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Study of the Comparison between Wind Speeds in a Naturally and Artificially Ventilated Greenhouse

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Abstract: *Winds speed, temperature and humidity are all key factors influencing heat and mass transfer in developed greenhouses. These factors profiles in the entire ventilated greenhouse with tomato crops, were investigated by means of a customized and programmable (TPS- greenhouse-THE SESGREEN) anemometer system, and base on sensor. The experimental results showed that air speed was dependent on both external and greenhouse ventilation flux-φ, together with other factors of humidity and temperature. Under leakage, and due to negligible wind current and environmental temperature effects, air exchange rate remains constant, at a low value (below Maiduguri air velocity ; =4.6 m/s). Therefore, the measured air speed profiles and due ventilation flux, an estimation and mathematical model, calculation gives average internal air speed. This method of using an electronic measurement system, can still be applied to other crops' aerodynamic(s).*

Key words*; Anemometer, Customized, Flux, Greenhouse, SESGREEN*

Introduction

Ventilation, naturally or simulated by vent fans, in greenhouses, processes induce air exchange for the crop's chemistry both within interior air of a greenhouse and its external environment, as a result of air flux flow (wind) and temperature effects.

Ventilation processes induce an air exchange between the interior air of a greenhouse and its external environment due to wind and temperature effects. Air movement provided by natural ventilation influenced the convective heat exchange between the vegetation and the interior air, and thus the microclimate around the vegetation. Most recent studies on natural ventilation have used tracer gas techniques (Bot, 1983; De Jong, 1990; Fernandez and Bailey, 1992; Boulard and Draoui, 1995) and energy balance models (Fernandez and Bailey, 1992; Wang and Deltour, 1996). These two approaches, however, do not allow the air flow patterns in greenhouses to be determined.

Air movement between inside and external greenhouses, provides microclimate around the vegetation of the greenhouse. Most recently, study revealed that ventilation in a surrounding vegetation and energy balance, using balance models are enhanced by balance in the use of proper light shields and good ventilation. However, no data were provided for the support of the hypothesis of the relationships between the greenhouses' air exchange rate and the aerodynamics within.

The objective of this study is therefore to present an enquiry into the anemotry of air speed profiles, in a greenhouse, for external wind speed, buoyancy force and vent opening, humidity-temperature and greenhouse design. The experimental results provide the average air speed for the greenhouse environment's proposal and Gabble-Slopping type greenhouse for Maiduguri Coordinate.

Experimental set-up

The experimental greenhouse-the SESGREEN, was located in Maiduguri ($11^0$5000 N- latitude), and in the North of Maiduguri. This area is characterized by a strong wind of the sub-Sahara, channeled by the Sahara Desert in the East. Data for the anemotry were obtained directly from the SESGREEN-TPS, using computer logging system, in a location at the following coordinates; 11^0 5000 N and 13^0 000E, Altitude; 120.120520 m and Longitude; 130.174035 ^{0}, for all methods used. Cultivation of tomato begins with growing seedlings on a nursery, before transplant. The greenhouse size is ; $118 \times 710\ \mathrm{m}^2$ and outside cultivation is done at an area ; $31\times87\ \mathrm{m}^2$.The greenhouse therefore, contained mature tomato crops, growing on a substrate of rock wood-sand(loamy soil) and the crops were planted in twin rows of two.

Crops had 3-4 weeks required to produce a minimal plant size for study, i. e. about 0. 30 m-0.50 m, height. The crops were observed and data recorded, according to leaf size and stem height. Since greenhouse crops are self-pollinated through pollen dehiscence, therefore crops record for the data design are based on yields ,according to fruit weight freshness called its Dry mass. The yield development, during the production cycles were thus recorded.

Therefore, the distance for the vent windows (vent fans) corridors were in rows, separated 0.25 m apart. The leaf indices, during the first 3-4 weeks were 0.071 m and 0.093 m, respectively. The environmental temperature was taken to be the greenhouse (SESGREEN) room temperature at 38^0C, during the summer. Lamp heating device was also used.

Sonic anemotry and climatic measurement

Air, humidity and temperature profiles in the greenhouses were obtained, using the sensor device on Apllic-37, built within the greenhouse (SESGREEN) and base on two dimensional sonic system (Arieh, 2009).

