# Assessment of Workers' Body Temperature and Workload in Tomato Production Greenhouse Work

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***Abstract***

*Many workers work in the tomato production greenhouse in Japan, exposed to unfavorable environmental conditions during their work, especially in the summer season. In this study, workers' body temperatures of internal, facial, and head area temperature were measured, so did the workers' workload. They were related to environmental conditions of solar radiation and air temperature to clarify their relationships. Three workers in semi-commercial tomato production greenhouse were employed for this research. Jobs were classified into upper and lower canopy job, to examine the working condition in the greenhouse. Ear thermometer and thermal camera were used to measure worker's body temperatures. Workload of the jobs was assessed and determined the level with Heart Rate Reserve (HRR). Workers' heart rate itselves was measured using finger pulseoxymeter. Significant correlations were found between workers' body temperature and environmental conditions. Worker's workload could change on changing environmental conditions. Workload level of tomato production greenhouse job is considered low, as the job relatively does not require heavy physical work.*

***Keywords:*** *Body temperature, greenhouse, workload*

## 1. INTRODUCTION

In spite of automation and mechanization, involvement of human in the greenhouses is a certainty. Maintaining the crop and harvesting do rely on human intelligence and ability, and are much more difficult to automate (Henten, 2006). A job in a greenhouse involves a great deal of manual labor (Shry Jr. and Reiley, 2011). In a tomato production greenhouse, which is increasing in many parts of the world (Jones Jr, 2008), there are daily activities like removing old leaves, training and lowering stem, and harvesting fruits. The greenhouse tomato crop, as it is traditionally grown, is highly labor intensive (Fischer et al., 1990).

Closed environment of greenhouse means that the workers working inside are exposed to the environmental conditions. Therefore, climate, combinations of temperature, humidity, thermal radiation, and air movement is an important environmental factor at the workplace (Spath et al., 2006), including in the greenhouses. Moreover, there are many researches on tomato plants and illness from working in the greenhouse. But only few researches related to environmental conditions and worker's physiological parameters relationship have been conducted, such as physiological and biomechanical response during cherry tomato harvesting in the greenhouse (Seonwoo et al., 2011). On this study, we will assessed the workers' physiological parameters by means of body temperature.

Greenhouse workers work throughout one year maintaining the plants, experiencing changes in environmental conditions because of changing season. Ehime University in Ehime Prefecture, Japan operates semi-commercial tomato production greenhouse in a small scale. Workers sometimes work in unfavorable environment conditions, especially in hot and humid summer season. Sometimes they wear protective clothing, and change the work schedule to avoid working in an unfavorable condition.

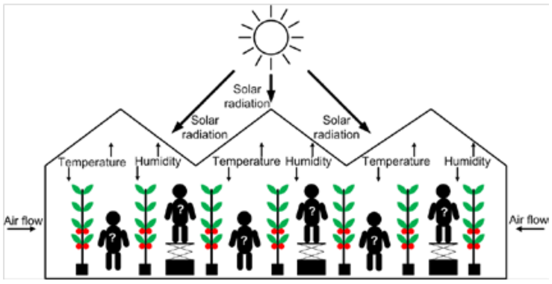


Figure 1. Scheme of environmental conditions affecting the greenhouse workers.

This research is aimed to 1) Assess the workers' body temperature, in terms of internal, facial, and head area temperature, while working in tomato production greenhouse; and 2) Identify the working condition and workload of tomato production greenhouse job.

Figure 2. Worker working inside the tomato production greenhouse in Ehime University, Japan.

## 2. MATERIALS AND METHODS

### 2.1 Objects

Research was pursued in semi-commercial tomato production greenhouse in the Research Center for High-technology Greenhouse (Faculty of Agriculture, Ehime University, Japan), between March 3rd, 2012 and July 27th, 2012 on workdays of the greenhouse schedule. The tomato plants were seeded on August 2011 and started harvesting on November 2011. Three workers in this greenhouse were employed for this study.

### 2.2 Jobs Classification

Classification of jobs was pursued as there are similar jobs found in the greenhouse, and possibility of different effects from environmental conditions to workers in different job. There are six jobs discovered in the greenhouse. Those six jobs then classified into two classifications of upper canopy job and lower canopy job, with three jobs on each classification as shown on Table 1. This job classification is mainly based on the job's working space, which is considered having different effect from environmental condition exposure. The lower canopy job, which is done in the lower part of the plants, is a more enclosed space than the upper canopy job. This is because the tomato plant, which height is around two meters, provides cover to the workers when doing their work, from top until bottom area of body.

