Canopy temperature and water relations of kiwifruit cultivar Allison in response to deficit irrigation and *in situ* moisture conservation

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The present article discusses the effect of different irrigation levels and *in situ* moisture conservation on canopy temperature and water relations, viz. leaf water potential, stomatal resistance, transpiration rate, leaf photosynthetic rate and chlorophyll content in kiwifruit cultivar Allison during the years 2011 and 2012 in Solan, Himachal Pradesh, India. The kiwifruit vines were subjected to seven treatments, viz. irrigation at 80% FC (field capacity); irrigation at 60% FC; irrigation at 40% FC; irrigation at 60% FC plus mulching with grass; irrigation at 60% FC plus black polythene mulching; irrigation at 40% FC plus mulching with grass and irrigation at 60% FC plus black polythene mulching applied from March to October with three replications in randomized block design. The deficit irrigation treatments resulted in increased canopy temperature and stomatal resistance and decrease the leaf water potential, transpiration rate, leaf photosynthetic rate and chlorophyll content in the leaves of kiwifruit cv. Allison, whereas the application of mulches (grass and black plastic) along with deficit irrigation levels resulted in mitigation of the effect of deficit irrigation. Application of black plastic mulch along with irrigation at 60% field capacity was observed to be the best treatment as its effect nearly similar to that of standard irrigation.

Keywords: Canopy temperature, irrigation, kiwifruit, moisture conservation, mulch.

KIWIFRUIT or Chinese gooseberry is native to the Yangtze valley of south and central China[1]. The kiwifruit vine is dioecious in nature, bearing pistillate and staminate flowers separately. It requires 700–800 chilling hours below 7°C and mild summer with temperatures not exceeding 35°C; otherwise the fruits will be injured by sun burn. Approximately, 84% of the world production is contributed by China, Italy, New Zealand and Chile. The area under kiwifruit is negligible in India; however, it can be successfully grown in the mid hills of Himachal Pradesh (HP), Uttarakhand, states of North East India, Nilgiri Hills and Kerala. In HP, it occupied an area of 128 ha with annual production of 118 metric tonnes during 2009 (ref. 2). Irrigation is important for the successful establishment of a kiwifruit orchard to meet the requirements of the vine during the first 2–3 years of planting. After this, foliage covers the entire surface area of the soil and acts as mulch and reduces the need for irrigation. The use of different mulching materials is known to be beneficial for *in situ* moisture conservation during drought periods[3]. Mulches also regulate soil temperature, prevent soil erosion, surface run-off and control weeds. Kiwi vines probably die more often from some type of water stress than any other reason. Therefore, during dry season, frequent irrigation is essential for this fruit vine. The sensitivity of kiwifruit to leaf temperature and the consequent reduction in photosynthesis have important implications for its field management[4]. Further, the leaf temperatures above 25°C in *Actinidia deliciosa* resulted in a decrease in photosynthetic rate (*Pn*). Under moderate water stress, kiwifruit vines may have the leaf temperatures higher (2.5°C) than well-watered vines and this difference could be 5–6°C under severe water stress. Therefore, application of irrigation water could cool the canopy and thus avoid leaf heating and potentially leaf damage, including necrosis[5].

An 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 2011 and 2012. Twenty-five-year-old uniform vines of kiwifruit cultivar Allison planted at 6 × 4 m spacing and trained on T-bar system were selected for the experiment. Seven irrigation treatments were applied in different forms to the kiwifruit vines, viz. T_1: irrigation at 80% field capacity (FC) (standard irrigation); T_2: 60% and T_3: 40% field capacity; T_4: irrigation at 60% field capacity plus grass mulch; T_5: irrigation at 60% field capacity plus black polythene mulch; T_6: irrigation at 40% field capacity plus grass mulch; T_7: irrigation at 40% field capacity plus black polythene mulch. These treatments were applied from March to October with three replications in randomized block design (RBD). The number of vines per replication was one and the time of application of mulching was mid-March.

The canopy temperature was recorded using an infrared thermometer (Figure 1). Temperature was recorded from all the four sides of the vine canopy from a distance of 5 m. The temperature recording was started at 12 am

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from May to August at weekly intervals. The average values were expressed in degrees Celsius (Appendix 1).

