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The variation of root zone temperatures in three different greenhouses

Rodzonetemperaturens variation i tre væksthustyper

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Summary

This publication presents the dynamic variation of the root zone temperature of potplants in black plastic pots, measured in two greenhouses clad with single glass and in one greenhouse clad with twin walled PMMA (acrylic).

The root zone temperature shows a strong seasonal variation. In the early autumn it exceeded the temperature limits where damage to root growth or other root activities may be expected. The dynamic variation of the root zone temperature, shows that there is a typical hysteresis from late day time values until early night time values.

No substantial differences between the three types of greenhouses were found. The type of bench seems to be of greater importance than the cladding.

Key words: Root zone temperatures, greenhouse.

Resumé

Denne beretning beskriver den dynamiske variation af rodzonetemperaturen af potteplanter i sorte plastpotter. Denne temperatur blev målt samtidig i to forskellige potter på samme bord, og det er den gennemsnitlige timeværdi af disse målinger, der danner grundlaget for vurderingerne og konklusionerne.

Undersøgelsen er en del af en større undersøgelse over energianvendelse i forskellige væksthustyper og omhandler et væksthus dækket med enkelt glas, et væksthus dækket med dobbelt glas og et væksthus dækket med kanalplader af PMMA.

Rodzonetemperaturen indsamlet på denne måde viser, at der er en stærk afhængighed af årstiden.

Tidlig på efteråret overstiger rodzonetemperaturen de temperaturgrænser, hvor alvorlige skader på plantevækst og rodvækst må forventes, hvis disse temperaturer vil fortsætte i længere tid.

Den dynamiske variation af rodzonetemperaturen viser en typisk hysterese ved dagens slutning.

Det har ikke været muligt i denne undersøgelse at påvise nogen væsentlige forskelle i rodzonetemperaturen mellem de forskellige væksthustyper. Inden for samme væksthustype synes det at have større betydning, om planterne står på lukkede borde eller på rendeborde.

Nøgleord: Rodzonetemperatur, væksthus.

Introduction

Plant growth and development in greenhouses are affected by different environmental factors, which vary within certain limits. Minimum temperatures are set at one level, while maximum temperatures may occur at a much higher level. Mean temperatures have often been related to plant growth, but mean temperatures do not reveal variations and, what is more important, the range of these variations.

In other words, we control root zone temperature at a certain setpoint, the minimum temperature. However, the final root zone temperature may differ due to solar radiation, cladding material, time of day and time of year.

The room temperature also changes from day to night, depending on the application of thermal screen, or changes in temperature setpoints.

Control of root zone temperatures has been the subject of a number of experiments, and it is well known, that the temperature of the root zone has a strong effect not only on root growth, but also on water uptake and nutrient absorption (1, 3, 4, 5, 6). The temperature range, around the maximum for the absorption of many nutrients is very narrow. Changes of only 2°C may have a noticeable effect upon the nutrient absorption (7, 9, 10). From this it appears that root zone temperatures exceeding 27°C are undersirable.

Nevertheless root zone heating in commercial nurseries seems to be mainly concentrated on minimum temperature control, rather than maximum temperature control (2).

As a result of this, only very little attention has been given to estimating whether root zone temperatures during day time exceed undesirably high values.

In August 1983 severe root damage was found in *Hedera* plants, which could not be related to excess watering or salt damage due to high nutrient levels.

An analysis of the root zone temperature showed that temperatures as high as 42°C had occurred. This initiated the investigation in the variation of root zone temperatures.

The results shown in this report are based on data collected during a research program on energy saving in different types of greenhouses. This experiment covers the experimental period from 28 August, 1984–5 May, 1985. Therefore information from the midsummer period is not available. The authors presume, however, that the situation will be the same or more severe during the summer.

This publication presents the ranges of root zone temperature as a result of their interaction with the cladding material or type of bench when a specified climatic control routine is applied.

Materials and methods

The greenhouses

In 1979 the Ministry of Energy supported the building of a multi factorial unit of five different greenhouses for research in the biological effect of energy saving (8). The greenhouses are identical in shape and size, 8×21.5 m^2 and lie 16 m apart.

