EFFECTS OF VENT CONFIGURATION ON MICROCLIMATE CONTROL IN POLYHOUSE

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ABSTRACT

Effects of vent configuration on microclimate characteristics inside polyhouse were analysed for different seasons. The study was conducted in a polyhouse located at central farm, Agricultural Engineering College and Research Institute, Kumulur, Trichy. The parameters affecting ventilation rate are temperature, humidity, intensity, wind speed, solar radiation. The ventilation rate of polyhouse having different vent configurations of roof and side ventilation, side alone and roof alone ventilation were estimated. The ventilation rate was found out by using energy balance model and physical mechanism approach. The readings were taken from March to December 2018 includes summer and winter seasons. Comparison of inside-outside temperatures and inside-outside relative humidity were studied. Comparison of ventilation rates for different vent configurations was also done to find the best vent configuration for a particular season. The ventilation mechanism of the existing naturally ventilated polyhouse of size 6 m x 12m was found out. Comparison of measured and estimated temperature, relative humidity was done graphically to find the best fitted data. The regression analysis showed good fit of estimated temperature having R^2 value as 94% and estimated relative humidity having R^2 value as 90%. The effect of insect screen in ventilation performance of polyhouse was studied, and it was found that ventilation rate was reduced by 10.1% with insect screens. From the study, it was determined that roof plus side opening ventilation was most suitable for summer season, and only roof opening ventilation was most suitable for winter season.

KEYWORDS: Poly House, Vent Configurations & Micro Climate

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1. INTRODUCTION

Effects of vent configuration on the variation microclimate characteristics inside polyhouse were analysed for different seasons. The study was conducted in a polyhouse of size 6 m x 12 m. The ventilation rate of greenhouse having different vent arrangements of roof and side ventilation, side alone and roof alone ventilation are estimated. The ventilation rate is found out by using energy balance model and physical mechanism approach. The readings were taken from March to December 2018 include summer and winter seasons. Suitable technology for manipulation of the environment is very important for sustainable development of agriculture in the country. Normally, plant growth will be affected by weather parameters like maximum and minimum temperature, relative humidity and light intensity. There is no way to suitably modify or control light, temperature, and air composition parameters in open field cultivation. To get better production of crop the micro climatic parameters needs to be controlled. It can be possible in polyhouse environment to achieve maximum yield of best quality. As

the ventilation in polyhouse controls air flow inside polyhouse, the vent configuration should be analyzed.

Bartzanas *et al.*, 2004 studied the airflow by sonic anemometer and temperature patterns by tracer gas technique in a tunnel greenhouse, and computed that ventilation rates varied from 10 to 58 air changes per hour for the wind speed of 3 ms⁻¹ and for a wind direction perpendicular to the openings. Teitel *et al.*, 2006 compared roof plus side and roof alone ventilation and studied the effects of air flow through vents. They found that both roof and side vents effectively reducing temperature and humidity than roof ventilation alone. Lopez *et al.*, 2013 evaluated micro climate and air flow inside greenhouse and found the fans placement nearer to the side vents increase air exchange rate inside greenhouse and increase values of kinetic turbulence energy by 550%.

Santosh *et al.*, 2017 reported that change in micro climate was due to energy transfer and mass balance, and it was necessary for proper plant growth and maximizing yield. Baptista *et al.*, 2001 suggested that micro climate inside greenhouse could be adjusted by proper ventilation method either to cool the greenhouse or to remove water vapour. Lorenzo *et al.*, (1990) observed that due to increase in solar radiation temperature inside greenhouse increased and reported that air circulation inside greenhouse was uniform when excess heat was removed. Kittas *et al.*, (1996) defined ventilation that pressure differences were produced by wind and temperature gradients inside and outside of greenhouse.

