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STUDY OF INLET LIGHT SPECTRUM'S EFFECT ON PLANTS GROWTH - THE LIGHT TRANSMITTANCE DECREASED WITH INCREASING GLASS THICKNESSES

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Abstract

The aim of this study was to measure some effects of light spectrum on the growth of greenhouse plants to be able to reduce overheat in hot summer periods. To reduce the light's impact two series of experiments were carried out. In the firs tests various double glass panels were involved. Light spectrometer was used to measure the transmitted light spectrum of the panels in empty and in different colour water-filled state. The red colour fluid was the one which transmitted the spectrum range appropriate for the photosynthesis of plants the best, it also filtered the IR range most. In the second test series three groups of strawberry seedlings were used to test the effect of filtered light transmittance. The plants below the red panel were taller, their leaf number was larger, and no sunburn was found compared to those under plain water and plain air.

Keywords

light spectrum, greenhouse, photosynthesis

1. Introduction

Light is one of the most important climatic factors for the photosynthetic activities of the plants. Crop growth is directly related to the available solar radiation [1]. Spectrally analyzing the absorption recesses of the various plant species are in the same places for each plant species (a water content manifestation), given the differences in the number of DN-levels [2].

Greenhouses create optimal climate conditions for crop growth and protect crops from outside pests. At the same time greenhouse production increases water use efficiency and makes integrated production and protection (IPP) possible [3].

The abiotic stress reduces the growth of plants, the intensity of the photosynthesis. Such stress is the high-intensity light and excessive heat. These conditions occur in greenhouses not only during the high summer heat waves. The short-wave solar radiation (300 to 2500 nm wavelength) enters through the transparent roofing material in the greenhouse and is absorbed by plants, installation and construction parts. This heats the air temperature of the greenhouse. The technical requirement for greenhouses is to reach the optimum light transmission and thermal insulation for the high plant productivity by the use of appropriate covering [4]. With theoretical advances an understanding of light transmission processes an improved evaluation and design of greenhouses can be achieved [5], [6].

The greenhouse production is most typical in the vegetable production. The production is continuous, running also in summer. The operating costs in summer give the shading and the ventilation . The aim of this study was to measure the spectrum of transmitted light through a variation of glass covers to improve light and temperature conditions for plants grown in greenhouse, and so to reduce the costs with simple technical methods [7].

2. Materials and Methods

To reduce the impact of light two series of experiments were carried out. In the first one different double glass panels were tested to see their light transmittance. All the panels were 20x20 cm large. Their thickness was different, due to the different glass sheets thicknesses (3, 4 and 6 mm respectively) and inner distances between the glass sheets (8, 12 and 20 mm respectively). This way 9 different panel variation were constructed. The tests were carried out with empty, plain water filled and colour water filled panels. The transmitted light spectrums through the panels were measured by an Ocean Optics, USB 2000 spectrometer. As light source a Landlite (GU10, 230V, 50W) halogen electric lamp was used. Its spectral image compared with the sun's spectrum is shown on Figure 1. There is a considerable difference between them, but for the comparison of different panel arrangements it seemed to be an acceptable solution. During the tests red, yellow, green and blue coloured water was used. For colouring the water Max Color food colours were used, made by the Hungarian company Szilas Aroma Ltd.

The testing rig was composed of the lamp, the panel and the spectrometer arranged in a black box. It enabled the easy change of panels (Figure 2).