Table 1. Classification of jobs in tomato production greenhouse

| Classification | Jobs |
|---|---|
| Upper canopy job | Stem training and |
| | Hormone spraying |
| | Side shoot removal |
| Lower canopy job | Tomato fruits harvest |
| | Old leaves removal |
| | Unmarketable fruits removal |

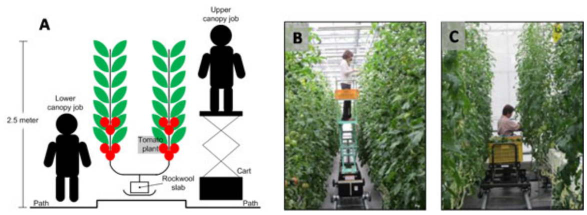


Figure 3. Scheme of jobs in the greenhouse (A), upper canopy job of stem training and lowering (B),and lower canopy job of old leaves removal (C).

### 2.3 Measurement of Physiological Parameters and Environmental Conditions

An ear thermometer (Omron, MC-510, Japan) was used to measure workers' internal temperature, and a thermal camera (NEC/Avio, TH-7800N, Japan) was used to measure workers' facial and head area temperature. Measurement was done three times on each measurement, on various time and condition to get various workers' internal temperature values on various environmental conditions. Workers' facial temperature of nasal area was measured as that area is strongly suggested to be measured in the face (Genno et al., 1997) beside of the stabile area of forehead (Genno et al., 1997 and Naemura et al., 1993). Head area temperature was also measured to see the effect of solar radiation to the workers.

Environmental data of solar radiation and air temperature were obtained from the greenhouse environment monitoring system (MC-5013, NEPON, Japan). Solar radiation and air temperature were measured because they are considered to be having significant effect and relation to the workers' body temperature.

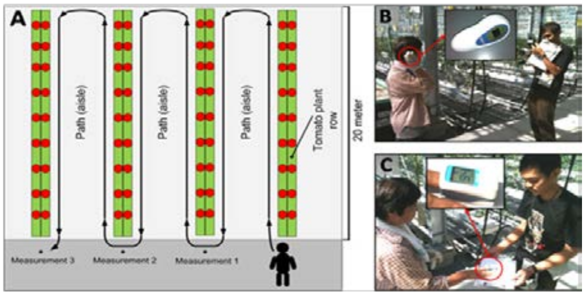


Figure 4. Measurement of physiological parameters scheme (A), ear thermometer attached to worker's ear (B), and finger pulse oxymeter attached on worker's finger (C).

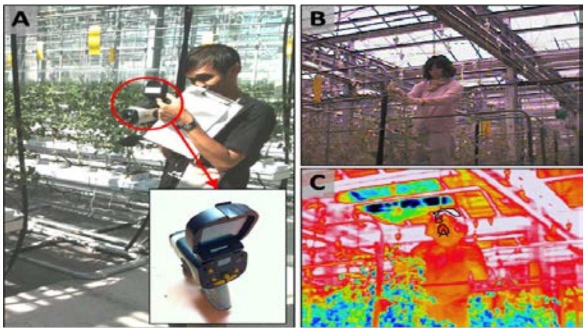


Figure 5. Thermal image capture with a thermal camera (A), visible image captured (B), and thermal image produced (C).

### 2.4 Workload Assessment

Workers' workload will be assessed with the Heart Rate Reserve (HRR [%]) calculation. Workers' heart rate was measured with a finger pulseoxymeter (NISSEI, PulsFitBO 600, Japan). HRR is the difference between resting HR and maximal HR (Hottenrott, 2007). Workload calculation was derived using the HRR equation (Louhevaara et al., 1985) :

$$HRR\ (\%) = \frac{HR_{work} - HR_{rest}}{HR_{max} - HR_{rest}}$$

$HR_{max}$ was derived from equation $HR_{max}$=208-(0.7×age) (Tanaka et al., 2001), while $HR_{rest}$ measured before work.