The leaf water potential was recorded with the help of a portable plant water status console in May and June (Figure 2). Water potential was recorded between 10 : 00 am and 12 : 00 am by placing a freshly detached leaf in the pressure chamber. The leaf was inserted into the pressure chamber through two halves of a rubber stopper of an apparatus placed upside down, in such a way that its blade was inside the chamber, while the cut end of the petiole protruded out of the apparatus. The metal-retaining plate was placed over the stopper and the bolts were firmly tightened using an Allen wrench. Pressure was applied slowly inside the pressure chamber using the pressure regulator in the apparatus. The leaf water potential was recorded by observing the effect of slowly increase in pressure supply in the pressure chamber. For this, the cut surface of the petiole should be carefully observed until the cut surface changed dramatically in appearance. Originally the surface had a dull white appearance. When the pressure in the chamber equalled the water potential of the sample, xylem fluid returned to the cut surface giving it a water-saturated, glossy appearance. At this the stage water potential was recorded on the pressure gauge. Readings of five leaves per replication were taken separately; the results so obtained were averaged and expressed in -bars.

The stomatal resistance, transpiration rate and photosynthetic rate were recorded when soil moisture content under the respective treatments reached the required tension (i.e. 80%, 60% and 40% FC). Ten mature leaves from each experimental vine were selected randomly from all over the tree periphery. Observations were recorded during active growth periods between 9 : 00 and 11 : 00 am with the help of LI-COR 6200 Portable Photosynthesis System (Figure 3). The results were expressed in s/cm, mmol/m^2/S and μmol/m^2/S for stomatal resistance, transpiration rate and photosynthesis respectively.

Figure 1. Infrared thermometer.

For measurement of chlorophyll content, ten representative, fully grown leaves of each vine from the current season were detached in the morning hours, during the first week of August[6], immediately placed in an ice-box and brought to the laboratory. The samples were then kept in the refrigerator below 0°C to avoid degradation of chlorophyll pigments. The extraction of chlorophyll was done as follows: leaves taken from each sample were washed and chopped into fine pieces under subdued light. Then 100 mg of chopped material was placed in a vial containing 7 ml of dimethyl sulphoxide (DMSO). The contents

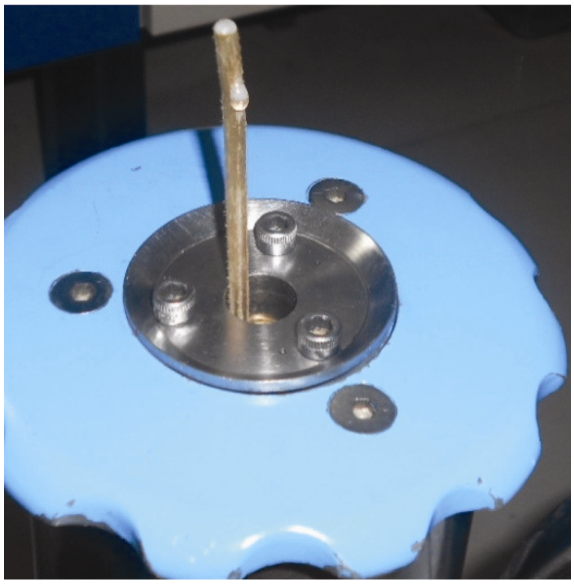

Figure 2. Plant water status console.

Figure 3. LI-COR 6200 portable photosynthesis system.

Table 1. Effect of irrigation levels and mulching on canopy temperature (°C), leaf water potential (-bars) and stomatal resistance (S cm^{-1}) of kiwifruit cv. Allison during the years 2011, 2012 and 2011–12 (pooled)

	2011			2012			2011–12 (pooled)		
Treatment	Canopy temperature	Leaf water potential	Stomatal resistance	Canopy temperature	Leaf water potential	Stomatal resistance	Canopy temperature	Leaf water potential	Stomatal resistance
T_1: Irrigation at 80% field capacity (FC)	27.6	8.70	4.24	27.5	8.67	4.26	27.6	8.69	4.25
T_2: Irrigation at 60% FC	29.5	8.84	4.37	30.0	8.86	4.38	29.8	8.86	4.38
T_3: Irrigation at 40% FC	30.0	9.15	4.40	30.3	9.13	4.41	30.1	9.14	4.41
T_4: Irrigation at 60% FC + mulching with grass	28.1	8.81	4.32	28.1	8.75	4.33	28.1	8.78	4.33
T_5: Irrigation at 60% FC + black polythene mulching	27.9	8.74	4.30	27.9	8.69	4.28	27.9	8.72	4.29
T_6: Irrigation at 40% FC + mulching with grass	29.2	9.12	4.35	29.9	9.10	4.36	29.6	9.11	4.36
T_7: Irrigation at 40% FC + black polythene mulching	28.9	9.05	4.32	28.9	9.02	4.34	28.9	9.04	4.33
$CD_{0.05}$	0.1	0.01	0.01	0.3	0.01	0.01	0.2	0.01	0.01