To produce good quality produce, favorable micro climatic parameters should be ensured with proper ventilation rate. Hence, vent configuration and characteristics should be analyzed properly to ensure proper air exchange. Short and Lee (2002) found that temperature distribution was uniform between crop canopy when the side opening was provided at lower level. Ould Khaoua *et al.*, (2006) reported that vent placement towards windward side increase in ventilation rate inside greenhouse. American Society of Agricultural Engineers (ASAE, 2003) recommended 0.04 m³ s⁻¹ ventilation rate per unit floor area during summer season and half of the ventilation rate was sufficient during winter. Hence, the study was carried out to assess the relation between vent configuration and ventilation rates for providing good environment for the plants during summer and winter seasons, and to study about the benefit in changing vent configuration during summer and winter seasons

2. METHODOLOGY

The field study was conducted in a polyhouse located at central farm, Agricultural Engineering College and Research Institute, TNAU, Kumulur, Trichy. The polyhouse is saw tooth type has one number of spans. The size of the greenhouse is 6 m x 12 m. It has side and roof vent configuration. The average maximum temperature was 34°C and average minimum temperature was 24°C. The average maximum relative humidity was 62% and minimum relative humidity was 41% during observation period.

The air humidity meter was used to measure relative humidity in air. Temperature was measured thermometer. The meteorological parameters were measured at certain spatial distribution inside polyhouse. The spatial distribution of measurements is shown below.

Spatial Distribution of Measurements.

2.1. Determination of Ventilation Rate

Energy balance method and physical mechanism approach were used to determine ventilation rate inside greenhouse.

2.1.1. Energy Balance Method

Fernandez and Bailey (1993) predicted ventilation rate in a greenhouse by energy balance model and it was validated by tracer gas technique. The model was run based on the assumption of without any heating inside greenhouse

Removed Energy by thermal leakage (E_L) = Heat Energy collected in greenhouse (E_S) - temperature losses and ventilation (E_V) through cover (E_C) - stored energy (E_{ST})

The thermal leakage and ventilation is given by

$$E_L + E_V = E_S - E_C - E_{ST}$$

$$E_L + E_V = E_{SEN} + E_{LAT}$$

The sensible heat flux and latent heat flux are given by:

$$E_{SEN} = \frac{\phi_v}{A_g} \rho C_p (\theta_i - \theta_o) E_{LAT} = \frac{\phi_v}{A_g} \rho L (w_i - w_o)$$

Where,

ρ - density of the air in Kg m^{-3} ;

C_p - specific heat of the air in $\text{J Kg}^{-1} \text{K}^{-1}$

L - latent heat of vaporization of water in J Kg^{-1}

θ - temperature of the inside and outside air in K

w -absolute humidity of inside and outside air in Kg Kg^{-1}

ϕ_v -ventilation rate in $\text{m}^3 \text{s}^{-1}$

A_g - ground area in m^2

The solar energy accumulated inside greenhouse depends on co-efficient of absorption of solar radiation

$$E_S = \alpha I_0 = I_i - I_r$$

where

I_i - internal solar radiation;

I_r -solar radiation reflected from the crop.

The heatlosses through unit area of cladding material are given by

$$E_{CL} = U \frac{A_c}{A_g} (\theta_i - \theta_o)$$

Where,

A_c -area of greenhouse cover in m²;

U - thermal transmittance of the cladding material.

The accumulated energy inside the greenhouse involves the cladding material, air inside greenhouse, crops grown and soil

$$E_{ST} = E_{ST}^{cover} + E_{ST}^{air} + E_{ST}^{crop} + E_{ST}^{soil}$$

The accumulated energy is given by

$$E_{ST} = \frac{MC_P(\theta_1 - \theta_2)}{t_1 - t_2}$$

Where,

M - Mass per unit greenhouse area in Kg.m⁻²;

θ_1 - Initial temperature in K

θ_2 - End temperature in K

t_1 - Starting time of the experiment

t_2 - End time of the experiment

2.1.2. Physical Mechanism Approach

Based on the physical mechanism approach proposed by Boulard&Baille, 1995; Baptista et al., 1999 and Kittas *et al.*, 1997 the ventilation rate G is calculated by

$$G = C_d \sqrt{\left(\frac{A_R A_S}{\sqrt{A_R^2 + A_S^2}} \right) * \left(2g \frac{\Delta T}{T_0} h \right) + \left(\frac{A_T}{2} \right) * C_w u^2}$$

Where,

A_R - area of roof vent in m²;

ΔT - temperature difference

A_s - area of side vent in m^2 ;

g - gravitational constant $m.s^{-2}$

A_T - area of total vent in m^2 ;

T_0 - outside air temperature (K);

C_d - discharge coefficients;

h - vertical distance from the midpoint of side to roof openings in m;

