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EFFECT OF VENT TYPES AND INSECT SCREENS ON VENTILATION OF "PARRAL" GREENHOUSES

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Abstract

A study was carried out at the Experimental Station Las Palmerillas of Cajamar with the aim of characterising the natural ventilation of the "parral" greenhouse. For this purpose the ventilation rate for two different types of roof ventilators (rolling and flap windows) was determined. Natural ventilation rate was measured in a symmetric multispan (5 spans) "parral" greenhouse with polyethylene cover by means of the dynamic tracer-gas method (decay rate method), using N_2O as tracer-gas. For rolling openings, no influence of the position of the window in the span (leeward or windward) on the ventilation rate was observed. For flap windows, windward ventilation was found to be around 50% higher than leeward. Flap windows have proved to be much more efficient than rolling windows for wind induced ventilation. In the same way, we have found and important reduction of the ventilation rates due to the presence of an anti insect screen in the openings.

INTRODUCTION

One of the most outstanding problems in Mediterranean greenhouses is the high values of the inside temperature reached during the day, from the beginning of the spring until the end of the autumn. These high temperatures cause negative effects on yield and quality of the different crops. Ventilation rate is generally insufficient, which influences negatively inside air composition, mainly because of a decrease in the CO_2 levels (Hand, 1984; Lorenzo et al., 1990; Lorenzo, 1994) and excess humidity which favours condensation in the inner side of the cover and therefore, continuous dripping over the crop. This condensation also reduces solar radiation transmission (Jaffrin and Makhlonf, 1990) leading to yield losses. Under these conditions fungal diseases are favoured (Hand, 1984; Mistriotis et al., 1997) as well as nutritional disorders, mainly mineral deficiencies(Lorenzo, 1994; Mistriotis et al., 1997) as a consequence of transpiration restrictions (Stanghellini and van Meurs, 1992; Holder and Cockshull, 1990). Mechanical ventilation can be discarded because of its costs, in terms of energy and maintenance (Mistriotis et al., 1997). Natural ventilation sets up as the most used, cheap and practical method to ensure optimal indoor climate during both summer and winter conditions (Papadakis et al., 1996; Boulard and Draoui, 1995; Montero et al., 1996).

In the past decade there has been a great increase in the number of works studying natural ventilation in the tunnel type greenhouse with polyethylene cover, a very usual greenhouse in mild climate areas(Boulard, 1993; Papadakis et al., 1996; Boulard and Draoui, 1995; Boulard et al., 1996; Montero et al., 1996; Kittas et al., 1995 & 1996; etc.), but until today no works characterising "parral" type greenhouse have been carried out.

The great importance of the "parral" greenhouse derives from its great extension (84% of the total Spanish greenhouse area), being Almería the most outstanding province with around 25.000 ha (Sanjuan, 2000). The “parral” greenhouse is the dominant greenhouse structure in Spanish south east as well as in the Canary Islands. It also has an increasing expansion in other Mediterranean climate areas such as North Africa (Morocco), North America (Mexico), South America, etc. It must also be pointed out the great transcendence of this greenhouse in the social and economic development of the mentioned areas (Pérez Parra, 2000).

“Parral” greenhouse can be defined as a simple crop protection structure, craft construction and low cost, consistent of a vertical semirigid structure made with wood posts or with other materials, joined on their upper side by a flexible structure executed as a double wire grid which at the same time holds the covering material (Pérez Parra,1998).

The objectives of this paper are (1) evaluate the effect on ventilation rate of vent position on the span in relation to wind direction (2) to compare the ventilation efficiency between rolling and flap vents (3) to evaluate the effect on the ventilation rate of an anti insect screen placed in the openings.

Ventilation rate measurements have been carried out using the dynamic tracer gas method, using N_2O as tracer gas. According to Goedhart et al.(1984), the best method to determine air exchange rate in a greenhouse is to make direct measurements by means of one of the tracer gas methods. For greenhouse measurements, two methods are more appropriate: the continuous flow method (static) and the decay rate method (dynamic) (Bot, 1993; Goedhart et al.,1984; de Jong, 1990; Muñoz, 1998). The dynamic method is the most commonly used for its simplicity and standardisation.