The data were taken at a frequency of 3 Hz and 2-Dimensional resultant air speed in the horizontal plane, at one position and was averaged over 3 times-minutes and recorded on the computer logging (El Hassan, 2000).

The external wind or wind speed and direction, were all based on the coordination of Maiduguri position, and were used for the experiment, found in the data given by the Nigerian Meteorological Agency. Therefore, at Maiduguri flux constant of 5.67 Kw/m^2/day, the path, is at accuracy of about 1.3%, also at 1.68 m/s^2 .

Hence, all climatic parameters were then sampled for every 3-4 weeks and recorded on data logger (Fernie *et al*, 2006)

The climatic conditions during measurements, however provided the constants for the various short wave radiation ($11.99 \sim 12.\mathrm{o}\ \mathrm{Wm}^2$), wind speed ($3.0 \sim 2.0 \mathrm{ms}^{-1}$) and relative humidity(for various0 months, between 25 and 83 %), all at optimal temperature of 28 ^{0}C-38^{0}C, variation is at different situations between day and night periods, induced by ventilation (Harrigan *et al*, 2007).

Results and analysis

Values for Specific heat, at constant pressure (C_{pa})in J/kgk, Enthalpy of water repair, at 0^0 C (HW), thermal radiation (T_p),"violation rate" (VR), which is the rate of moisture balance due to perspiration per leaf of crops – in m^3, mass density(ρ) in Kgm^{-3}, Area of greenhouse-(55.5×35.5) in m^2, mass balance (σ) in Kgm^{-3} and diffusion per leaf area (R_p) in $Sm^{-3}kghr^{-1}$, were all recorded on a table 1 below.

Table 1: values obtained from experiments

S/No.	Quantity	Value	Unit
1	Enthalpy of water repair/0^0C (HW)	2.502×10^6	J/Kg
2	Wind Velocity (v)	27.259	M^3/S
3	Violation rate (VR)	2.18	M^3
4	Mass density (ρ)	0.0252	Kg/M^3
5	Area (A)	1970	M^2
6	Diffusion per unit leaf area (R_p)	2.5	S/ M^3 Kg/hr
7	PH-Maiduguri (Damboa road)	6.28	
8	Mass balance (δ)	0.0252	Kg/M^3
9	Humidity ratio of moist air (WI)	0.001470	Kg/Kg
10	Humidity ratio of greenhouse (WP)	0.003767	Kg/Kg
11	Diffusion rate per leaf area (R_p)	2.5	S/m^3Kg/hr
12	Electric conductivity of moist air $_{maiduguri}$	0.024	W/mK

Therefore, the physical parameters obtained in greenhouse, by weight according to the environmental constants are shown in table 2 below.

Table 2: physical parameters obtained

Name of crop	Fruit dry mass (g)	0ptimal temp. (^{O}C)	R.H. (%)
Tomato	0.048	23-28	50 - 60

Effect of wind speed, under varying humidity and temperature

During the measurements for the various months, the wind effects on internal greenhouse was recorded, the relationship between air velocity, at different heights of crop stem, the internal/external air speed, however continue to vary , January -2.0 ms^{-1}, march -3.0 ms^{-1}, and october – 2.0 ms^{-1}.

Specific calculations and programmes, using programming logger on the APPLIC-37 on SESGREEN uses sensors logger, and have been designed to enable processing. Therefore, environmental physical climatic conditions were recorded at the frequency 0.5Hz, humidity and temperature of between 25^{0} C–75^{0} C , at accuracy of $\pm$ 0.01^{0} C and humidity, ranging between 0 % and 100 % at accuracy of $\pm$ 3%.The wind speed, however was measured at the range of 0 to 40 ms^{-1}, at accuracy $\pm$ 5% (Henderson *et al*,1993).

Mathematical models used

The relationship accounting to the combination of thermal and wind effects was used to calculate the ventilation flux (φm^{3}/s).

$\therefore \varphi = \frac{L_0 C_d T_e}{3\, g\, \delta T} \times [(\frac{g\delta T}{T_e} h + C_w {U_e}^2)1^{\frac{3}{2}} - (C_w {U_e}^2)1^{\frac{3}{2}}]$, where C_d and C_w are empirical discharge and wind effect coefficients, respectively, at between 0.64 and 0.09, g is the gravitational acceleration in ms^{-1}. However the vertical air speed profiles, perpendicular to the air flow can be used to estimate the mean greenhouse air speed, $v_{cal} = \frac{\varphi_v}{A}$, where A is the greenhouse area (Gupta, 2002).