### 2.5 Statistical Analysis

Statistical analysis was conducted with SPSS 17 software (IBM, New York).Kendall-Tau test was pursued to obtain correlation between parameters, and Kruskall-Wallis test was pursued to analyze significant difference, on 95% interval confidence.

## 3. RESULTS AND DISCUSSION

### 3.1 Assessment of workers' body temperature

Workers' body temperature data measurement was resulted in 160 data on 35 datasets for upper canopy job. Significant correlations ($p$-value of correlation <0.05) were found between all relationships on upper canopy job. This shows that there are strong relationships between worker's body temperature and environmental factors.

Table 2. Measurement data on upper canopy job

| Parameters | $N$ | Range | Min. | Max. | Mean | SD | Var. |
|---|---|---|---|---|---|---|---|
| Solar radiation ($MJ.m^{-2}$) | 35 | 19.97 | 0.62 | 20.59 | 6.88 | 5.31 | 28.14 |
| Air temperature (°C) | 35 | 17.93 | 18.00 | 35.93 | 26.79 | 4.32 | 18.68 |
| Internal temperature (°C) | 35 | 1.26 | 36.07 | 37.33 | 36.62 | 0.25 | 0.06 |
| Facial temperature (°C) | 35 | 8.59 | 28.00 | 36.59 | 33.5 | 1.69 | 2.85 |
| Head area temperature (°C) | 35 | 14.46 | 29.68 | 44.14 | 36.02 | 3.59 | 12.91 |

Higher value of solar radiation and air temperature could affect or changes workers 'body temperature as shown on Fig. 6. Workers' body temperature increased as solar radiation and air temperature increased. This can be caused by higher solar radiation from the sun could raise the air temperature in the greenhouse, and make the working condition hotter. People can feel warmer mainly because of solar radiation (Givoni and Noguchi, 2000), affect the body work, such as sweating, which is related to heart rate and body temperature. Working on hot condition could make heart rate work faster to regulate the body's physiological work, and raise body temperature.

R-squared ($R^2$) and correlation coefficient value of relationships between solar radiation-facial temperature and solar radiation-head area temperature are higher than solar radiation-internal temperature. This can be cause by solar radiation has stronger direct effect to worker's facial temperature and head area temperature than the air temperature. However, strong relationships based on $R^2$ and correlation coefficient were not found on relationships between air temperature-facial temperature and air temperature-head area temperature. Air temperature affect internal temperature more than surface temperature, as human skin is more responsive to radiative heat.

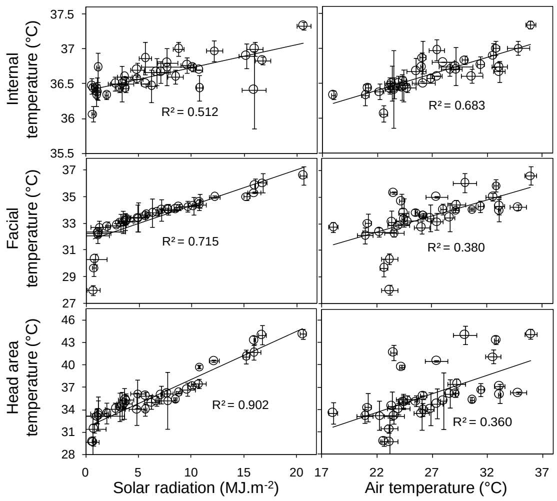


Figure 6. Relationship between worker's body temperature and environmental condition on upper canopy job.

On lower canopy job, body temperature data measurement was resulted in 185 data on 41 datasets.

Table 3. Measurement data on lower canopy job

| Parameters | N | Range | Min. | Max. | Mean | SD | Var. |
|---|---|---|---|---|---|---|---|
| Solar radiation ($MJ.m^{-2}$) | 41 | 18.50 | 1.32 | 19.82 | 6.53 | 5.17 | 26.75 |
| Air temperature (°C) | 41 | 15.16 | 21.38 | 36.53 | 27.93 | 3.59 | 12.94 |
| Internal temperature (°C) | 41 | 1.33 | 36.13 | 37.47 | 36.62 | 0.27 | 0.075 |
| Facial temperature (°C) | 41 | 7.19 | 27.03 | 34.23 | 31.45 | 2.27 | 5.19 |
| Head area temperature (°C) | 41 | 12.49 | 29.68 | 42.17 | 34.46 | 3.41 | 11.62 |

