MICROCLIMATIC CONDITIONS IN TROPICAL AND SUBTROPICAL GREENHOUSES IN THE WINTER PERIOD

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Abstract

This paper summarises the results of measurement of air temperature, humidity and global radiation in two different types of greenhouses used for very special plants and flowers during a winter period of the year. According to the results of measurement the indoor conditions were optimal in the Tropical greenhouse. The inside conditions in the Subtropical greenhouse were considerably low during the coldest days when the minimum of inside temperature was closed to critical value for cultivated plants. The course of indoor radiation in greenhouses agreed with trend of outside global radiation measured by official meteorological station of CULS Prague. The average global radiation in tropical greenhouse is influenced by the shadow of the central corridor, but nevertheless the global radiation in the subtropical greenhouse was significantly lower than in tropical greenhouse in the same time.

Key words: special plants, greenhouse, tropics, subtropics, microclimate

INTRODUCTION

New technological and technical aspects of new greenhouses should be based on experience obtained from performance of existing constructions. Proposals of new designs and suitable projects influence in large scale also production parameters, related industry, human health etc. (De Montis, 1999). Optimal environmental factors for crops are temperature, humidity, radiation, air concentration of CO_2. Light, heat, air humidity and CO_2 are indispensable for crops developing (Volf, 1991; Abreu, 1994; Baptista, 2001). This article is focused on the air temperature, air humidity and global radiation conditions. The relationship between the air temperature and plant growth is extremely complex (Serrano, 2002). There are physical models describing this relationship and mathematical models based on these parameters. For this reason a particular attention was paid to measuring of these microclimatic parameters (Krasovitski, 1996; Boulard, 1997; Litago, 1998; Gascone, 1999; Baptista, 2001).

For all crops are defined minimum, maximum and optimum conditions for the best growing and development. In our case, these conditions temperatures are defined by crops, which are cultivated in tropical and subtropical greenhouse. Practical values recommended for tropical greenhouse are following. Optimum air temperature is 15°C during the winter period and maximum average temperature should be under 18°C. In the subtropical greenhouse, there is an optimum temperature about 10°C during winter and average humidity between 70 to 80%. Minimum temperature in subtropical greenhouse should be above 5°C because of the cultivated plants.

MATERIALS AND METHODS

Data for this study were measured in a tropical and a subtropical greenhouse in Czech University of Life Sciences Prague. Several previous experiments were made in greenhouses used for cultivation of decorative flowers (Kic, 2005). First set of these data were collected in winter period during seven days, every 15 minutes, (since January 17th to January 24th 2009). Second set of these data were measured during one day, (27th January 2009). The outdoor conditions were measured by The Meteostation of the Czech University of Life Sciences Prague.

The tropical greenhouse is 20 m long, 12 m wide; the mean height is 6 m. Typical plants are: Vanilla planifolia (Mesoamerica), *Anona muricata*, *Citrus grandis*, *Musa cavendishii* (China), *Cocos nucifera* (Southeast Asia) and others. Sensors for recording measurement were situated 8 m from the south side, 6.5 m from east side and 2 m above the floor. Immediate readings were taken on 15 sites in two different heights (100 cm and 200 cm). First 5 sites were 3 meters from west part of greenhouse, second 5 sites were in the middle of greenhouse and the last 5 sites were on east part of greenhouse (3 m off).

The subtropical greenhouse is used for cultivation of typical plants like *Camelia sinensis* (China), *Macada-*

mia integrifolia, *Catha edulis*, *Citrus deliciosa* (China), *Diospyros kaki* (China), *Olea europea* and the others. The greenhouse dimensions are: 25.4 m long, 6 m wide and the main height is 3 m. Sensors for recording measurement were situated 10 m from the south side, 1.5 m from east side and 0.7 m above the floor. Immediate readings were taken on 14 sites in two different heights (80 cm and 200 cm). This measurement was taken in two lines, first 7 sites were on west side and second 7 sites were on east side, both of them 1 m from east and west walls.

Both greenhouses are with North-South orientation and they are almost 40 years old. A wall that connected greenhouse and central corridor is situated on the North in subtropical greenhouse and on the South in tropical greenhouse.

The variables of humidity and temperature in greenhouses were directly measured by capacitive humidity sensors FHA6461 with Almemo connector, measuring range: 5 to 98% rh, operating temperature: –20 to +80°C. Data logging was allowed by Almemo data loggers.

