Greenhouse climate investigations for advanced IPM management

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WP7 -PURE: “IPM solutions for Protected vegetables”
Task: Climate control for IPM

- Microclimate in the leaf boundary layer in the ecological niche of pests.
- Thrips occurrence distribution with respect to climate patterns.
- Climate control and use of insect screening as a substitute to pesticide use.
- Evaluation of substitute materials to leaf domatia presents on Viburnum tinus.

- Leaves boundary layer is the ecological niche of major biotic agents
- Boundary layer of leaf is affected by factors such as the transpiration, temperature, humidity and air speed around the leaf
- Heterogeneity of climatic parameters inside greenhouse affect the microclimate in the boundary layer of leaves

Microclimate at the leaf boundary layer : difficult to measure

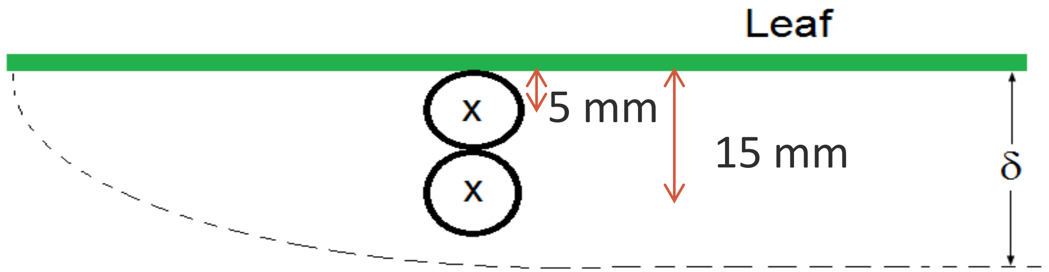
Need to combine experimental and modeling approaches

To realistically reproduce the biotic agent environment at their niche level

Local microclimate in the leaf boundary layer
Experimental approach

Customized mount bracket of temperature and humidity sensors on the leaf

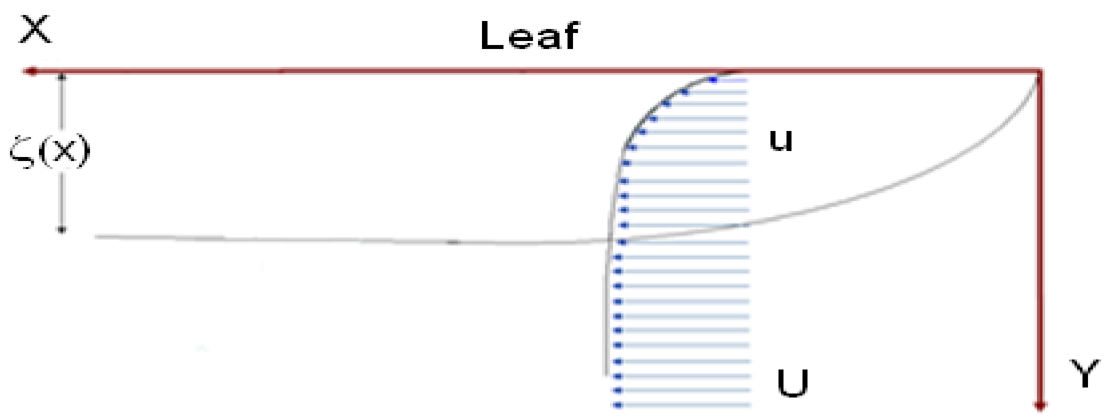
Temperature sensor (EE06-FT1A1-K300,
E E Elektronik)



Temperature and humidity measurement in the BL under the leaf

Air speed measurement around the leaf

Numerical modeling of the microclimate in the boundary layer of the leaves



Schlichting (1974):

$$T(\eta) = T_\infty + [0.0046\eta^3 + 0.0108\eta^2 - 0.3621\eta + 1.0005] \big/ (T_f - T_\infty)$$

$$q(\eta) = q_\infty + [0.0093\eta^3 - 0.0248\eta^2 - 0.2787\eta + 0.9969] \big/ (q^*{}_f - q_\infty)$$

