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# APPROACH TO HEAT STRESS MANAGEMENT IN THE MEDITERRANEAN CONSTRUCTION INDUSTRY OF GREENHOUSES

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**ABSTRACT** According to previous work, the risk of heat stress on workers who build and perform maintenance work in Mediterranean greenhouses was identified, therefore, this paper establishes the level of heat stress for workers between June and September. Those months correspond to the period of the year when greenhouses are usually built or converted and are also in direct relation to the most adverse climatic parameters in terms of heat stress. For this study, the heat stress index was determined and contrasted with the internationally WBGT index (wet bulb globe temperature heat stress index)for that period of months that were referred to in Almería (Spain). This region has the largest amount of greenhouses surface in the Mediterranean area, with total surface of approximately 30 000 hectares. It was concluded that the most damaging heat stress period of work during the day for those months is between 10:00 AM and 4:00 PM (GMT), and with regards to the months it was in decreasing order: July, August, June and September. However, in the greenhouse construction industry work schedules consider these occupational risks for their employees, and carry on with their work during these time periods, stopping only work one hour during the lunch period. It is necessary to propose a modification of the work schedule in this sector to help protect human health.

**Keywords:** heat stress, safety, Mediterranean greenhouses, WBGT index, globe temperature.

**INTRODUCTION** Spain is the country with the greatest surface area of plastic-covered greenhouses, reaching 45000 ha (Castilla and Hernández, 2005; Callejón-Ferre et al., 2009), with the greatest concentration situated in SE Spain, particularly in the province of Almería, with 26500 ha (Fundación Cajamar, 2007). Here, intensified agriculture specializes in greenhouse-grown vegetables, with high input and yield, which generates the greenhouse-construction industry. Greenhouses are agricultural buildings with light, low-cost structures that provide the microclimatic conditions needed for year-round crops (Soriano et al., 2004). The traditional greenhouse model used in south-eastern Spain is called "parral", although in recent decades, this has been replaced by improved models called "*raspa y amagado*" and the multi-gabled model, which allow better climate control as well as automation (López and Pérez, 2006). New greenhouse construction as well as the maintenance and rehabilitation of the pre-existing ones occur mainly from June to September (Pérez et al., 2009), raising high demand for labourers and making it common to hire workers without training or experience. Saha et al. (2004), Waehrer et al. (2007), Fabiano et al. (2008), and Pérez et al. (2009) relate this to labour accidents in the construction industry. In addition, the greenhouse-construction companies are small, with limited resources and few workers (Pérez et al., 2009), leading to a greater probability of accidents due to poor preventive measures (Beaver, 2003; Fabiano et al., 2004; Hasle et al., 2008). In this sense, Pérez et al. (2008) have identified the risk of heat stress on workers who build and maintenance work in the greenhouses of the Mediterranean area, therefore, this paper addresses the determination of heat stress for workers between June and September, and that is where it usually build and convert these greenhouses and agrees with most adverse climatic parameters in terms of heat stress.

**MATERIAL AND METHODS** To determine the degree of heat stress for workers who build greenhouses in the Mediterranean area, was taken as an indicator of the WBGT (Wet-bulb globe temperature) heat stress index, since it´s the heat stress index most widely used internationally (Moran et al., 2001; Parsons, 2006; Budd, 2008; Gaspar and Quintela, 2009). According to ISO 7243 (1989), in the case of outdoor environments exposed to solar radiation, the calculation of the WBGT index requires the measurement of three parameters: the natural wet bulb temperature $T_{nw}$, the globe temperature $T_g$ and the air temperature $T_a$. In the case of outdoor environments exposed to solar radiation, the WBGT index is then calculated by the equation (1):

$$WBGT = 0.7 \cdot Twn + 0.2 \cdot Tg + 0.1 \cdot Ta \quad (1)$$

According to ISO 7243 (1989), the Tnw is the value indicated by a temperature sensor covered with a wetted wick which is naturally ventilated, and $T_g$ is the temperature indicated by a temperature sensor placed in the center of a globe with a diameter of 150 mm, as thin as possible and matt black painted.