The variables of global radiation were directly measured by global radiation sensors FLA613GS with Almemo connector, measuring range: 0 to 1200 W/m^2, 400 nm to 1 100 nm, operating temperature: –20 to +60°C. The measurement in tropical greenhouse was shorter because of technical fault on sensor.

To receive exact information about the internal microclimate during the winter period, data of main microclimatic parameters were registered and also the space microclimatic uniformity was evaluated by immediate readings.

RESULTS AND DISCUSSION

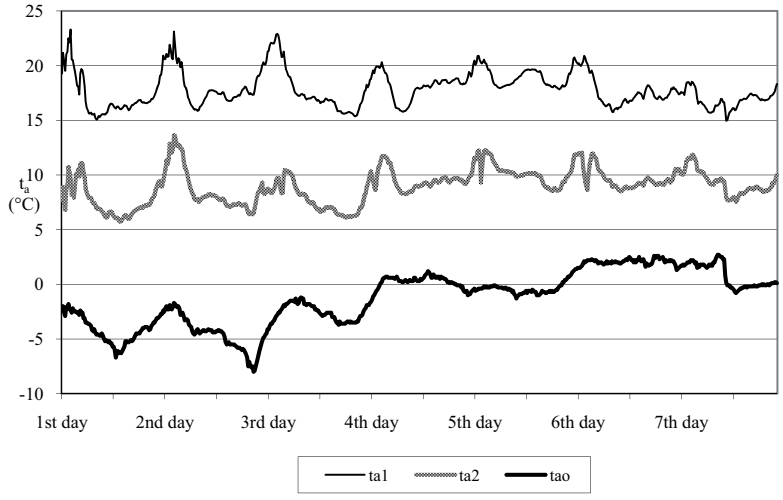
Temperature as a main parameter is under particular interest in many publications (Papadakis, 1989; Krasovitski, 1996). The main statistical parameters of the recording measurement, air temperature t_a, relative humidity rh_a and global radiation E, are observed in Table 1. Table 1 contains of average (aver), maximum (max), minimum (min) and standard deviation (sdev) of the measured variables.

The Figure 1 shows the air temperatures in the greenhouses and outdoor air temperature during recording measurement. The changes of temperature have similar

Tab. 1: Statistical parameters of air temperature, relative humidity and global radiation in tropical and subtropical greenhouse and outdoor conditions during recording measurement

	Air temperature t_a (°C)				Relative humidity rh_a (%)				Global radiation E (W/m^2)			
	aver	max	min	sdev	aver	max	min	sdev	aver	max	min	sdev
Tropical greenhouse	17.84	23.3	14.96	1.6	62.88	81.3	48.1	7.79	16.8	120	0	73.93
Subtropical greenhouse	8.98	13.61	5.74	1.57	86.56	97.3	53.9	5.87	5.86	47	0	9.28
Outdoor conditions	–1.23	2.7	-8	2.55	83.56	95.3	53.5	9.22	31.15	352	0	54.56

Figure 1: Air temperature in tropical greenhouse (t_{a1}), subtropical greenhouse (t_{a2}) and outdoor air temperature (t_{ao})



progress like outdoor temperatures, which is obvious between first till third day of measurement, when the outdoor temperature was under the zero, in Figure 1. We can see also, that the temperatures were more invariable during the nights than during the days.

The highest individual air temperatures in the greenhouses were almost in same time, afternoon, similarly in both greenhouses.

The Figure 2 shows the relative humidity in the greenhouses and outdoor relative humidity during recording measurement. The highest average of relative humidity was in subtropical greenhouse 86.6% and it resembled average outdoor relative humidity 83.6% by the contrast to average relative humidity in tropical greenhouse where the average relative humidity was only 62.9%. In subtropical greenhouse, there was interesting that when the temperature was above zero (see Figure 1) the relative humidity inside almost copied the outdoor relative humidity (see Figure 2). This relation was well obvious between the third and seventh day of measurement. Internal relative humidity was analysed and compared in different publications (Litago, 1998; Baptista, 2001). Especially problems of condensation on the cover during the winter period are motivation for humidity evaluation.

The Figure 3 describes the global radiation in the greenhouses and outdoor global radiation during recording measurement. The average global radiation in tropical greenhouse was 16.8 W/m^2 and it was a little bit more than one half of the average outdoor global radiation where it was 31.15 W/m^2. In subtropical greenhouse there was the value of average global radiation only 5.86 W/m^2.