$$\eta = y\sqrt{\frac{u_\infty}{\nu x}}$$

Non-dimensional variable

Summary of used models for the CFD modeling

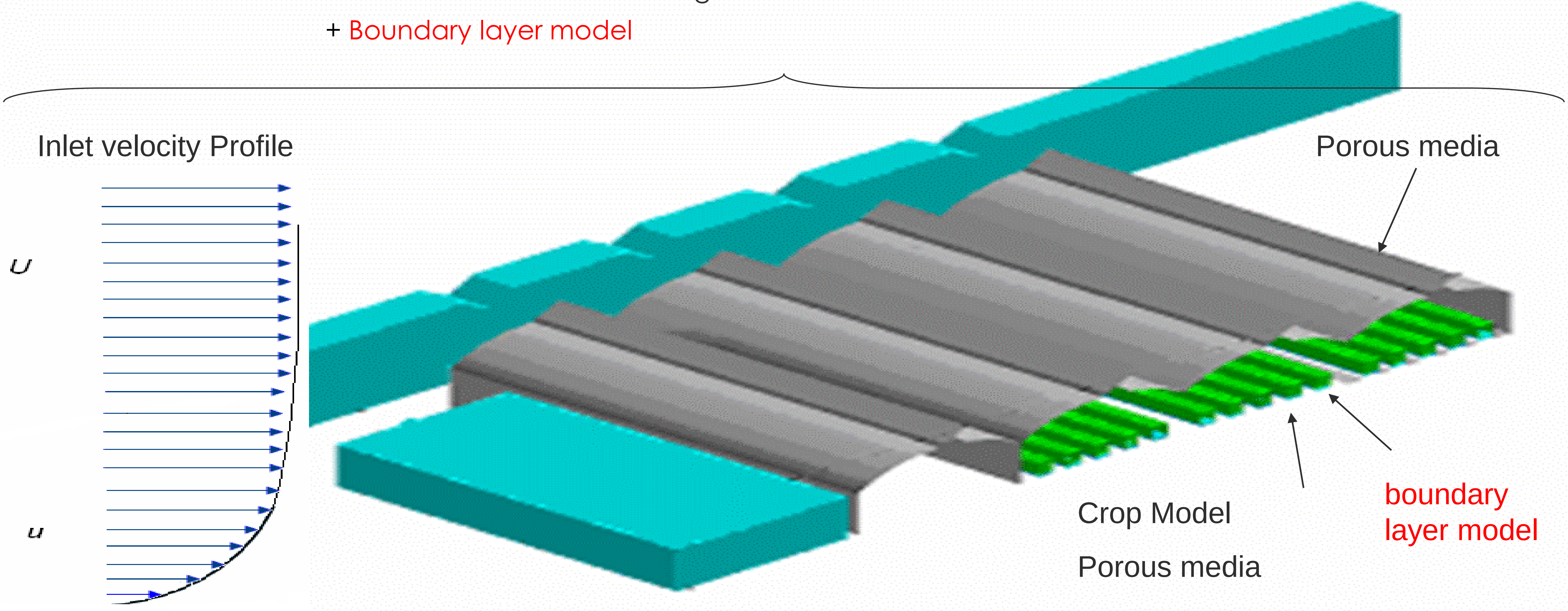
Energy and mass aerial transfers

+ Buoyancy forces (Boussinesq) natural convection

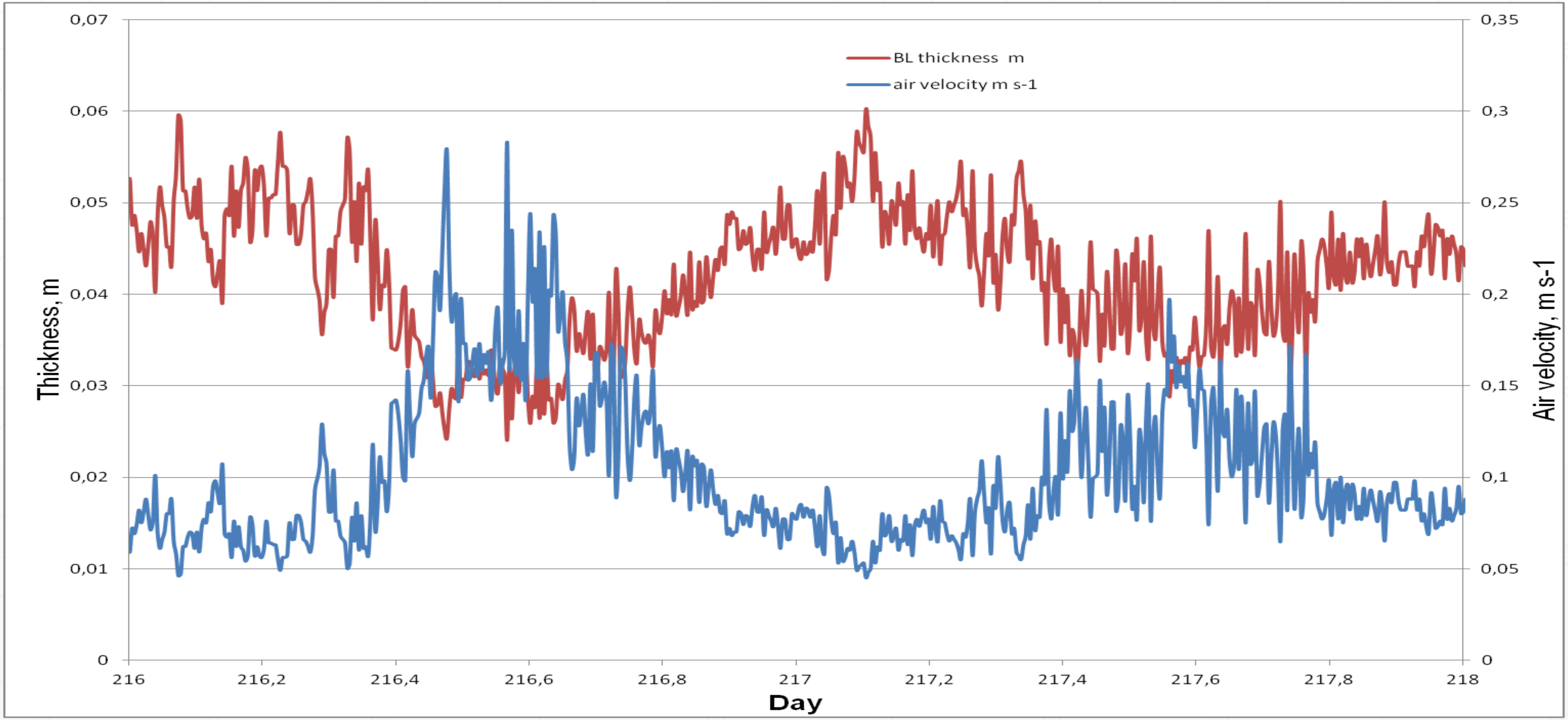
+ Turbulent flows (k-ε)

