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Response of kiwifruit cultivars to deficit irrigation in terms of canopy temperature and water relations

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ABSTRACT

The present investigation was conducted with the comparative study of response of five kiwifruit cultivars, *viz*., Allison, Hayward, Abbott, Monty and Bruno to deficit irrigation. This experiment was carried out during 2011 and 2012 at Nauni, Solan (HP). These five cultivars were subjected to two irrigation levels, *i.e.*, standard irrigation (at 80% Field capacity) and deficit irrigation (at 60% Field capacity). The canopy temperature and stomatal resistance in leaves of kiwifruit cultivars were increased due to deficit irrigation treatment, whereas, the leaf water potential, chlorophyll content, transpiration rate and photosynthetic rate were decreased. The Hayward cultivar was proved to be more sensitive to deficit irrigation levels in terms of canopy temperature, leaf water potential, chlorophyll content, stomatal resistance, transpiration and photosynthetic rates, whereas the cultivar Bruno was proved to be least sensitive.

Key words: Kiwifruit, irrigation, water relation, canopy temperature, chlorophyll, photosynthetic rate.

INTRODUCTION

The kiwifruit (*Actinidia deliciosa*) is a large, woody, deciduous vine native to the Yangtze valley of south and central China. Kiwifruit bears pistillate and staminate flowers separately and requires 700-800 chilling hours below 7°C and mild summer with temperature not exceeding 35°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 this fruit is negligible, however, it can be successfully adapted 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 study was undertaken.

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 2011 and 2012. The experimental area falls under sub-temperate sub-humid climate. The summers are moderately hot during May-June and winters are severe during Dec-Jan. 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 × 4 m 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). These treatments were applied from March to October with four replications and each replication with one kiwifruit vine. The experiment was laid in randomized block design (RBD).

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The average canopy temperature of kiwifruit vines under different irrigation treatments, recorded with Infra red thermometer from all the four sides of vine canopy from a distance of five metre from the month of May to August during 2011 and 2012. The temperature was recorded at 12:00 noon from the month of May to Aug. 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 noon by placing freshly detached leaf in pressure chamber. 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°C to avoid degradation of chlorophyll pigments. Chlorophyll was estimated as per method of Hiscox and Israelstam (6). 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 A M with the help of Li-COR 6200 portable photosynthesis system. The results were expressed in S cm^{-1}, m mol/m^2/s and µmol/m^2/s for stomatal, resistance, transpiration and photosynthetic rates, respectively.

RESULTS AND DISCUSSION

The canopy temperature increased with the deficit irrigation treatment during both the years of study. During the year 2011-12 (pooled), the average canopy temperature of different cultivars significantly increased from 27.6°C under irrigation at 80 per cent of field capacity to 29.4°C under irrigation at 60 per cent of field capacity (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 (26.9°C) followed by Allison (27.6°C). The data depicted in Fig. 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. Water stress caused a decrease in transpiration, an increase in foliage temperature and closure of stomata (Tan and Buttery, 14). Lakso (8) 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 (vapour pressure deficit, air temperature and wind velocity), soil (mainly available soil moisture) and plant (canopy size, canopy architecture and leaf adjustment to water deficit). However, relatively lower canopy temperature in cultivars Allison, Abbott and Bruno under water stress condition may indicate relatively better capacity for taking up soil moisture and for maintaining a relatively better plant water status by various plant adaptive traits (Blum, 1).

Table 1. Effect of different irrigation levels on canopy temperature, leaf water potential and chlorophyll content in leaves of kiwifruit cultivars.

Cultivar	Pooled (2011-12)					
	Canopy Temperature (°C)		Leaf water potential (-bars)		Chlorophyll content (mg/ FW)	
	SI	DI	SI	DI	SI	DI
Allison	27.6	29.2	8.69	8.85	3.13	2.59
Hayward	27.8	30.2	10.47	12.40	3.07	2.11
Abbott	27.7	29.6	7.85	8.13	3.08	2.15
Monty	27.9	29.7	9.14	9.33	3.09	2.43
Bruno	26.9	28.4	9.58	9.75	3.05	2.58
Mean	27.6	29.4	9.14	9.69	3.08	2.37
$CD_{0.05}$						
I	0.1		0.05		0.02	
C	0.1		0.08		0.03	
I × C	0.2		0.11		0.05	

