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Impact Of Heat Stress Among Workers In Naturally Ventilated Greenhouse

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Abstract

Natural ventilated Greenhouses are the structures which gives a microclimate upto certain extent that make the plants to grow well in an unfavorable climate. These are extremely helpful in a particular period of year when some plants cannot be grown in open field. But Greenhouses cannot be considered a very suitable place to work for the workers specially in early or in summer season. Workers have to work in unfavourable conditions and exposed with stress to the body from physical activity can be dangerous to worker's health. The experiment was carried out to study the impact of heat stress of workers in a naturally ventilated greenhouses in the Horticultural campus of College of Agriculture, OUAT, Bhubaneswar, Odisha in 2014. During 9^{th} week the average greenhouse temperature and relative humidity was around 40^0C and 50 per cent respectively which is unsuitable for agril. labourers to work inside the greenhouse from 12 to 2 PM. These average values rose over 50^0C of temperature as well as 55 per cent relative humidity during 12^{th}, 13^{th} and 14^{th} week in which it was impossible to work from 12 to 3 PM. Again during $8^{th}$and 9^{th} week the nature of work i.e. field preparation or digging of soil inside greenhouse from 10 to 4 PM was again above the limit suitable to workers. The value of working heart rate(WHR) increased upto 120 beats/min with a corresponding value of oxygen consumption rate 0.939 $lmin^{-1}$ after 20 minutes of digging. However the value in case of simple operation like weeding remain with acceptable limit. Hence to prevent from heat stress the workers should allow to work inside greenhouse from 6 to 10 AM in the morning as well as 5 to 7 PM in the evening. No doubt the greenhouse provides a conducive climate for plant growth, yet a greater overall knowledge and preventive measures would help the workers to avoid risks of inhouse work.

Keywords: Greenhouse, Working Environment, Working heart rate, Health risk

I. INTRODUCTION

Agriculture is the backbone of India's economic activity and our experience during the last 50 years has demonstrated the strong correlation between agricultural growth and economic prosperity. We need a new and effective technology which can improve continuously the productivity, profitability, sustainability of our major farming systems. One such technology is the green house technology. It is the most practical method of achieving the objectives of the protective agriculture where the natural environment was modified by using some engineering principles to achieve optimum plant growth and yield. Greenhouses are framed or inflated structures covered with transparent or translucent material large enough to grow crops under partial or full controlled environmental conditions to get the desired growth and productivity. They are extremely useful when plants, in particular period of the year, cannot be grown in open country or in areas where the climatic never guarantees a good quality crop. Vegetables need very high levels of temperature with a peak of 30^0C and 55 per cent relative humidity but these levels cannot be considered favorable to agricultural workers who work in this environment. To prevent workers from taking periodic breaks during warmest months, it's necessary to control the temperature utilizing shading and common or mechanical ventilation systems work hard during the day. Workers are exposed to two different

kinds of stress: firstly the long time exposure to sever environmental conditions, according to the standards, secondly the thermal change, when they leave their work site. Prevention against chemicals disease has been the main focus of research but now climatic risks from exposure to heat environment is increasingly being recognized. Hence the study has been undertaken to evaluate the risk from long period of exposure to unfavourable environmental conditions of workers inside a natural ventilated greenhouse.

II. MATERIAL AND METHODS

2.1. Experimental Site

The experiment was conducted for a period of three month in a greenhouse with a floor area of 100m^2, covered with a UV stabilized LDPE plastic film (0.2mmthick). The greenhouse is oriented in a E-W direction on the Campus of college of Agriculture, OUAT, Bhubaneswar; 20° 14' 0" N, latitude , and 85° 50' 0" E, longitude with an elevation of 25.9 meter above the mean sea-level and nearly 64 k.m. west of Bay of Bengal.