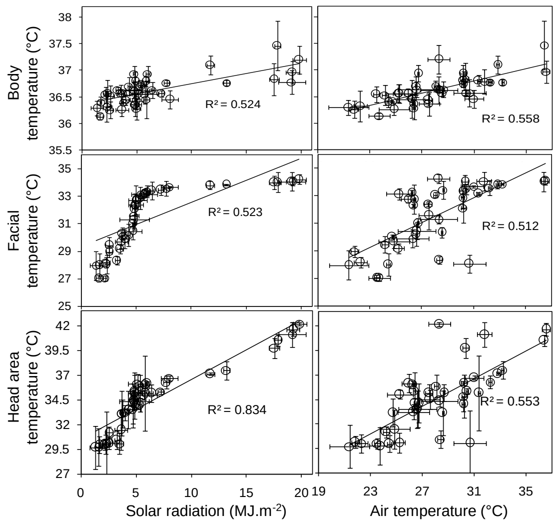


Figure 7. Relationship between workers' body temperature and environmental condition on lower canopy job.

Relationships between body temperature and environmental factors on lower canopy job showed similar tendency as on upper canopy job. Significant correlations (*p*-value of correlation <0.05) were found among all relationships on lower canopy job. $R^2$ and correlation coefficient value of relationships between solar radiation-head area temperature is higher than the other relationships. This is because solar radiation has more direct effect to worker's head area temperature. The more enclosed work space on lower canopy job than upper canopy job could make worker's head area the body part exposed to solar radiation the most. Strong relationships based on $R^2$ and correlation coefficient value was found on all relationships between workers' body temperature and environmental conditions.

Relationships between worker's body temperature and environmental factors on upper and lower canopy job showed similar tendency. Significant correlations (*p*-value of correlation <0.05) found between relationships, showed that there is strong relationship between environmental conditions and workers'body temperature. This can occur as working environment design, i.e. lighting, noise, mechanical vibrations, climate, harmful substance, and radiation are relevant factors to human factor (Spath et al., 2006).

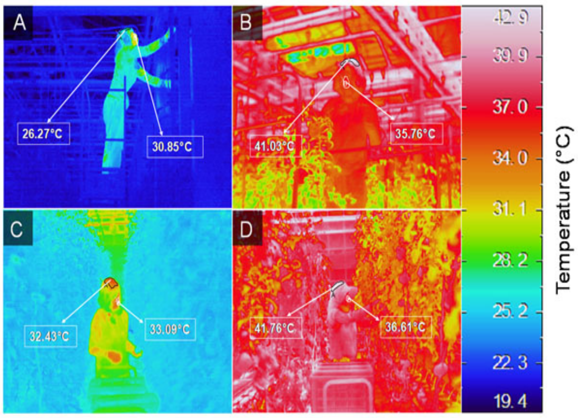


Figure 8. Thermal image example of upper canopy job in cloudy condition (A), upper canopy job in sunny condition (B), lower canopy job in cloudy condition (C), and lower canopy job in sunny condition (D).

Facial temperature and head area temperature could increase on higher solar radiation, as solar radiation can present load and stress (Burton and Edholm, 1956).Significant correlation (*p*-value of correlation <0.05) also found between them. This can occur because of the exposure of solar radiation radiated the workers when they work. Therefore facial temperature and head area temperature could raise. Highest facial temperature observed was 36.92°C, which is become unacceptable and can cause discomfort feeling when exceeds 34.5° (Gwosdow et al.,. 1989; DuBois et al., 1990). Highest head area temperature observed was 45.57°C, which is considered hot. This showed that worker's could experience high facial temperature and head area temperature which should be taken account as it can have effect to the workers.

### 3.2 Workload Assessment

HRR value calculated on each data then put it into datasets, the same as calculation for environmental conditions and physiological parameters. Calculation resulted in 160 data on 35 datasets for upper canopy job, and 185 data on 41 datasets for lower canopy job.