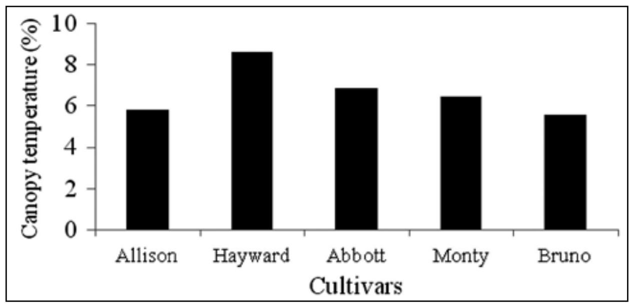

Fig. 1. Per cent increase in canopy temperature of different kiwifruit cultivars at irrigation at 60 per cent FC over 80 per cent FC.

The leaf water potential decreased significantly when kiwifruit vines were subjected to water deficit condition. The leaf water potential was found to be the least negative in cv. Abbott and more negative in cv. Hayward under well irrigated conditions (Table 1). The per cent reduction in the leaf water potential by deficit irrigation treatment (Fig. 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.* (13) in grape rootstocks. 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, 15). 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 leaf chlorophyll content has been suggested important for leaf colour development as well as for better performance of leaf under drought stress condition (Sanchez, 12). The chlorophyll content in leaves of kiwifruit vines varied significantly among the different cultivars under well irrigated conditions (Table 1). 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. The higher reduction in leaf chlorophyll content of cultivar Hayward under deficit irrigation (Fig. 3), reflect its sensitivity to drought stress (Kadam *et al.*, 7; Romero *et al.*, 11; Miraghaee *et al.,* 10).

The stomatal resistance and transpiration rate were noted higher in cultivars Allison and Hayward, respectively, whereas Bruno recorded lowest stomatal resistance and transpiration rate, in well irrigated vines (Table 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' (Fig. 4). Conversely, the per cent decrease in the transpiration due to water stress was lowest in 'Hayward' and highest in 'Bruno' cultivar (Fig. 5). In general, the vine of Allison recorded lower transpiration rates at higher value of stomatal resistance. Leaf stomatal resistance and transpiration varied with genotype (Escalona *et al.*, 4), 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

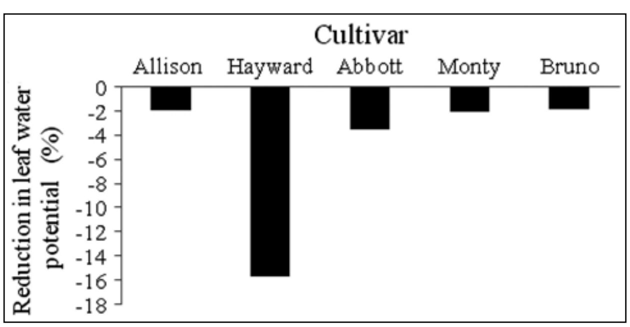

Fig. 2. Per cent reduction in leaf water potential of different kiwifruit cultivars at irrigation at 60 per cent FC over 80 per cent FC.

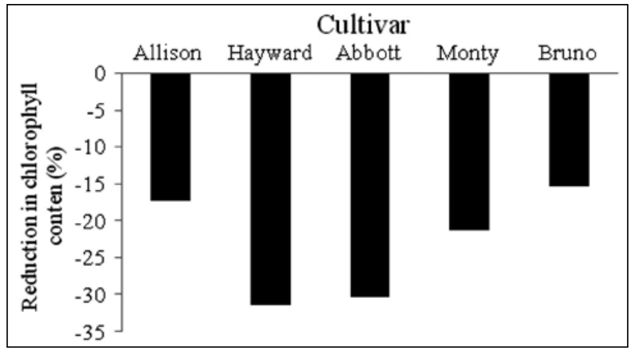

Fig. 3. Per cent reduction in chlorophyll content of different kiwifruit cultivars at irrigation at 60 per cent FC over 80 per cent FC.

