Parametric and Performance Analysis of Polyhouse.

1. Subodh B. Patil, 2.Prashant Kumkale, 3. Dinesh S Pol, 4. Roshan U. Pipare, 5. Manik N. Shrimangle, 6. Ajim H. Shaikh
1, 2. Asst Prof. Department of Mechanical Engineering
3, 4. 5, 6 UG Student Department of Mechanical Engineering
JSPM's Imperial College of Engineering And Research Pune, Maharashtra, India.

***Abstract :** Polyhouse technology provides the controlled microclimate for the cultivation of crops, vegetables and flowers. In tropical and subtropical regions cultivation of flowers in greenhouse is increasing worldwide. Artificial ventilation is necessary for maintaining suitable temperature and humidity in greenhouse specially during those month when condition of climate is adverse. This study has been undertaken to investigate, how different parameters such as leaf area index, characteristic length, wind speed, ventilation area affects on the performance of polyhouse. Analytical calculations were done by using varying these parameters and keeping other parameters constant. From analysis of parameters, it is revealed that plant leaf temperature could be maintained within permissible limit for the cultivation of carnation flower.*

Keywords – Leaf area index, Characteristic length, shading effect.

I. Introduction

Polyhouse is the closed structure that provides the controlled environment to save the crops from adverse climatic conditions like high temperature, heavy rainfall, high solar radiation, storm etc. which are not favorable for raising the crops throughout the year. It is challenging to maintain controlled efficient environment under polyhouse in warmer outside conditions. Each plant requires friendly environment in terms temperature and humidity for optimum growth. This environment can be artificially maintained in greenhouse which not possible in atmospheric climate conditions. In coastal areas climate remains hot and humid for greater part of year, high temperature is harmful for growth of plants and in open field ambient humidity promotes growth of pests and storm.

In greenhouse improvement in ventilation and actuating system is done by predicting microclimate which promotes growth of crop production. Many artificial methods like humidity sensor, cooling pads, fans etc. have been applied to control greenhouse microclimate. The study of present work is to analyze performance of greenhouse under artificial ventilation in which cultivation of certain varieties of carnation flower is done. By simulation methods variation of microclimate in greenhouse can be investigated. Simulation methods are performed with high speed compared to physical modeling with a scope of repetition. The thermal model developed by authors earlier [2] and by using that model analysis is done. Parametric analysis has also been included in this paper to understand performance of system by the effect various crop and climatic parameter. The best suitable day temperature and night temperature for carnation flower is between 22 ºC to 27 ºC and 14 ºC to 16 ºC respectively. Beyond these temperature range flowering gets affected adversely harmed.

II. Nomenclature

Kc = overall heat transfer coefficient (W/m²K)
K_s = sensible heat transfer coefficient of ventilation (W/m²K)
K_L= latent heat transfer coefficient of ventilation (W/m²Pa)
rs = stomatal resistance (s/m)
ra = aerodynamic resistance of leaf (s/m)
mu = heating efficiency (%)
G_o = ambient solar radiation (w/m²)
d_v = characteristic length of leaf (m)
U = greenhouse inside wind speed (m/s)
C = specific heat of air (J/kgK)
Rn = net radiation (W/m²)
ρ = fluid density (kg/m³)
T_o = Polyhouse outside temperature (K)
e_o = Water vapour pressure at outside air (Pa)
e^* = Saturation water vapour pressure at outside air (Pa)
e_i = water vapour pressure of inside air (Pa)
q = air flow (m^3/s)
di = inside water vapour pressure deficit
do = ambient water vapour pressure dificit
I_{LA} = leaf area index
γ = psychometric constant (Pa/K)

III. Thermal Model Development

Already authors have presented a detailed thermal model of greenhouse [2]. The main governing equation of this model is given in brief in this section.

$$(K_s + K_c)\Delta T + K_L\Delta e = (1 - I_{sh})(mu)G_o$$

$$[di - do]\Delta T + \left[\frac{\gamma(r_s + r_a)}{RCI_{LA}} K_L + 1\right] \Delta e - (di)\Delta T_{fo} = D_o$$

$$\frac{RCI_{LA}}{r_a}\Delta T - K_L \Delta e - \frac{RCI_{LA}}{r_a}\Delta T_{fo} = -R_n$$

Knowing the greenhouse parameters (K_c, K_s, K_L and mu), the crop parameters (dv, r_a and r_s) and the measured ambient climatic conditions (Go, To and eo), the three unknown variables (ΔT, ΔT_{fo} and Δe) in eqns. (1), (2) and (3) have been calculated analytically using Gauss-Siedel iteration technique.