In this method, tracer gas is injected inside the closed greenhouse and mixed with the inside air until a certain concentration is reached. If we assume that the dispersion of the gas in the greenhouse air is homogenous, the gas concentration decreases uniformly when ventilators are opened following the equation

$$c(t)=c_0\, e^{-\Phi t} \qquad (1)$$

where c(t) is the gas concentration at any time t, c_0 is the gas concentration at t=0,t is the time and Φ is the ventilation rate.

After a logarithmic transformation of equation (1)

$$\ln\left(\frac{c(t)}{c_0}\right) = -\Phi(t) \qquad (2)$$

Φ can be calculated from the slope of the graph obtained by plotting ln (c(t)/co) against t.

MATERIALS AND METHODS

Experimental measurements were carried out in a 861 m^2 polyethylene five-span “parral” greenhouse, oriented N-S, situated in the Experimental Station “Las Palmerillas” of Cajamar (El Ejido). The greenhouse was equipped with five continuous roof vents (one per span), located near the ridge, in the west side of each span. In the first set of measurements roof vents were of the rolling type, being replaced later, in a second set of measurements, for flap vents. No crop was present during the measurements.

Part of the measurements were made placing a 39% porosity insect-proof screen in the windows.

The N_2O was released and distributed homogeneously inside the greenhouse with the help of a fan and five polyethylene perforated tubes. Once the desired concentration was reached (between 100-200 ppm), after waiting approximately 10 minutes for good homogenisation, the ventilators to be evaluated were opened.

The air inside the greenhouse was sampled at 9 different points equally distributed over the greenhouse and located at height of between 1 and 2 meters above the ground. The air was mixed within a mixing bottle and pumped trough an infrared gas analyser that measured continuously the N_2O concentration.

Simultaneously to these measurements, the following climatic parameters were measured: temperature inside (in the middle of the greenhouse) and outside the greenhouse using aspiro-psychrometers located at a height of 2 meters above the ground; wind velocity and direction using an anemometer at a height of 1 m above the greenhouse ridge; global radiation was also measured using a pyrometer.

A first set of measurements was taken, for two different roof vents configurations: rolling vents with and without insect-proof screen. The vents were fully opened and the measurements were taken for a wide range of wind velocities and directions. Later, rolling vents were replaced by flap vents, making a second set of measurements for this new configuration (with and without insect-proof screen), again for a wide range of wind velocities and directions. Most of the measurements were made with highest opening angle (67º), but measurements for smaller opening angles were also made (10º, 15º, 25º, 35º, 45º and 55º).

The rolling vents had an opening area of 92,3 m^2 (10,5 % of the covered ground area) while the flap vents where smaller, with an opening area of 30,51 m^2 (3,5 % of the opening area).

Ventilation rate was calculated from the slope of the graph obtained by plotting $ln(c_0/c)$ against time t [see equation (2)] since we know the volume of the greenhouse (V=3250 m^3). The duration of the experiments ranged from 5 min up to 40 min, depending mainly on the wind speed.

RESULTS AND DISCUSSION.

Roof rolling vents

Air flow values obtained with the dynamic tracer gas method have been related with the wind velocity (for both windward and leeward winds). As we can observe in table 1, air flow G and wind velocity v data were fitted to a linear relation of the type

$$G=a\cdot v+b \qquad (3)$$

This is in agreement with other works studying other greenhouse structures (Bot, 1983; De Jong, 1990; Fernández and Bailey, 1992; Muñoz, 1998). Air flow values are expressed in relation to the total opening area: unitary air flow G′ ($m^3/m^2\cdot s$).