Table 2. Effect of different irrigation levels on stomatal resistance, transpiration and photosynthetic rates in leaves of kiwifruit cultivars.

Cultivar	Pooled (2011-12)					
	Stomatal resistance (S cm^{-1})		Transpiration rate (mmol $m^{-2}s^{-1}$)		Photosynthetic rate (μmol $m^{-2}s^{-1}$)	
	SI	DI	SI	DI	SI	DI
Allison	4.25	4.38	9.80	8.20	19.08	18.59
Hayward	4.01	4.06	11.1	10.8	16.01	15.30
Abbott	4.05	4.11	10.4	9.70	16.18	15.56
Monty	4.11	4.19	10.3	9.10	18.04	17.52
Bruno	3.87	4.12	6.40	4.40	19.80	19.56
Mean	4.06	4.17	9.60	8.50	17.82	17.31
$CD_{0.05}$						
I	0.01		0.1		0.02	
C	0.01		0.1		0.03	
I × C	0.02		0.1		0.04	

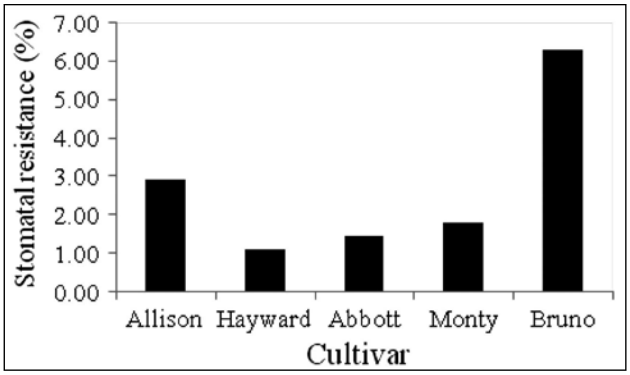

Fig. 4. Per cent increase in stomatal resistance of different kiwifruit cultivars at irrigation at 60 per cent FC over 80 per cent FC.

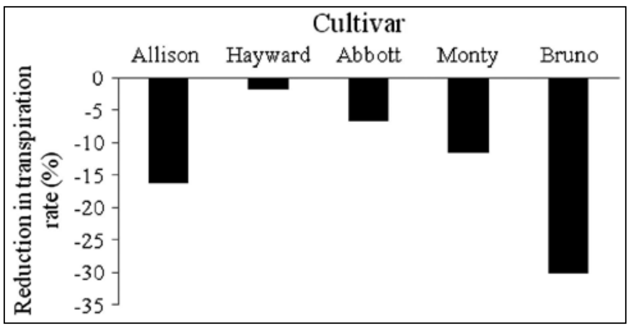

Fig. 5. Per cent reduction in transpiration rate of exposed leaves of different kiwifruit cultivars at irrigation at 60 per cent FC over 80 per cent FC.

cultivar Bruno under water stress can be attributed to higher decrease in stomatal width and xylem vessel development in this cultivar. Buwalda and Smith (2) observed that kiwifruit cultivar Hayward had higher transpiration rate with poor stomatal control. Ghaderi *et al*. (5) also observed that the drought tolerant grape cultivar maintained lower transpiration rate under water deficit conditions. During the course of study, the photosynthetic rate was significantly reduced by deficit irrigation (Table 2), however, the cultivars Hayward and Abbott registered higher per cent decrease, while cultivars Bruno and Allison recorded lower decrease in these attributes (Fig. 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*. (3).

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 and smaller

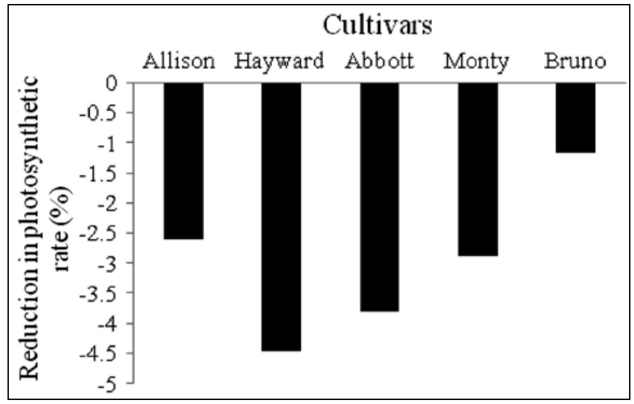

Fig. 6. Per cent reduction in photosynthetic rate of exposed leaves of different kiwifruit cultivars at irrigation at 60 per cent FC over 80 per cent.