2.2. Collection of climatic data

The climatic data pertaining to the temperature of ambient air, greenhouse temperature and relative humidity of inside and outside of greenhouse were taken. Finally the same were used to evaluate the thermal performance and for the validation of proposed graphs for better understanding. The temperature of the outside ambient air and the enclosed room air of green house were measured with the help of thermometer. It was measured on hourly interval for 12 hour cycle for typical days from February 2015 to April 2015.Weekly average temperature was recorded . With increase in the enclosed air temp inside greenhouse the presence of large amount of water at various location results in the rise of relative humidity. The evapotranspiration from the plants, soil water in the ground under normal conditions cause excess water to be present, which rises the relative humidity inside the greenhouse. The high relative humidity inside the house was beneficial in cushioning the impact of very high or low outside temperature to some extent. It has been well established that the optimum level of relative humidity for proper plant growth is around 55 per cent which is available inside the greenhouse. The hourly variation of relative humidity for typical days from February 2015 to April 2015 were recorded.

2.3 Measurment of Physioological Parameters

The physiological parameters of selected male and female worker working in a naturally ventilated greenhouse were measure in the Ergonomic laboratory of OUAT. The age of the workers varied in the range of 18-45 years because the efficiency of the workers decreasing with increase in age of the workers. The Anthropometric parameters of selected subject were measured using integrate composite anthropometer unit. As the workers for both male & female worked operated in standing mode only the anthropometric parameters of standing posture were measured. The polar heart rate monitor was used to measure the resting heart rate and the working heart rate in beats $min^{-1}$of the workersduring the study.The advnatge of using this instrument is that those dates upto 99 hours can be stored in the heart rate monitor and data can be transferred to computer. For every strenuous work in any field require adequate rest to have an optimum work output. Better performance result can be expected from the workers when proper attention is given for the work rest schedule for different operation.

III. RESULTS

3.1 Temperature

Greenhouse temperature was very much suitable for the workers working inside greenhouse working inside an natural ventilated greenhouse during the cool months of the year i.e. from November – February as it gives a favorable working environment. During that period the inside greenhouse temperature was found to be more than 2-3^{0}C higher temperature as compared to the

ambient temperature. But in advancement of weeks i.e. from 8th week of the year which is the last part of February, the greenhouse inside environment started rising. The inside greenhouse temperature in the early hours of the day i.e. from 6 -10 AM varied from 18-30^0 which was observed to be 3-5^{0}C higher than the outside temperature. Similarly during the afternoon hour the greenhouse inside temperature varied from 30^0-25^{0}C i.e. from 4-6 PM. However during the mid hours the inside temperature recorded to be round 40^{0}C. Therefore during 8-9th week the working environment inside greenhouse during early and late hours of the day was found to be acceptable for the workers. Further during advancement of weeks i.e. on 12th week the temperature inside the greenhouse was recorded to be 20-38^{0}C i.e. 6 to 10 AM as compared to outside temperature was observed to be 35-30^{0}C i.e. from 4-6 PM against 32-27^{0}C being the outside temperature. The inside temperature was recorded to be 5^{0}C higher than the outside temperature. But the inside temperature recorded to be 45^{0}C against 40^{0}C being outside at mid hour of the day i.e. 12 noon. Similarly moving ahead to 14th week i.e. month of April the greenhouse inside temperature observed to be 10^{0}C higher than the outside temperature both in morning and afternoon hours. The inside temperature at 10 AM recorded to 40^{0}C which rise upto even 50^{0}C during mid day (12 noon). Greenhouse inside temperature was also observed to be 40^{0}C at 6 PM while it was 28^{0}C outside.

3.2 Relative humidity

The relative humidity which was also recorded during cool months found to be around average 45 per cent inside the natural ventilated greenhouse was conducive for the workers. On the starting of summer i.e. on 8th week (end of February) the inside relative humidity observed to be 60 per cent against 52 per cent outside at 10 AM in the morning. The same was recorded 68 per cent and 58per cent respectively at 6 PM. Hence it was 10per cent higher in the both the cases. Similarly in 12th week the relative humidity recorded to be 62per cent inside the greenhouse where it was 55per cent at outside at 10 AM. The values found to be 66 per cent to58 per cent in the evening at 6 PM The higher Relative Humidity observed to be higher in the morning session was due to irrigation to the crops. Similarly the relative humidity observed to be more than 50per cent at 10 AM and 6 PM in the 14th week inside the greenhouse.