Separating the set of data (If the total set of data is splitted) in two groups according to the wind direction, that is, windward winds (180º-360º) and leeward winds (0º-180º), we obtain two new regression lines that relate air flow (per unit hole area) and wind velocity (table 1). The terms of both regression lines can be statistically compared using the methodology proposed by Kleinbaum (1988). The results of comparing the slopes and the intercepts are shown in table 2.

P value for the slopes is greater or equal than 0,1, so there are not statistically significant differences among the slopes at a 90% or higher level of significance. We can state that windward and leeward ventilation are statistically equal. For the intercepts, P value is also greater or equal than 0,1, so there are no significant differences among the intercepts at 90% or higher level of significance.

The previous calculations clearly indicate that both regression lines are statistically equal. Therefore, ventilation rate is not dependent on the position of the roof rolling vents at one side or another of the span. Two factors can explain this result:

- The window type : rolling vents do not have flap, which serve as a “wind catcher” when wind blows windward, making ventilation rates different depending on the wind direction (windward or leeward). This effect does not exist for rolling vents.
- The roof slope was small) (11º), compared with other greenhouse types such as the Venlo, which is also a multispan greenhouse, but with slope in the spans.

A 39 % porosity insect-proof screen was placed in the roof rolling vents to evaluate its effect on the air exchange flow. New tracer gas measurements were taken and a new regression line relating air flow and wind velocity was obtained. Figure 1 shows airflow through roof rolling vents with and without insect-proof screen versus wind velocity. For the range of wind velocities comprised between 0-9 m/s, the 39% insect proof screen reduced the air flow in a constant percentage of 32,9 %.

Roof flap vents

Ventilation rate measurements for roof flap vents completely opened (67º in relation to the span) were taken. Air flow (per unit hole area) was calculated and related to the wind velocity, fitting the results to a linear regression (table 3).

As can be observed in table 3, measurements were separated again in two different groups according wind direction (one group for windward winds and another one for leeward winds). Air flows were calculated for each group, and related to the wind velocity with a linear regression as can be observed in table 5.

Figure 2 shows regression lines of air flows versus wind velocity for roof flap vents (windward and leeward) and roof rolling vents. It can be observed that windward air flows are higher than leeward, in agreement with results obtained by De Jong (1990) and Muñoz (1998) in Venlo and tunnel greenhouses respectively. Both regression lines were statistically compared (slopes and intercepts) showing statistically significant differences at 99% confidence level. Windward air flows are between 35 % and 60% higher than leeward unitary air flows for the range of wind velocities comprised between 2 m/s and 7 m/s respectively.

Air exchange efficiency of the studied window types (rolling and flap vents) can also be compared as shown in figure 2. It shows flap vents are much more efficient than rolling vents for both windward and leeward winds. For windward winds air flows are between 3 and four times higher than in the rolling vents and between 2 and 2,5 higher for leeward winds, for a range of wind velocities of 2 m/s to 7 m/s respectively.

CONCLUSIONS

Ventilation flows measurements performed in a “parral” greenhouse with roof ventilators are presented with reference to the wind velocity. Results showed the strong dependence of ventilation on the wind. Wind direction effect (windward or leeward) on the ventilation flow was also studied for both rolling and flap continuous vents. No effect of vent position was found for rolling vents whereas a clear difference in the exchange rates for windward and leeward winds was found for the flap vents, being windward air flows approximately 50 % higher than leeward.

For a range of wind velocities of 2-9 m/s, a decrease of approximately 33 % of the air flow was measured when an anti-insect screen with 39% porosity was placed in the openings of the rolling vents. Flap vents are more efficient than rolling vents for both windward and leeward winds, being air flows 3-4 times higher for windward winds and 2-2,5 higher for leeward winds.

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Table 1
Regression equations and coefficients for unitary air flow (G′) ($m^3\ s^{-1}\ m^{-2}$) versus wind velocity v ($m\ s^{-1}$). Roof rolling vents.

