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Occupational heat stress to the greenhouse workers

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Abstract
Greenhouse farming involves controlling the environment to cultivate horticultural crops throughout the year. However, despite its advantages, greenhouse workers face unique job-related challenges due to factors like high temperatures, humidity, carbon dioxide levels, and pollutants. These conditions can result in health problems such as respiratory issues, fatigue, and reduced mental alertness among workers. A study was conducted to examine temperature fluctuations and humidity imbalances, particularly during the hot summer months, which can lead to heat-related illnesses. The study found that the Wet Bulb Globe Temperature (WBGT) in walk in type greenhouses averaged around 34 °C, putting workers at risk of heat exhaustion, dehydration, respiratory problems, and muscle cramps due to the physically demanding nature of their work. To address these health issues, ergonomic interventions were implemented as part of the study's recommendations.

Keywords: Greenhouse workers, wet bulb globe temperature (WBGT), heat stress, ergonomics

Introduction
Agricultural work is mostly performed outdoors or in facilities such as greenhouses, which can be directly affected by the outdoor temperature. Thus, farmers are likely to be exposed to heat stress, and elderly farmers can be even more vulnerable. The heat stress can have severe health effects; various techniques have been suggested to evaluate heat stress. It is important to examine the level of heat exposure in hot environments because such environments can affect cardio respiratory, mental, heat-related illnesses, for example, as stroke, exhaustion, cramps, collapse, and fatigue (Jung and Kim, 2022) [7].

India is currently experiencing a surge in horticultural production, surpassing even food grain production, despite utilizing much less land, approximately 28.7 million hectares (Anon., 2022) [2]. Within this horticultural area, approximately 127,000 hectares are dedicated to protected cultivation, with 70,000 hectares using greenhouse structures (Kumar *et al*., 2023) [10]. The rising trend in greenhouse farming enables year-round production of high-quality fruits and vegetables, resulting in increased income for growers. To address the health concerns of farmers, some ergonomic solutions have been proposed. For instance, headgear was designed to reduce heat stress among farmers in Rajasthan (Dharaiya, 2014) [6]. Clothing plays a crucial role in regulating the body's heat dissipation, leading to the development of heat-resistant clothing by Chan *et al*. (2016) [4]. The water, rest, shade cycle, introduced by Bodin *et al*. (2016) [3], was implemented for sugarcane workers in Salvador to mitigate heat-related issues. Functional clothing, including aprons, gloves, headgear, masks, and ear muffs, was recommended by Alapati and Shaik (2017) [1] to address occupational health hazards in farming activities. Kesarwani (2017) [8] designed personal protective wear, including broad-brimmed hats, to enhance farmer safety while working in radiant heat. Kossambe and Phaldessai (2020) [9] incorporated phase-changing materials into cooling jackets to create a comfortable working environment for farmers. While studies have evaluated the heat exposure levels of farmers working outdoors, there has been limited research on heat stress within greenhouses. Hence, the study was performed to assess the heat stress to the greenhouse workers.

Materials and Methods
With the aim of analyzing the heat stress to the greenhouse farmers walk in type tunnel type of greenhouses were investigated. The structure examined was walk in tunnel (n=8) with area of 1.4 acre. The structures were covered with plastic film of 200 micron thickness. The covering material in the selected greenhouse was polythene. The greenhouse farmers were engaged in cultivation of watermelon, muskmelon, hybrid cucumber, cherry tomato, tomato, pointed guard, ginger and papaya. The study commenced from April to September month.

The working hours of the greenhouse farmers were from 8:00 am to 5:00 pm with lunch break of 1 h from 01:00 to 02:00 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.

