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Investigation of Heat Stress among Greenhouse Workers in Chhattisgarh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Greenhouse cultivation is spreading as it offers the grower a higher net yield per hectare from high quality crops as it reduces the likelihood of yield decline. The greenhouse is kept at 30-40˚ C with a relative humidity of up to 70%, which could be ideal for plant growth, but is not suitable for workers. Heat exposure in the workplace causes discomfort to the human while working. So, the main goal of conducting this research is to address the extent of heat stress and associated health issues for the greenhouse workers. The study was planned for 2022 in the Raipur district of Chhattisgarh. Prior to the assessment, a questionnaire survey was conducted among 50 greenhouse workers to learn perceptions of heat exposure, heat-related health issues and awareness of heat management. To get the heat exposure air temperature, wet bulb temperature, relative humidity, black globe temperature were measured on hourly basis. The wet bulb globe temperature (WBGT) was measured along with greenhouse workers' physiological parameters to quantify heat exposure. With

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the help of clock diagram showing Humidex Index (HI). The time period at which farmers most likely to suffer from heat stress was estimated. It was reported that in April, May, June, July, August and September WBGT index reaches varied between 30 and 34°C. According to ISO 7243 the recommended WBGT for comfortable workplace should be less than 31℃. Further study was conducted to get physiological responses of the 21 farm workers in three different type of greenhouses and at three time slots. It resulted that heart rate was maximum i.e. 156 bpm in walk in tunnel at 11 am to 1 pm. The average working heart rate was 20 % more than the open field condition. Hence, the study will help to make the strategies to reduce the exposure of heat stress conditions to the greenhouse workers.

Keywords: Ergonomics; greenhouse; greenhouse farmers; heat stress; Chhattisgarh; WBGT.

1. INTRODUCTION

Global climate change has significant impacts on human health and livelihoods [1]. Heat waves also become more frequent, longer and more intense as temperatures rise. India ranks second in the world in terms of heatwave-related disaster mortality [2]. Most Indian farmers carry out agricultural activities under the scorching sun. This leads to occupational heat stress, which leads to health problems in farm workers. Therefore, farm worker efficiency and productivity decreases. Climate change affects not only grain production, but also the health of farm workers. It causes the loss of many lives from heat stroke. According to the report of the Intergovernmental Panel on Climate Change [3], the temperature increase is projected to reach 3-6°C by the end of the century.

Heat stresses refers to a level of heat that exceeds body's capacity to tolerate without causing physiological damage. Human thermal comfort is defined as a state of mind that is expressed through satisfaction with the surroundings. Climate change has a significant impact on human health in this regard.It is caused by three factors: intra-body heat production from muscular activity, ambient heat, and clothing that affect sweat evaporation and convection [4]. To face the challenging weather conditions plants are being preferred to be grown in protected cultivation. This not only protects the plants from unfavorable weather but also enhances the production. Presently in India 70,000 ha is under protected cultivation [5]. There farmers usually prefers to grow flowers like roses, gerbera, carnation and vegetables such as tomato, cherry tomato, cucumber, ginger, pumpkin, muskmelon, watermelon etc. The protected cultivation area or greenhouse environment is designed according to the requirement of the crop. The temperature and relative humidity is artificially maintained up-to 30-40˚C and relative humidity up-to 60-70% which is favorable for plant growth [6]. Also the environmental parameters such as light, CO_2 etc are also maintained. Although this may be ideal place for plant growth but it is not ideal workplace for greenhouse workers. It has also been reported by Castro et al*.* [7] that the farm workers working in extreme climatic conditions for more than 3 hours of moderate to vigorous activities per day have a higher risk to heat related illness. Researchers from around the world have studied the effects of occupational heat stress on agricultural workers including Simane et al*.,* [8] showed that the WBGT index was 18.1˚C to 31.5˚C in greenhouse which is to be recommended to be 26˚C for 3 - 6 working hours daily. Lima et al*.* [9] who studied the two most heat vulnerable regions such as sub- Saharan Africa and Southeast Asia. There reduction of labour capacity was observed due to heat stress of 3◦C global warming by 30-50%. Furthermore Wagoner et al*.* [10] said that in harvesting seasons threshold limit of heat exceeds. Due to occupational heat stresses many health issues such as respiratory disorder, kidney disorder, heat cramps, heat stroke, radiation burn, heart disorders, heat rash, and headache. In addition to it heat related fatigue like physiological strain and mental fatigue. This tends to reduce the performance and capacity of worker. [4,11-15]; (luo et al*.,*2017). Another study was done by Gupta et al*.,* [16] about the microclimate in double span greenhouse in west coast area of India. They proved that natural ventilation is inadequate to maintain the homogeneous microclimate in greenhouse. Venugopal et al*.,* [17] monitored heat exposure exceeded the threshold level for workers. The core body temperature increased by 1˚C and urine specific gravity was more than 1.020. This shows the prevalence of kidney disorders and dehydration. Similar study was performed by Surendra et al*.,* [18] of environmental heat in naturally ventilated polyhouse at Udaipur. Here, WBGT index of