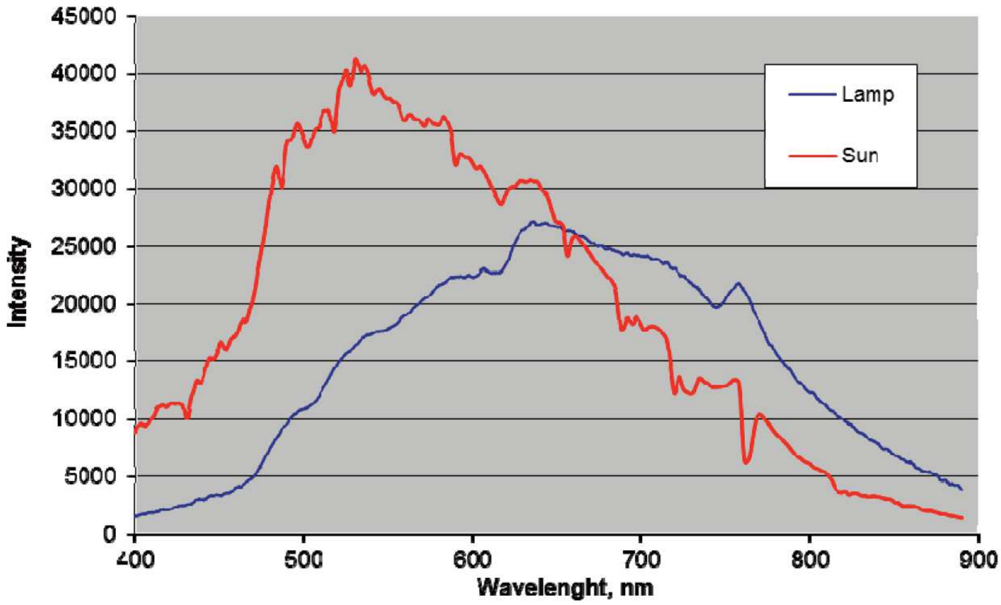

Figure 1. The light spectrum of the Landlite halogen lamp and the Sun

Figure 2. The arrangement of transmittance tests of panels

In the second test series three groups of strawberry seedlings were used to test the effect of filtered light transmittance. The test arrangement included two double glassed panels of 80 cmx80 cm size, fixed on a frame at 50 cm above ground in horizontal position, next to each other. In both cases the top glass was 3 mm, the bottom one 6 mm tick to withstand the water pressure. One panel was filled with clear water, the other one with pale red water. One group of strawberry was placed below the pale red water filled panel, the other group below the clear one (Figure 3). The third group was regarded as control: it was not sheltered.

Figure 3. Test arrangement for comparing plant growing

Table 1. Temperatures of surfaces and of air

	Temperatures (°C)				
Date	plants	roof	panel with water	panel with red water	ambient air
2015.08.07	32,8	57,9	34,4	37,4	35,8
2015.08.10	34,2	58,2	34,5	37,6	36,5
2015.08.17	24,1	28	24,6	25,3	28,5

The seedlings were the same kind, the same generation, had the same physiological capabilities. The measurements were carried in August 2015. The temperature under the panels and in the environment was regularly measured by a Fluke thermal camera. Some characteristic values are shown in Table 1.

Gas exchange measurements were also carried out on the leaves of the plants using an infrared gas analyser (LCI, ADC Bioscientific Ltd., Hoddesdon, UK). CO_2 assimilation, transpiration rate, leave temperature, photosynthetic activity and PAR (Photosynthetic Active Radiation) spectrum were measured.

3. Results and Discussion

The results for light absorptivity of empty glass panels are shown in Figure 4. The data in the left figure indicate the effect of glass thickness, the figure on the right show how the size of the spacer influences the absorptivity.

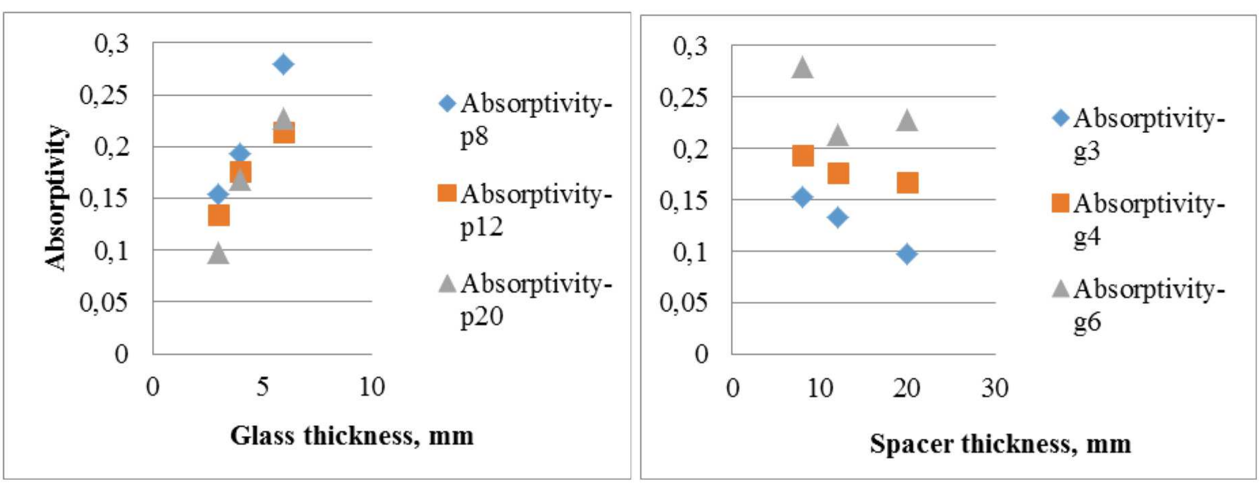

Figure 4. Absorptivity of the of empty glass panels

From the measured data it was clear, that the light transmittance decreased with the increase of glass thickness, but with the increase of spacer the transmitted light intensity also increases.