IV. Flow chart

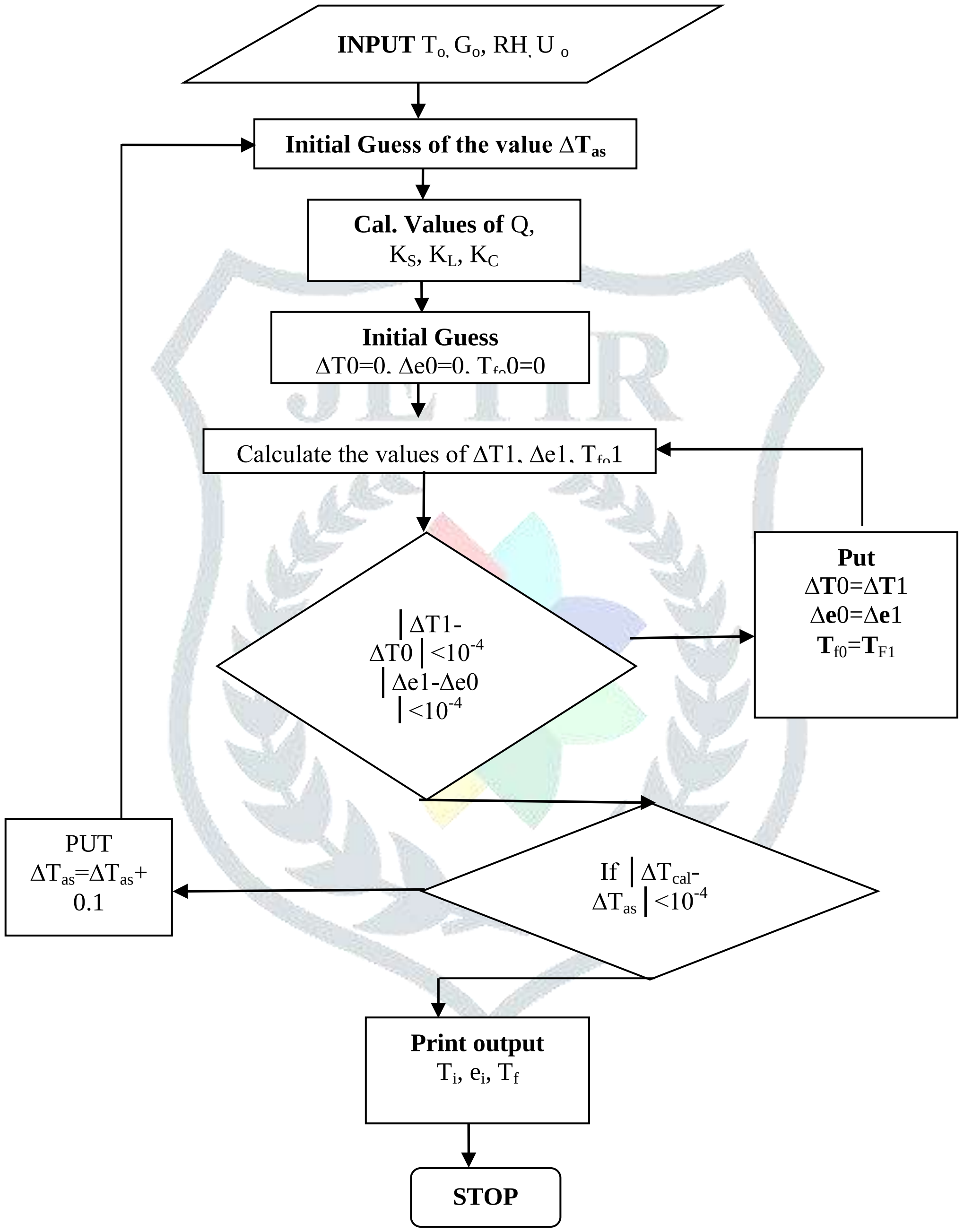

Fig. 1. Flowchart for estimating microclimatic parameters by using Gauss Siedel method.

V. Results and Discussion

A MATLAB program has been developed to predict greenhouse air temperature, plant leaf temperature and inside water vapour pressure considering monthly values of hourly data for solar radiation intensity, ambient temperature, relative humidity.