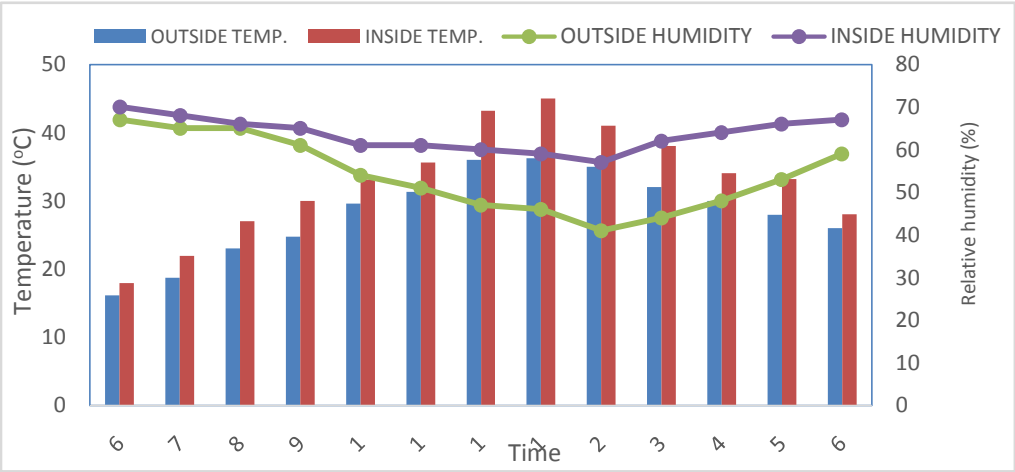

Figure 1. Average temperature and relative humidity inside greenhouse during 8th week

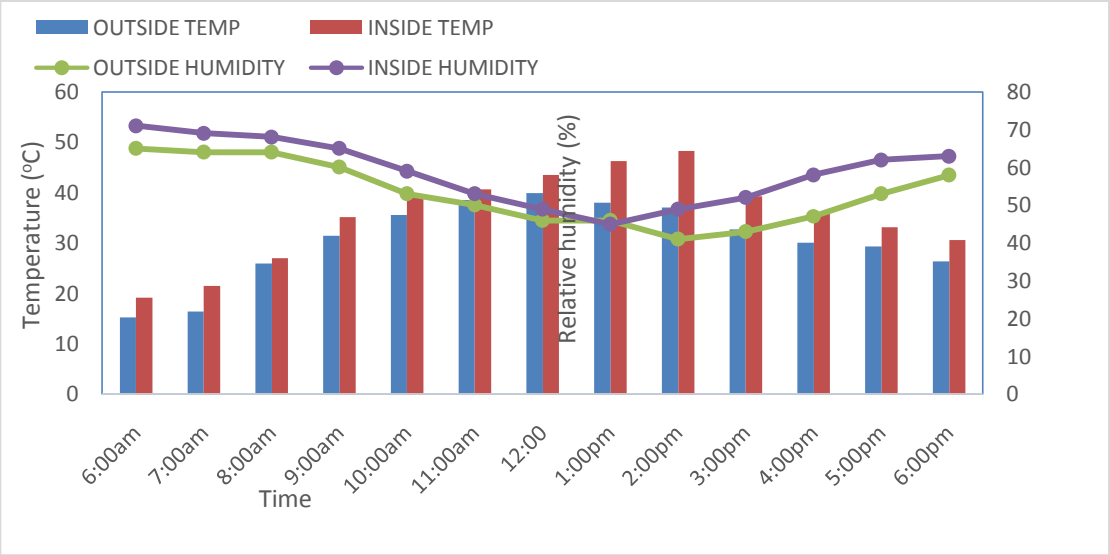

Figure 2. Average temperature and relative humidity inside greenhouse during 12th week

