Diurnal and Night Change in Greenhouse's Microclimatic Condition.

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Abstract

In modern greenhouses, measurements of climate conditions are required to give the grower a better understanding on how each factor affect growth and how to achieve maximal crop productiveness. The measurements and resultant optimal conditional adjustments enable the grower to improve productivity and achieve maximum costs and energy savings. Data of climate parameters were collected and analyzed to determine night and diurnal change of solar radiation, air temperature and humidity inside greenhouse, temperature and humidity difference between inside and outside air of a greenhouse, the temperature difference between the soil and the inside air and the transparency behaviour of the covering material. Results shows that diurnal solar radiation is higher outside than inside of greenhouses as expected. The maximum solar radiations were about 742 W/m^{2}and 545 W/m^2 for both outside and inside of the structure respectively towards noon. However, the ratio of solar radiation inside to solar radiation outside the greenhouse ratio was quite constant throughout the daytime at values of 0.8 – 0.7. There was lower temperature inside the greenhouse during the night or at the sunset while in the daytime the inside temperature was higher with a steady increase in the difference between the two up to noon time. Also, there was clear difference between inside relative humidity and outside relative humidity in the night and day up to 11:00 AM. Opening the screens for ventilation was used to control or regulate the microclimate condition of the greenhouse. Soil temperature was higher/lower than air temperature during night/day indicating on the possibility to use the soil as a heat buffer.

Keywords: Greenhouses, relative humidity, temperature, solar radiation.
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Introduction

Accurate measurement of microclimate inside the greenhouse is a prerequisite for devising an efficient climate control system and integrated pest management strategies for greenhouse vegetables production. According to Hansen and Porter (2006), various greenhouse structures exist to meet the needs and financial realities of the greenhouse farmer, but nearly all such structures share the following four controllable attributes namely; isolation, irrigation and/or fertigation, ventilation and shading.

Measurements of climate conditions inside Greenhouses are challenging. Constant high humidity, risks of condensation and exposure to solar radiation are factors of a challenging environment. Only instruments designed to work in harsh environment will survive greenhouse conditions.

Understanding diurnal change of solar radiation, air temperature and humidity in naturally ventilated greenhouses, better decisions could be made on ventilation and manipulation of the insect proof screen. According to Sabel *et. al.* (2006) wind tunnels can be used to study the effects of several factors on air movement and temperature distribution inside a greenhouse model in a short period of time. The specific objectives of this study are to determine night and diurnal change of solar radiation, air temperature and humidity inside greenhouse; to determine temperature and humidity difference between inside and outside air of a greenhouse; and determine temperature difference between soil and inside air.

Materials and Methods.

Description of the Experimental Greenhouse Structure.

The experimental tunnel greenhouse used for this experiment was located in the Institute of Agricultural Engineering, Volcani Centre, Beit Dagan, Tel-Aviv, Israel (Plate 1). The dimension of the structure is 12 m by 8 m by 2.5 m (Maximum height). The side wall height is 0.6 m. The structure is oriented North – South.

Plate 1. Experimental Set-up inside the tunnel greenhouse.

Description of the Sensors used in the Experiment.

The sensors used in this experiment includes: pyranometer, thermocouple, psychrometer, windsonic anemometer. Parameters measured includes: inside and outside global radiation, dry and wet bulb temperature of the air inside and outside the greenhouse, soil temperature, inside and outside humidity. All the sensors were connected to a Campbell Scientific data logger which was also connected to a computer system as shown in plate 2.

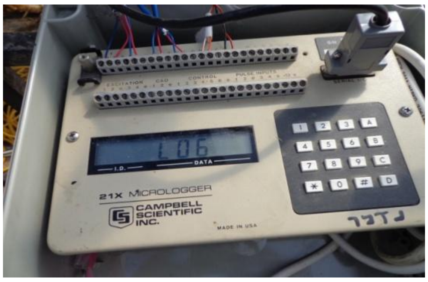

Plate 2. Campbell Scientific Data logger used.

Pyranometer.

LI-200 Pyranometer is designed for field measurement of global solar radiation in agricultural, meteorological, and solar energy studies. The LI-200 contain a high stability silicon photovoltaic detector mounted in a fully cosine-corrected miniature head with current output, which is directly proportional to solar radiation, calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions in units of watts per square meter (W m^{-2}). Under most conditions of natural daylight, the error is <5% with sensitivity of about 90 µA per 1000 W m^{-2}. The sensor is housed inside a weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware as shown in plate 3.

Plate 3. Pictorial view of Pyranometer used.

Psychrometer.

The psychrometer used was Model 225-5230 Assmann Psychrometer which utilizes two precision mercury thermometers with 3-point calibrations. The double-tube thermometers are protected by a chrome-plated brass case. The thermometer bulbs are guarded by double-walled radiation shields thermally isolated from the main housing by a plastic bushing. Aspiration of the bulbs is accomplished by a spring wound fan which will provide eight minutes of aspiration per winding. It measures over a range of -30° to +50°C. The instrument has a wind shield, a mounting support, a syringe to moisten the wet-bulb wick, extra wicks, psychrometric tables, and a carrying case.