Parametric Analysis of the Thermal Model

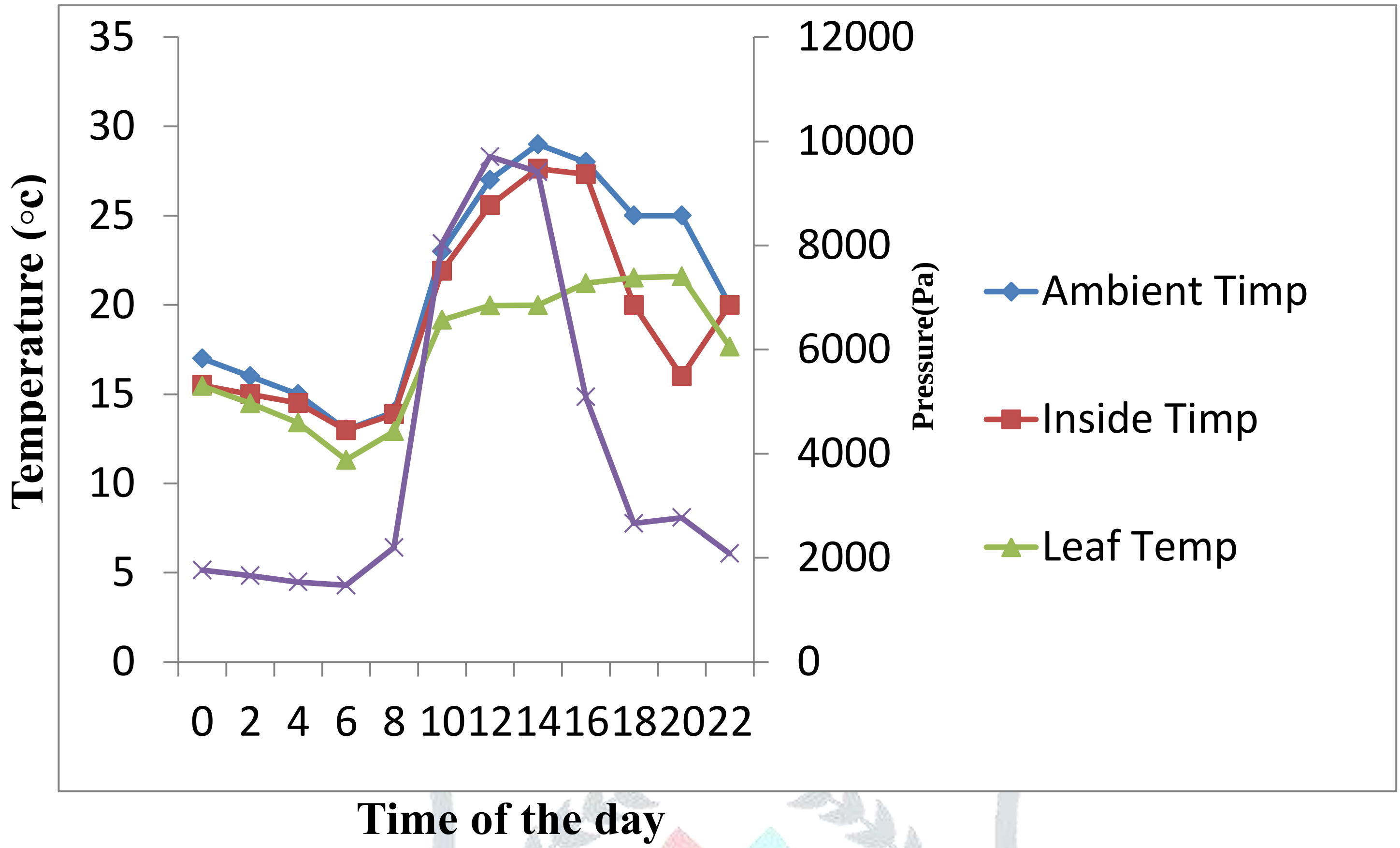

Fig. 1: Variation of temperature with time of the day in December 2017 with 50% shading.

Fig. 1 shows hourly variation of ambient, greenhouse and plant temperature with time of the day for month of December 2017. The temperature difference between the greenhouse air and plant temperature 10 to 16 hours. The maximum temperature can be restricted around 27 ºC even during peak sunshine hours of day when corresponding ambient temperature exceeds 28 ºC.