+ DO model radiative exchange

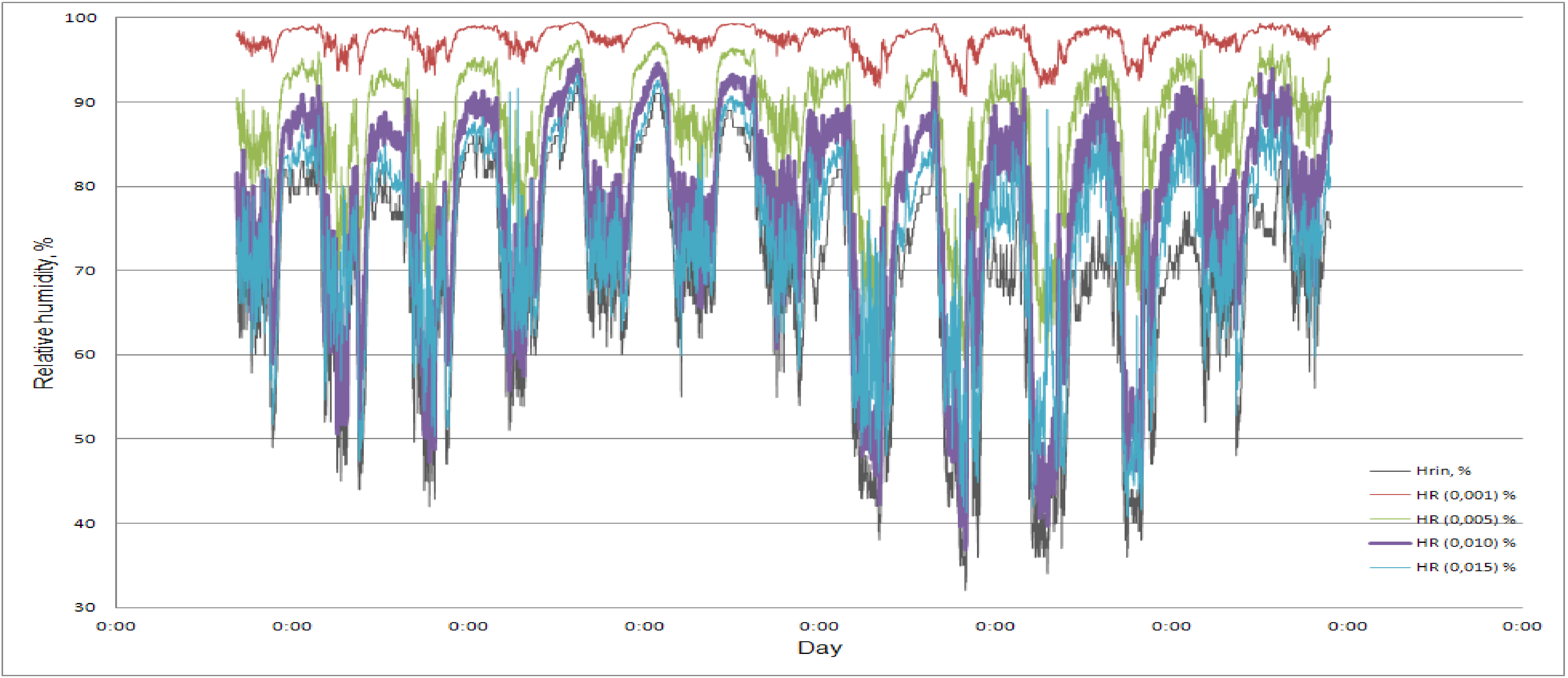
+ Boundary layer model



Boundary layer thickness as a function of the air velocity around the leaf



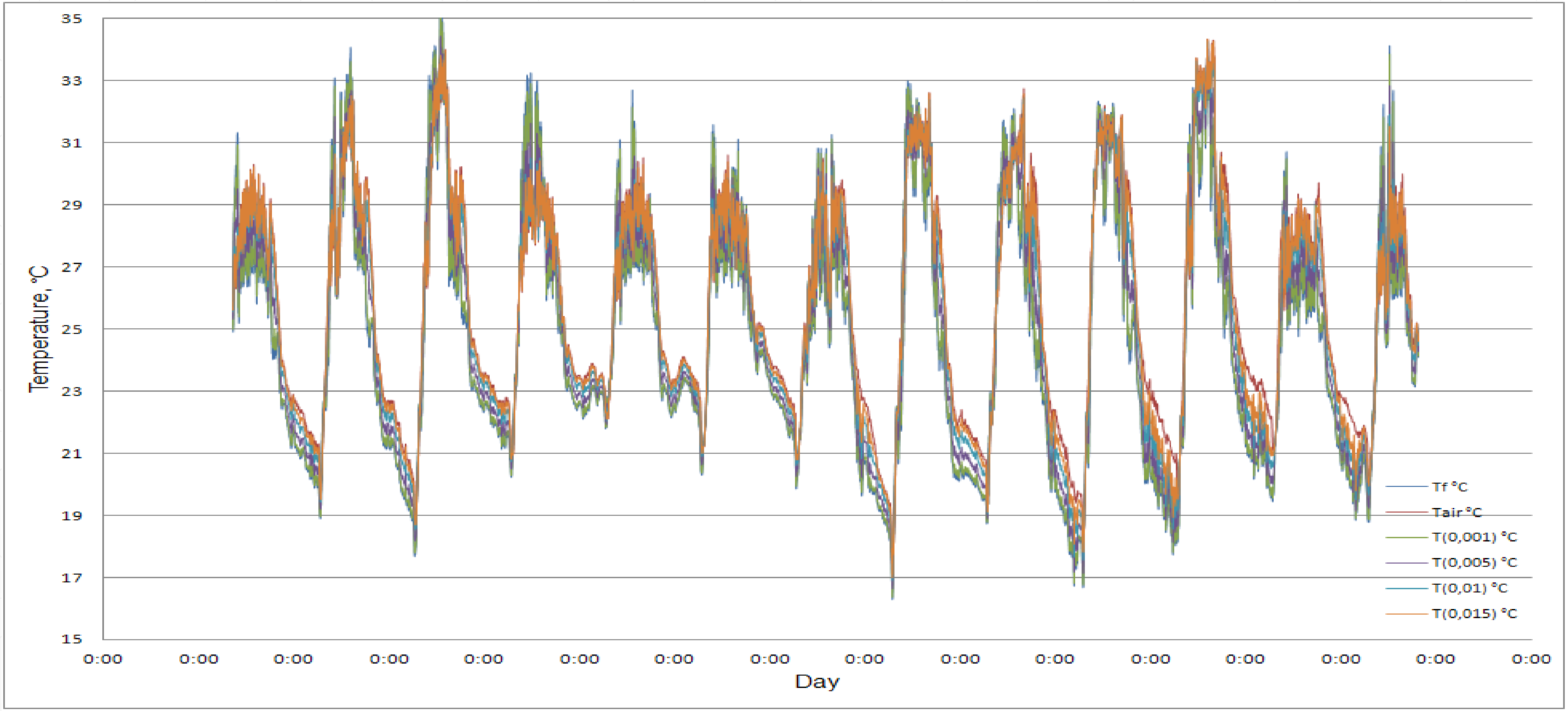
Air humidity conditions prevailing in the boundary layer of leaves over time



