

A Comparative Study of the Effects of High Temperature Regime on Cherry Tomato Plant Water Status When Cultivated in Different Growing Substrates Systems

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Abstract: Plants vary in their abilities to resist damage due to various stresses. The degree of plant stress or deficit depends on the extent to which water potential and cell turgor are reduced below their optimum values. The aim of our research was to study the effects of high temperatures on tomato plants in different cultivation systems during the two first growth stages: vegetative stage and flowering stage. Our research objectives were to study the physiological responses of tomato plants subjected to heat stress and then evaluate the interaction of temperature and growing media on plant water status.

In this experiment, it was observed that when roof ventilations were closed at noon, the greenhouse temperature could rise as high as 50°C. This resulted in serious plant injury and in certain cases, death of plants. Highly significant differences in water potential caused independently by temperature and growing medium (at dawn or at midday) were noticed in our study. Leaf relative water content was not significantly affected either by temperature or by growing medium. A significant difference in leaf chlorophyll B content caused by the interaction of temperature and growing media was detected. At midday, we noted a strong effect caused by temperature on air/leaf temperature gradient. Respiration and photosynthesis were seriously affected at relatively higher temperatures (Midday temperatures) as shown by the air/leaf temperature gradient.

Key words: cherry tomato, plant water status, air/leaf temperature gradient, DAS (Days after Sowing)

1. Introduction

The primary objective of protected cropping is to provide sufficient control of the aerial and root environments so as, to enable production of high quality of crops at greater economic benefit. Tomato is one of the most popular and widely grown fresh vegetables in the World, particularly in Burundi. Nowadays, tomatoes are available at the market every day, but the price changes dramatically and the season consumption correlates to the market price. In some tropical regions also, air temperature can reach 38°C to more than 40°C for several days. This situation affects the plants' physiology and consequently the quality of the production. In addition, plants are capable of responding rapidly to changes in environmental factors particularly temperature. Thus, determining limiting factors and then developing cultural methods and technologies to overcome successive limiting factors will be a significant challenge for growers today and in the future.

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In recent years, many studies have focused on temperature that can maximize production and minimize the growing period (Stanghellini *et al*, 1999, Abou-Hadid *et al*, 1999, Newton *et al*, 2000). Other reports were related to the impact of temperature on the quality of production, and yield (Limonse *et al*, 1999, Schwartz, 1999). The stress caused by high temperature has most of the time been associated with water stress, especially during drought period. Short *et al*, (1998), Saucer *et al* (1999) reported interesting results which allowed them to set up different models which have already been put into practice in Hydroponics' productions. Further studies by Ferris *et al* (1998), Massai *et al* (2000), Bunce *et al* (1999) were focused on the recovery process after an environmental stress along a precise period.

Despite a number of studies being done on stress caused by high temperature on plants, limited work has been carried out concerning the plant physiological response. Using the current physiological stress indicators, we have tried a new approach with the aim of proposing a cultivation system which could bring down the losses during summer.

The aim of our research was to study the effects of high temperatures on tomato plants in different cultivation systems during the two first growth stages: vegetative stage and flowering stage. The specific objectives were to study the physiological responses of tomato plants subjected to heat stress and then evaluate the interaction of temperature and growing media on plant water status.

2. Materials and Methods

The experiment was carried out from May to the end of September 2007 in the Institute of Agriculture and Bioenvironmental Engineering (Zhejiang University-China). The main object was to evaluate the tomato plant's reaction to temperature stress during summer time. Thirty five days after sowing, the plants were about 6-10 cm in height. Tomato seedlings at 5 to 7 true leaves were transplanted in pots with appropriate growing medium: Soil, peat moss, peat / perlite (3 / 2), perlite. Another soilless culture was the Nutrient film Technique (recirculation system) with 10 plants in each room. The NFT timer was set at a 1:2 minutes interval. Plants were selected for uniformity prior to treatments as described below for all subsequent experiments.