of the vials were incubated at 65°C for 30 min; the extract was transferred to a graduated test tube and final volume was made to 10 ml with DMSO[7].

Total chlorophyll content was estimated by recording the optical density (OD) of the prepared extract using spectrophotometer (Spectronic-20D) at 645 and 663 nm wavelength against a DMSO blank. The total chlorophyll content was calculated by using the following formula

$$\text{Total chlorophyll (mg/g)} = \frac{20.2A_{645} + 8.02A_{663} \times V}{A \times 1000 \times W},$$

where V is the volume of extract used, A the length of light path in the cell (1 cm), W the weight of the sample (g), A_{645} the absorbance at 645 nm wavelength and A_{663} is the absorbance at 663 nm wavelength.

The results were expressed as chlorophyll content in mg/g of fresh weight.

Table 1 shows that canopy temperature, leaf water potential and stomatal resistance of kiwifruit vines are significantly influenced by different irrigation levels and mulching treatments. In 2011 and 2012, the highest canopy temperature and stomatal resistance values were recorded with the application of irrigation at 40% of field capacity (T_3). The second highest canopy temperature and stomatal resistance values were observed in T_2 treatment. The lowest canopy temperature and stomatal resistance values were recorded under T_1, followed by T_5 and T_4 in increasing order. The pooled data (Table 1) clearly indicate that the vines irrigated at 40% field capacity had significantly higher canopy temperature and stomatal resistance. The lowest canopy temperature and stomatal resistance values were recorded in vines irrigated at 80% of field capacity (T_1), followed by treatment T_5. The well-irrigated vines had lower canopy temperature compared to vines under deficit irrigation (DI). However, mulching with black polythene or grass decreased the canopy temperature of DI deficit irrigated vines during the study (Table 1). Increased canopy temperature of deficit irrigated vines is understandable in this study, as DI decreases the transpiration rate (Table 2). On the contrary, mulching treatments increase the transpiration rate, which has a cooling effect on the plant canopy. The leaf temperatures increased due to reduced transpiration and photosynthetic rate in water-stressed vines of kiwifruit[8]. The present findings pertaining to mulching effects are in line with those of other researches[9,10].

During 2011 and 2012, leaf water potential (Table 1) was significantly least negative in the vines subjected to irrigation treatment T_1, which was followed by treatments T_5, T_4 and T_2. However, the leaf water potential was significantly more negative in vines irrigated at 40% of field capacity in comparison to all other treatments. The pooled data (Table 1) reveal that the vines irrigated at 80% of field capacity (T_1) have significantly least negative leaf water potential (–8.69 bar), followed by those under T_5. Conversely, irrigation at 40% of field capacity (T_3) resulted in the development of the most lower leaf water potential (–9.14 bar). The leaf water potential was significantly decreased by DI treatments compared to standard irrigation; however, the effect was moderated by applying mulches. The present results are in accordance with earlier findings that leaf water potential decreases under water stress[11,12] and increases by mulching[13].

Table 2 shows that transpiration rate, photosynthetic rate and chlorophyll content were influenced significantly by different treatments, during both the years of study. In 2011 and 2012, significantly highest transpiration rate, photosynthetic rate and chlorophyll content (Table 2) were recorded under treatment T_1, followed by treatments T_5 and T_4 in decreasing order. These parameters were

Table 2. Effect of irrigation levels and mulching on transpiration rate (mmol $m^{-2} s^{-1}$), photosynthetic rate (μmol $m^{-2}s^{-1}$) and leaf chlorophyll content (mg/g) of kiwifruit cv. Allison during the years 2011, 2012 and 2011–12 (pooled)