When the panels were filled with water, in the thermal range (in the IR range) a reduction appeared (Figure 5). According to other tests with growing spacer the decreasing transmittance trend appeared. Thicker layer of water reduced more the light intensity.

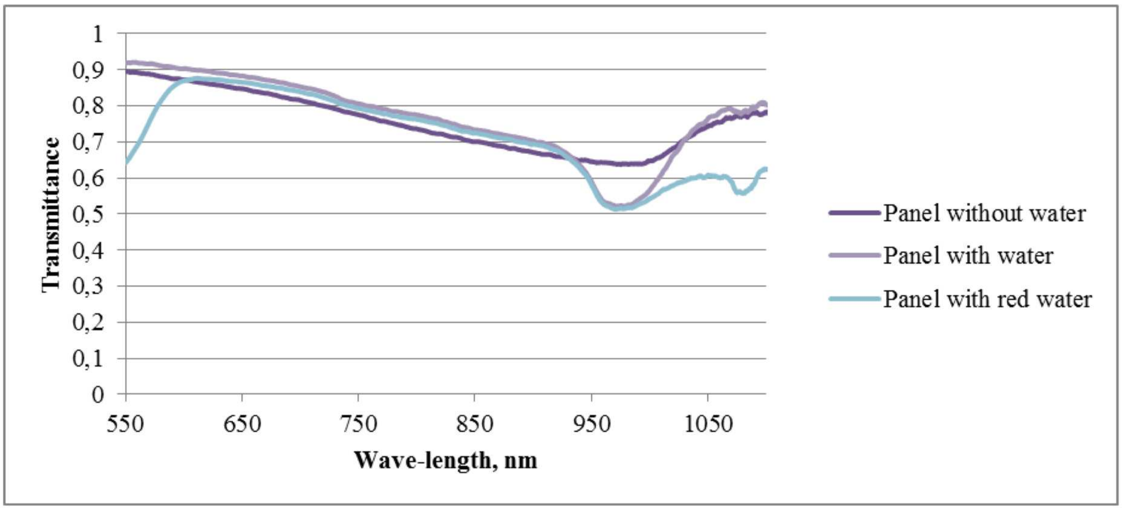

Figure 5. Transmittance of glass panel (without water, with water, with red water)

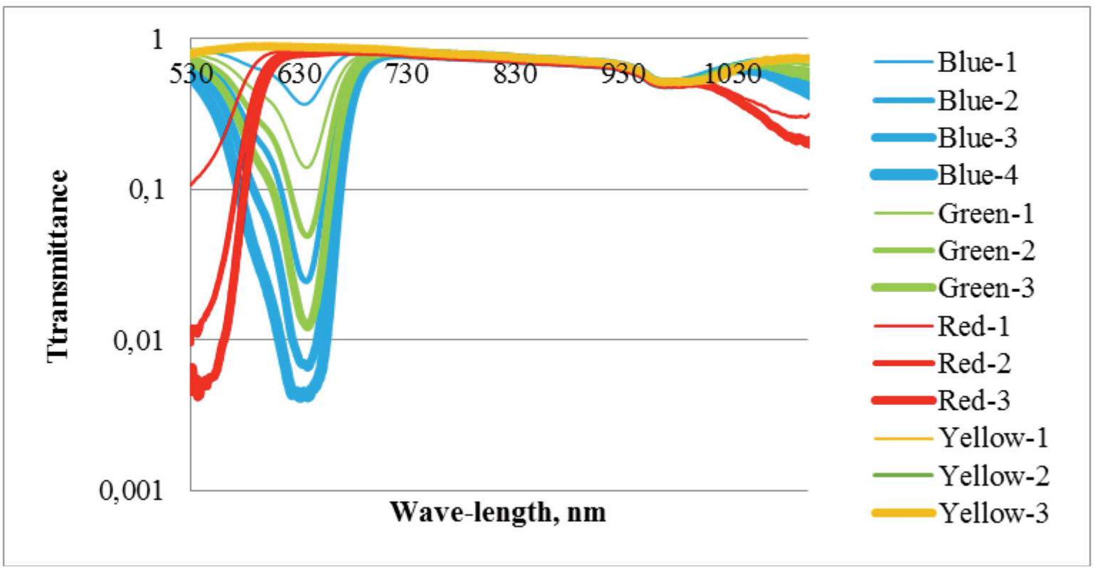

Figure 6. Transmittance of colored water panels

The transmittance test results of yellow, blue, red and green coloured water are shown on Figure 6. Compared with clear water the yellow water gave hardly any difference. A smaller reduction in higher wave-lengths was found in case of the blue and green fluid, but in the active region of photosynthesis the transmittance reduced significantly, which does not meet our expectations. Using the red colour fluid the spectrum range needed for the photosynthesis of plants was transmitted, while the IR range was filtered mostly. On Figure 6 the different thicknesses of colour lines belong to the different concentrations of colours in water.