March, April, July was recorded and it was observed that the value was 33.2˚C, 34.7˚C, and 36.8˚C respectively. As the physical environment also increase in working heart rate was increased along with increase in WBGT. Hence, from the above studies it is clear that the agricultural workers are facing the occupational heat stresses. Also farmers are also unaware about the management of heat stresses in farm. But limited studies have been done till now for heat stresses to workers working under greenhouse. Therefore the study is planned for assessment of heat stresses to the greenhouse workers. So that simple measures can be implemented to reduce the risk of heat stress.

2. MATERIALS AND METHODS

The study have been designed which compares the outcomes of the physiological parameters and heat stress. The physiological parameters are being analyzed in relation with the heat level in the workplace.

2.1 Study Area

The study was planned to evaluate the risk of excessive heat stress to the worker involved in greenhouse farming. The climate of Chhattisgarh is tropical that is hot and humid as it is near to tropic of cancer. The hot season starts from March and ends upto July. In state the maximum temperature in summer months reaches to 45˚C. But the microclimate developed for the production of crops in greenhouse causes extreme heat stress in month of March to September. With the aim of analyzing the thermal stress to the greenhouse workers three type of greenhouses were investigated. The structure examined were naturally ventilated polyhouse (n=4) with 4 acres, walk in tunnel (n=8) with area of 1.4 acres and shade net (n=3) covering the area of 3 acres as indicated in Table 1. The structures were covered with plastic film of 200 micron thickness. The covering material in walk in tunnel and naturally ventilated polyhouse is polythene. The greenhouse workers are engaged in cultivation of watermelon, muskmelon, hybrid cucumber, cherry tomato, tomato, pointed guard, ginger and papaya. The study commenced from January and ended at December 2022. The working hours of the greenhouse workers were from 8:00 am to 5:00 pm with lunch break of 1 hours from 02:00 to 03:00 pm. All the farming activities were done manually such as seed bed preparation, mulching, transplanting/sowing, pruning, weeding, harvesting, maintenance of greenhouse, sweeping and removal of residue of previous crops.

To conduct the survey scheduled survey has to be performed to get the scenario of the area [19]. Prior to study the questionnaire was prepared to determine the information from respondents. The first part of the questionnaire is socio-demographic information which comprises general demographic background, age, education level, martial status, height and weight. In second part, of the questionnaire working information such as type of work, duration of work, and employment duration. In next part health, injury and exposure of heat stress. The questionnaire was prepared and tested. The subjects were interviewed in their local language.

2.2 Demographic Factors of the Worker

The study was conducted on the 5 greenhouse farming workers from each selected greenhouse of Raipur, Chhattisgarh. The age of the subjects ranged between 20-48 years having minimum work experience of 5 years. The female workers in greenhouse farming ranged between 5-6. The average height of the workers ranged from 160-170cm and weight between 60-68 kg.

2.3 Environmental Parameters

The environmental parameters which effect the working efficiency of the workers are dry bulb temperature, wet bulb temperature and relative humidity [20]. Wet bulb globe temperature index is used to determine the workload requirement for work area using heat stress or strain threshold limit value (TLV). It is by far most widely used throughout the world. It is measured by the help of WBGT meter which measures the WBGT index with the help of three temperature;

- Dry bulb temperature Tb:
- Wet bulb temperature Tnwb:
- Black globe temperature Tg:
- Relative humidity (RH%)

The above parameters were recorded with the help of wet bulb globe temperature meter.

2.4 Physiological Parameters

The physiological parameters were recorded during the greenhouse farming activities. The selected subjects were asked to perform the farming activities no restrictions on speed of operation. The design of experiment is shown in the Table 2. The analysis of the heart rate was done as suggested by Singh et al. [21];

i. **Resting heart rate-** prior to the study the subject was asked to take rest. After that heart rate monitor was snuggled to the subject. The 5min reading of heart rate was monitored and considered as the resting heart rate.
ii. **Peak heart rate-** the maximum heart rate measured during the experiment.
iii. **Average working heart rate-**measured from value 6^{th} to 30^{th} min of work.