Each treatment unit (pot) was replicated 4 times and each experimental unit had 4 plants. Thereafter the plants were moved to the three identical glasshouse rooms at different temperature regimes (as treatments): Room-1 for 25/20°C (day/night temperature), Room-2 for 35/25°C (The maximum temperature was maintained for 6 hours) and Room-3 for >35°C/ >25°C. In room-3, when day temperature was about 40°C, it was only maintained for 2 hours maximum. Measurements, observations or analysis done were for the vegetative period and the flowering period.

All the parameters (temperature, relative humidity, dioxide carbon) necessary to compute gas exchange were continuously recorded at 10 minutes interval using a computerized climate control system. Plant height was measured every two-weeks. It was determined as the average of the 4 plants from each growing medium. Internodes length was also measured. The Ec and pH of the nutrient solution was measured using the Ec meter (Hanna Instruments, HI 9033 Multi-range conductivity meter) and the pH (Hanna Instruments, HI 9024 microcomputer, pH meter) meter respectively. The measurements were done at a four-day interval for the recirculation system from the three rooms and for the tank. The feeding solution was prepared and kept in the tank. The Ec and pH were kept at 6.9mS/cm and 6.2 respectively. The nutrient solution was stirred regularly and renewed after each ten-day period. The plants were watered daily

at dawn and in the late afternoon. Water potential was determined two times a day: at predawn and at noon. The measurement was carried out using the HR 33T Dew Point Micro voltmeter with the C-52 sample chamber. Readings were divided by -0.75 in order to get leaf water potential in “Bars” then in MPa. The leaf pigment chlorophyll content was determined using the extraction by acetone 80% followed by measurements by spectrophotometer - CAMSPEC UV-Spectrophotometer- (Jiang De An, 1999). Determination of Chlorophyll content from light absorption was deducted from the following equations:

$$CA = 12.7 OD_{663} - 2.69 OD_{645} \text{ (OD=Optic Density)}$$

$CB = 22.9 OD_{645} - 4.68 OD_{663}$; $CT = CA + CB$ (CA is Chlorophyll A, CB is Chlorophyll B and CT is Total Chlorophyll). Leaf samples were taken at midday. Leaf relative water content was measured by obtaining a fresh mass of the tissue sample (W_f), allowing the tissue to absorb water until it is saturated, weighing again to get a turgid mass (W_t), and weighing it yet again after drying in an oven at 105°C for 2 hours and then maintained at 70°C for 24 hours to get a dry mass (W_d).

$$LRWC = (W_f - W_d / W_t - W_d) \times 100. \text{ (Salisbury, 1991).}$$

The leaf temperature was determined using an infra-red camera (NL/ISG Thermal System Ltd, UK). It was taken early in the morning (6-7 o'clock) and at midday (12-13 o'clock). The measurements were done on fully exposed leaves from each room and for each growing medium.

The trial was a factorial completely randomized design. The data were analyzed statistically using the SAS system (1996), general linear model procedure. The means difference were analyzed using the DPS 2000.

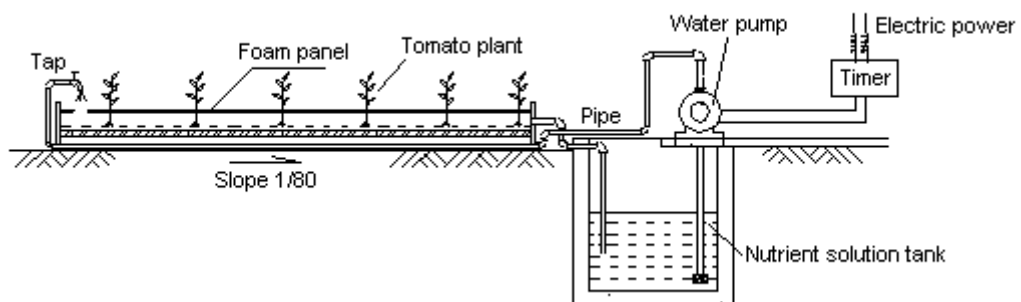


Fig 1: Nutrient Film Technique design.