Two of the greenhouses are clad with 4 mm glass in aluminium bars 800 mm apart. The gables are insulated with twin walled PMMA (greenhouses no. 1 and 4).

One of the greenhouses is clad with twin walled PMMA, 16 mm (steggdobbeltplatte), in aluminium bars, 1600 mm apart (greenhouse no. 3).

The height of the foundation is 0.8 m, which is substantially higher than in a traditional greenhouse.

Heating system

The system (excluding the bench heating) is designed to meet a temperature difference of 30°C between inside and outside air temperature. It consists of three separately operated systems. The top- and wall-heating, the bottom heating and the bench heating. The designed heat output is 83 kW (greenhouse no. 1).

The designed heat output in the greenhouse clad with twin walled PMMA is reduced with appr. 30% as compared to this value.

This is obtained by a reduction of the top- and wall heating system only.

The floor heating in all there greenhouses consists of 12 pipes, 0.5 m above the ground level.

The bench heating is placed in contact with the lower bench surface and insulated with 1 cm expanded polystyrene. The designed heat output is 9.3 kW (greenhouse no. 1 and 3).

The greenhouse with slatted benches has no bench heating (greenhouse no. 4).

Benches

Each greenhouse is equipped with four movable benches, $1{,}6 \times 18$ m^2 each. The closed benches are equipped with a dry capillary watering system, which consists of a capillary mat, Vattex, covered with a perforated plastic film and a watering and feeding outfit of five capillary nozzles/m^2 distributed below the mat.

The watering is controlled by an evaporimeter, which supplies 1.2 mm of water, whenever 1 mm is evaporated (greenhouse no. 1 and 3).

The slatted benches consist of ten troughs 10 cm wide and 6 cm apart. Each trough can only contain one single row of potplants.

Watering and feeding is performed by a flood and drain system, which allows the water level to rise approx. 2 cm. After half an hour the water is drained away and collected in a tank. The electrical conductivity of the fluid is automatically readjusted to preset values.

Watering intervals are regulated and vary from once a week in winter time to daily intervals in summer time. The intervals are chosen due to the expected need for water of the plants.

Screens

All greenhouses are equipped with top going shading screens of woven material which reduce the irradiance by appr. 40%. The screens are also applied during the night to improve the thermal abilities of the greenhouse. The greenhouse clad with single glass (no. 1 and 4) have an additional thermal screen of peritherm. The thermal screen is placed over the shading screen.

Aspirated screen

Dry and wet bulb temperatures for room temperature and airhumidity are measured by pt 100 thermosensors placed in an aspirated screen at an air velocity of 1 m/sec. The aspirated screen is placed 0.3 m above the average plant canopy. The sensors for the thermostat and hygrostat are also placed in the same aspirated screen.

Root zone temperature

The root zone temperature is measured by two pt 100 thermosensors. The thermosensors are placed in two 10 cm black plastic pots in which plants of *Begonia elatior* are grown during the experiment.

The mean temperature of two measurements is used for analysis.

Solar radiation

The solar radiation is measured by a Kipp & Zonen solarimeter, mounted on a revolving rod of 0.5 m. The rotation takes 3 minutes. The sensor is placed above the heating pipes but below the screens. The values will therefore be dependent on whether the shading screens have been drawn or not.

Climatic control

Room temperature

The room temperature is controlled by a thermostat at 18°C. The heating is supplied by alternating activation of firstly the top- and wall heating system, and with further demand of heat, the bottom heating system (greenhouse no. 1 and 3).

The greenhouse with the slatted benches (greenhouse no. 4) has the first priority on the bottom heating system.

Bench heating

The bench heating is activated by a thermostat, of which the sensors are placed in two pots in which plants are grown on the bench.

Heat is supplied whenever the average temperature in the pots is below 20°C.

The greenhouse with the slatted benches has no bench heating system and the soil heating is supplied by the convective heat transfer from the bottom heating system to the pots.

Air humidity

The air humidity is controlled by a hygrostat at a setpoint of 92% RH. Air drying is performed by alternating heating and ventilation until air humidity has dropped to 88% RH.