The results of the gas exchange measurements are presented in Figures 7 and 8. The leaves of 8 plants under the clear water panel and 9 plants under the red panel were measured with the infrared gas analyser.

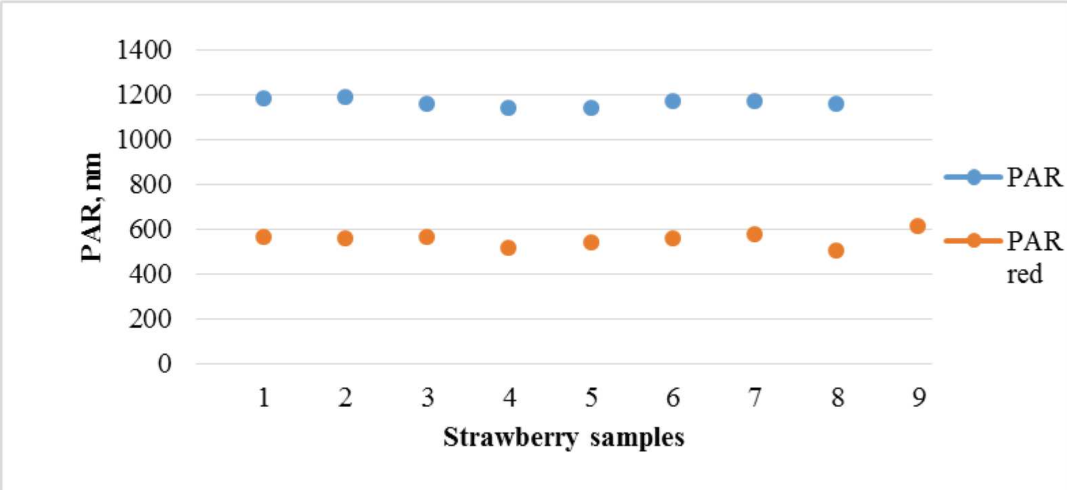

Figure 7. PAR values of strawberry samples under the panels

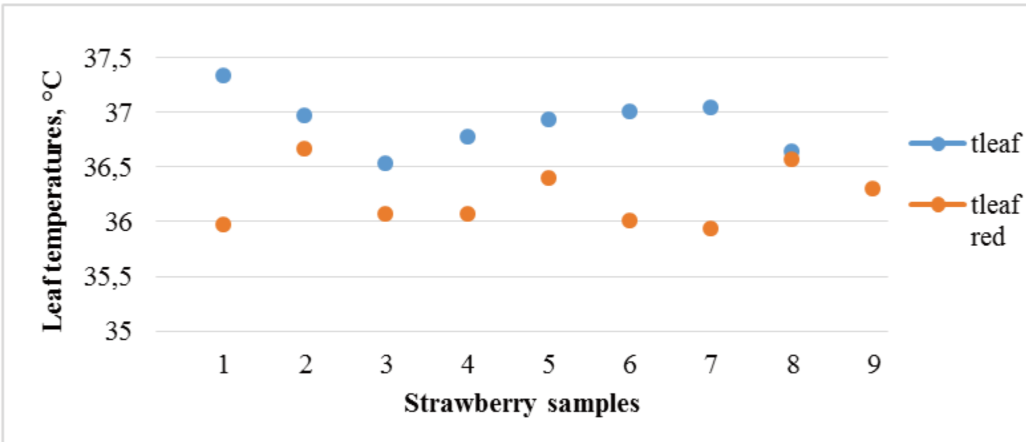

Figure 8. Leaf temperatures of strawberry samples in °C

Under the red panels, the PAR values was only half of that measured under the "clear" panel. Under the red panel the leaf temperatures were always lower by 0,5-1 °C compared with the clear water filled panel. The red panel protected better the plants from light and heat stress. The active transpiration values (Figure 9) were also higher (or the same) as under the "clear" panels.