3. Results and Discussion

Effects of temperature and growing media on leaf water potential

Leaf water potential (ψ_{leaf}) measured at predawn, showed significant differences in all the rooms. The ψ_{leaf} was progressively lower from room-1 to room-2 and from room-2 to room-3. It was in the range of -0.67 to -0.47 MPa for room-1, from -0.79 to -0.62 MPa for room-2 and -0.87 to -0.73 MPa in room-3. Other differences were noted among growing media. The NFT showed a lowest ψ_{leaf} while the peat moss showed the relatively higher ψ_{leaf} (Table-5).

At midday (between 12 and 13 o'clock), the differences in ψ_{leaf} according to the temperature regimes were remarkable except for the plants in peat/perlite pots, where there wasn't any significant difference caused by different treatments. We also observed differences, in leaf water potential, among the growing

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media. We can therefore rank growing media decreasingly from peat moss, perlite, soil, NFT and peat/perlite respectively.

Tomato plants require a high water potential for optimum vegetative and reproductive development. (Torrecillas *et al*, 1994). The report of Weng (1998) suggested that the plants adjusted their internal water status in response to high Ec (electrical conductivity) and substrate water potential. Also, Yang (1999) noted that plants grown in substrates with high organic content and coarse structure (peat) were less affected by water logging than those grown in sand and loam.

From our results (Table-1), the analysis of variance showed a significant effect on the interaction of temperature and growing media on leaf water potential ψ_{leaf} , when the treatment is applied either at predawn or at midday. Also, the effect of temperature was highly significant either at dawn or at midday. A little effect caused by growing medium was noticeable only at midday.

Table 1. The effect of temperature on leaf water potential (ψ_{leaf}).

Period	Treatment	Growing media				
		Soil	Peat	Peat/Perlite	Perlite	NFT.
Predawn	Room-1	-0.58(0.05)a	-0.54(0.10)a	-0.58(0.03)a	-0.47(0.11)a	-0.67(0.07)a
Predawn	Room-2	-0.70(0.06)b	-0.62(0.10)a	-0.77(0.14)b	-0.58(0.1)ab	-0.79(0.04)b
Predawn	Room-3	-0.74(0.08)c	-0.73(0.15)b	-0.91(0.14)c	-0.77(0.25)b	-0.87(0.13)b
Midday	Room-1	-0.83(0.15)a	-0.75(0.06)a	-1.46(0.46)b	-0.77(0.13)a	-0.88(0.07)a
Midday	Room-2	-1.01(0.13)b	-0.88(0.03)a	-1.67(0.56)b	-0.99(0.3)ab	-1.21(0.18)b
Midday	Room-3	-1.20(0.13)c	-1.06(0.18)b	-1.68(0.49)b	-1.11(0.42)b	-1.39(0.35)b

*Different letters: significantly different at p= 5% (DMRT)

*The values in parentheses represent the Standard deviation of the means.

*The unit for ψ_{leaf} is “MPa”

The findings of Herppich (1996) suggested that neither predawn nor day time leaf water potential changed with leaf age under conditions of limited soil water availability. Our results showed that leaf water potential decreased due to the progressive heat stress in the three different rooms, regardless of the growing medium.

The measurements of ψ_{leaf} done at predawn and at midday were quite different regardless of the room. These results are in analogy with those of Bussotti *et al*, (2001) that differences between predawn ψ_{leaf} and midday ψ_{leaf} were always significant. Our observations are in agreement with those of Savin *et al* (1999) that the leaf water potential is considerably higher at dawn than at noon. Schulze (1991) reported that predawn leaf water potential closely follows seasonal change of water potential, while the minimum daily leaf water potential closely follows leaf osmotic potential.

From his findings Schulze (1991) noted that the integrated regulation of leaf water potential,

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osmotic adjustment and transpiration is probably related not only to Carbon and water relations in the leaf, but the whole-plant functioning. As expected, in our study, the ψ_{leaf} was decreased by heat stress in both rooms. In the late afternoon after re-watering, a relatively rapid recovery of ψ_{leaf} was noticed the following day.

The conclusions of Kramer (1980) quoted by Rahman (2000), that water loss from plants is greater under high ambient temperature regimes than low temperature, due to the higher transpiration demand under high temperature conditions were confirmed in our study. Our results suggest that the lowest ψ_{leaf} was in room-3 where the temperature regime was highest.

