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Effect of Deficit Irrigation on Canopy Temperature and Water Relations of Various Kiwifruit Cultivars

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ABSTRACT: The five Kiwifruit cultivars viz. Allison, Hayward, Abbott, Monty and Bruno were investigated for their tolerance to water stress condition. These cultivars were subjected to two irrigation levels standard irrigation (at 80 % Field Capacity) and deficit irrigation (at 60 % Field Capacity). The comparative study of canopy temperature and water relations of these cultivars was conducted. The deficit irrigation resulted in increase in canopy temperature and stomatal resistance; reduction in leaf water potential, transpiration rate, leaf photosynthetic rate and chlorophyll contents of different cultivars. The Hayward cultivar was proved to be more sensitive to deficit irrigation levels in terms of canopy temperature, leaf water potential, stomatal resistance, transpiration rate, photosynthetic rate and chlorophyll content whereas the cultivar Bruno proved to be least sensitive.

Keywords: Kiwifruit; deficit irrigation; water stress; canopy temperature; chlorophyll content.

INTRODUCTION: The Kiwifruit (*Actinidia deliciosa*) is a dioecious fruit vine, native to Yangtze valley of south and central China (Ferguson, 1984). Kiwifruit 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. Kiwifruit has an excellent table and keeping quality and acclaimed for its nutritive and medicinal values. Approximately, 84 per cent of Kiwifruit production is contributed by China, Italy, New Zealand and Chile. In India, the area under cultivation for this fruit is negligible, however, it can be successfully grown in areas situated at elevation of 900-1800 m above mean sea level where, the winters are cold and summers are warm and humid and receive well distributed annual rainfall of about 150 cm. A deep friable well drained sandy loam to clay soil coupled with assured irrigation is one of the ideal conditions for growing Kiwifruit. The water requirement of Kiwifruit plants is high due to their vigorous vegetative growth, larger leaf size, vine habit and high humidity in their natural habitat. Kiwifruit vines are prone to water stress mainly because of their very large leaves and very high rate of water conductivity and transpiration rate. Kiwifruit vines probably die more often from some type of water stress than any other problems. In Himachal Pradesh, however, Kiwifruit cultivation has extended to those areas where, demand for water exceeds that of local resources. The problem of water limitation may prove to be a more critical constraint to temperate fruit productivity in future due to global environmental change. However, some plants may adapt to changing environment more easily than others.

Plant responses to water scarcity are complex, involving adaptive changes and/ or deleterious effects. Plant strategies to cope with drought normally involve a mixture of stress avoidance and tolerance 'strategies' that vary with genotype. In Kiwifruit, the potential of cultivar (s) to adapt under water scarcity conditions is not much known therefore, to know the adaptation of cultivars for water stress, this evaluation was done.

MATERIALS AND METHODS: The experiment was conducted at the Department of Fruit Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (H P) during the year 2011 and 2012. The experimental area falls under sub- temperate subhumid climate. The summers are moderately hot during May-June and winters are severe during December-January. Twenty five year old uniform vines of five different Kiwifruit cultivars viz., Allison, Hayward, Abbott, Monty and Bruno were selected for experiment. These vines were planted at 6 x 4 m spacing and trained on T-bar system. Irrigation was given at two different levels of Field Capacity (FC) i.e. irrigation at 80 per cent FC (standard irrigation) and irrigation at 60 per cent FC (deficit irrigation).

The average canopy temperature of Kiwifruit vines under different irrigation treatments, was recorded with Infra red thermometer from all the four sides of vine canopy from a distance of five meter during the months of May to August during 2011 and 2012. The temperature was recorded at 12:00 AM during the months of May to August. at weekly intervals. The average values were expressed in degree Celsius. Leaf water potential was observed in portable 'Plant Water Status Console' during May and June. Water potential readings were recorded between 10:00 AM to 12:00