Although in general situations the measurements should be made at three heights, when the radiative field is uniform the measurements can be carried out at only one intermediate height (1.1 m), an assumption that was considered in this approach. The evaluation of the thermal stress is performed by comparing the measured hourly averaged values of the WBGT index with reference values (maximum admissible hourly values) which are a function of the metabolic rates (ISO 7243, 1989) shown in Table 1.

Table 1. Reference limit values of WBGT (º C) for various situations (ISO 7243, 1989)

| TYPE OF METABOLISM | METABOLIC (M) RANGE | | REFERENCE LIMIT VALUES WBGT (ºC) | |
|---|---|---|---|---|
| | Referred to unit surface area of skin (W $m^{-2}$) | TOTAL For an area of 1.8 $m^{-2}$ (W) | Persons acclimatized to heat | Persons not acclimatized to heat |
| 0 - Rest | M<65 | M<117 | 33 | 32 |
| 1 | 65<M<130 | 117<M<234 | 30 | 29 |
| 2 | 130<M<200 | 234<M<360 | 28 | 26 |
| 3 | 200<M<260 | 360<M<468 | 25* - 26** | 22* - 23** |
| 4 | M>260 | M>468 | 23* - 25** | 18* - 20** |

* in still air;  ** moving air

On one farm only 2 km away from the University of Almería (Almería, Spain), a set of field measurements were performed with the order to obtain the necessary parameters to determine the WBGT index. The experimental period was from 1 June until 30 September 2009, as measured from 06:00 h to 19:00 h (GMT).

The parameters $T_g$, $T_{nw}$, $T_a$ and U (air velocity) were measured and recorded with the HD32.1-Thermal Microclimate from Delta Ohm Srl. The characteristics of the $T_g$, $T_{nw}$, $T_a$ and U probes are listed in Table 2. The WBGT probes was mounted on a tripod 1.1 m above the ground, considering a uniform radiative field and a standing activity.

As the WBGT index is based on an hourly work period the 5-min recorded data were collected into hourly mean values.

Table 2. Characteristics of the $T_g$, $T_{nw}$, $T_a$ and U probes

| **Parameters** | **Probe characteristics** |
|---|---|
| $T_g$ (ºC) | Temperature probe Pt100 sensor globe, globe Φ 150 mm matte black surface |
| $T_{nw}$ (ºC) | Natural double-bulb probe and temperature probe (dry bulb), temperature sensor Pt100 |
| $T_a$ (ºC) | Probe combined temperature and relative humidity. Capacitive RH Sensor, temperature sensor Pt100 |
| U (m $s^{-1}$) | Omnidirectional hot wire probe. Measurement range: Air velocity 0-5 m $s^{-1}$, temperature 0-100 ºC |

**RESULTS AND DISCUSSION** Table 3 shows the average hourly values for each month of the WBGT index calculated from the experimental data and their mean, standard deviation and range. Similarly, Table 4 shows the maximum hourly values of WBGT for each month and the mean, standard deviation and range.

Table 3. Mean values of the WBGT index for periods of times of day and month, and their statistical

| | **Mean values of the WBGT index (ºC)** | | | |
|---|---|---|---|---|
| **Hours (h)** | **June** | **July** | **August** | **September** |
| 06-07 | 20.70 | 24.89 | 23.73 | 19.55 |
| 07-08 | 22.76 | 26.00 | 25.61 | 21.47 |
| 08-09 | 24.85 | 27.64 | 27.42 | 23.45 |
| 09-10 | 25.85 | 28.60 | 28.30 | 24.37 |
| 10-11 | 26.41 | 28.92 | 28.72 | 24.99 |
| 11-12 | 26.48 | 29.30 | 28.99 | 25.17 |
| 12-13 | 26.63 | 29.43 | 29.14 | 25.45 |
| 13-14 | 26.71 | 29.63 | 29.03 | 25.37 |
| 14-15 | 26.34 | 29.76 | 28.96 | 25.04 |
| 15-16 | 25.64 | 29.34 | 28.75 | 24.44 |
| 16-17 | 24.91 | 28.88 | 28.05 | 23.61 |
| 17-18 | 23.42 | 27.65 | 26.75 | 22.22 |
| 18-19 | 21.90 | 25.91 | 25.19 | 20.81 |