Even though the growing media showed little effect on leaf water potential, we can assume that the ψ_{leaf} is more related to temperature regimes than to growing media. Since the plants were watered adequately, we can attribute the variation of ψ_{leaf} to the temperature regimes applied. Moreover, Beppu *et al* (1999) in his study on sweet cherry, noted that: though the trees did not show symptoms of water stress under low temperature/moist soil regime, the leaf water potential under high temperature/moist soil regime decreased to almost the same level as that under both dry soil regimes. Our results were somehow different from those of Machado *et al*, (2001) that crops maintain nearly stable water relations regardless of temperature when moisture is ample, but high temperature strongly affects water relations when water is limiting.

Table 2: Effect of Growing media on leaf water potential (ψ_{leaf}).

	Predawn / Room-1	Predawn / Room-2	Predawn / Room-3
Soil	-0.58(0.05)ab	-0.70(0.06)bc	-0.74(0.08)a
Peat	-0.54(0.10)a	-0.62(0.10)ab	-0.73(0.15)a
Peat/Perlite	-0.58(0.03)ab	-0.77(0.14)c	-0.91(0.14)a
Perlite	-0.47(0.11)a	-0.58(0.11)a	-0.77(0.25)a
NFT.	-0.67(0.07)c	-0.79(0.04)c	-0.88(0.13)a
	Midday / Room-1	Midday / Room-2	Midday / Room-3
Soil	-0.83(0.15)a	-1.01(0.13)a	-1.20(0.13)a
Peat	-0.75(0.06)a	-0.88(0.039)a	-1.06(0.18)a
Peat/Perlite	-1.46(0.46)b	-1.67(0.56)b	-1.68(0.49)b
Perlite	-0.77(0.13)a	-0.99(0.34)a	-1.11(0.42)a
NFT.	-0.87(0.07)a	-1.21(0.18)b	-1.39(0.35)ab

*Different letters: significantly different at p= 5% (DMRT)

*The values in parentheses represent the Standard deviation of the means.

*The unit for ψ_{leaf} is “MPa”

Leaf water potential and plant physiology

The ψ_{leaf} measurements carried out during the plant's development showed a net decrease in ψ_{leaf} with plant growth.

During the first stage (vegetative growth), the ψ_{leaf} was in the range of -0.47 to -1.07 MPa at predawn, and in the range of -0.70 to -1.75 MPa at midday, irrespective of the growing media of concern. It then decreased gradually until the flowering period when there was a net drop in ψ_{leaf} especially at midday. The decrease in ψ_{leaf} was faster at the flowering stage than during the vegetative growth (Fig 8).