All the parameters were statistically analyzed with the help of OPSTAT software. The design of experiment for evaluation of heart rate at different working environment in varied time slot is shown in Table 2.

2.5 Humidex Index (HI)

Humidex index is calculated in order to determine the hours during which greenhouse worker could experience heat stress on each day of the experimental period. In extreme hot condition the body produces sweat to maintain the body temperature upto 37˚C. But as the humidity in the air increases, sweat does not evaporate easily. Sweat does not evaporate at higher relative humidity this causes increase in body temperature and causes illness. The humidex index expresses the workers perception of temperature, humidity level around the body which obstructs the sweat evaporation. HI value associated with heat stress are given in Table 3. The index value is calculated using the following equation (i) given by [22].

$$\mathrm{HI} = \mathrm{T} + \frac{5}{9}[\left(6.112 \times 10^{\frac{7.5\times \mathrm{T}}{237.7+\mathrm{T}}} \times \frac{\mathrm{RH}}{100}\right) - \quad \ldots(\mathrm{i})$$

Where,

HI= humidex index
T=dry bulb temperature, ℃
RH= relative humidity, %

Table 1. Characteristics of greenhouse to be studied

Type of greenhouse	Area per unit (m^2)	Total area (m^2)	Covering material
Walk in tunnel (n=8)	72.5 × 9.6 Height = 3m	696	Polythene
Naturally ventilated polyhouse (n=4)	105×38.4 Height =6 m	4042.5	Polythene
Shade net house (n=2)	92×44 Height =6m	4048	White net

Table 2. Design of experiment for evaluation of physiological parameters at different time period

Response	Independent parameters	levels	Description
HR	Type of farming area	4	G_1- open field G_2- Shade net house G_3- Naturally ventilated polyhouse, G_4- Walk in tunnel,
	Time slot	3	T_1-(8am to10 am), T_2-(11 am to 01 pm), T_3-(3 pm to 5pm)
	Working method	1	Seed bed preparation by spade

Table 3. Humidex index value with associated heat stress (Masterton and Richardsonn, [22])

Humidex index value	Effect
HI less than 29	Comfortable
30-39	Some discomfort
40-44	Great discomfort
45-54	Dangerous
More than 55	Heat stroke

3. RESULTS AND DISCUSSION

The environmental parameters of the workplace play a key role on the working efficiency of the worker [19]. Heat stress to the greenhouse farmers depends on the environmental factors as farmers work under the scorching sun or greenhouses. This increases the risk of heat related illness to the farmers. Farmers working under the greenhouse experience heat stress as solar heat are trapped inside. The infrared radiation is reflected back and keeps the temperature inside the greenhouse 8-10℃ more than the outside [5]. The application of heat reduction may interfere the growth of the crop. Therefore, in this study the WBGT and HI levels were measured and calculated inside and outside the greenhouse.

3.1 Heat Exposure of the Greenhouse Workers

3.1.1 Humidex index

The average of the monthly value of the humidex index for on hourly basis of the day is given in Fig. 1. The greenhouse performing heavy workload such as seed bed preparation, mulching, transplanting, weeding, cleaning the residue, pruning, and harvesting causes sweating to maintain the body temperature. But the sweat is unable to evaporate which causes discomfort to the greenhouse workers in drenched condition. In the month of November, December, January, February the humidex index is under the comfortable limit. The heat stress to the greenhouse worker slightly starts from the last week of February and end at the October. The extreme heat stress is experienced in the month of May, June July and August. The Humidex index reaches to maximum value of 45 in May where the greenhouse farmers are at great discomfort as suggested by [22]. The heat stress starts from 8:00 am with humidex index value of 40 and reaches its extreme value to 45 at 10:00 am and drops after 16:00 pm as indicated in Fig. 1. Due to higher humidity and temperature in the months July, August and September the greenhouse workers experience discomfort while working. The index value was higher in the month of October but for shorter period of time i.e. from 12:00 noon to 14:00 pm. The crop grown in greenhouse during summer season such as pointed guard, cucumber, cowpea, bitter guard, and muskmelon reaches upto height of 2m which interrupts the air flow and increases the humidity due to transpiration. Here the workers are engaged in harvesting, pruning, irrigation and weeding which are labour some job creates problem while working in hot environment. The workers exposed to sunlight are comparatively at less risk to heat as the air flow makes their body temperature at 37℃.