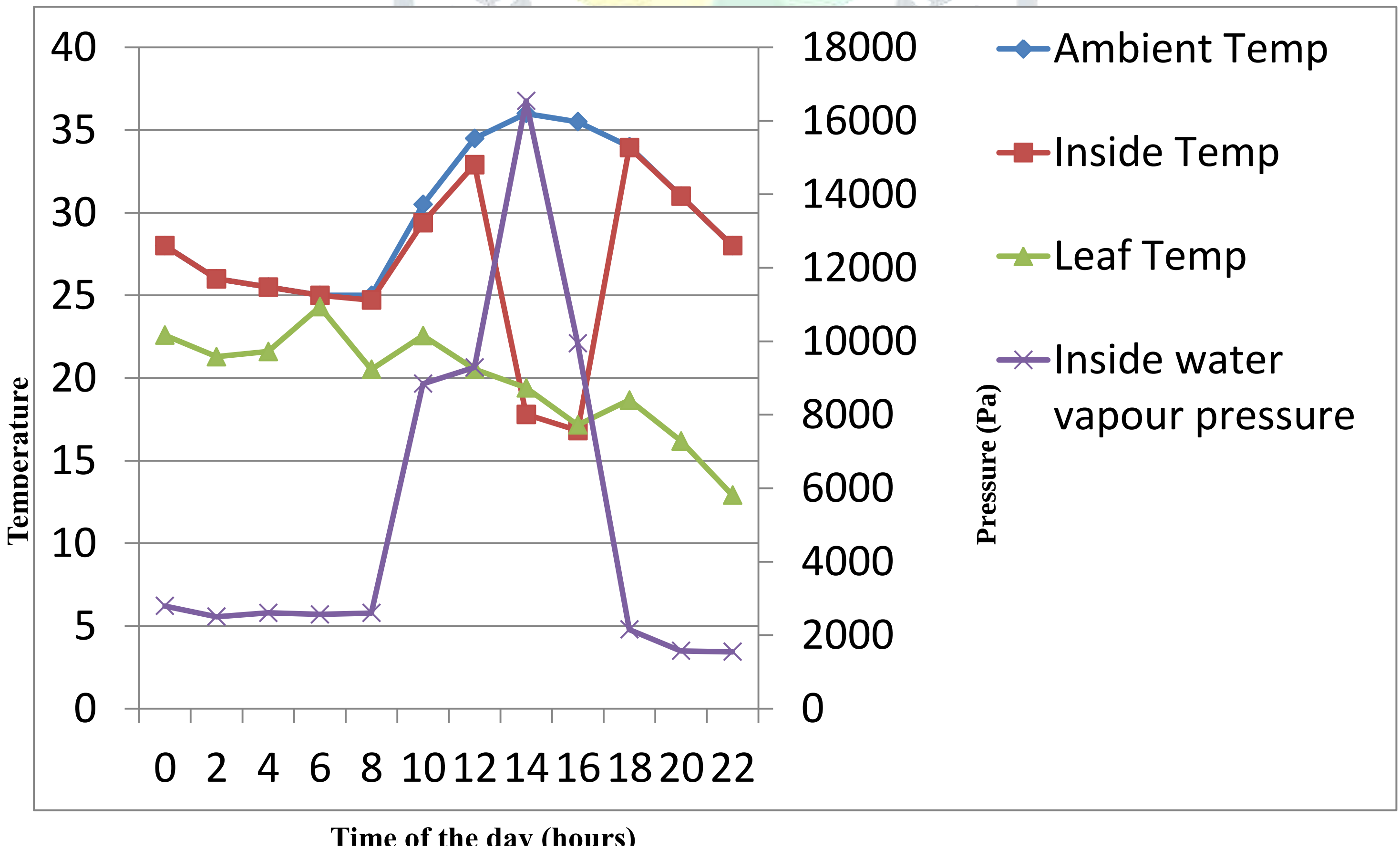

Fig. 2: Variation of temperature with time of the day in March 2018 with 50% shading.

Fig. 2 shows hourly variation of ambient, greenhouse, plant, ambient temperature with time of the day for month of March 2018 when 50% shading is applied the maximum greenhouse temperature can be restricted around 34ºC even during the peak sunshine hours of the day. The temperature difference between the greenhouse air and plant temperature decreases between 0 to 6 hours and further increases up to 12 hour. Water vapor pressure remains constant between 0 to 8 hours because solar radiation is zero. From 8 to 14 hours solar radiation increases because of that water vapor pressure increases and then further decreases.