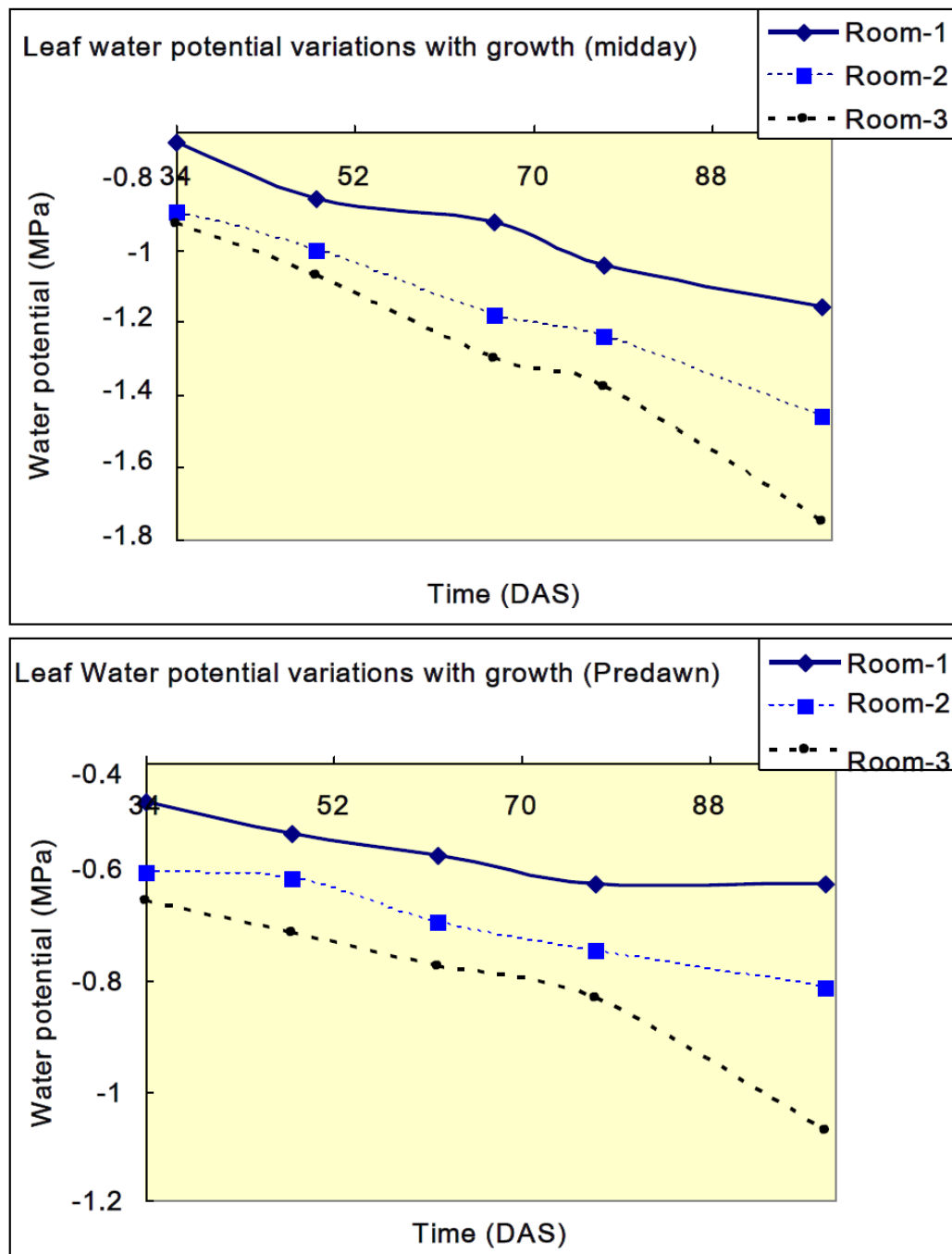


Fig 2. Leaf water potential variations and plant's development

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These observations were similar in all of the growing media (including the NFT). At midday, the leaf wilting was severe in room-3, to an extent of being irreversible when the temperature rose to 42°C (the top of the plants were damaged). In room-2, leaf wilting was severe but, the plants recovered after the late afternoon watering and the decrease in temperature in the early evening. Wilting was not observed in room-1, either at dawn or at midday. Nevertheless, Rajeev, (1998) in his work on geranium leaf tissues, indicated that the temperature causing half-maximum injury was about 51°C, and that temperatures up to 45°C did not cause any injury to the leaf tissue.

After re-watering, vegetative growth of stressed plants recovered, indicating a reversibility of morphological changes promoted by heat stress. However, at late development stages, recovery was not complete. It is argued that wilting substantially contributes to creating a sufficient driving force for water uptake from the soil, and reducing the Vapor Pressure Deficit (through a decrease in radiation load and thus leaf temperature) to avoid excessive dehydration (Schultz, 1997). Turner (1998) noted that a stronger relationship existed between stomatal conductance and ψ_{leaf} than any assessment of leaf water status. Later, the report of Bunce (1999) showed that there can be a significant and sometimes dominant role of ψ_{leaf} in affecting plant physiology.

Effects of temperature regime on leaf relative water content

The leaf samples (4 from each growing medium) were the young fully expanded leaves, from the top of the plants. The measurements were done at midday when in all the rooms temperature was maximum. We noticed that as long as the plants were watered adequately, the variation in the leaf relative water content was very small. The leaf relative water content was decreased slightly from room-1 to room-2 and then from room-2 to room-3.

