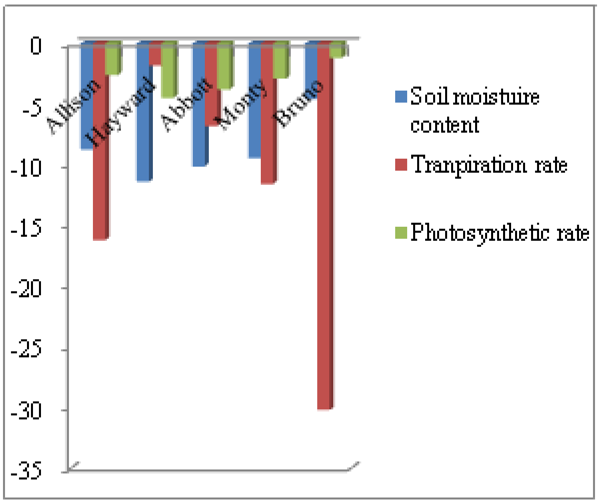

Figure 3 Per cent reduction in soil moisture content, transpiration rate and photosynthetic rate of different cultivars of kiwifruit at irrigation at 60 per cent FC over 80 per cent FC

flower bud development, depending upon the genetic makeup of a species or cultivar might provide favourable hormonal balance to promote flowering, qualitatively and quantitatively [13]. The reduced net assimilation of the leaf under drought stress condition is considered as main cause of reduced return bloom in olive trees [14]. Carbohydrate supply and water stress during critical period of fruitlet development may be a limiting factor in fruit [15]. Sahu *et al.* [16] reported that in pomegranate cultivar Kandhari grown under rainfed conditions of H. P. the higher soil moisture content conserved through a soil working technique i.e. crescent bund with open catchments pits, resulted in higher physiological characteristics such as photosynthetic rate and transpiration rate and ultimately improved fruit growth and production over untreated control.

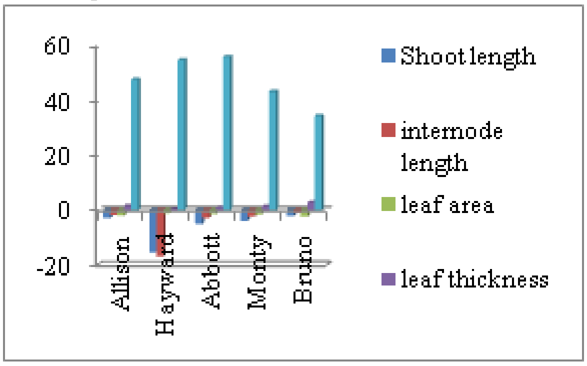

Figure 4 (a) Per cent reduction in shoot length, internode length, leaf area and (b) per cent increase in leaf thickness and leaf yellowing of different cultivars of kiwifruit at irrigation at 60 per cent FC over 80 per cent FC

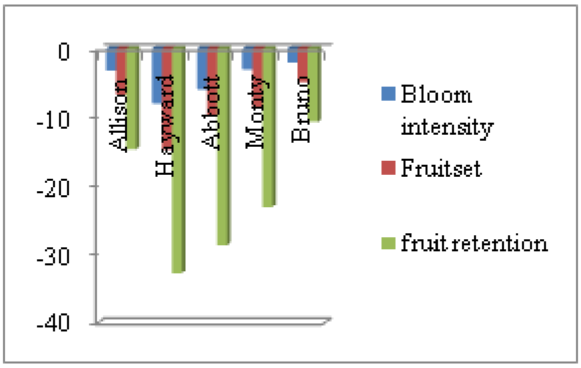

Figure 5 Per cent reduction in bloom intensity, fruit set and fruit retention of different cultivars of kiwifruit at irrigation at 60 per cent FC over 80 per cent FC

Reduced bloom intensity, fruit set and fruit retention under DI may be due to decreased photosynthesis (Table 6), hormonal metabolism, particularly increased ABA level [17]. in this study. In the present study, the fruit yield was higher in cultivars Allison and Bruno and lower in cultivar Hayward under standard irrigation regime. Under deficit irrigation, the

Table 5: Effect of different irrigation levels on C and D grade fruit yield of kiwifruit cultivars