| | | | | |
|---|---|---|---|---|
| **Average ± SD** | 24.82 ± 2.00 | 28.15 ± 1.61 | 27.59 ± 1.75 | 23.53 ± 1.93 |
| **Range** | 6.01 | 4.87 | 5.41 | 5.9 |

Table 4. Maximun values of the WBGT index for periods of times of day and month, and their statistical

| | **Maximun values of the WBGT index (ºC)** | | | |
|---|---|---|---|---|
| **Hours (h)** | **June** | **July** | **August** | **September** |
| 06-07 | 26.15 | 27.10 | 27.10 | 25.30 |
| 07-08 | 27.71 | 28.60 | 28.60 | 26.90 |
| 08-09 | 29.45 | 30.90 | 30.90 | 28.60 |
| 09-10 | 30.47 | 31.20 | 31.20 | 29.60 |
| 10-11 | 30.49 | 31.60 | 31.20 | 29.70 |
| 11-12 | 30.60 | 33.50 | 32.00 | 29.80 |
| 12-13 | 30.72 | 34.90 | 31.60 | 29.60 |
| 13-14 | 30.68 | 35.20 | 31.80 | 29.80 |
| 14-15 | 30.35 | 35.20 | 31.40 | 29.40 |
| 15-16 | 30.30 | 34.10 | 31.20 | 29.40 |
| 16-17 | 29.53 | 33.90 | 30.30 | 28.50 |
| 17-18 | 28.42 | 31.60 | 29.10 | 27.20 |
| 18-19 | 26.73 | 28.70 | 27.20 | 25.10 |
| **Average ± SD** | 29.35 ± 1.59 | 32.04 ± 2.70 | 30.28 ± 1.71 | 28.38 ± 1.70 |
| **Range** | 4.57 | 8.10 | 4.90 | 4.70 |

These same values of average and maximum WBGT index for time periods of each month, you can see in Figure 1.