The analysis of variance didn't show any significant difference in Leaf relative water content (LRWC) caused neither by temperature nor by growing medium. Their interaction did not also show any significant effect. Small differences were detected by DMRT (Duncan Multiple Range Test, 5%) due to the temperature regimes difference.

Our results didn't show any significant difference due to the growing medium. The study of Lacape *et al* (1998) indicated that the stability in LRWC under conditions of reduced ψ_{leaf} is usually associated with stability in turgor potential resulting from osmotic adjustment. In contrast, Bacci *et al* (1996) reported that leaf moisture content did not vary with temperature. On the other hand, Huang *et al* (1998) and Manabendra *et al* (2000) suggested that reduction in leaf water content results in reduced photosynthetic competence in many plants under drought conditions.

Table-3. The effect of temperature regime on leaf relative water content

Treatment	Growing		Media		
	Soil	Peat	Peat/Perlite	Perlite	NFT
Room-1	89.2(1.3) a	93.9(4.3) a	92.2(2.7) a	89.0(1.9) a	86.7(4.6) a
Room-2	88.2(0.6) a	91.0(0.9) b	87.3(2.3) ab	85.1(1.1)b	83.5(5) a
Room-3	84.4(0.7) b	89.6(4.3) b	83.2(6.3) b	83.9(2.2)b	82.1(3.2)a

*Different letters: significantly different at p= 5%(DMRT)

*The values in parentheses represent the Standard deviation of the means.

*The unit for Leaf relative water content (LRWC) is “ % ”

Effects of temperature and leaf chlorophyll content

In order to determine the relative chlorophyll content (Chlorophyll A, Chlorophyll B, and Total Chlorophyll), the three first fully expanded leaves were taken daily as samples. These samples were collected everyday at noon over a two week-period during the late vegetative growth stage. The results (Table-4) show the leaf mean in leaf Chlorophyll-A, Chlorophyll-B and Total Chlorophyll content in the three different rooms (different temperature regimes) for the five growing media.

In room-1, we observed the lowest leaf chlorophyll content (3.036 to 4.035 mg/gr.) while room-2 had the highest concentration (3.444 to 4.373 mg/gr). There was a slight decrease in leaf chlorophyll content (3.319 to 4.313 mg/gr) in room-3. It seems that if temperature increases, the leaf chlorophyll content also tends to increase up to a certain limit, irrespective of the growing medium. The growing media had a very little effect on leaf chlorophyll content.

We found highly significant effect in leaf chlorophyll content caused both by temperature and growing media as well; but their interaction had no effect on total chlorophyll content. These observations were similar with those of leaf chlorophyll A content. Nevertheless, although temperature did not significantly affect the leaf total chlorophyll content, the difference in leaf chlorophyll B content caused by growing media, and the interaction between growing medium and temperature was found significant.

Our results are analogous with those of Bacci *et al* (1996) who found that at the lowest growth temperature (15°C) there was a significant decrease in total chlorophyll content compared to the intermediate temperature (25°C); the highest temperature (35°C) mainly influenced efficiency of excitation energy capture by photosystem II, with a slight but significant decrease in total chlorophyll content. Herrera *et al* (1999) also indicated that the total chlorophyll content did not differ significantly between photoperiods in watered plants; it decreased significantly with heat stress only in very short day plants.

The findings of Manabendra *et al* (2000) also suggested that leaf chlorophyll activity decreased significantly under stress in all cultivars of tomato. In addition, our results confirm the study of Hirokazu *et al* (1999) who showed that the chlorophyll content increased with leaf age until 6 weeks after unfolding at both temperature regimes (20/15°C and 30/25°C). Thereafter, it decreased significantly at 30/25°C but it continued to increase at 20/15°C.

Leaf chlorophyll content is somehow linked with stomatal conductance and leaf carbon exchange rate,

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and is therefore, among the main principal indicators of the leaf photosynthetic efficiency. The report of Gratani *et al* (2002) indicates that net photosynthesis was directly correlated to leaf area, dry mass and total chlorophyll content and inversely correlated to leaf water content.