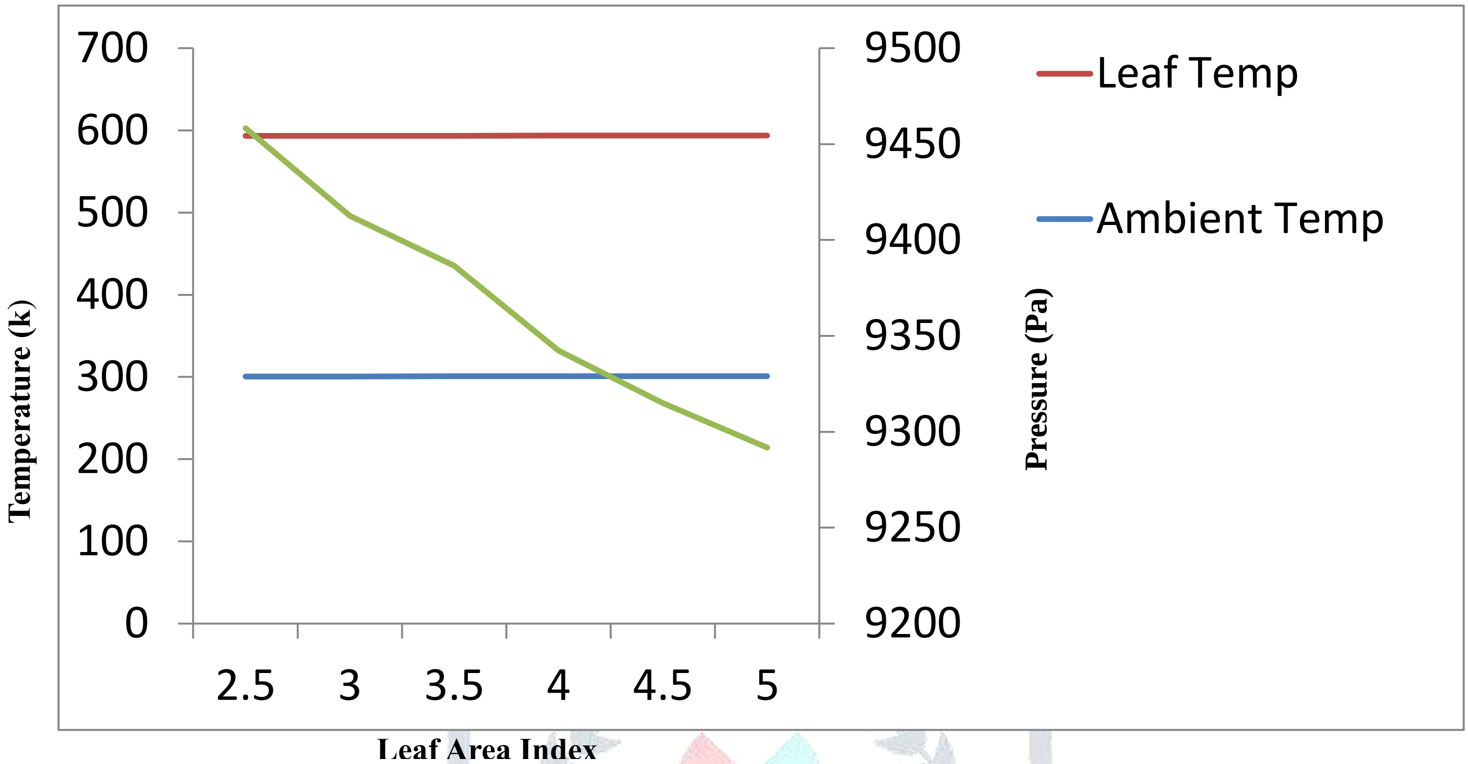

Fig.3: Variation of Greenhouse air, Leaf temperature and air water vapor pressure with leaf area index for 50% shading

Fig. 3 shows variation of greenhouse air, leaf temperature and water vapour pressure for various leaf area index for a given value of solar radiation intensity, ambient temperature humidity, and wind speed and characteristics length of leaf. The climatic data used here pertains to the data corresponding to 12 Noon for the month of December 2017. A shading of 50% has applied to restrict the entry of solar radiation inside the greenhouse. As observed from the figure, both the greenhouse air and plant leaf temperature remain almost constant and water vapour pressure decreases with increase in value of leaf area index.