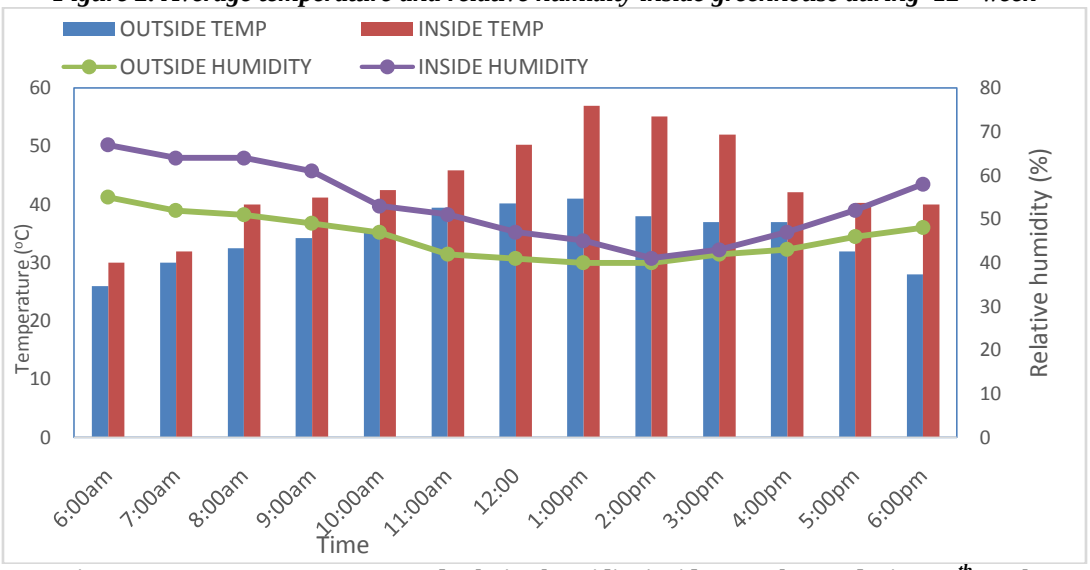

Figure 3. Average temperature and relative humidity inside greenhouse during 14th week

3.3 Impact of heat stress

Natural ventilated greenhouses give a microclimate uptocertain extent that make plants to grown well even in unfavourable condition. Hence during cool months as the temperature rises around 40^0C than the ambient temperature it was very much suitable to grow vegetables or flowers in the study area which is 60 Km away from the coast. The same greenhouse was also suitable during rainy season which protects the crop very well. Hence growing crops under natural ventilated greenhouse round the year or indirectly to achieve a quick payback period the selection of crop should be accordingly made. One of such alternate is growing some off season vegetable for raising both vegetables as well as floriculture seedlings/ cuttings round the year or propagation of fruit grafts of mango, cashew, etc. Therefore after 12th week i.e. March-April i.e. summer season as the inside temperature rises around or more than 40^0C and relative humidity more than 50per cent it is difficult on the physical part of labours to go for different operations under greenhouses. Which was observed for typical operations like digging the soil with a trench hoe/spade or weeding.

Table 1. Anthropometric data of male & female workers of Odisha (Values are in cm)

Sl. No.	Dimension	Male			Female		
		Average	5th percentile	95th percentile	Average	5th percentile	95th percentile
1	Weight, Kg	51.8	40.3	63.2	44.0	33.8	54.1
2	Stature, cm	163.6	151.8	175.4	151.5	141.8	161.2
3	Vertical grip reach, cm	198.9	183.5	241.2	179.4	166.3	192.5
4	Acromial height, cm	135.9	123.0	148.5	125.0	115.8	134.2
5	Olecranon height,cm	100.5	92.4	108.6	93.8	86.2	101.4
6	Lliospinale height,cm	88.6	40.6	136.7	82.5	74.9	90.1
7	Metacarpal-height,cm	68.8	60.7	76.9	64.3	57.6	71.1
8	Knee height,cm	48.5	42.4	54.7	43.6	37.1	50.1
9	Span, cm	172.3	158.4	186.1	158.0	141.7	174.3
10	Sitting height, cm	84.9	76.1	93.8	78.4	69.8	87.1
11	Elbow rest height, cm	21.8	16.4	27.2	22.1	17.4	26.8
12	Functional leg length, cm	98.3	89.5	107.1	90.9	82.0	99.8
13	Age, yrs	38.5	19.4	57.5	33.9	21.3	46.5
14	BMI, Kg/m^2	19.4	17.7	20.6	19.3	17.0	20.87