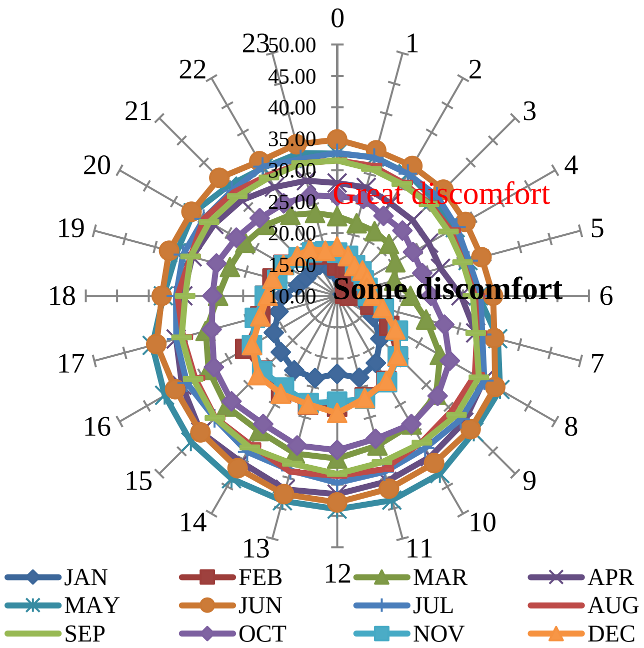

Fig. 1. Clock diagram showing the mean monthly HI for each hour of the day

3.2 Physiological Responses of the Greenhouse Farming Workers

It has been observed in above sections that the greenhouse farm workers experience heat stresses in the month of March, April, May, June, July, August and September. The farmers are involved in seed bed preparation for growing cucumber, transplanting of cucumber, harvesting of tomato, harvesting of muskmelon and removal of residue of previous crop. Therefore, the physiological parameters were assessed during seed bed preparation at different WBGT index value. The greenhouse farmers prepare seed bed manually with the help of spade. The working heart rate was measured at different WBGT index value. As observed that in summer season the WBGT index was 25-26℃ from 7:00 am to 8:00 am so the subject's heart rate was assessed. It was examined that the resting heart rate was ranged between 80 to 90 bpm. In the Fig. 2 the heart rate of the greenhouse farmers were shown at different WBGT index. It was observed by Nag and Chatterjee, [23] that the average working heart rate while seed bed preparation with spade is 144 bpm. Although the average working heart rate as indicated in Table 4 was observed 138 bpm, 147 bpm, and 153 bpm at A, B and C WBGT respectively. It was determined that the working heart rate of the workers at C is 10% greater than A and 4% more than B. Also, the maximum heart rate reached was 167 bpm at extreme WBGT i.e. at 30-33℃ condition. In Fig. 2 the working heart rate reaches to the peak after 10 min of working. Further the recovery heart rate was latter in case of higher WBGT index [24-27].

3.2.1 Statistical analysis of working heart rate at different types of greenhouse

In order to find the significance of the physiological parameters at different type of greenhouses and time slot data were analyzed in OPSTAT software. Further the results were compared with open field conditions [28,29].

Table 4. Physiological responses of the greenhouse worker (N=21) preparing seed bed at different WBGT

Parameters	A- 25-26℃	B- 28-29℃	C- 30-33℃
Average Resting heart rate (bpm)	72	75	78
Average working heart rate (bpm)	138.35 ± 12.7	147.15 ± 16.2	153.85 ± 12.7
Maximum heart rate (bpm)	154	162	167