	Regression equation	R^2	N	Standard error of the residuals
All data	G′=0,056+0,015·v	0,85	21	0,014
Windward	G′=0,057+0,015·v	0,85	12	0,012
Leeward	G′=0,054+0,015·v	0,84	9	0,017

R^2 = regression coefficient; N = number of measurements

Table 2
Comparison of the regression lines (windward - leeward) for roof rolling vents.

	Slopes			**Intercepts**		
	N	**F**	**P**	**N**	**F**	**P**
Roof rolling vents	21	0,01	0,9266	21	0,07	0,7976

N=number of measurements

Table 3
Regression equations for air flow (G´)($m^3\ s^{-1}\ m^{-2}$) versus wind velocity($m\ s^{-1}$). Roof flap vents.

	Regression equation	R^2	N	Standard error of the residuals
All data	G´=0,16+0,046·v	0,39	26	0,631
Windward	G´=0,089+0,081·v	0,89	18	0,012
Leeward	G´=0,01+0,045·v	0,84	8	0,017

R^2 = regression coefficient; N = number of measurements

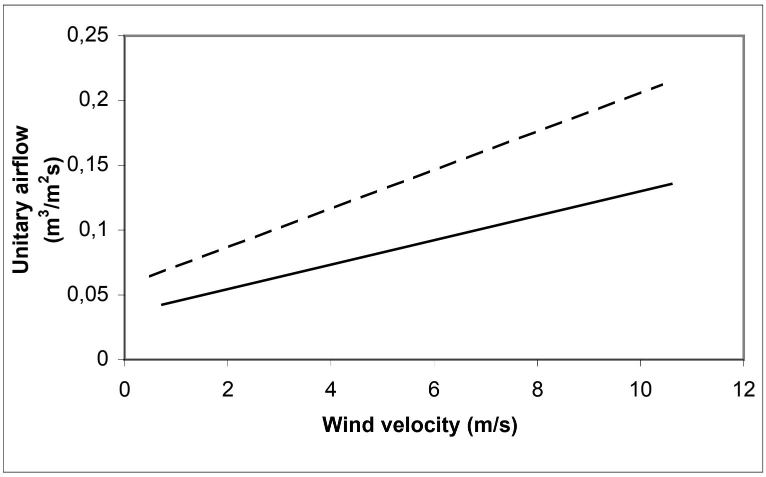

Fig.1 Airflow through roof ventilators with anti-insect screen (——) and without anti-insect screen(----) versus wind velocity. (a)With anti insect screen: G′=0,036+0,009·v; (b) Without anti-insect screen: G′=0,056+0,015 · v

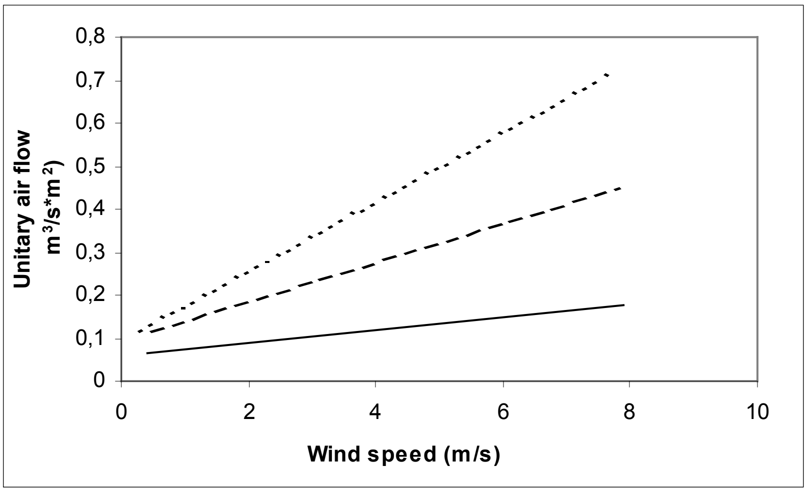

Figure 2. Air flow versus wind velocity. Roof flap vents (windward and leeward) an roof rolling vents.