H ext < H int < H 15 mm < H 5 mm

ΔH (5 mm – int) ~ 10 %

Air temperature in the leaf boundary layer of crop rose over time



T ext < T int < T 15 mm < T 5 mm

ΔT (5 mm – int) ~ 2.5 °C

Conclusion 1

- Heterogeneity of the microclimate in the boundary layer ecological niche of pests.
- Temperature and humidity conditions prevailing in the pests and predators habitat (BL) are strongly disconnected from the ambient greenhouse air.
- Boundary layer micro climate conditions should be the most important controlled parameters instead of the ambient air climate.
- Determine climate preference of pests to derive climate control strategies allowing for a wiser control of greenhouse pest infestations.

H. Fatnassi, T. Boulard, C. Poncet, T. Bartzanas, N. Katsoulas, M. Kacira. 2013. CFD Modeling of Microclimate in the Leaf Boundary Layer, Ecological Niche of Pests. International congress on new technologies for enriroment control, energy savign and crop production in greenhouse and plant factory, Greensys 2013 October 6-11, 2013, Jeju, Korea . Acta Hort. (ISHS) (in press)

Aims of study

Alternative control methods require knowledge about thrips development in greenhouse conditions and particularly about the effects of micro-climate (air temperature and humidity) in the thrips habitat

- Characterizing the effect of air temperature and humidity on the spatio-temporal distribution of *F. occidentalis* populations in a protected rose cropping system
- To define the most favourable climate conditions for thrips adults and larvae in real crop conditions

Experimental measurements

- *Climatic measurements*

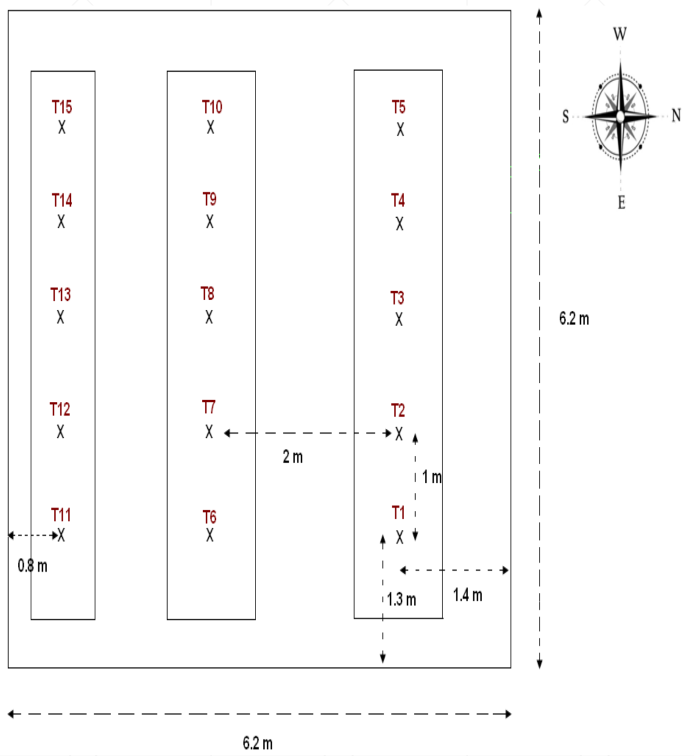
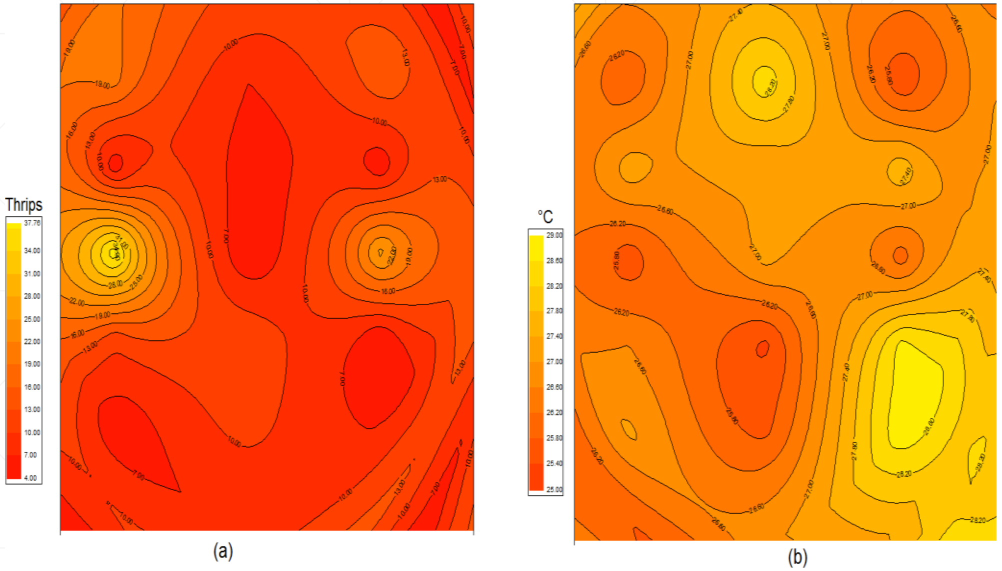


Fig. 1. Temperature and humidity sensors distributions inside the greenhouse compartment.