AM by placing freshly detached leaf in pressure chamber. Stomatal resistance, transpiration and photosynthetic rate were recorded when soil moisture content under the respective treatments reached the required tension (i.e 80 % FC and 60% FC). Ten mature leaves from each experimental vine were selected randomly from all over the tree periphery. The observations during active growth periods between 9:00 to 11:00 AM with the help of Li- COR 6200 Portable Photosynthesis System. The results were expressed in s cm^{-1}, m $mol/m^2/S$ and μ $mol/m^2/S$ for stomatal, resistance, transpiration and photosynthetic rate, respectively. The chlorophyll content was recorded by taking ten fully grown leaves in morning hours from the current season's growth of each vine during first week of August. The leaves were collected and immediately placed in ice box and then brought to the laboratory. The samples were then kept in the refrigerator below 0^oC to avoid degradation of chlorophyll pigments. For chlorophyll extraction the leaves were washed and chopped into fine pieces and 100 mg of chopped material was placed in vial containing 7 ml of dimethyl sulphoxide (DMSO). The contents of the vial were incubated at 65^oC temperature for 30 minutes and then extract was transferred to graduated test tube and final volume was made to 10 ml with dimethyl sulphoxide. The optical density (OD) of the prepared extract was recorded on Spectronic -20 D at 645 and 663 nm wave length against a DMSO blank and total chlorophyll content was calculated by using the following formula:

$$\text{Total Chlorophyll} = \frac{20.2\ A_{645} + 8.02\ A_{663} \times V}{A \times 1000 \times W}$$

Where,
V= Volume of extract used
A= Length of light path in cell (1cm)
W= Weight of the sample (g)
A_{645}= Absorbance at 645 nm wavelength
A_{663}= Absorbance at 663 nm wavelength
The results were expressed as chlorophyll content in mg/g of fresh weight.

RESULTS AND DISCUSSION: The canopy temperature increased with the deficit irrigation treatment during both the years of study. During the year 2011, the average canopy temperature of different cultivars significantly increased from 27.6 ^OC under irrigation at 80 per cent of field capacity to 29.3 ^OC under irrigation at 60 per cent of field capacity. In the year 2012, the average canopy temperature increased from 27.5 ^OC in control to 29.5 ^OC under deficit irrigation treatment (Table 1). The cultivars also showed significant variations in canopy temperature under two different water regimes during both the years of study. The canopy temperature was observed significantly lowest in cultivar Bruno (27.7 ^OC and 27.6 ^OC during 2011 and 2012, respectively) followed by Allison. The data depicted in Figure 1 showed that, the per cent increase in canopy temperature due to deficit irrigation was highest in cultivar Hayward (8.63 %), and lowest in cultivar Bruno (5.58 %) followed by Allison (5.80 %). Canopy temperature may be affected by genetic makeup of the species or variety, transpiration rate and internal water regime. Transpiration has a cooling effect on leaf surface as it releases radiant energy (Jones, 1992) and therefore the increased canopy temperature under water stress conditions may be attributed to lower transpiration rate, in this study. Water stress caused a decrease in transpiration, an increase in foliage temperature and closure of stomata (Tan and Buttery, 1982). Lakso (1990) suggested that the large round leaves of Kiwifruit do not exchange heat efficiently with the bulk air unless there is significant air movement and are likely to have significant temperature increases under reduced stomatal conductance (g_s). The relationships between canopy temperature, air temperature and transpiration is not simple, involving atmospheric conditions (vapor pressure deficit, air temperature and wind velocity), soil (mainly available soil moisture) and plant (canopy size, canopy architecture and leaf adjustments to water deficit). However, relatively lower canopy temperature in cultivars Allison, Abbott and Bruno under water stress condition may indicates a relatively better capacity for taking up soil moisture and for maintaining a relatively better plant water status by various plant adaptive traits (Blum, 2009).