	2011			2012			2011–12 (pooled)		
Treatment	Transpiration rate	Photosynthetic rate	Chlorophyll content	Transpiration rate	Photosynthetic rate	Chlorophyll content	Transpiration rate	Photosynthetic rate	Chlorophyll content
T_1	10.43	19.1	3.14	10.46	19.0	3.12	10.45	19.1	3.13
T_2	9.67	18.6	2.60	9.80	18.5	2.58	9.74	18.6	2.59
T_3	8.10	17.2	2.30	8.18	17.1	2.29	8.14	17.2	2.30
T_4	9.83	18.8	2.80	9.86	18.7	2.74	9.85	18.8	2.77
T_5	9.94	19.0	3.05	9.97	18.9	3.07	9.96	19.0	3.06
T_6	8.60	17.4	2.42	8.71	17.3	2.40	8.66	17.4	2.41
T_7	8.30	17.5	2.58	8.40	17.4	2.57	8.35	17.5	2.58
$CD_{0.05}$	0.03	0.1	0.08	0.02	0.1	0.03	0.01	0.1	0.04

Appendix 1. Average canopy temperature (°C) of kiwifruit cv. Allison under different irrigation levels and *in situ* moisture conservation treatments (2011–12)

	2011				2012			
Treatment	May	June	July	August	May	June	July	August
T_1	28.5	27.6	26.8	27.1	28.3	27.6	26.6	27.5
T_2	29.7	29.6	29.2	29.5	30.2	30.1	29.7	30.0
T_3	31	30.1	29.1	29.8	31.5	30.4	29.3	30.0
T_4	28.2	28.1	28.0	28.0	28.4	28.2	27.8	28.0
T_5	28.1	28	27.6	27.9	28.4	27.9	27.5	27.8
T_6	29.4	29.3	29.0	29.1	30.2	30.0	29.6	29.8
T_7	28.5	29.2	28.9	29	29.7	29.4	27.6	28.9

recorded significantly lowest under T_3. The pooled data (Table 2) further clarify that the vines irrigated at 80% of field capacity have significantly highest transpiration rate, photosynthetic rate and chlorophyll content followed by those under the treatments T_5 and T_4. The minimum transpiration rate, photosynthetic rate and chlorophyll content were recorded in vines irrigated at 40% of field capacity. Increased transpiration rate under mulch could be due to higher availability of soil moisture content. These findings are similar to those of Smart and Coombe[14] in respect of the effect of DI on stomatal resistance, and of Escalona *et al.*[15] and Grant *et al.*[16] on transpiration rate. The results are also in line with earlier findings that mulching tends to decrease the stomatal resistance[17] and increase the transpiration rate[10,18].

The photosynthetic rate and chlorophyll content of kiwifruit vines decreased linearly with decrease in water supply (Table 2). However, spreading of mulches over the soil surface in the basin area of vines under different DI treatments significantly increased the photosynthetic rate and chlorophyll content in comparison to vines subjected to DI treatments alone. There are reports to suggest that DI slows down the photosynthetic rate[19], whereas mulching mitigates this DI-induced response[10–18]. The results are also in line with earlier findings that leaf chlorophylls content is decreased by DI[20,21] and increased by mulching[22]. The stomatal closure due to water stress may result in a reduction in CO_2 influx, which further limits photosynthesis[23]. An increase in leaf chlorophyll content of strawberry cv. 'Oso Grande' was observed when grown under black polyethylene mulch in semi-arid conditions[22]. The decrease of leaf chlorophyll content is a typical symptom of oxidative stress and may be the result of chlorophyll degradation or due to chlorophyll synthesis deficiency together with changes of thylakoid membrane structure[24]. In this study, mulching increased the level of cytokinins, which can directly affect the photosynthetic parameters, e.g. chlorophyll and photosynthetic protein synthesis and degradation, chloroplast composition and ultrastructure electron transport and enzyme activities[25]. It has also been suggested that reduced chlorophyll content under water stress condition may be due to reduction in cytokinin content[23].

Thus the use of black plastic mulch is beneficial under moderate water stress conditions, as it conserves soil moisture under DI regime and thus helps mitigate the effect of water stress in canopy temperature and water relations. The results observed in vines under this treatment are almost similar to those observed under standard irrigation. Therefore, in water-scarce areas, where the normal irrigation requirements cannot be fulfilled, black plastic mulch may be used.

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