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

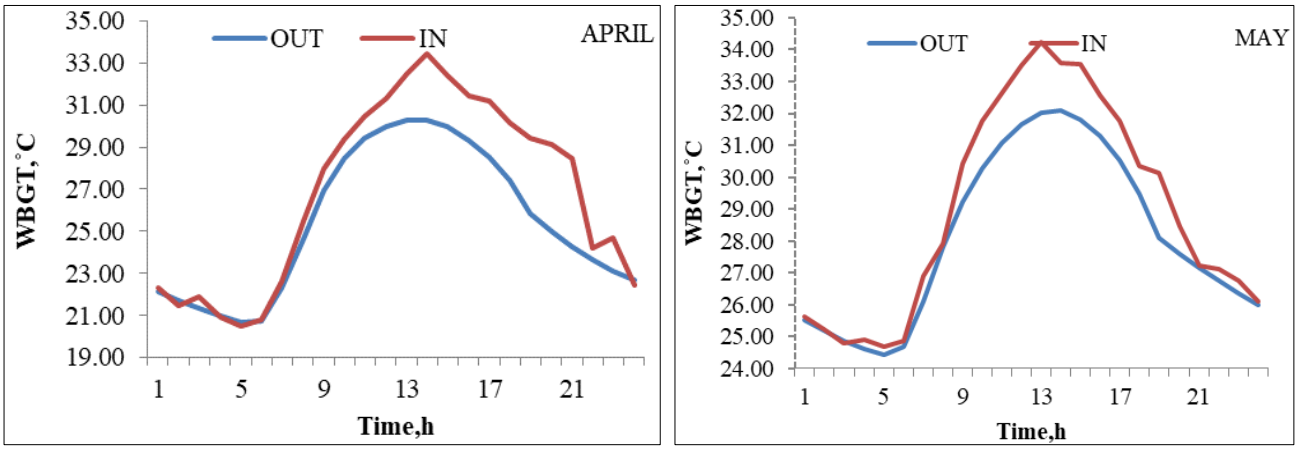
A heat index stress monitor was used to measure key environmental factors, including wet bulb temperature, dry bulb temperature, globe temperature, wet bulb globe temperature (WBGT) for outdoor and indoor conditions, relative humidity, and heat index. WBGT and relative humidity were assessed to gauge heat stress levels and ensure the safety of agricultural workers, particularly those working in greenhouses. The Wet Bulb Globe Temperature (WBGT) index is a composite temperature used to estimate the effect of temperature, humidity, wind speed, and visible and infrared radiation on humans. It is used to determine the workload requirement for work area using heat stress or strain threshold limit value (TLV). It is measured by the help of heat index WBGT meter which measures the WBGT index with the help of three temperature like air temperature (T_a), wet bulb temperature (T_w) and black globe temperature (T_g).

$$WBGT = 0.7\ T_w + 0.2T_g + 0.1$$

Where,
WBGT= Wet bulb globe temperature, °C
T_w = Wet bulb temperature, °C
T_g = Globe temperature, °C
T_a = Air temperature, °C

Results and Discussion

The WBGT index of the inside and outside greenhouse was measured. The values of WBGT index is denoted in the Fig.1. The comparison between the WBGT index of the inside greenhouse and outside shows that the WBGT index inside greenhouse is higher than the outside. On an average the value rises from 08:00 am to 17:00 pm as compared to outside the greenhouse. During night hours there was no significant difference between the values of inside and outside the greenhouse. The monthly mean WBGT index for each hour of the day is indicated in the Fig.1. It shows that the greenhouse farmers were at heat stress in April, May, June, July, August and September. In April month some heat discomfort is associated due to heat around mid day as WBGT reaches above 30 ℃ between 11.00 am and 15.00 pm with maximum of 34 ℃ as shown in Fig.1. In the month of May the greenhouse farmers experience more heat stress. The WBGT increased from 08:00 am till 16:00pm with maximum WBGT index 34 ℃ between 12:00 to 14.00 pm which is unsafe according to Simane *et al*., (2022) [11]. The WBGT index in June mild heat stress started from 7.00 am to 8.00 am and reached 33.4 ℃ at 12.00 noon to 13.00pm. The greatest discomfort experienced by the farm worker from 8.am to 15.00 pm. In July month the discomfort experienced is between 11.00 am till 15.00 pm because of increase in moisture along with temperature. This shows that the dangerous working hour in summer season from 8.00 am till 16.00 pm where extreme discomfort is reported from 9.00 am till 15.00 pm with highest WBGT index up-to 34 ℃. The mean WBGT on hourly basis of August showed lesser heat stress compared to summer months although the heat discomfort was observed at 11.00 to 15.00 pm. The maximum WBGT level in September month was observed similar to the august month although the discomfort experienced was from 12.00 to 15.00 pm as shown in Fig.1. It was found that the wind velocity is negligible inside the greenhouse i.e. less than 0.3 km/h. This does not allows the air to circulate from the greenhouse. In the previous studies done by (Callejon-Ferre *et al*., 2011) [5] also showed the significant difference between the heat stress values during less wind velocity. This may be the cause for the farmers suffering from heat stress while working inside the greenhouse. That indicates that the greenhouse environment is not ergonomically fit for greenhouse worker. Therefore there is the dire need of the ergonomic interventions for developing comfortable working environment for greenhouse farmers.