- *Monitoring of thrips population dynamics*



Statistical models

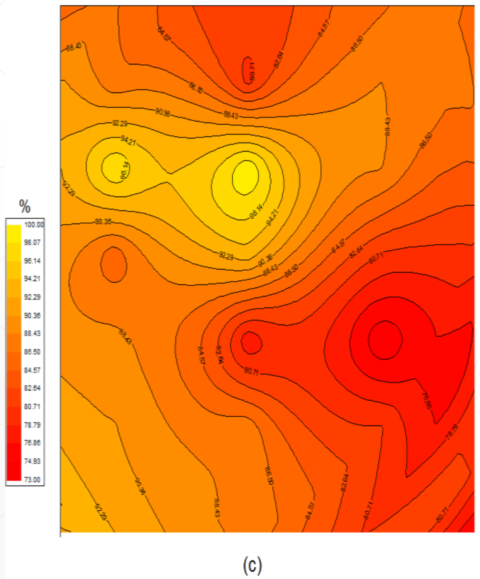


Fig. 2. Contour maps of the (a) mean diurnal temperature (b) mean diurnal air humidity and (c) thrips population inside the greenhouse

Model 1: Does larva presence statistically depend on adults present a week before under favourable climatic conditions?

$$\lambda^{L}_{i,t_j} = e^{\alpha_0^L} + N^{A}_{i,t_j-7}\, e^{\left\{\alpha_A^L - \alpha_H^L (H_{i,t_j-7} - m_H^L)^2 - \alpha_T^L (T_{i,t_j-7} - m_T^L)^2\right\}}$$

Model 2: Does adult presence statistically depend on larvae present two weeks before under favourable climatic conditions?

$$\lambda^{A}_{i,t_j} = e^{\alpha_0^A} + N^{L}_{i,t_j-15}\left(e^{\alpha_L^A} + e^{-\alpha_H^A (H_{i,t_j-15} - m_H^A)^2 - \alpha_T^A (T_{i,t_j-15} - m_T^A)^2}\right)$$

Results:

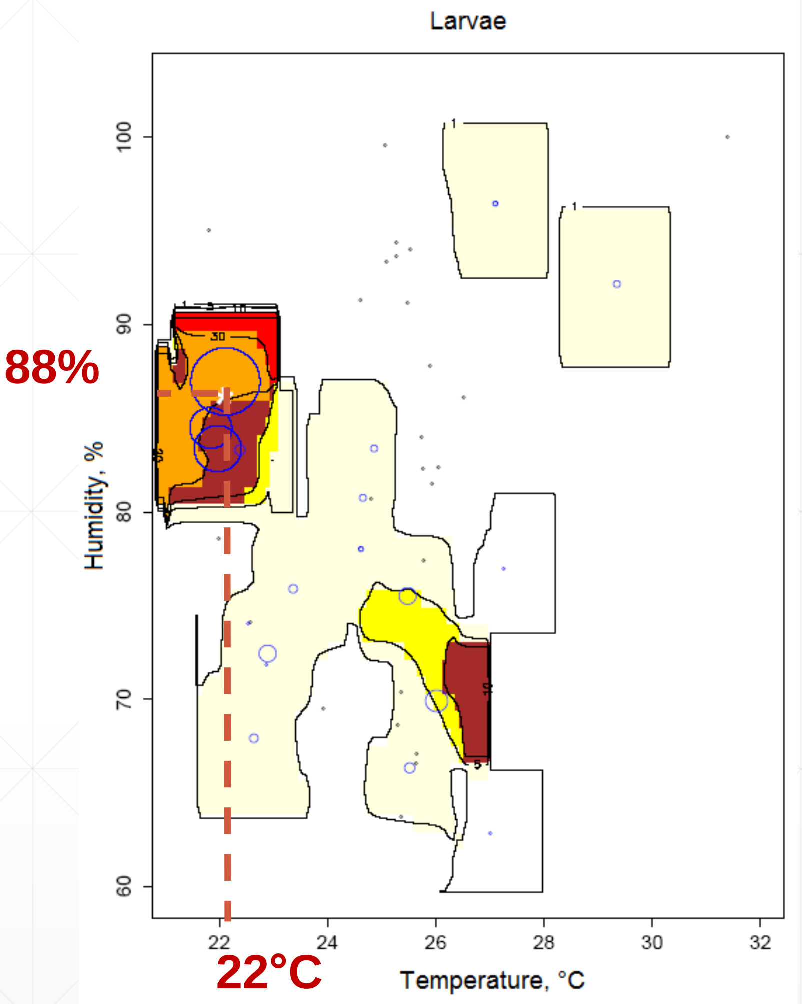


Fig. 3. Distribution of thrips larvae with respect to the temperature and humidity