The trend of global radiation in both greenhouses was practically similar with outside global radiation, see Figure 3. A number of authors have studied the influence of greenhouse and their cladding surfaces upon the solar ir-

Figure 2: Air relative humidity in the tropical greenhouse (rh_{a1}), subtropical greenhouse (rh_{a2}) and outdoor relative humidity (rh_{ao})

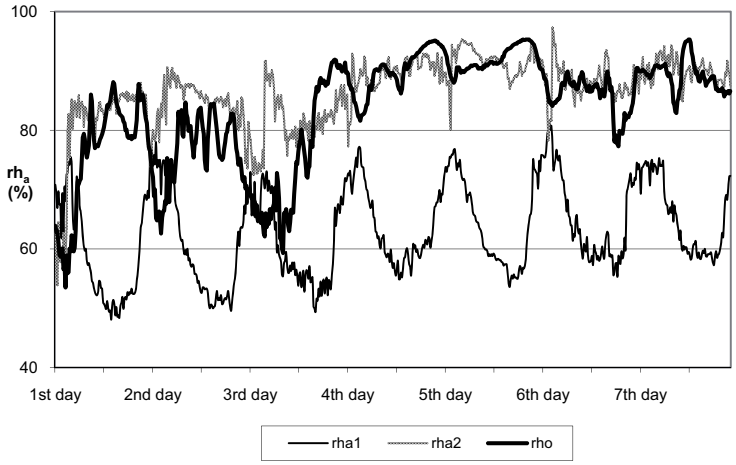
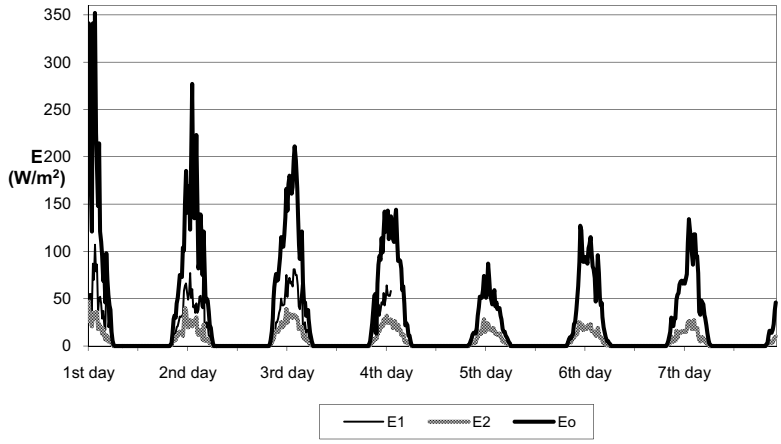


Figure 3: Global Radiation in the tropical greenhouse (E_1), subtropical greenhouse (E_2) and outdoor global radiation (E_o)



Tab. 2: Statistical parameters of air temperature, relative humidity and global radiation in definite levels of tropical and subtropical greenhouse during immediate readings.

		Air temperature t_a (°C)				Relative humidity rh_a (%)				Global radiation E (W/m^2)			
		aver	max	min	sdev	aver	max	min	sdev	aver	max	min	sdev
Tropical greenhouse	100 cm	20.84	21.73	19.9	0.58	64.6	70.5	55.6	4.75	24.87	72	7	19.51
	200 cm	20.87	21.9	19.85	0.64	67.66	77.6	53.7	5.78	31.87	91	7	26.53
	average	20.86	21.9	19.85	0.61	66.13	77.6	53.7	5.5	28.37	91	7	23.55
Subtropical greenhouse	80 cm	11.70	14.53	10.41	1.35	59.44	63.9	54.9	2.16	36.07	86	14	20.59
	200 cm	11.66	14.28	10.42	1.29	62.76	66.7	60.1	1.66	67.71	128	7	31.11
	average	11.67	14.53	10.41	1.32	61.1	66.7	54.9	2.55	51.89	128	7	30.76

radiation observed inside (Albright, 1985; Critten, 1986; Rosa, 1989; Geoola, 1994). Our results will be used in the next research work to develop more these ideas.

The main statistical parameters of immediate readings, air temperature t_a, relative humidity rh_a and global radiation E, are shown in the Table 2. The Table 2 contains of average (aver), maximum (max), minimum (min) and standard deviation (s. dev) of the measured variables.