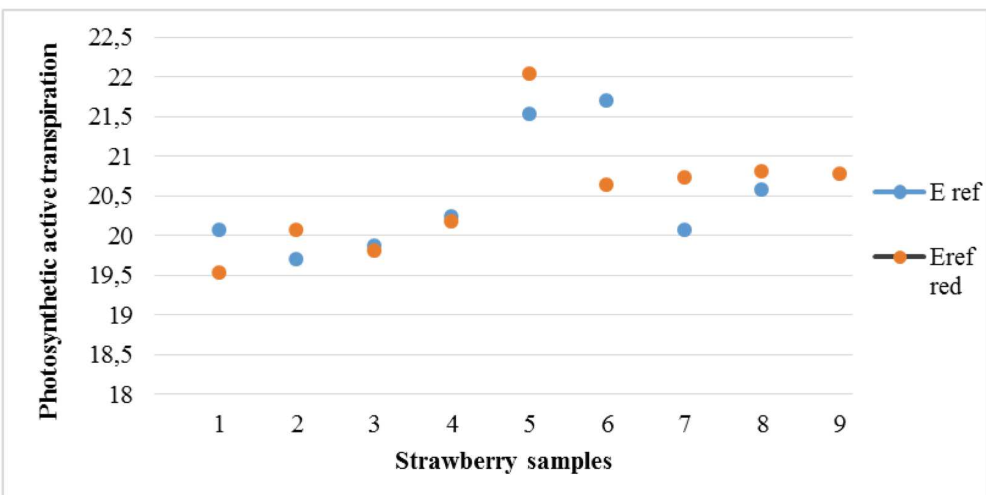

Figure 9. Photosynthetic active transpiration values of strawberry samples

Visual examination at the end of August has shown, that all control plants (not under the panels) died, almost all plants under the plain water panel was smaller and signed of a slight sunburn on the leaves, especially along the edges, the inside of the stock has remained completely intact. The plants below the red panel were taller, the leaf number was larger, and no sunburn at all was found. The number of plants has grown, the typical vegetative reproduction of strawberries started. In addition, several fruits have been on the seedlings.

4. Conclusion

From the test results it is clear, that the light transmittance decreased with increasing glass thicknesses, but the transmitted light intensity increased with the higher inner distance values. Compared to other coloured water only in the red fluid transmitted the spectrum range needed for the photosynthesis of plants, while the IR range was filtered strongly. This statement was proven by a simple fruit growing test: strawberries grown under pale red shelter were much less impacted by high ambient temperature, while plants under no colour shelter suffered from sunburn, and control plants without any shelter died off. On the base of these first results further research work is planned to clarify more exactly the effect of the red colour fluid filled double glass cover.

References

[1.] Soriano T., Hernandez J., Montero J. I., Castilla N.: 2009. Solar radiation transmission in Mediterranean plastic greenhouses. Acta Horticulturae, Vol. 807, pp. 73–78.
http://dx.doi.org/10.17660/ActaHortic.2009.807.6

[2.] Kardeván P., Reisinger P., Tamás J., Jung, A.: 2005. A parlagfű detektálás távérzékelési módszerei-nek vizsgálata. I. rész – A távérzékelési képek osztályozási hatékonyságának növelése a parlagfű (Ambrosia artemisiifolia L) reprezentatív spektrumai-nak terepi DGPS mérésekkel történő kiválasztásával. Magyar Gyomkutatás és Technológia, Vol. 6., No. 2, pp. 53–67.

[3.] von Zabeltitz C.: 2011. "Light Transmittance of Greenhouses." Integrated Greenhouse Systems for Mild Climates. Springer Berlin Heidelberg, 2011, pp. 137-143.

[4.] Briassoulis D., Waaijenberg D., Gratraud J., von Elsner B.: 1997. Mechanical Properties of Covering Materials for Greenhouses: Part 1, General Overview, Journal of Agricultural Engineering Research, 06/1997, pp. 67-69.

[5.] Critten D. L.: 1989. Light Transmission Into Greenhouses. Acta Horticulturae, Vol. 245, pp. 377-383.
http://dx.doi.org/10.17660/ActaHortic.1989.245.50

[6.] Jung A., Kardeván P., Tőkei L.: 2006. Hyperspectral Technology in Vegetation Analysis. Progress in Agricultural Engineering Sciences Vol. 2, pp. 95–117.
http://dx.doi.org/10.1556/Progress.2.2006.1.5

[7.] Nagygál J., Tóth L.: 2014. Növényházaknál használható energiahordozók összehasonlító elemzé-se. Mezőgazdasági Technika, 55. évf. 12. sz., pp. 2-5.