The leaf water potential decreased significantly when Kiwifruit vines were subjected to water deficit condition during both the year (Table 1). The cultivars also showed significant variations in leaf water potential under two water regimes during both the years of study. The leaf water potential was found to be the least negative in cultivar Abbott and more negative in cultivar Hayward under well irrigated condition. The per cent reduction in leaf water potential was observed higher in cultivar Hayward and lower in cultivars Allison and Bruno (Table 1). The per cent reduction in the leaf water potential by deficit irrigation treatment (Figure 2) was more pronounced in cultivar Hayward (15.61 % reduction), while the reduction in leaf water potential by applying lesser than normal irrigation was the least in cultivar Bruno (1.75 %). The present findings that water stress lead to decline in leaf water potential are in accordance with those of Satisha *et al.* (2007) in grape rootstocks, Boughalleb and Hajlaoui (2011) in olives and Medeiros *et al*. (2014) in Barbados cherries. In "Bruno" and "Allison" Kiwifruit vines, the lesser decline in water potential and consequently maintenance of higher internal water status under deficit irrigation indicated that these cultivars were more capable of performing better at the advent of water stress (Thakur, 2004). These findings clearly demonstrated that the leaf water potential may be used as a strong indicator of drought tolerance because of its high sensitivity to irrigation regimes.

The stomatal resistance and transpiration rate were noted higher in cultivars Allison and Hayward, respectively, whereas the cultivar Bruno recorded lowest stomatal resistance and transpiration rate, in well irrigated vines (Table 1 & 2). The deficit irrigation however, increased stomatal resistance, and decreased the transpiration rate. It was observed that the extent of increase in stomatal resistance under water stress was highest in cultivar Bruno and lowest in "Hayward" (Figure 3). Conversely, the per cent decrease in the transpiration due to water stress was lowest in "Hayward" and highest in "Bruno" cultivar (Figure 4). In general, the vine of Allison cultivar recorded lower transpiration rates at higher value of stomatal resistance. Leaf stomatal resistance and transpiration varied with genotype (Escalona, *et al.,* 2003), which may also be related with differences in anatomical characters of leaves and water conducting tissues. In this study, higher increase in stomatal resistance and decrease in transpiration rate in cultivar Bruno under water stress can be attributed to higher decrease in stomatal width and xylem vessel development in this cultivar. Buwalda and Smith (1990) observed that Kiwifruit cultivar Hayward had higher transpiration rate with poor stomatal control. Reynolds and Naylor (1994) and Ghaderi *et al*. (2007) also observed that the drought tolerant grape cultivar maintained lower transpiration rate under water deficit conditions. These findings in terms of decline in transpiration rate due to deficit irrigation are in line with the findings of Xiloyannis (1988), who reported sudden drop in transpiration rate at 50 per cent of available soil water in Kiwifruit. The photosynthetic rate and chlorophyll contents varied significantly among the different cultivars under well irrigated conditions (Table 2). During the course of study, these parameters were significantly reduced by inducing water stress, however, the cultivars Hayward and Abbott registered higher per cent decrease and cultivars Bruno and Allison recorded lower decrease in these attributes (Figures 5 & 6). The reduction in photosynthetic rate in response to water stress may be due to reduction in diffusion of CO_2 to the chloroplast, both by stomatal closure and changes in mesophyll structure, which decreases the conductance to CO_2 diffusion within the leaf as suggested by Ennajeh *et al*. (2010). The leaf chlorophyll content has been suggested important for leaf colour development as well as for better performance of leaf under drought stress condition (Sanchez, 2001).

The reduction in chlorophyll content is a typical symptom of oxidative stress and may be the result of chlorophyll degradation or due to deficiency in chlorophyll synthesis together with changes of thylakoid membrane structure (Smirnoff, 1993). The higher reduction in leaf chlorophyll content of cultivars Hayward under deficit irrigation, reflect its sensitivity to drought stress (Kadam *et al*., 2005; Romero *et al.*, 2010; Miraghaee *et al.,* 2012). The vines of cultivars Bruno and Allison under water stress exhibited higher rate of photosynthetic activities than other cultivars probably because of higher relative water content and more efficient in terms of long-distance water transport (Teulat *et al*., 1997) and smaller diurnal variation in leaf water potential. Therefore cultivars Bruno and Allison can be rated as water stress tolerant based on maintaining better photosynthetic rate in under deficit irrigation (Chartzoulakis *et al*., 2002; De Herralde *et al*., 2003; Ennajeh *et al*., 2010). Liu *et al*. (2012) also considered the rootstocks viz., *Malus. sieversii, M. prunifolia* and *M. toringoides* of apple cv. Gale Gala as more drought tolerant due to smaller decline in relative water content, chlorophyll content and photosynthetic rate.