Screens

Whenever solar radiation surpasses 210 W/m^2, shading screens are drawn. Both thermal screens and shading screens are applied, whenever the irradiance is below 5 W/m^2.

Computations

All observations are made, with a crop of eight different potplants in the greenhouse from 27 August, 1984–5 May, 1985.

The curves are based on identical computations for all factors.

Measurements take place every ten minutes and the hourly averages are used for analyzing. The trimmed range is based upon fractiles which show the highest value after excluding 5% of the observed maximum values (upper 5% fractile) or the lowest value after excluding 5% of the observed minimum values. The area between shows the trimmed range of 90% of all observations (90% trimmed range). Furthermore the means of all observed values were calculated.

The application of shading screens and/or the abscence of solar radiation totally changes the progress of environmental parameters during the night.

Therefore both day and night values are presented separately in this paper.

On the other hand, a pronounced hysteresis is observed for root zone temperatures, from the late day values to the early night values (Fig. 2.).

While looking at the curves and tables, one must well bear in mind, that the values represent hourly averages of six observations at two places and not instant temperatures. This process will level out extreme values and consequently the variation.

Results and discussion

Seasonal variations

The 90% trimmed range and the mean of the root zone temperatures are strongly related to the time of the season, for all three greenhouses.

During the winter the range of the variation is reduced and high root zone temperatures do not occur.

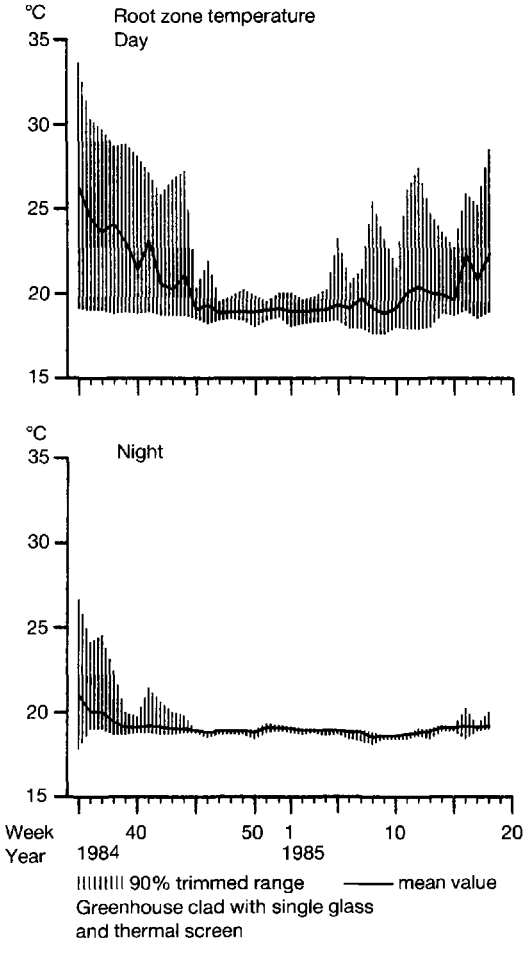

Fig. 1. *The 90% trimmed range and the mean root zone temperatures in a greenhouse with single glass and thermal screen. Day and night values from the experimental period 27 August, 1984–5 May, 1985.*
Note that high root zone temperatures lag behind from day to night in week 35–38.

This is not as much revealed by the lower 5% fractile as by the mean and especially by the upper 5% fractiles. High temperatures do occur during the month of September and April. If root zone temperatures over 27°C are considered for undesirable, this limit is exceeded quite often.

The general impression is the same for all three greenhouses, and therefore only the results from the green house clad with single glass are shown (Fig. 1).

Diurnal variations of root zone temperatures

It is obvious that high root zone temperatures are found during the day. It is also obvious that the high temperatures are strongly related to the time of the year.

The range of the variation of the root zone temperature shows a distinct difference between day and night in the late summer and early spring.

During the night a stable situation prevails with small variations. In the late morning hours this changes totally. A steep rise in the trimmed range indicates that root zone temperatures at any level may occur.

Furthermore a distinct hysteresis is observed from the late day time value towards the early night time values (Fig. 2).