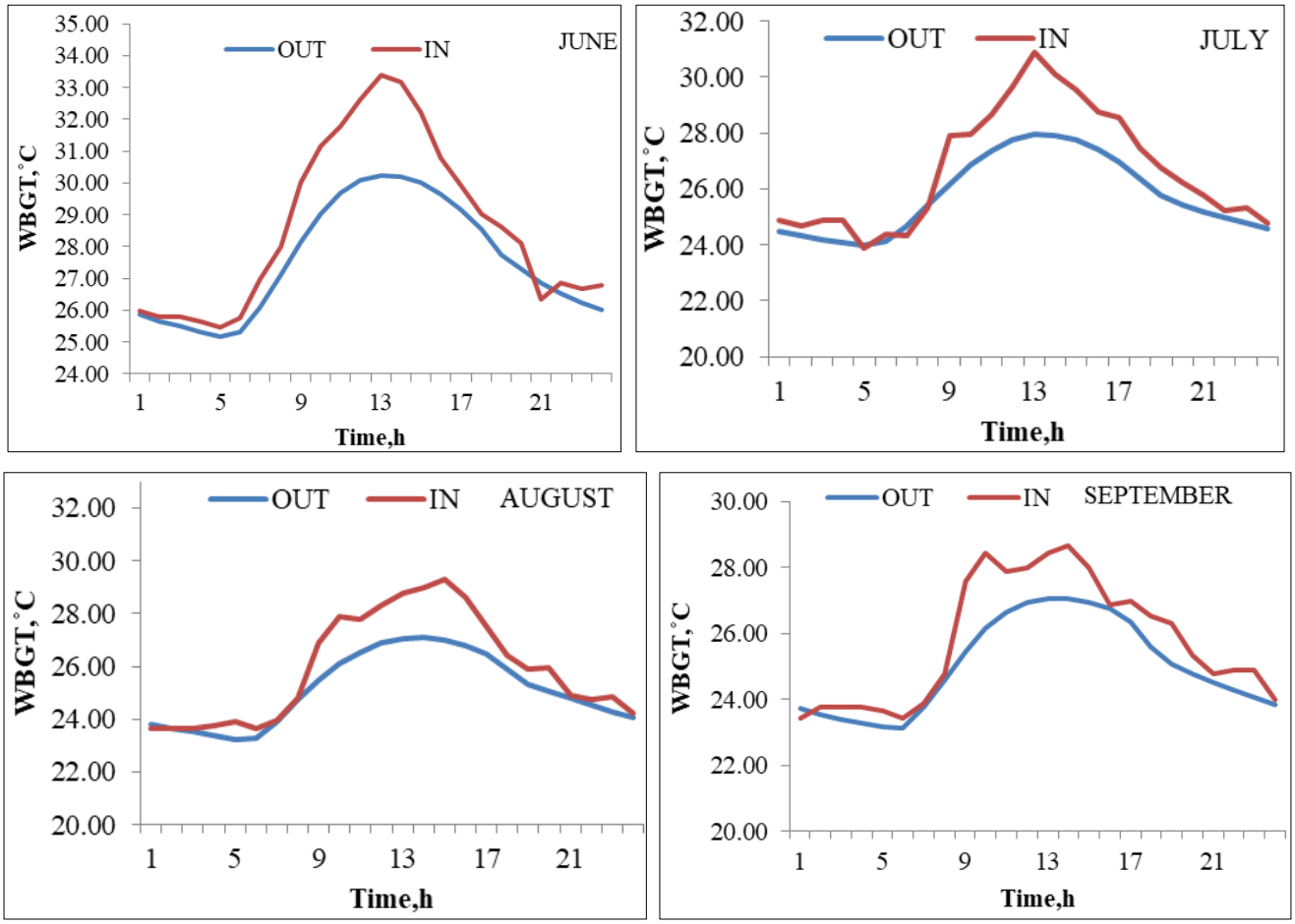


Fig 1: Mean monthly WBGT index for each hour of the day

Conclusions

In this study, the heat stress level inside the greenhouse in summer in Chhattisgarh was evaluated. The WBGT index inside the greenhouses was higher as compared to the open field. The heat stress was significantly higher during 08:00 to 17:00 h. Certain environmental parameters were controlled under the greenhouse like temperature and humidity but its favorable for plant growth only. The WBGT index reaches maximum i.e. 34 °C at extreme heat condition inside the greenhouse. Therefore it is recommended to perform light work to the farmers. The rest period was also recommended at the time slot of 12.00 to 14.00 h as the WBGT observed maximum. This reduces the risk of heat related illness to the farmers. In addition to this frequent water breaks were allowed to the farmers to avoid heat exhaustions and dehydration. Farm workers were allowed to enter inside the greenhouse in shifts so that they can work comfortably.

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