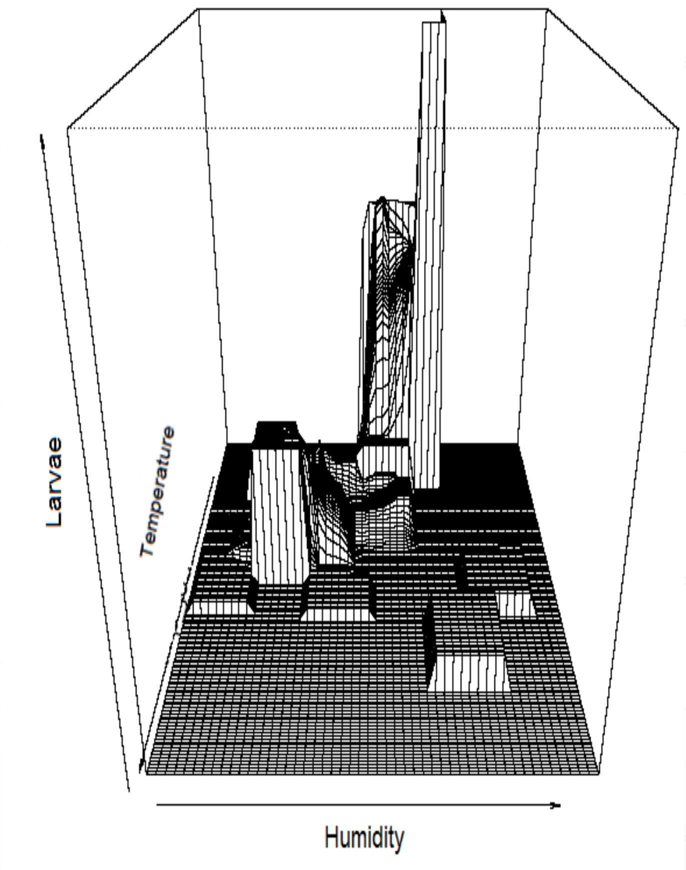


Fig. 4. 3D representation of thrips larvae density as a function of temperature and humidity

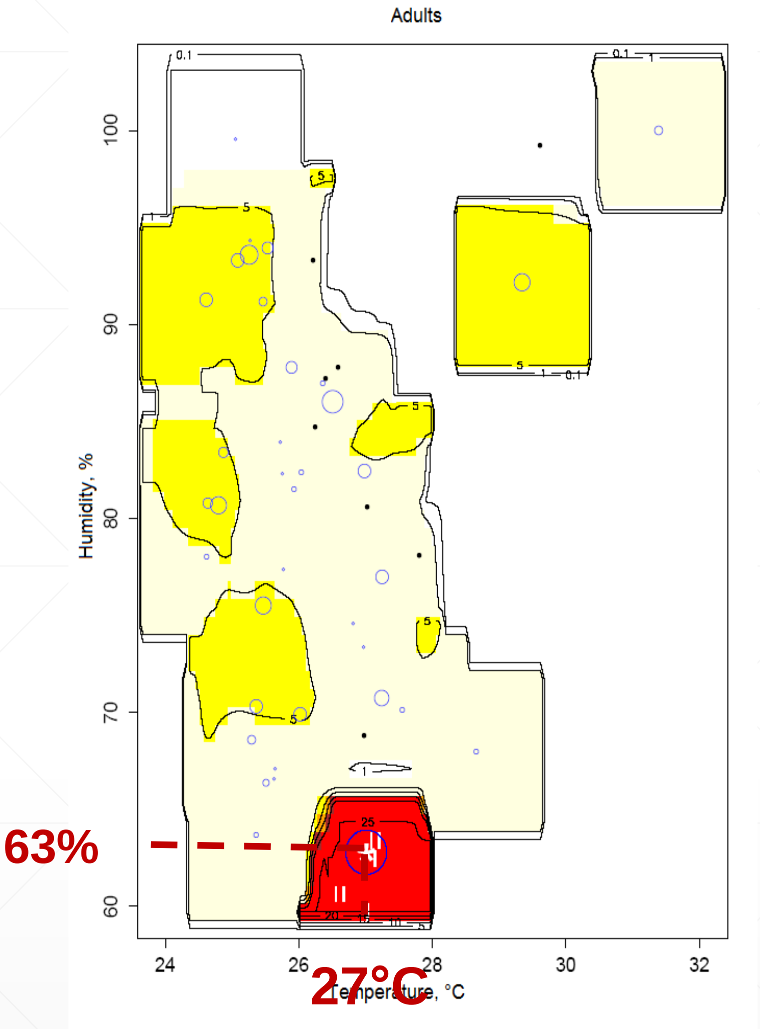


Fig. 5. Distribution of thrips adults with respect to the temperature and humidity

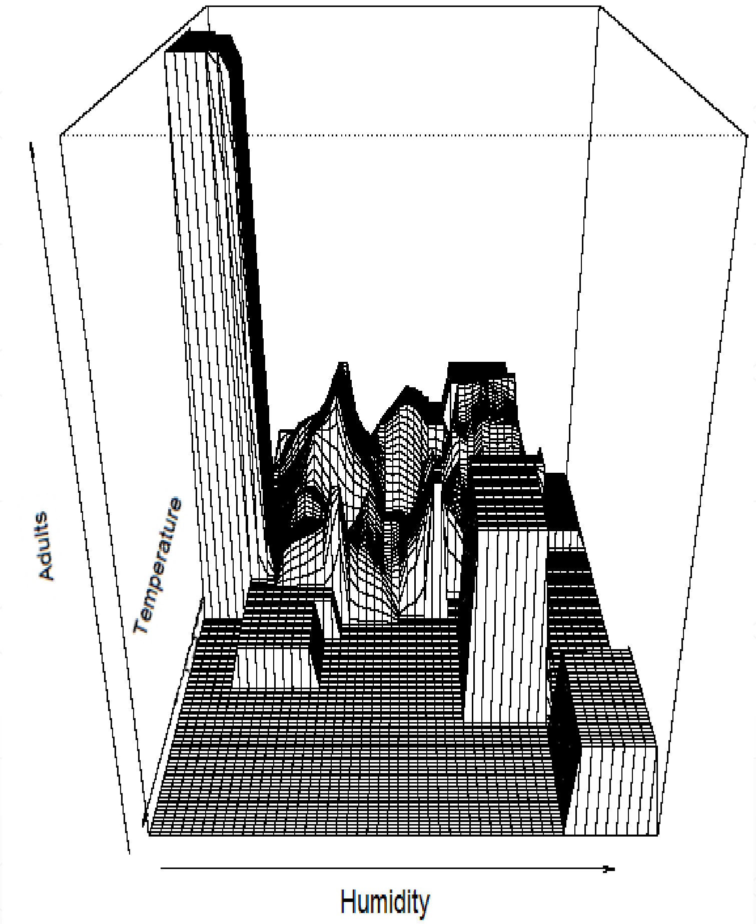


Fig. 6. 3D representation of thrips adult's density as a function of temperature and humidity