Observations that are made in April, though showing the same pattern, have a more reduced variation and significantly lower mean values during the day time (Fig. 3).

Levels of root zone temperatures

In the previous sections it has been seen that undesirable high temperatures may occur during day- and night-time in the month of September and April. Dividing all collected day time values into different temperature levels shows, that high temperatures do occur quite often. Furthermore the values show that the difference in the type of bench seems to be of more importance in avoiding high root zone temperatures, than the type of greenhouse (Table 1).

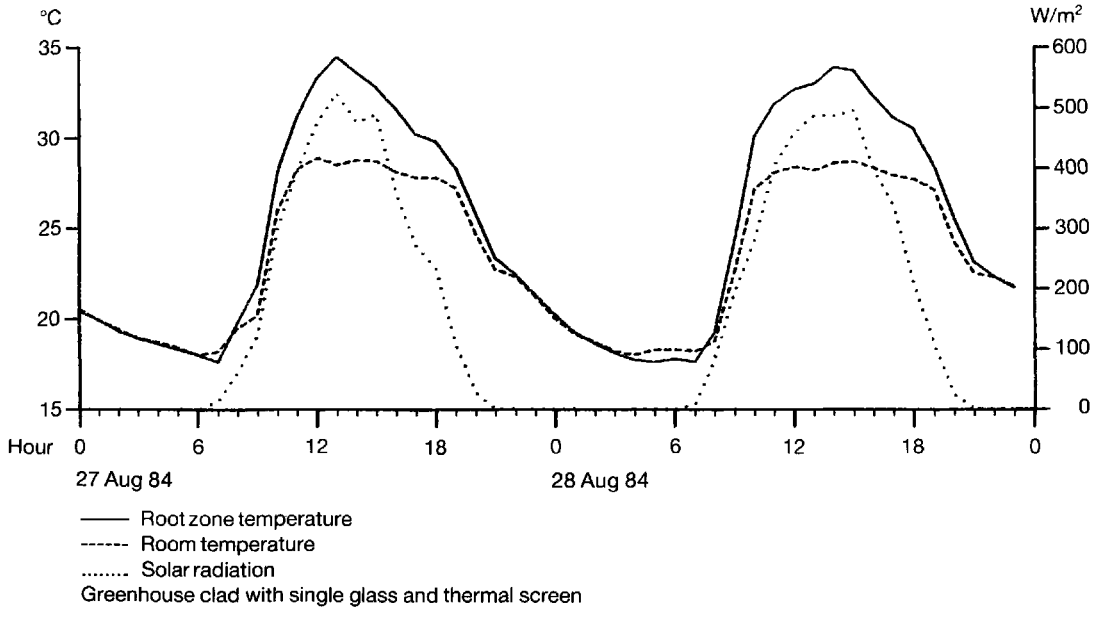

Fig. 2. The root zone temperatures and the room temperature in two adjacent diurnal periods. Note that shading screen and ventilation at 28°C do affect room temperatures while root zone temperatures increase unaffected.

Table 1. Accumulated number of hours, where root zone temperature has exceeded the temperatures indicated. The values are collected separately for the day and night during the experimental period from 27 August, 1984–5 May, 1985. Note that there is a greater difference between the two types of benches in the same type of greenhouse, than between the two types of greenhouses and the same type of benches.

Greenhouse no.:		1		4		3	
Greenhouse type:		single class				twin walled	
Benches:		dry capil.		slatted		dry capil.	
Root zone temperature	°C	day	night	day	night	day	night
	34	1		0		0	
	33	5		3		6	
	32	9		5		10	
	31	14		6		17	
	30	33		15		51	
	29	66		41		83	
	28	125	1	74	0	144	0
	27	184	2	125	1	202	2
	26	248	4	178	2	289	5
	25	345	12	256	5	388	9
	24	428	18	348	8	490	20
	23	505	31	431	15	589	36
	22	585	51	518	29	701	61
	21	737	84	616	50	852	96
	20	975	128	799	95	1088	160

The durations of high root zone temperatures

In the previous section it was obvious, that high root zone temperatures would occur, but it is also important to know how quick these temperatures rise and how long they will prevail.