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 (Ennajeh *et al*., 3). Liu *et al*. (9) 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 per cent increase in stomatal resistance whereas the reverse was observed in cultivar Hayward. The per cent reduction in leaf water potential, chlorophyll content and photosynthetic rate was least in Bruno, whereas the per cent reduction in transpiration rate was highest in Bruno and the least in Hayward under deficit irrigation treatment and therefore, the Bruno cultivar has better tolerance to water stress as compared to other cultivars.

REFERENCES

1. Blum, A. 2009. Effective use of water (EUW) and not water-use efficiency (WUE) is the target of crop yield improvement under drought stress. *Field Crop Res.* **112**: 119-23.
2. Buwalda, J.G. and Smith, G.S. 1990. Acquisition and utilization of carbon, mineral nutrients and water by the kiwifruit vine. *Hort. Rev.* **12**: 307-47.
3. Ennajeh, M., Vadel, A.M., Cochard, H. and Khemira, H. 2010. Comparitive impacts of water stress on the leaf anatomy of a drought-resistant and a drought-sensitive olive cultivar. *J. Hort. Sci. Biotech.* **85**: 289-94.

4. Escalona, J.M., Flexas, J., Bota, J. and Medrano, H. 2003. Distribution of leaf photosynthesis and transpiration within grapevine canopies under different drought conditions. *Vitis*, **42**: 57-64.

5. Ghaderi, N., Siosemardeh, A. and Shahoei, S. 2007. The effect of water stress on some physiological characteristics in Rashe and Khoshnave grape cultivars. *Acta Hort.* **754**: 317-22.

6. Hiscox, J.D. and Isralistan, J.F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian J. Biol.* **57**: 332-34.

7. Kadam, J.H., Tambe, T.B. and Kaledhonkar, D.P. 2005. Effect of irrigation regimes on chlorophyll content and chlorophyll stability index in different grape rootstocks. *Indian J. Hort.* **62**: 293-95.

8. Lakso, A.N. 1990. Interactions of physiology with multiple environmental stresses in horticultural crops. *Hort. Sci.* **25**: 1365-69.

9. Liu, B.H., Cheng, L., Liang, D., Zou, Y.J. and Ma, F.W. 2012. Growth, gas exchange, water use efficiency, and carbon isotope composition of Gale Gala apple trees grafted onto 9 wild Chinese rootstocks in response to drought stress. *Photosynthetica*, **50**: 401-10.

10. Miraghaee, Sharam, S., Ali, M. and Kahrizi, D. 2012. Acclimatization related proteins and factors in somaclone lines in kiwifruit (*Actinidia deliciosa*). *J. Food, Agric. Env.* **10**: 198-205.

11. Romero, P., Fernandez, J.I.F. and Cutillas, A.M. 2010. Physiological thresholds for efficient regulated deficit irrigation management in winegrapes grown under semi-arid conditions. *American J. Vitic.* **61**: 300-12.

12. Sanchez, F.J., Manzanares, M., de Andres, E.F., Tenorio, J.L. and Ayerbe, L. 2001. Residual transpiration rate, epicuticular wax load and leaf colour of pea plants in drought conditions influence on harvest index and canopy temperature. *European J. Hortic. Sci.* **15**: 57-70.

13. Satisha, J., Prakash, G.S., Murthi, G.S., Murthi, G.S.R. and Upreti, K.K. 2007. Water stress and rootstocks influences on hormonal status of budded grapevine. *European J. Hortic. Sci.* **72**: 202-05.

14. Tan, C.S. and Buttery, B.R. 1982. The effects of soil moisture stress to various fractions of the root system on transpiration, photosynthesis, and internal water relations of peach seedlings. *J. American Soc. Hort. Sci.* **107**: 845-49.

15. Thakur, A. 2004. Use of easy and less expensive methodology to rapidly screen fruit crops for drought tolerance. *Acta Hort.* **662**: 231-35.

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