Table 4. Effects of temperature on Chlorophyll content

Chlorophyll-A					
	Growing media				
Treatment	Soil	Peat	Peat/Perlite	Perlite	NFT.
Room-1	2.25(0.10)b	2.84(0.39)a	2.44(0.33)a	2.11(0.02)b	2.15(0.08)b
Room-2	2.99(0.32)a	3.10(0.24)a	2.90(0.31)a	2.61(0.17)a	2.43(0.18)a
Room-3	2.57(0.19)ab	3.06(0.21)a	2.79(0.12)a	2.52(0.20)a	2.3590.21)a
Chlorophyll-B					
Room-1	0.97(0.21)a	1.18(0.14)a	1.08(0.14)a	0.91(0.15)a	0.92(0.17)a
Room-2	1.17(0.13)a	1.26(0.14)a	1.18(0.11)a	1.05(0.06)a	1.00(0.12)a
Room-3	1.04(0.07)a	1.24(0.08)	1.16(0.23)a	1.02(0.08)a	0.96(0.09)a
Tot.Chlorophyll					
Room-1	3.22(0.27)b	4.03(0.37)a	3.52(0.40)a	3.03(0.16)b	3.08(0.12)a
Room-2	4.01(0.03)a	4.37(0.19)a	4.08(0.43)a	3.669(0.24)a	3.44(0.15)a
Room-3	3.61(0.27)ab	4.31(0.28)a	3.96(0.10)a	3.54(0.18)a	3.31(0.30)a

*Different letters: significantly different at p= 5%(DMRT)

*The values in parentheses represent the Standard deviation of the means.

*The unit for Leaf Chlorophyll Content is “mg/gr.”

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Table 5: Effect of growing media on Leaf Chlorophyll Content

	Growing media	Room-1	Room-2	Room-3
Chlorophyll-A	Soil	2.25 (0.1)b	2.99(0.32) a	2.57 (0.19)bc
	Peat	2.85(0.39) a	3.10(0.24) a	3.06 (0.21) a
	Peat/Perlite	2.44(0.33) ab	2.90(0.31) a	2.80(0.12) b
	Perlite	2.12(0.02) b	2.61(0.17)b	2.52(0.2)bc
	NFT	2.16(0.08) b	2.44(0.18)c	2.35(0.21)c
Chlorophyll-B	Soil	0.97(0.21)b	1.17(0.13)a	1.04(0.07)b
	Peat	1.18(0.14)a	1.26(0.14)a	1.24(0.08)a
	Peat/Perlite	1.08(0.14)ab	1.18(0.11)a	1.68(0.22)ab
	Perlite	0.91(0.15)b	1.05(0.06)b	1.16(0.22)bc
	NFT	0.92(0.17)b	1.00(0.12)b	0.96(0.09)c
Total Chlorophyll	Soil	3.22(0.27)b	4.01(0.03)b	3.61(0.27)bc
	Peat	4.03(0.37)a	4.37(0.19)a	4.31(0.28)a
	Peat/Perlite	3.52(0.4)ab	4.08(0.43)b	3.96(0.1)b
	Perlite	3.03(0.16)b	3.66(0.24)bc	3.54(0.18)c
	NFT	3.08(0.12)b	3.44(0.15)c	3.31(0.3)c

*Different letters: significantly different at p= 5%(DMRT)

*The values in parentheses represent the Standard deviation of the means.

*The unit for Leaf Chlorophyll Content is “mg/gr.”

Moreover, Ceccato *et al* (2001) showed that variations in chlorophyll content are not only caused by water stress and radiation stress, but also by phenological status of the plants. Willits *et al* (1999) reported that good correlations have been found between chlorophyll fluorescence and root growth potential, gas exchange, visible leaf damage and leaf water potential.

Heat stress and air/leaf temperature gradient

The air/leaf temperature gradient is the difference between the air temperature in the room and the leaf temperature. For the last few years, leaf temperature is being used to quantify the plant stress. Most temperature based models require a parameter to link leaf temperature with plant metabolism. Weng (1998) suggested that LATD (Leaf/air temperature difference) and PAR (photosynthetic active radiation) were significantly positively correlated ($P < 0.001$) when relative humidity was maintained above 40%.