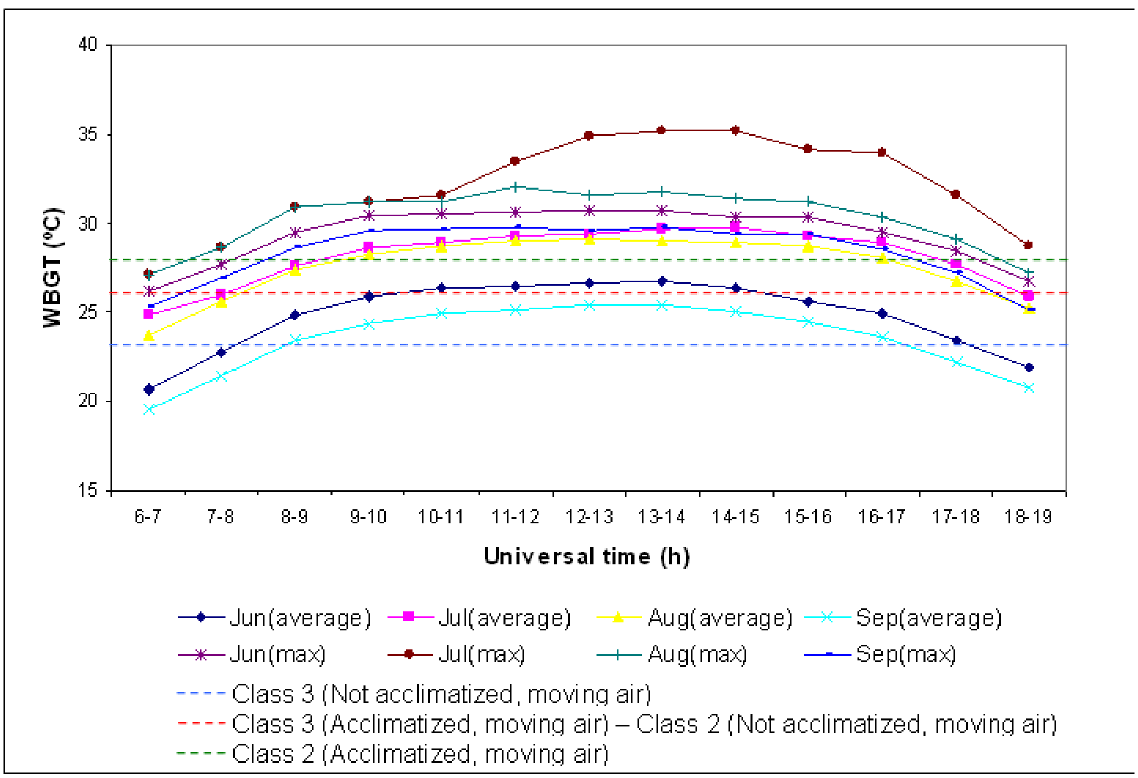

Figure 1. Mean and maximun values of the WBGT for time periods of each month

Figure 1 identifies the WBGT index variability along the periods of the day for each month. The interpretation of Figure 1, the months can be classified by descending order of severity of heat stress to which you can see workers put as follows: July, August, June and September. These results partially coincide with those obtained by Gaspar and Quintela (2009) for an experimental measurement made in Coimbra (Portugal) similar to this study. They get to Coimbra in descending order of the months of decreasing thermal stress intensity is: July, August, September and June. Also, taking the limits of the WBGT index (Table 1) prescribed by ISO 7243 (1989) for workers not exposed to heat and moving air, and because workers in the construction of greenhouses have a class metabolism 2 or 3 depending on the activity, there are problems of heat stress for all months analyzed by considering the maximum WBGT index values, and which exceed the 26 ºC, being noted that in the months of July and August the critical period ranging from 06:00 to 19:00 h. But if we only consider the values of WBGT average in the months of June and September, not be presented for thermal stress problems persons acclimated. But for persons not acclimatized to heat, even for values of WBGT average in the months of June and September heat stress also appear from 09:00 h to 17:00 h, since it exceeds the limit of 23 ºC metabolism characteristic of type 3. According to ISO 7243 (1989), the characteristic values must correspond to the situation of maximum thermal stress. Therefore, the monthly maximum values are considered relevant in such an analysis.

Therefore, and overlapping with the study of Gaspar and Quintela (2009) in Coimbra (Portugal), considering the monthly mean and maximum values of the WBGT index, a critical period between 10:00 and 16:00 hours (GMT) can be suggested for outdoor work. This means that during that period the workers are not supposed to perform their normal activities, a good practice that is not considered nowadays. In fact, some decades ago, agriculture was characterised by a rest period during the hottest summer hours, which from the health and safety point of view represents a highly recommended procedure, but one which became neglected by the industrialisation and the growing demands of the modern economy. Thus, it is important to consider work schedules where the hottest period could be used for rest or to the development of light activities in places with solar radiation protection.

**CONCLUSION** Besides the simplicity of use recognized to the WBGT index as well as some of its restrictions and limitations, it has the capability to consider subjective evaluations since it is possible to distinguish between the very important effects related to acclimatisation.

Therefore, new construction workers in greenhouses, to begin their work during these months, should perform a heat acclimation period of at least 8-10 days. Similarly, all workers who perform work during these critical months, should conduct a work-rest regime so that the body can restore the heat balance, which will own for each worker. Although it would be more advisable, who have a non-working period from 10:00 h to 16:00 h (GMT), especially during July and August, as is done for decades in the field in own work agricultural labor.

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