The average air temperature was nearly 3°C higher during immediate readings (see Table 2) than the average air temperature during recording measurement in tropical greenhouse (see Table 1). In subtropical greenhouse, there was the average air temperature higher by 2.7°C during immediate readings than the average air temperature during one week measurement.

There was significant difference between air temperatures of immediate readings in both levels in tropical greenhouse from east side to west side. The temperature difference was the utmost between north-west corner and south-east corner of greenhouse and the difference was almost 2 K in 200 cm high level and 1 K in 100 cm high level. The west middle part of greenhouse in 200 cm high level was the hottest place with 21.9°C and the coldest place in greenhouse, it was in south-east corner in 200 cm high level with 19.85°C. The minimum variance of air temperature was in middle part of greenhouse, where temperature was with differences less than 0.57 K in both levels of measurement.

The air temperature uniformly increased from the south part to the north part of subtropical greenhouse in both measured levels. There was detected difference more than 3 K between temperatures in north (more than 14°C) and south parts (less than 11°C) of subtropical greenhouse in both height levels. There were no higher vertical difference of the temperature than 0.6 K in any place or level.

The average relative humidity during immediate readings was lower by 3.25% than the average relative humidity during recording measurement in tropical greenhouse. The minimum of relative humidity during immediate readings was higher by 3.6 % than a minimum relative humidity during recording measurement in tropical greenhouse (Table 1 and 2).

The average relative humidity during immediate readings was lower by 25.5% than the average relative humidity during recording measurement in subtropical greenhouse. The minimum fo relative humidity during immediate readings was higher by 1% than minimum relative humidity during recording measurement in subtropical greenhouse.

The relative humidity was very variable in both measured levels of tropical greenhouse. The relative humidity was significantly lower in west part of greenhouse than in the middle or east part of greenhouse. The maximum of relative humidity was 70.5% in tropical greenhouse also in 100 cm height level near to north-east corner. The minimum in this height level 55.6% was in south-west corner. The difference was about 15%. The maximum 77.6% of relative humidity for 200 cm height level was in the east site of tropical greenhouse and the minimum 53.7% was near to north-west corner. The difference was more almost 24%. The relative humidity was increasing from south to north part of greenhouse at 200 cm level in the whole profile.

In the Table 1 and Table 2 we can see that the maximum of global radiation in tropical greenhouse during immediate readings was lower by 29 W/m^2 than the maximum of global radiation during recording measurement. There was significant difference between north-west corner and rest of tropical greenhouse in both height levels of measurement. The highest value 91 W/m^2 was in 200 cm high in north-west corner. Horizontal distribution of global radiation in the middle part of tropical greenhouse was similar in both height levels.

Tables 1 and 2 show that the maximum of global radiation was higher by 81 W/m^2 during immediate readings

than maximum of global radiation during recording measurement in subtropical greenhouse. The global radiation was continuously decreasing from the north part to the middle of subtropical greenhouse and from the middle to the north part continuously increasing in 80 cm height level. The global radiation in 80 cm height level was notably lower than in 200 cm height level, where the distribution was not so continuous, nevertheless with resembling character.

CONCLUSIONS

The indoor conditions characterised by relative humidity and temperature microclimate were optimal in tropical greenhouse which is used for cultivation of specifically sensitive plants. The inside conditions in subtropical greenhouse were considerably low in some days when the minimum of inside temperature was closed to critical value for cultivated plants (5°C).

This situation could be dangerous for cultivated plants if the critical value of the temperature approximating 5°C, would stay for longer time. Also the minimum relative humidity in tropical greenhouse was under the required value for plants from this area.

The indoor temperature was influenced by the attached heated central corridor. The temperature in the neighbouring north part of subtropical greenhouse was higher by 3°K than at the other end.

The course of indoor radiation in greenhouses agreed with trend of outside global radiation measured by official meteorological station of CULS Prague.

The average global radiation in tropical greenhouse is influenced by the shadow of the central corridor, but nevertheless the global radiation in the subtropical greenhouse was significantly lower than in tropical greenhouse in the same time.

ACKNOWLEDGEMENT

This paper was prepared with a kind support of grant Nr. 31170/1312/3118.

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Received for publication on December 15, 2009
Accepted for publication on January 11, 2010

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