Cultivars	"C" Grade fruit yield (%)		"D" Grade fruit yield (%)	
	SI	DI	SI	DI
Allison	25.8	29.0	9.5	16.4
Hayward	17.3	30.9	11.3	20.6
Abbott	23.4	30.9	10.2	18.3
Monty	42.8	48.8	6.9	12.1
Bruno	9.1	9.9	4.7	6.7
$CD_{0.05}$				
I	0.1		0.1	
C	0.2		0.2	
I x C	0.3		0.3	

fruit yield declined invariably in all the cultivars, however, sharper decline in fruit yield was found in cultivars Hayward and Abbott, however cultivar Bruno recorded marginal reduction in fruit yield. The higher total fruit yield (Figure 6 a) in cultivars "Allison" and "Bruno" under standard irrigation regime can be attributed to higher bloom intensity and fruit set (Table 3). The proportionate yield of "A", "B" and "C" grade fruits were higher in well irrigated vines

Table 6: Effect of different irrigation levels on transpiration rate and photosynthetic rate in leaves of kiwifruit cultivars

Cultivars	Transpiration rate		Photosynthetic rate	
	SI	DI	SI	DI
Allison	9.8	8.2	19.08	18.59
Hayward	11.1	10.8	16.01	15.30
Abbott	10.4	9.7	16.18	15.56
Monty	10.3	9.1	18.04	17.52
Bruno	6.4	4.4	19.80	19.56
$CD_{0.05}$				
I	0.1		0.02	
C	0.1		0.03	
I x C	0.1		0.04	

irrespective of cultivars, however, cultivars Hayward, Allison and Monty were superior in these production parameters (Table 6 b). In this study, the DI treatment

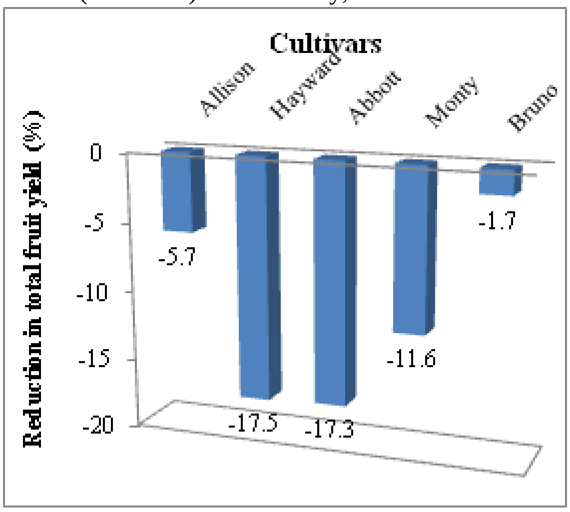

Figure 6 (a) Per cent reduction in total fruit yield of different cultivars of kiwifruit at irrigation at 60 per cent FC over 80 per cent FC

Significantly decreased the yield under "A" "B" grade and increased the fruit yield under "C" and "D" grade (Figure 6 b) in all the cultivars, but to a greater extend in cultivar Hayward. The fruit yield reduction in "Hayward" under DI regime can be attributed to higher decrease in bloom intensity, fruit set and fruit retention (Figure 5).

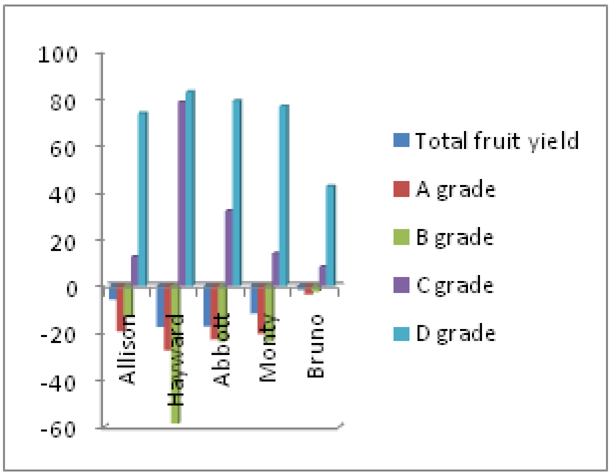

Figure 6 (b) Per cent reduction in total fruit yield, A and B grade fruit yield and per cent increase in C and D grade fruit yield of different cultivars of kiwifruit at irrigation at 60 per cent FC over 80 per cent FC

Similar decline in fruit yield due to water stress were reported by Chaves *et al.* [18] and Klamkowski and Treder [19] in grapes and strawberry, respectively.

5. Conclusion

Based on these results, it may be inferred that the cultivar Bruno exhibited less reduction shoot length and internode length, leaf area, flowering, fruit set and fruit yield and less increase in leaf yellowing, C and D grade fruit yield and more leaf thickness under deficit irrigation treatment and therefore can tolerate water stress better than other cultivars under study.

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