Therefore we have looked upon the temperature changes from one hour to the next.

This reveals that changes only occur in small steps – 1 to 2°C. From this it may be concluded that high root zone temperatures increase and decrease slowly and consequently, that coherent periods of high (or low) root zone temperatures prevail. In this the three types of greenhouse do not vary much (Table 2).

Root zone temperature progress

Root zone temperatures and room temperature show the same progress until maximum room temperature control setpoint at 28°C. The application of ventilation and shading screens showed to have an effect upon the room temperature. Root zone temperatures, on the other hand, continue to increase apparently unaffected (Fig. 2).

Table 2. Changes in root zone temperature from one hour to the next during the experimental period from 27 August, 1984–5 May, 1985. Note that changes up or down only presumely occur in small steps, this indicates that stable periods are prevailing.

Greenhouse no.:		1	2	4
Greenhouse type:		single glass		twin walled
Benches:		dry capil.	slatted	dry capil.
Changes in °C	7	0	0	2
	6	1	1	1
	5	1	1	1
	4	3	5	7
	3	7	13	14
	2	85	78	81
	1	229	196	241
	0	2774	2428	2620
	− 1	2532	2842	2661
	− 2	263	215	272
	− 3	74	72	65
	− 4	4	6	5
	− 5	0	1	2

From this we may conclude that while shading screens and ventilation are adequate means to control maximum room temperatures they do not seem to have a noticable effect on the root zone temperature.

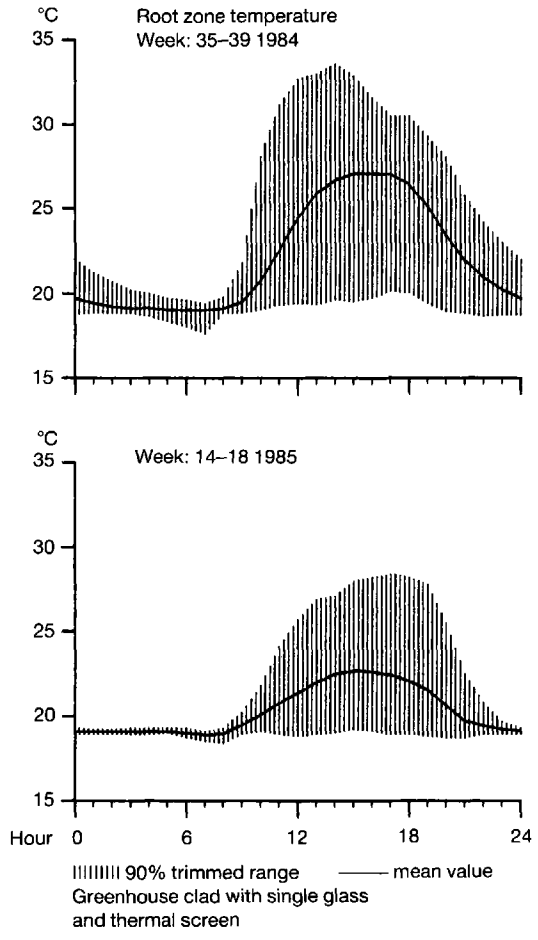

Fig. 3. *The 90% trimmed range and the mean root zone temperature in a greenhouse with single glass and thermal screen. Diurnal variation from late summer and early spring. Note the identical progress though less pronounced in the spring.*

Conclusion

The measurements of the root zone temperature in three different greenhouses show that undesirably high values will occur during day time in newly potted plants in the month of September. Also in April a risk of high root temperatures is present. It seems to be important to draw the attention of growers and research workers to these phenomena. This temperature progress has so far rarely been reported due to the fact that the main interest has been in minimum temperature control. Root decay or other less noticeable damage may occur when the high root zone temperature prevails for a longer period. The effect of the shorter periods reported in this paper is not known. At this time no advice can be given as to how to avoid these high root zone temperatures nor how to avoid possible damages.

The application of shading screens, in the three greenhouses, does not seem to avoid the problem.

The type of bench (closed capillary or slatted) seems to be of greater importance than the type of greenhouse (single glass or twin walled PMMA).

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