Fig.3: Variation of Greenhouse air, Leaf temperature and air water vapor pressure with leaf area index for 50% shading

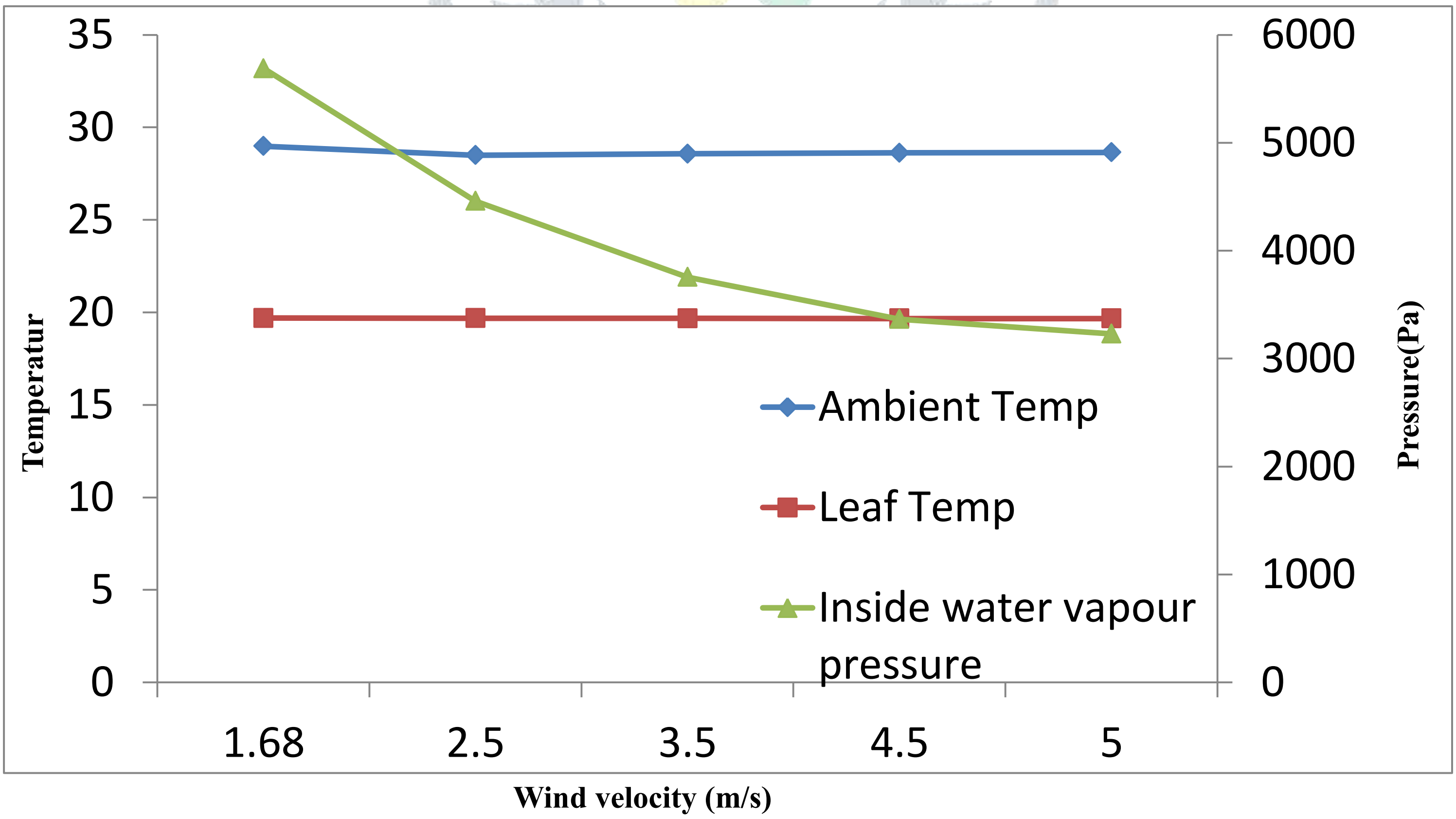

Fig. 4: Variation of Greenhouse air, Leaf temperature and air water vapor pressure with ambient wind speed

Fig. 4 shows the variation of greenhouse air temperature, plant leaf temperature, and air water vapour pressure as predicted by the model for different ambient wind speeds keeping other parameters constant. It is found from the figure that with the increase in the wind speed, the temperature remains almost constant and water vapor pressure is found to decrease with wind velocity.