On the basis of these results, it may be concluded that in response to deficit irrigation the cultivar Bruno exhibited least increase in canopy temperature but highest percentage increase in stomatal resistance whereas the reverse was observed in cultivar Hayward. The percentage reduction in leaf water potential, photosynthetic rate and chlorophyll content was least in Bruno whereas the per cent reduction in transpiration rate was highest in Bruno and the least in Hay ward under deficit irrigation treatment and therefore, the Bruno cultivar has better tolerance to water stress as compared to other cultivars under this study.

Table 1: Effect of different irrigation levels on canopy temperature, leaf water potential and stomatal resistance of Kiwifruit cultivars during the year 2011 and 2012

Cultivars	2011						2012					
	Canopy Temperature (°C)		Stomatal resistance (S cm^{-1})		Leaf water potential (-bars)		Canopy Temperature (°C)		Stomatal resistance (S cm^{-1})		Leaf water potential (-bars)	
	SI	DI	SI	DI	SI	DI	SI	DI	SI	DI	SI	DI
Allison	27.6	29.1	4.24	4.37	8.70	8.84	27.5	29.2	4.26	4.38	8.67	8.86
Hayward	27.8	30.0	4.00	4.05	10.20	12.39	27.7	30.3	4.02	4.06	10.73	12.41
Abbott	27.7	29.5	4.04	4.10	7.82	8.12	27.6	29.6	4.06	4.12	7.88	8.14
Monty	28.0	29.6	4.10	4.18	9.14	9.32	27.8	29.8	4.12	4.19	9.13	9.34
Bruno	27.0	28.3	3.88	4.10	9.57	9.73	26.8	28.4	3.86	4.13	9.58	9.76
$CD_{0.05}$												
I	0.1		0.02		0.01		0.1		0.01		0.10	
C	0.2		0.03		0.02		0.1		0.01		0.15	
I x C	0.3		0.04		0.03		0.1		0.02		0.22	

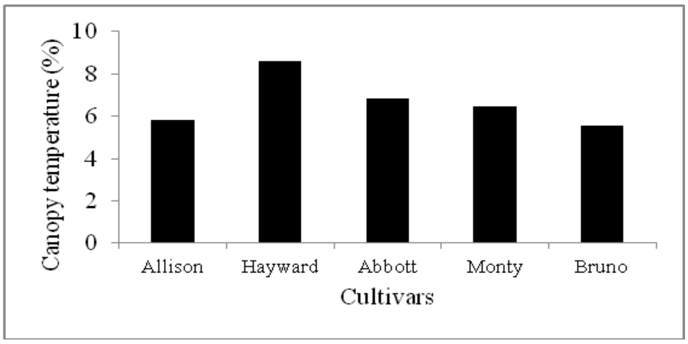

Figure 1: Percent increase in canopy temperature of different cultivars of Kiwifruit at irrigation at 60 percent FC over 80 percent FC

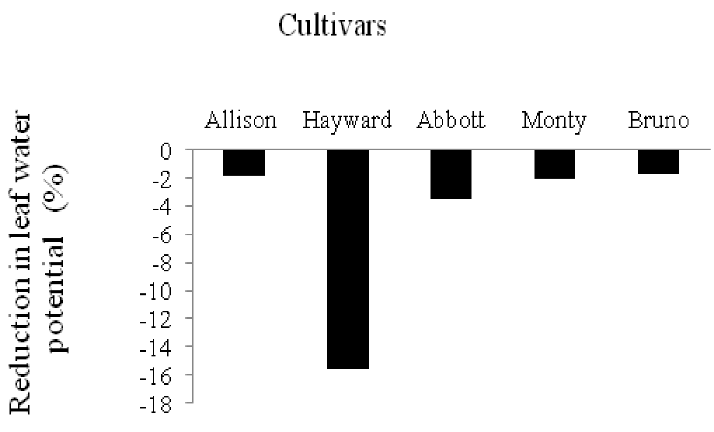

Figure 2: Percent reduction in leaf water potential of different cultivars of Kiwifruit at irrigation at 60 percent FC over 80 percent FC