In our study, the measurements for the five fully expanded leaves located on the top of the plant were taken using an infrared camera thermometer. In each room, plants from 2 pots for each growing medium were considered. Leaf temperature was measured in the early morning (7 o'clock: when the air room temperature is minimum) and in the early afternoon (1 o'clock: when the room air temperature is considered lowest) for a period from 34 DAS to 99 DAS.

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The day air/leaf temperature gradient was positive during our study. In the morning, in room-1 and room-2 the air/leaf gradient didn't show any significant differences. This may be due to the fact there isn't much difference in the morning room air temperatures in the two rooms. The temperature gradient in room-3 is slightly lower than in the two other rooms, possibly due to the persistence of the effects of past environmental conditions which were particularly unfavorable in room-3.

At midday, the air/leaf temperature gradient was in the range of 3.8 to 4.6 for room-1, 4.5 to 5.1 for room-2 and 6.7 to 7.5 for room-3; with minima gradients for the peat/perlite and perlite as growing media, and maxima gradients for soil cultivation. The analysis of variance (ANOVA) shows a highly significant effect of temperature on air/leaf temperature gradient. The interaction of temperature and growing media was significant only for the measurements done at midday, showing the metabolic effect of the plant to face the harshness of the climatic change. The interaction was not effective in the morning. The main metabolic activities involved are transpiration and photosynthesis.

Mattos *et al* (1998) reported that midday depression of Net Photosynthesis and stomatal conductance seemed to be related to the leaf temperature and high irradiance. However, Weng (2001) noted that during the dry season when relative humidity (RH) was lower than 20% after 3-4 hours from sunrise, LATD (leaf/air temperature difference) was the same in low and high PAR (photosynthetic active radiation) in all species. When RH of less than 20% was excluded from the analysis, the slope of LATD and PAR was significantly correlated to air temperature.

Table 6. Effect of heat stress on air/leaf temperature gradient

Period	Treatment	Growing media				
		Soil	Peat	Peat/Perlite	Perlite	NFT.
Morning	Room-1	3.5(0.49)a	3.5(0.19)a	3.3(0.45)a	3.4(0.28)a	3.4(0.55)a
Morning	Room-2	3.1(0.34)a	3.4(0.42)a	2.9(0.26)ab	3.2(0.23)a	3.2(0.26)a
Morning	Room-3	2.6(0.17)b	2.4(0.29)b	2.6(0.28)b	2.5(0.24)b	2.3(0.33)a
Midday	Room-1	4.6(0.81)b	4.5(0.41)b	3.8(0.64)c	3.8(0.34)c	3.8(0.25)b
Midday	Room-2	5.1(0.65)b	4.5(0.6)b	4.9(0.52)b	4.9(0.56)b	4.1(0.52)b
Midday	Room-3	7.5(0.26)a	7(0.92)a	6.8(0.51)a	6.7(0.56)a	7(0.84)a

*Different letters: significantly different at p= 5%(DMRT)

*The values in parentheses represent the Standard deviation of the means.

*The unit for Air/Leaf temperature gradient is "°C"

The Air/leaf temperature difference is the driving force; the greater the difference, the greater the driving force for convection (Salisbury, 1991). Rajeev *et al* (1998) indicated that elevated leaf temperature of stressed leaves may be brought about by stomatal closure and resultant reduced evaporative cooling. Nainanayake (1998) also reported that leaf temperature increased significantly in the absence of transpirational cooling and consequently enhanced breakdown of chlorophyll leading to a decrease in the

photosynthesis rate. Furthermore, the report of Fukamachi-H *et al* (1999) shows that high leaf temperature and high vapor pressure deficit causes high transpiration, leading to low leaf water content.

4. Conclusions

The interaction between temperature and growing medium had a strong effect on the leaf water potential variation. Leaf water potential variation decreased inversely with temperature. The leaf chlorophyll was noted to be more related to the growing medium than to the temperature. However, when the plants were watered adequately, the leaf water relative content was less affected in all the rooms and for all the growing media.

Respiration and photosynthesis were seriously affected at relatively higher temperatures (Midday temperatures) as shown by the air/leaf temperature gradient. The air/leaf temperature gradient was as higher as the room air temperature increased.

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