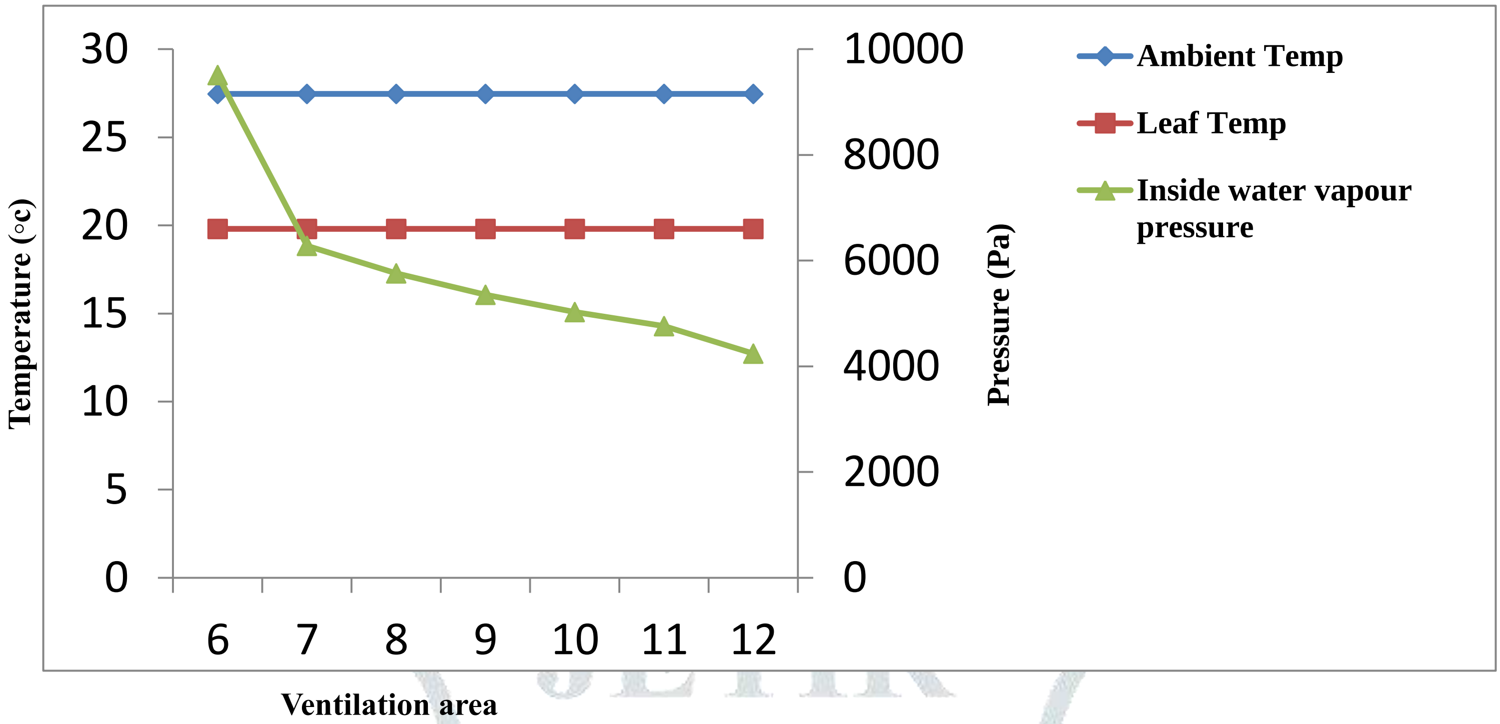

Fig. 5: Variation of Greenhouse air, Leaf temperature and air water vapor pressure with Ventilation area

Fig. 5. shows the variation of greenhouse air temperature, plant leaf temperature and greenhouse air water vapour pressure with area of ventilation keeping other parameters constant. It is found that with the increase in the area of openings both greenhouse air and plant temperature remains constant and inside air water vapour pressure decreases, this is due to the fact that with increase in the vent opening area the volume flow rate of air increases leading to more heat transfer from the greenhouse to ambient.