Table 2: Effect of different irrigation levels on transpiration rate, photosynthetic rate and chlorophyll content in leaves of Kiwifruit cultivars during the year 2011

Cultivars	2011						2012					
	Transpiration rate (m mol $m^{-2}s^{-1}$)		Photosynthet-ic rate (µmol $m^{-2}s^{-1}$)		Chlorophyll content (mg/g)		Transpiration rate (m mol $m^{-2}s^{-1}$)		Photosynthetic rate (µmol $m^{-2}s^{-1}$)		Chlorophyll content (mg/g)	
	SI	DI	SI	DI	SI	DI	SI	DI	SI	DI	SI	DI
Allison	9.8	8.2	19.06	18.59	3.14	2.60	9.8	8.2	19.10	18.58	3.12	2.58
Hayward	11.1	10.8	16.00	15.31	3.07	2.10	11.1	10.9	16.02	15.28	3.06	2.11
Abbott	10.4	9.6	16.17	15.57	3.08	2.15	10.5	9.8	16.18	15.55	3.07	2.14
Monty	10.2	9.0	18.02	17.52	3.09	2.44	10.3	9.1	18.05	17.51	3.08	2.42
Bruno	6.4	4.4	19.98	19.62	3.06	2.59	6.4	4.5	19.61	19.50	3.04	2.57
$CD_{0.05}$												
I	0.1		0.03		0.04		0.1		0.02		0.01	
C	0.1		0.05		0.06		0.1		0.03		0.01	
I x C	0.1		0.07		0.09		0.1		0.04		0.02	

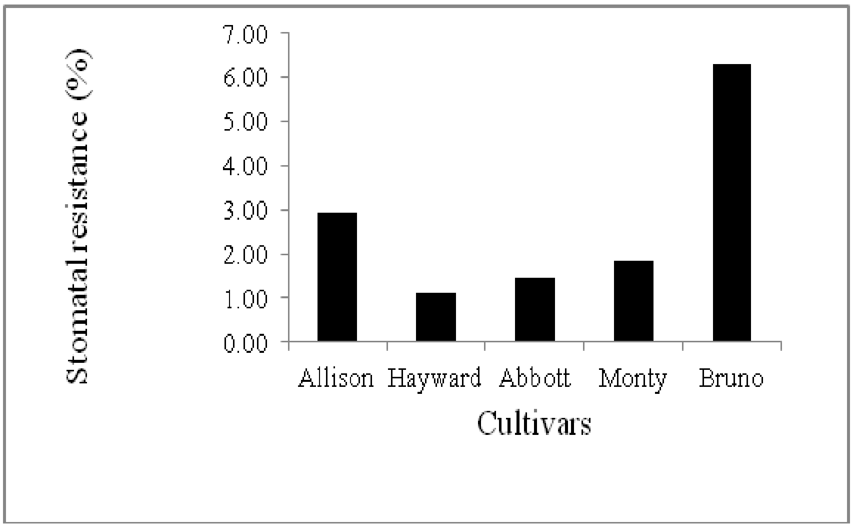

Figure 3: Percent increase in stomatal resistance of different cultivars of Kiwifruit at irrigation at 60 per-cent FC over 80 per cent FC