Table 2. Physiological Parameters of selected subject during Operation

	Digging				Weeding			
	Outside the Greenhouse		Inside the Greenhouse		Outside the Greenhouse		Inside the Greenhouse	
	Male	Female	Male	Female	Male	Female	Male	Female
Working heart rate (beats/min)	130.5	132.8	135.6	133.8	127.3	128.0	130.5	129.8
Increase in heart rate (beats/min)	60.5	62.8	65.3	69.6	57.8	56.5	60.3	59.8
Oxygen consumption rate(l/min)	0..98	0.99	1.12	1.08	0.92	0.94	0.99	1.02
Energy Expenditure rate(kCal/min)	20.5	20.6	23.4	22.5	19.3	19.5	20.61	21.31
Relative cost of workload (% of VO_2 max.)	46.6	53.8	53.3	58.7	43.8	51.08	47.1	65.21
Body parts feeling maximum discomfort	6.5	7.0	8.0	7.5	6.0	6.5	7.5	7.0

The physical and physiological characteristics of the workers are given in Table No.1 & 2. On average, the weight of a male worker is 51.8 Kg against 44.0 Kg for female agril. Workers. The Body Mass Index of the male and female worker are under normal weight category. In almost all cases the working heart rate of male workers is more than that of female workers both in digging and weeding operation. The increase in heart rate was observed to be 60.5 beats/min for male for digging operation and 65.3 beats/min while digging inside green house. But in case of female workers it was 69.6 beats /min inside a green house against 62.8 beats/min working outside. Similar trend was observed for female workers in case of weeding. But digging recorded in higher cardiac cost against manual weeding. The oxygen consumption rate and observed to be 1.12 l/min and 0.99

l/min for male workers in digging and weeding operation respectively while working inside a naturally ventilated green house. The energy expenditure rate and body parts feeling maximum discomfort followed the same trend for digging and weeding operations. The higher cardiac cost inside a naturally ventilated green house may be due to the fact that the inside temperature and relative humidity are recorded more than that of outside temperature. The study provided an understanding of the peripheral thermoregulatory adjustability that limits the ability of a worker to withstand heat exposure in inside naturally ventilated green house environment.

IV. CONCLUSION

During the field investigation the different climatic parameters such as temperature and relative humidity during the summer period (March-April) inside the natural ventilated greenhouse are above a reasonable level of comfort of agricultural workers working inside the greenhouse. Both inside air temperature as well as relative humidity clearly show that the human body is stressed in non-appropriate mode even though the labourers are acclimatized. Working under around 40^0C temperature and more than 55 per cent relative humidity will lead to a loss of water and mineral salts through remarkable perspiration and breathing which will ultimately may lead to the immediate and remote serious consequences as heat stroke.
Besides this some precautions may be taken up for minimizing the risk.

a) To take the advantage of climatic conditions workers should work earlier in the morning i.e. from 6 to 10 PM and 5 to 7 PM in the afternoon hours.
b) The heavy operations like digging of soil with spade/trench hoe may be taken only for 15 to 20 minutes in the morning session followed sufficient rest.
c) Cotton clothing should preferred by the workers which is comfortable.
d) The workers should be supplied with sufficient water enriched with glucose and salt to overcome the exertion during the summer.
e) Both the sides of the naturally ventilated greenhouses should be opened intermittently so that excess temperature and humidity can be replaced due to natural ventilation.
f) The easiest technological solution to avoid these dangerous lies in drastic reduction of solar energy entering to the natural ventilated greenhouse during summer period of the year by providing a shade net over the greenhouse . This shade net should be of a pull over type which will be used during summer period and the rest of period it will be drag out so that required solar energy can be used for greenhouse production.

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