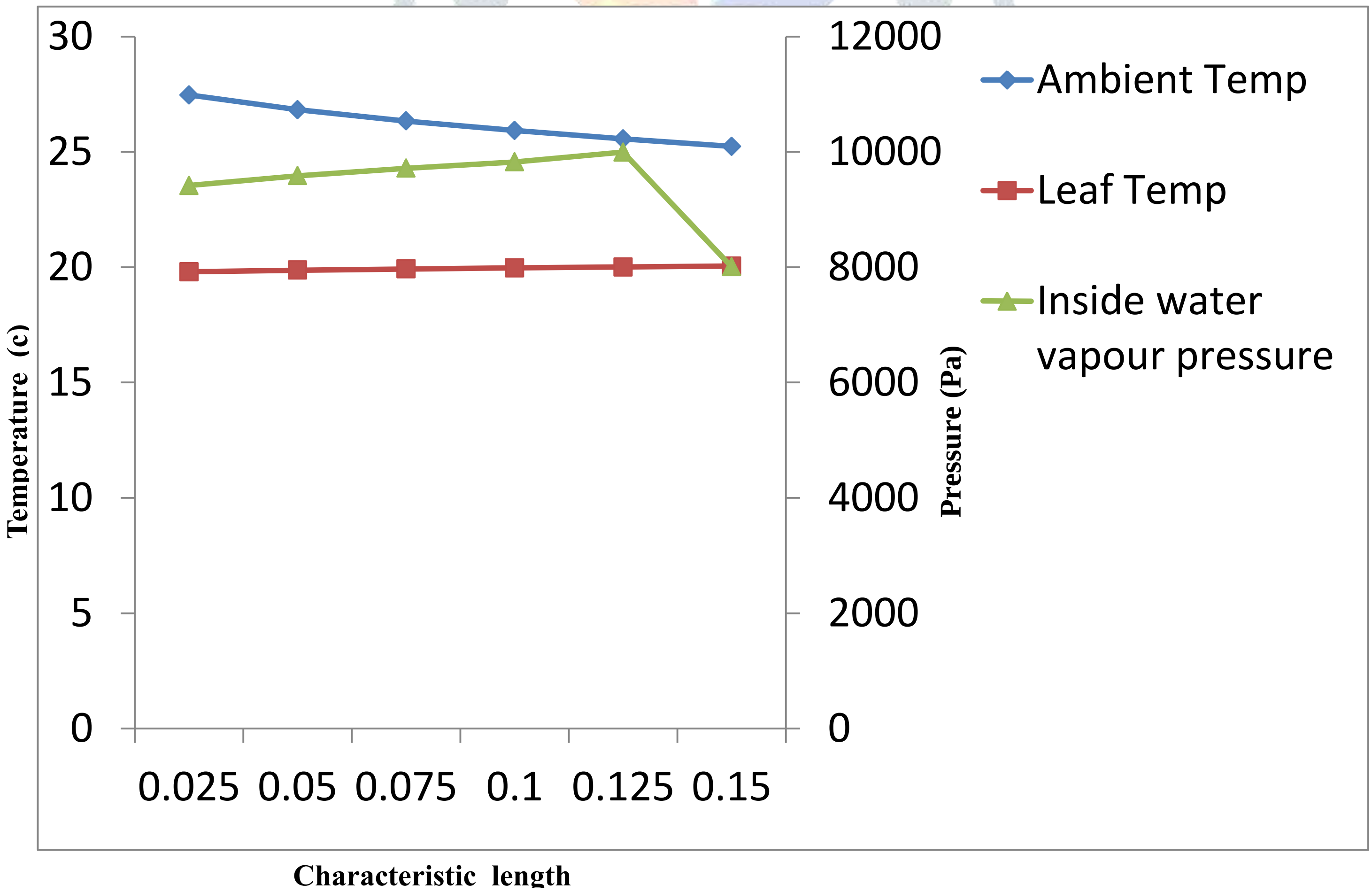

Fig. 6: Variation of Greenhouse air, Leaf temperature and air water vapor pressure with Characteristic length of Leaf

Fig. 6 shows the variation of greenhouse air temperature, plant leaf temperature, and the air water vapour pressure for various characteristic length of leaf, for the month of December 2017 considering the leaf area index and other parameters to be constant. As evident from fig. greenhouse air temperature decreases and leaf temperature remains almost constant with increase in characteristic length of leaf, while the greenhouse air water pressure increases up to 0.125 characteristic length of leaf and after that decreases. This is due to the fact that there is increase in aerodynamic resistance of leaf that leads to lower water loss through transpiration

VI. Conclusion

The present work discusses parametric and performance analysis of greenhouse using a thermal model. The model considers solar radiation, shading factor, wind velocity, ambient temperature, relative humidity as input parameters and predicts inside greenhouse temperature, air water vapour pressure and leaf temperature for a given degree of shadding. The solar radiation and relative humidity also play significant role in improving performance. From parametric analysis, it is reveled that for greenhouse inside temperature and plant leaf temperature can be maintained within range except few instances when temperature exceed target value. Greenhouse performance is highly influenced by various parameters like leaf area index, characteristic length, wind speed, ventilation area etc.

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