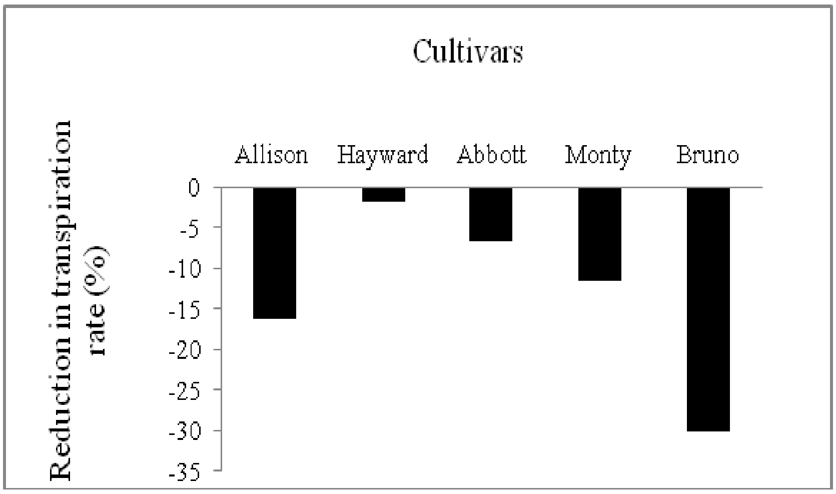

Figure 4: Percent reduction in transpiration rate of exposed leaves of different cultivars of Kiwifruit at irrigation at 60 percent FC over 80 per cent FC

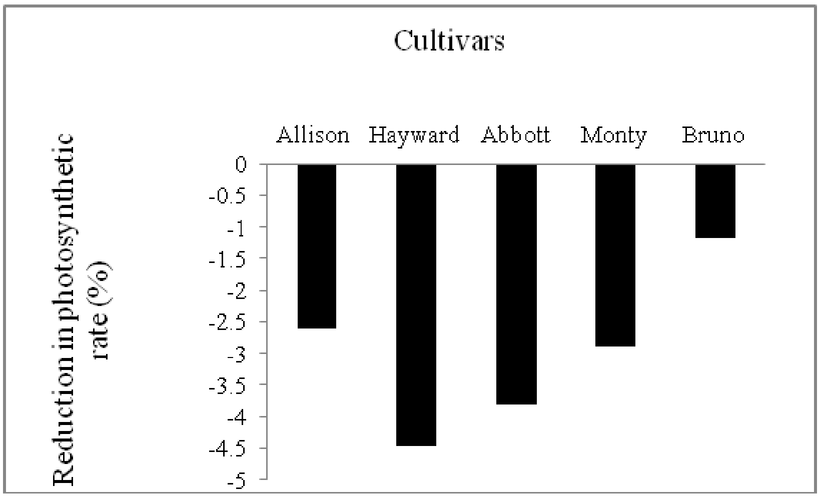

Figure 5: Percent reduction in photosynthetic rate of exposed leaves of different cultivars of Kiwifruit at irrigation at 60 percent FC over 80 per cent

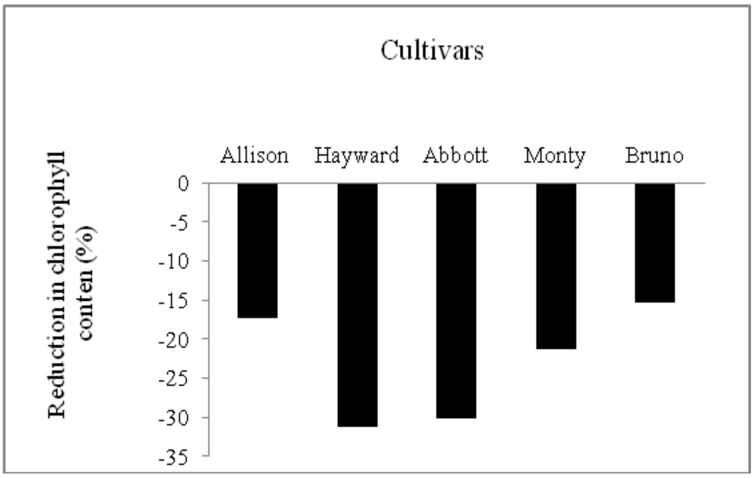

Figure 6: Percent reduction in chlorophyll content of different cultivars of Kiwifruit at irrigation at 60 percent FC over 80 per cent FC

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