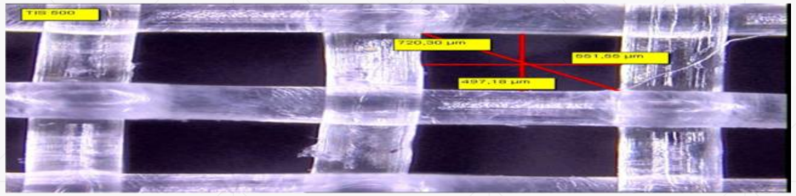
Conclusion 2

- Temperature and humidity exert a direct effect on the distribution of thrips (*F. occidentalis*) within the greenhouse space.
- Highest population density of thrips adults was recorded at 27°C for temperature and 63% for humidity.
- Number of thrips larvae is high around 22 °C of temperature and 86% of humidity.
- Once the climatic preferences of thrips identified, the infestation can be then effectively minimized by realizing natural enemies in small areas surrounding the risk zones.
- These findings could also be used to derive climate control strategies considering both thrips infestation occurrences and plant comfort and allowing to implement optimal climatic methods, alternative to chemical products use.

- **Fatnassi H.**, Pizzol J., Boulard T., Poncet C., S. Voisin, M. Zigler. 2012. Dependence of Thrips Infestation on Spatial Climate Distribution in a Rose Greenhouse Crop. Acta Hort. (ISHS) 927:261-266
- **Fatnassi** H., Pizzol J., Senoussi R., N. Desneux, A. Biondi, Boulard T., **Poncet** C. 2015. Effect of air temperature and humidity on the spatio-temporal distribution of *Frankliniella occidentalis* populations in a greenhouse rose crop. PloseOne (in press)

Aims of study

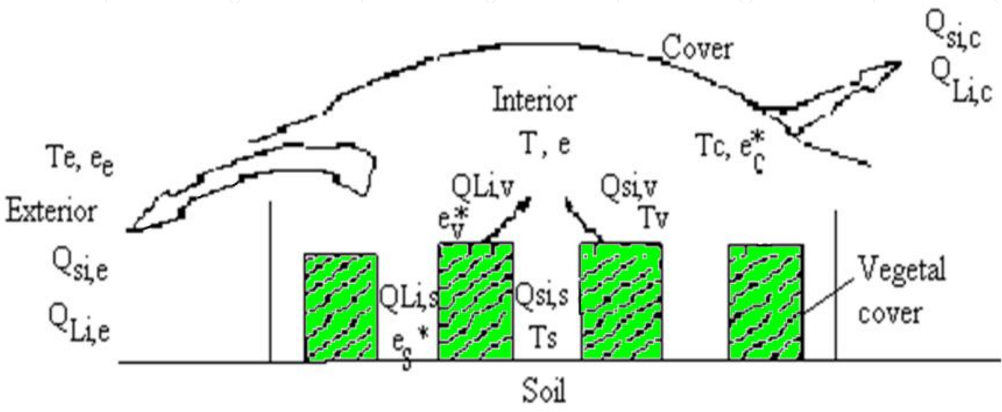
- Develop a global greenhouse climate model based on combined sensible and latent heat balances. The resulting model can be used to evaluate the inside climate in a large insect-screened greenhouse.
- Sensitivity study about the effects of various types of insect-proof nets (anti-thrips, aphids) was carried out to analyse the effect of varying the mesh size on inside greenhouse climate.



Energy balance model :

Sensible and latent heat balance of inside air model able to predict air temperature and water vapour content:

$$\begin{cases} Ca\dfrac{V}{S_g}\dfrac{dT_i}{dt} = PvI_{LA}h_{S_{v,i}}(T_v - T_i) - hs_{i,s}(T_i - T_s) - \dfrac{S_c}{S_g}h_{S_{i,c}}(T_i - T_c) - \dfrac{Ca}{S_g}G(T_i - T_e) \\ L_v\dfrac{V}{S_g}\dfrac{de_i}{dt} = PvI_{LA}h_{L_{v,i}}(e_v^* - e_i) - h_{Li,s}(e_i - e_s^*) - \dfrac{S_c}{S_g}h_{L_{i,c}}(e_i - e_c^*) - \dfrac{L_v}{S_g}G(e_i - e_e) \end{cases}$$



With:

$$G = \left(\frac{S_o}{2}\right)A_{\ell of}\left[2g\left(\frac{\Delta T}{T_e}\right)\left(\frac{H_c}{2}\right) + C_w U^2\right]^{0.5}$$