Conclusion

The greenhouse sensors are able to determine the wind flux rate, as velocity vector and temperature, together with that of the humidity.

In this study, the difference in the measured parameters were, therefore determined through censoring measures and in programming device of micro scale, and in ventilation rates of the greenhouse (Mehl, 2005).

This is as a result of buoyancy effects that also generate the difference in both the temperature and humidity levels, and also in evaporation, due to plant transpiration.

Since production of crops in greenhouses are not without challenges. Therefore crops production require adjustments when needed, as they are produced by growers under research, prior to making adjustments , comparisons are made, including all the factors involved , i.e., temperature, humidity and air speeds Since water perspiration in crops and water evaporation provide standard to which evapotranspiration of crops, in a period of the year are, when compared with an outdoor production, then transpiration of water along into humidity, from plant canopy to the surrounding air-water vapour is given by m_{t} ,and it thus gives the rate of diffusion that provides the rate of moisture transfer in greenhouse (Micheal, 2005).

In order to characterize the impact of the related factors involved in equilibrium with the environment, the crops responses, after monitoring with respect to developed temperatures and humidity recorded revealed a clearest profile in expected metabolic level of growth and crop yield Y_a

However, the yield development is from fruits weight and temperature deficit on plant, due to humidity.

Also, at air conductivity of 0.298 S/m, and light intensity 5.67 Kw/m^2/day and PH of 6.26, mass balance M_T was at 4.36 Kg/hr.

Pressure deficit above 3 Kpa in greenhouses are available in greenhouse cultivation in the arid region, due to the climate. Nonetheless, evaporation rates and radiation in outdoor production, in active solar radiation when exposed accompanies reflection of further radiation by other bodies with the effect that there is going to be potential elevation of temperature above a normal growth rate and this deceases yields and quality of crops (Smith,1987).

Therefore, $m_t = 2A_p\rho_p(W_p - W_p) \times \frac{1}{R_p}$

Where A_p is the area of the greenhouse, ρ_p the mass density of air and water mixture, W_p the humidity of greenhouse, W_p the humidity ratio of moist air and R_p is the diffusion rate per leaf area.

$$\therefore M_t = \frac{2\times1970.5\times0.0252(0.000376-0.001470)}{2.5} \text{ and}$$

$$m_{t.} = 436 \ \mathrm{Kgh^{-1}}$$

This value varies according to crop, but taken as a standard for measurement (Ahammad, 2001).

However, in an open cultivation plant, Eva transpiration is related in 4-steps, ET_c in $\mathrm{mmh^{-1}}$ of crop and T is the mean temperature.

$ET_c = K_c ET_o$, where ET_c is the actual transpiration and K_c is the specific heat of air from the crop canopy. ET_o and ET_c are the relative crop coefficient and reference transpiration, respectively.

Therefore, with TH as greenhouse cover(windows) estimated at 0.03453×10^3 m and considering water vapour is $4.36\ \mathrm{kghr}^{-1}$ and considering air is lighter than dry air, and that soil pressure is P, then the partial pressure of the day air temperature is (P – p), the ratio of the two components, water vapour and dry air is;

$$\frac{\text{kg of water vapour}}{\text{kg of dry air}} = \frac{\text{molar mass of water vapour} \times p}{0.029(P-p)} \quad \text{(Cockshill,1985)}$$

But at room temperature of a greenhouse, (P – p) is nearly equal to P, which at ground level (outdoor) is close to 1.0×10^5 Pa, approximately (Gavin, 2011).

The wind speed is determined by the flux used for ventilation, called the heat flux and is equal to 5.57×10^3 Wm$^{2.}$

$$\therefore \qquad V_{cal} = \frac{5.57 \times 10^3}{1970.5} = 7.83\ \mathrm{ms}^{-1}.$$

The value continue to vary according to months of the year, too. The temperature remains between the range of 32 ^{o} C and above slightly, given enthalpy rate is 19.107 W/m ^{3} as provided in the greenhouse, thus provides energy that needs no further ventilation for crops. The humidity ratio varies for the crop used, at an average of 60% to 80% and remains within the growth rates of the crop.

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