Table 3. Measurement data on lower canopy job

| Parameters | *N* | Range | Min. | Max. | Mean | SD | Var. |
|---|---|---|---|---|---|---|---|
| Heart rate (upper) (b/min) | 35 | 42.58 | 79.80 | 122.38 | 95.33 | 9.83 | 96.61 |
| %HRR (upper) | 35 | 43.36 | 7.66 | 51.02 | 20.76 | 9.75 | 95.02 |
| Heart rate (lower) (b/min) | 41 | 31.92 | 79.75 | 111.67 | 90.94 | 8.05 | 64.89 |
| %HRR (lower) | 41 | 28.60 | 2.95 | 31.55 | 16.17 | 7.21 | 51.94 |

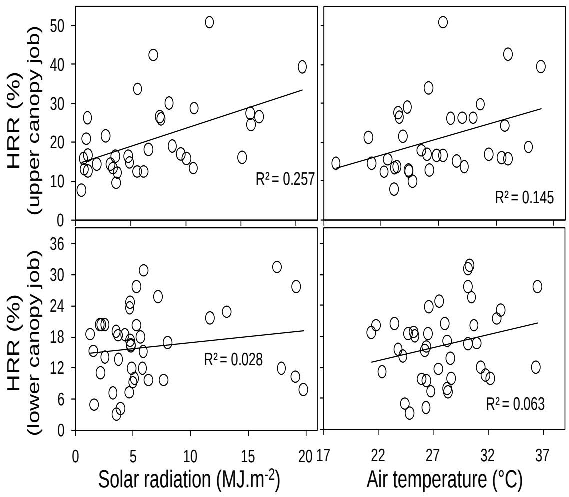


Figure 9. Relationship between environmental condition and HRR.

Higher solar radiation and air temperature could change HRR, as changing climate is a contributing factor to workload (Veenstra et al., 2009). Significant correlation (*p*-value <0.05) was found between HRR value and environmental conditions on upper canopy job, while no significant correlation (*p*-value >0.05) found on lower canopy job. Workload of upper canopy job could change depends on changing environmental conditions. The working space of upper canopy job exposed more directly to environmental conditions of solar radiation and air temperature. Furthermore, workload assessment was pursued to see if there is any significant difference of workload on low and high environmental conditions. Upper canopy job data, which is consisted of total 35 data, divided into 12 data each on low and high condition. Lower canopy job data, which is consisted of 41 data, divided into 13 data each on low and high condition.

Significant difference (*p*-value of *t*-test <0.05) was found in upper canopy job, between low and high solar radiation. While low and high air temperature showed no significant difference. This can be caused by the little effect air temperature has to body temperature and workload. On lower canopy job, no significant difference found between all low and high environmental conditions. This can be caused by lower canopy job is directly less exposed to the solar radiation

Furthermore, workload level based on HRR was performed based on Table 2. Determination of workload level based on HRR value was performed by calculation the average HRR value, both on upper and lower canopy job. Calculation results for upper and lower canopy job were 19.98% and 16.17%, respectively. Therefore, the workload level of the tomato production greenhouse job, both on upper and lower canopy job is considered very low. Relatively low physical work on tomato production greenhouse job could be one factor which made jobs there considered low in workload, based on HRR value. Solar radiation and air temperature, however, although it has significant effect to worker's physiological parameters and workload, does not significant enough to give heavier workload to workers.

Table 4. Classification of exercise intensity and ratings of perceived exertion.

| Percent MHR | HRR or percent of $VO_2$ max | Rating of perceived exertion | Classification of intensity |
|---|---|---|---|
| <35 | <30 | <9 | Very low |
| 35-39 | 30-49 | 10-11 | Low |
| 60-79 | 50-74 | 12-13 | Moderate |
| 80-89 | 75-84 | 14-16 | Heavy |
| >90 | >85 | >16 | Very heavy |

## SUMMARY AND CONCLUSION

Results showed that changes in solar radiation and air temperature could affect worker's body temperature. There are significant correlations between internal temperature-solar radiation, facial temperature-solar radiation, head area temperature-solar radiation on upper canopy job. Significant correlations were found on all relationships on lower canopy job.

Observation with thermal camera showed the working condition could risked the workers, especially in summer season. Workload measured with HRR significantly changes when solar radiation and air temperature increase, especially in upper canopy job. Workload level based on workers' HRR was classified as low. Although solar radiation and air temperature affect workers' body temperature, relatively low physical intensity of work does not give significant effect to physical workload.

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