Relative Humidity Sensors.

Relative Humidity Sensor is based upon the capacitance change of a polymer thin film capacitor. A one-micron thick dielectric polymer layer absorbs water molecules through a thin metal electrode and causes capacitance change proportional to relative humidity. The thin polymer layer reacts very fast, and therefore, the response time is very short; less than five seconds to 90% of the final value of relative humidity. The sensor responds to the full range from 0-100% relative humidity. Its response is essentially linear, with small hysteresis, and negligible temperature dependence.

Thermocouple Sensor.

A thermocouple consists of two conductors of different materials (usually metal alloys) that produce a voltage in the vicinity of the point where the two conductors are in contact. The voltage produced is dependent on, but not necessarily proportional to, the difference of temperature of the junction to other parts of those conductors. The controller measures the voltage signal in millivolt and converts it into a temperature reading.

Experimental Procedures:

1st Step: Calibration of the equipment used: the measurements taken by the sensors of the measuring or test instrument against the measurement taken by the standard Assman psychrometer. During the calibration, it was discovered that there was not enough water to moisten the wet bulb wick. Water was then added and allowed to reach a steady state before taking measurement.

2nd Step: Measurements of climate parameters including soil temperature were taken between 4:00 pm and 1:10 pm of the following day. The north and south sides were closed with insect proof screen from 4:00 pm to 11:00 am of the following day. The two sides were then opened between 11:00 am and 1:10 pm.

3rd Step: The data collected from the Campbell Scientific Data logger were analysed using Microsoft Excel Package to determine the diurnal change in temperature, temperature difference between inside and outside air ($T_{in} - T_{out}$), temperature difference between the soil and the inside air, diurnal change of inside air temperature and humidity, the transparency of the covering materials (R_{in}/R_{out}) and humidity difference between inside and outside air ($RH_{in} - RH_{out}$).

Results

Night and diurnal change of radiation inside and outside of experimental tunnel greenhouse between 6:00 pm and 1:10 pm the following day are shown in figure 1. Solar radiation inside and outside the greenhouse structure was almost zero throughout the night until around 6:00 am the following day.

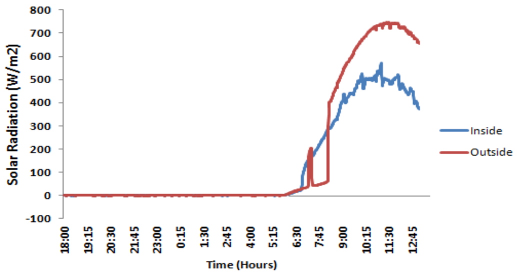

Figure 1. Diurnal change of solar radiation inside and outside of greenhouses versus time.

Diurnal change in the ratio of solar radiation inside to solar radiation outside the greenhouse between 6:00 am and 1:10 pm is presented in figure 2.

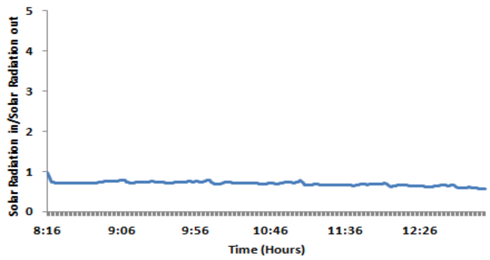

Figure 2. Ratio of inside solar radiation to outside solar radiation against time.

Night and diurnal change of dry bulb temperature inside and outside of experimental tunnel greenhouse between 6:00 pm and 1:10 pm the following day is presented in figure 3. The black vertical line indicates the time when the north and south insect proof screen were opened.

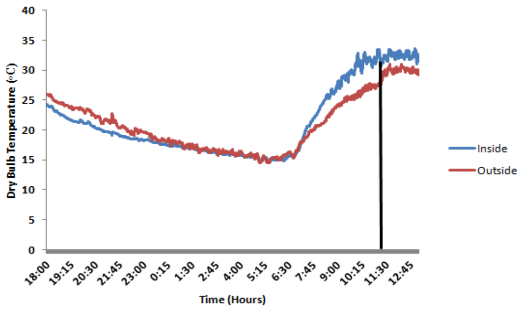

Figure 3. Inside and outside dry bulb temperature against time.

The variation in temperature difference between inside and outside air of the experimental greenhouse is presented in figure 4.

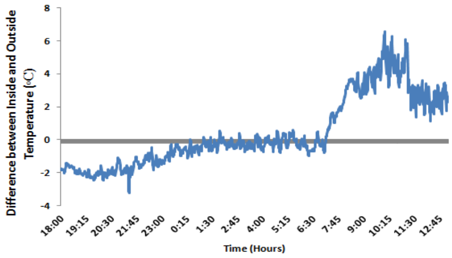

Figure 4. Temperature difference between the inside and outside air against time.

Night and diurnal change in relative humidity inside and outside of experimental tunnel greenhouse between 6:00 pm and 1:10 pm the following day is presented in figure 5.