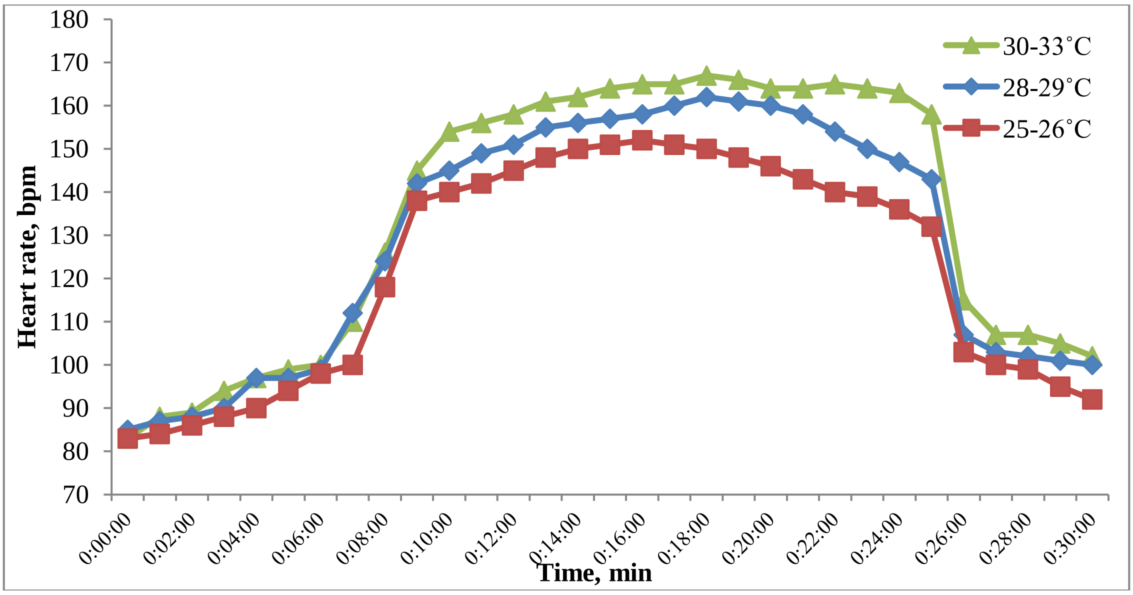

Fig. 2. Heart rate responses while performing manual seed bed preparation in greenhouse in different WBGT index

Table 5. Heart rate of selected subjects at different working environment

Treatment	G_1		G_2		G_3		G_4	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
T_1	136	0.889	136.41	0.937	144.03	1.968	154.03	2.883
T_2	142.95	1.156	144.13	0.881	146.433	1.94	156.633	0.725
T_3	139.81	0.781	139.1	0.866	144.43	1.452	153.00	0.303
SE(m)	0.995		0.869		0.662		1.685	
SE(d)	1.408		1.229		0.937		2.382	
CV	1.235		1.076		0.792		1.888	

Table 6. ANOVA table for analysis of the effect of type of greenhouse on physiological parameters

Source of Variation	Sum of Square	Degree of freedom	Mean Sum of Square	F	P-value	F crit
Between Groups	1514.541	11	137.685	23.069	4.07E-10	2.21630
Within Groups	143.2375	24	5.96823			
Total	1657.778	35				

Analysis of variance Tables 5 and 6 denotes that the heart rate was significantly affected by the type of greenhouse and time period. The first factor G_1-G_4 showed the significant difference in heart rate of the greenhouse worker. The workers working under greenhouse type G_4 i.e. walk in tunnel type indicates the highest working heart rate. In G_2 (shade net) the micro climate is similar to the open field condition as the air easily passes the net. Hence, the air movement regulates the inside temperature of the greenhouse. Therefore, the heart rate were significantly similar to the open field condition G_1. The second factor i.e. time slot showed significant effect on heart rate. The heart rate at T_2 (11 am -1 pm) is significantly higher than T_1 (8-10 am) and T_3 (3- 5 pm). In the previous section 4.1.2 it is perceived that the WBGT and HI values are at peak in these T_2 time slots and gradually decreases as time goes. Further the heart rate responses were also noticed lesser at T_3 as the temperature goes down the heart rate reduces. From the interaction between type of greenhouse and time slot ($G \times T$) it is obtained that the workers in walk in tunnel working at 11am-01pm experiences extreme heat stress as heart rate is at peak upto 156.6 bpm. At this time slot the WBGT index is also at peak. Also in G_3 the heart rate reached 146.3 bpm at T_2 but lesser than the G_4. This can be a walk-in tunnel covered with polythene, making the air movement inside negligible (<0.3 m/s). The results were in accordance with [30] as the physical environment changed physiological parameters also changes. As a result efficiency of the greenhouse worker reduces. This indicates that the greenhouse is not ergonomically suitable for the workers [31-33].

4. CONCLUSION

The study was undertaken to estimate the heat stress level inside the greenhouse of Chhattisgarh. The weather parameters such as dry bulb temperature, wet bulb globe temperature index, relative humidity and humidex index were observed higher in May, June, July, August and September. The WBGT index and Humidex index were significantly higher inside the greenhouse than outside. If proper work rest cycle is followed the heat related issues such as headache, heat cramps and nausea can be avoided. It is recommended to provide the proper hydration facilities with electrolytes may reduce the ill effects of heat to the greenhouse workers. Appropriate working hours with short hydration breaks must be considered while working for efficient work and productivity. Further it is concluded that for only 5 months of the year greenhouse workers are working under comfortable environment. But at rest of the year they have to perform their duties in extreme weather conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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