C_w -wind effect coefficients;

u - outside wind speed in ms^{-1}

The ventilation rate for the greenhouse provided with side and roof openings

$$G = \frac{A_T}{2} C_d \left(2g \frac{\Delta T h}{T_0} + C_w u^2 \right)^{0.5}$$

When stack ventilation is negligible, the ventilation rate is given by

$$G = \frac{A_T}{2} C_d \sqrt{C_w u}$$

When Leakage ventilation A_T is zero the equation becomes

$$G = \frac{A_T}{2} C_d \sqrt{C_w u} + G_0$$

The wind related co-efficient $C_d \sqrt{C_w}$ can be found by fitting experimental data in the ventilation equation along with regression analysis. Graph was plotted with x-axis ($\frac{A_T}{2} \cdot u$) and y-axis (ventilation rate G). R^2 value was found by regression analysis. Then from the obtained slope equation $C_d \sqrt{C_w}$ was found.

3. RESULTS AND DISCUSSIONS

3.1. Determination of Effective Opening Area of Vent

The side and roof vents were provided with insect screens in the greenhouse. Insect screens also influenced ventilation rate by causing restrictions to the inside and outside wind flow. The restrictions were due to the presence of plastic film mesh. In order to find the effective opening area for ventilation, the restriction was deducted from the area of vent.

3.2. Calculation of Effective Opening Area of Vent

Area of one hole = 0.045 cm^2

Number of holes in 1 cm^2 area = 6 holes

Number of holes in 1 m^2 area = 60,000 holes

Area of side vents = 52.8 m^2

Area of roof vents = 17.6 m^2

Effective area of side vents = $52.8 \text{ m}^2 - 38.54 \text{ m}^2 = 14.26 \text{ m}^2$

Effective area of roof vent = $17.6 \text{ m}^2 - 12.85 \text{ m}^2 = 4.75 \text{ m}^2$

Total Effective area of opening = 19.01 m^2

3.3. Distribution of Temperature Inside Greenhouse

Distribution pattern of temperature inside greenhouse in vertical and horizontal sections was determined. The readings were recorded for combination roof and side vent configuration. The readings were also correlated with estimated inside temperatures. The regression analysis was performed between measured inside temperature and estimated inside temperature. The regression R^2 value was found to be 94 % which was a good fit as shown in figure 1, 2 and 3. Taking this into account, the theoretical inside air temperatures for side only and roof only vent configuration were calculated. The Regression analysis for measured and estimated inside temperature for roof plus side vent configuration is given in figure 4.

Figure 1: Outside vs Inside Temperature for Roof Plus Side Vent Configuration.

Figure 2: Outside vs Inside Temperature for Side Vent Configuration.

Figure 3: Outside vs Inside Temperature for Roof Plus Side Vent Configuration.

Figure 4: Regression Analysis for Measured and Estimated Inside Temperature for Roof Plus Side Vent Configuration.

3.4. Distribution of Relative Humidity Inside Polyhouse

The relative humidity distribution inside the polyhouse in both vertical and horizontal section was determined. The readings of the instrument were recorded for combination roof and side vent configuration. The readings were also correlated with estimated inside relative humidity values. The regression analysis was performed between measured inside relative humidity and estimated inside relative humidity. The regression R^2 value was found to be 90 % which was a good fit as shown in figure 5, 6 and 7. Taking this into account, the theoretical inside air relative humidity for side only and roof only vent configurations were calculated. The monthly average ventilation rate was given in figure 8.

Figure 5: Outside vs Inside Relative Humidity for Roof Plus Side Vent Configuration.

Figure 6: Outside vs Inside Relative Humidity for Side Vent Configuration.

Figure 7: Outside vs Inside Relative Humidity for Roof Vent Configuration.

Figure 8: Monthly Average Ventilation Rate.

4. CONCLUSIONS

The vent configuration affects greenhouse micro climatic parameters like temperature, relative humidity and light intensity. The ventilation rate is different during summer and winter season. So, it is necessary to change vent configurations during

different seasons. In order to modify the weather inside, the greenhouse should be provided with roll-up sections of cover in the opening area. Whenever changes occur in the outside atmosphere, the cover can be rolled up or down to maintain required micro climatic conditions inside greenhouse. Due to the effect of insect screen, the ventilation rate was reduced to 10.1%. This data showed that restrictions caused by insect screen should be taken into account while designing opening area.

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