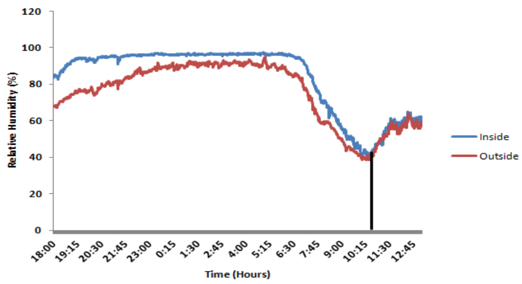

Figure 5. Relative humidity versus time.

The variation in relative humidity difference between inside and outside of experimental tunnel greenhouse between 6:00 pm and 1:10 pm the following day is presented in figure 6.

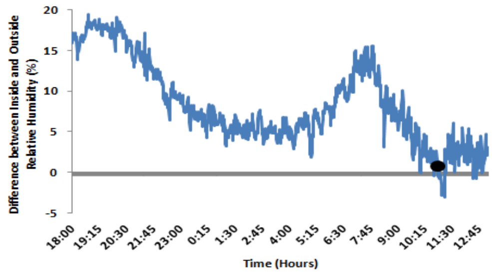

Figure 6. Difference between inside and outside relative humidity against time.

Night and diurnal variation in the temperature difference between the soil and the inside air of the experimental tunnel greenhouse between 6:00 pm and 1:10 pm the following day is presented in figure.

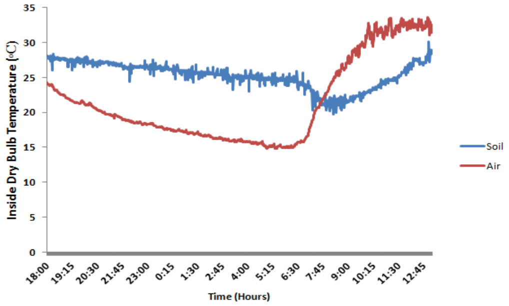

Figure 7. Inside temperature against time.

Discussions.

The solar radiation reached the apex (about 742 $W/m^2$and 545 W/m^2 for both outside and inside respectively) around 11:00 am. At this point the north and south sides with insect proof screen were opened for natural ventilation. The greenhouse structure was equipped with insect sucker to control insects at intervals inside the structure due to regular openings of the insect proof screen during the day to regulate both the temperature and relative humidity inside the greenhouse structure.

Highest difference between the relative humidity inside and outside was about 19.5 % at exactly 6:45 pm. This dropped over the night and rose again at dawn until about 7:45 am when it began to drop again. The smallest difference was 0.02 % at exactly 10:01 am after which the relative humidity outside increased above the inside relative humidity by 3.05 %.

The ratio of inside and outside solar radiation was quite constant throughout the daytime at values of 0.7 – 0.8. This is an indication of the percentage of solar radiation that was transmitted through the covering material. It is important that the crops cultivated within the greenhouse receive as much light as possible. Amount of light or radiation received in the structure depends on the slope and shape of the roof and covering material used. As the slope increases, the light transmission increases. An angle of 25^o (slope angle) is often recommended to eliminate condensation while a semi-circular roof shape such as tunnel type which was used in this experiment is preferred in terms of solar radiation transmittance.

There was lower temperature inside the greenhouse during the night or at sunset while during the daytime, inside temperature was higher with a steady increase in the difference between the two up to noon time.

The air inside the greenhouse could be about 2°C lower than outside while during the day temperature could be higher by 5°C as shown in figure 4. Also, there was unsteady increase in temperature difference in the daytime until 11:00 AM after which it started to decline unsteadily due to natural ventilation through openings from the north and south sides with insect proof screen and reduction in outside solar radiation.

In figure 5, it was shown that there was clear difference between inside and outside relative humidity in the night and day up to 11:00 AM. During the day when the insect proof screens were opened (11:00 AM); the difference between the inside and outside relative humidity decreased much and there was little difference between the two. The trend in figures 5 and 6 is similar.

In figure 7, the soil temperature inside the greenhouse was higher than the air temperature inside the greenhouse during the night. This is due to the fact that soil serves as the main thermal mass of the greenhouse system and therefore cools down and heats up much slower than the air. Comparison of soil temperature with air temperature demonstrated that there is a correlation between the two with regard to increase and decrease in temperature. It is also noted that there is a time lag between the dry bulb temperature of the air in the greenhouse and the soil temperature. It is also observed that minimum and maximum temperature values measured in the soil were much lower than those measured in the greenhouse air. It indicates that soil has been acted as preservative agent of thermal energy.

Conclusion.

Real time monitoring of both macro and microclimate conditions such as diurnal change of solar radiation, temperature difference between inside and outside air, temperature difference between the soil and the inside air, night and diurnal change of inside air temperature and humidity etc are necessary for effective ventilation control in greenhouse. Diurnal solar radiation was higher outside than inside of greenhouses as expected. Opening the screens for ventilation was used to regulate the temperature and relative humidity inside the greenhouse.

Soil temperature was higher than air temperature during night while during the day the air temperature was higher indicating the possibility to use the soil as a heat buffer. Air could be heated by the soil during night.

Acknowledgement:

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