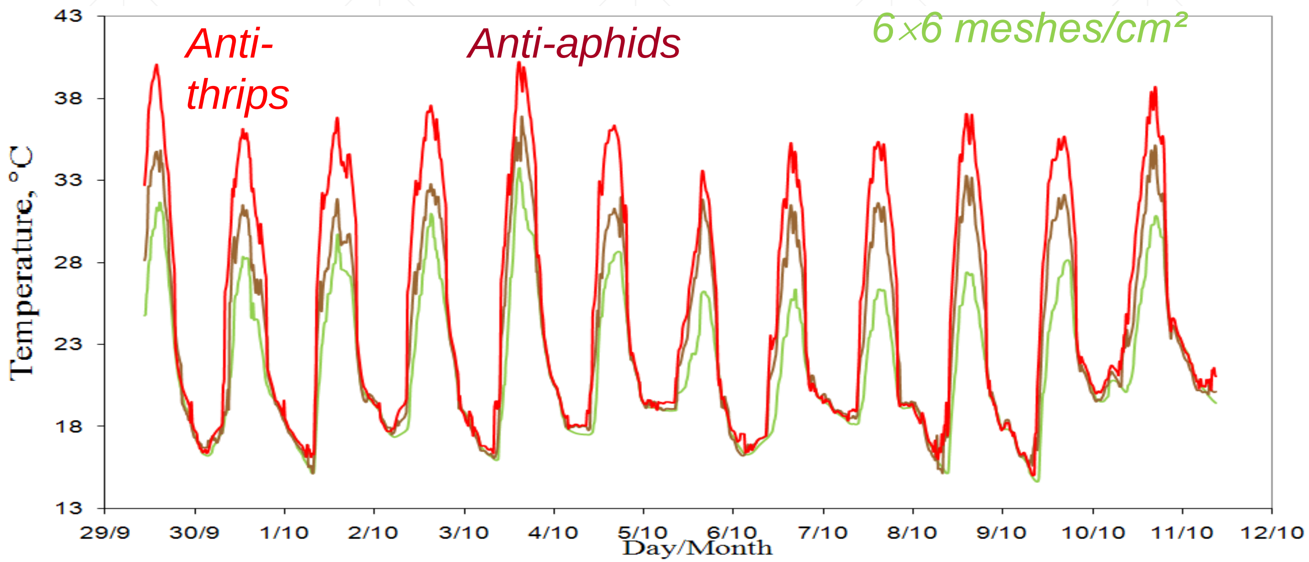
Al_{of}= 1/(Cpo+Cpf)^{0,5}

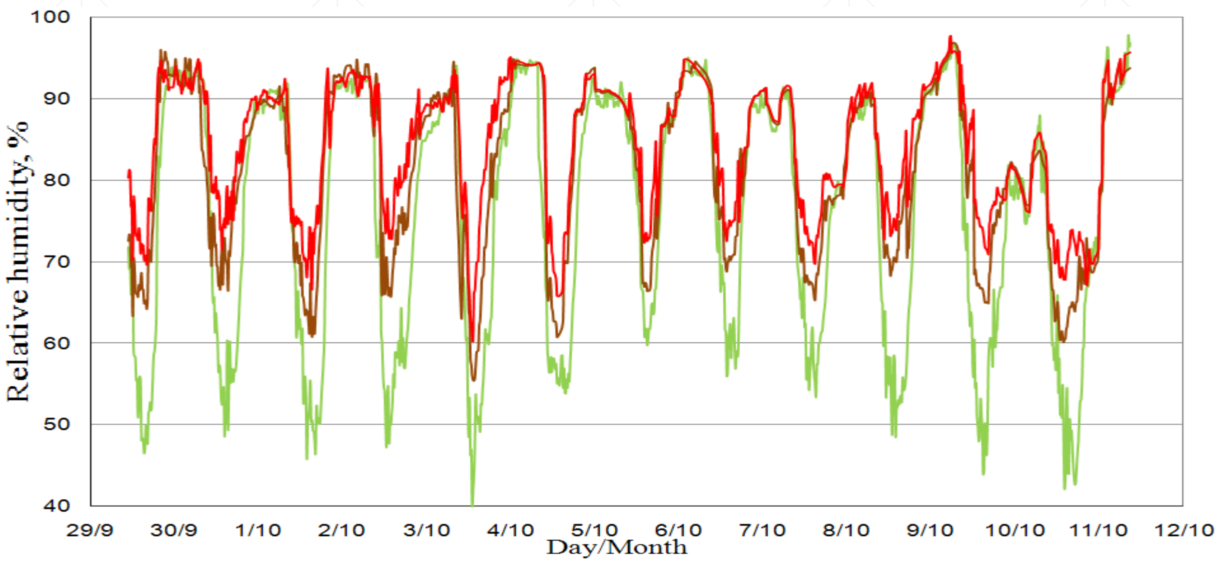
Cpo : Coeff of pressure drop of the opening = 2

Cpf: coeff of the pressure drop of the insect-proof

Insect-Proof	Cpf
0.6mmx0.6mm	4
0.8mmx0.22m anti-Bemisia	**6.25**
0.4mmx0.4mm anti-aphids	5
0.18mmx0.18mm, anti-thrips	9

Results:





Insect-Proof	Ti- Te (°C)	Wi–We (g/kg)
0.6mmx0.6mm	4	4
0.4mmx0.4mm anti-aphids	11	16
0.18mmx0.18mm anti-thrips	15	26

Conclusion 3

- After validation, the dynamic model was used for estimating the climatic consequences of the use of finer insect screens.
- Simulations with the model show that both anti-thrips and anti-aphids nets induce a very significant reduction in ventilation and consequently a severe increases in inside air temperature and humidity.
- Such climate conditions are not compatible with normal growth of the crop and could favour fungal disease attacks. To combine fine-mesh screens, providing good protection against insects, and a good climatic balance, it is then necessary to use additional climate control techniques which performances can be estimated using this model.

Fatnassi H., Boulard T., Bouirden L. (2013). Development, validation and use of a dynamic model for simulate the climate conditions in a large scale greenhouse equipped with insect-proof nets. *Computers and Electronics in Agriculture, 98, 54–61*.

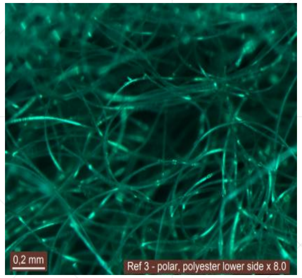
Aim of study

Identify which material can "mimic" the climatic characteristics of leaf domatia (structure produced by plants where beneficial insects can find shelter).

The experimental setup used to measure the microclimate in the domatia and the tissues

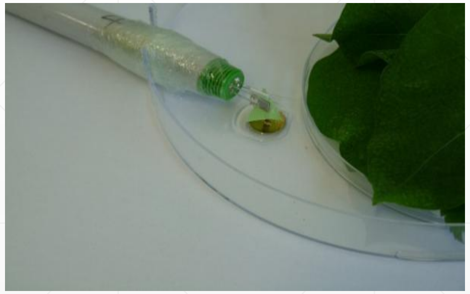
Domatia

Cotton



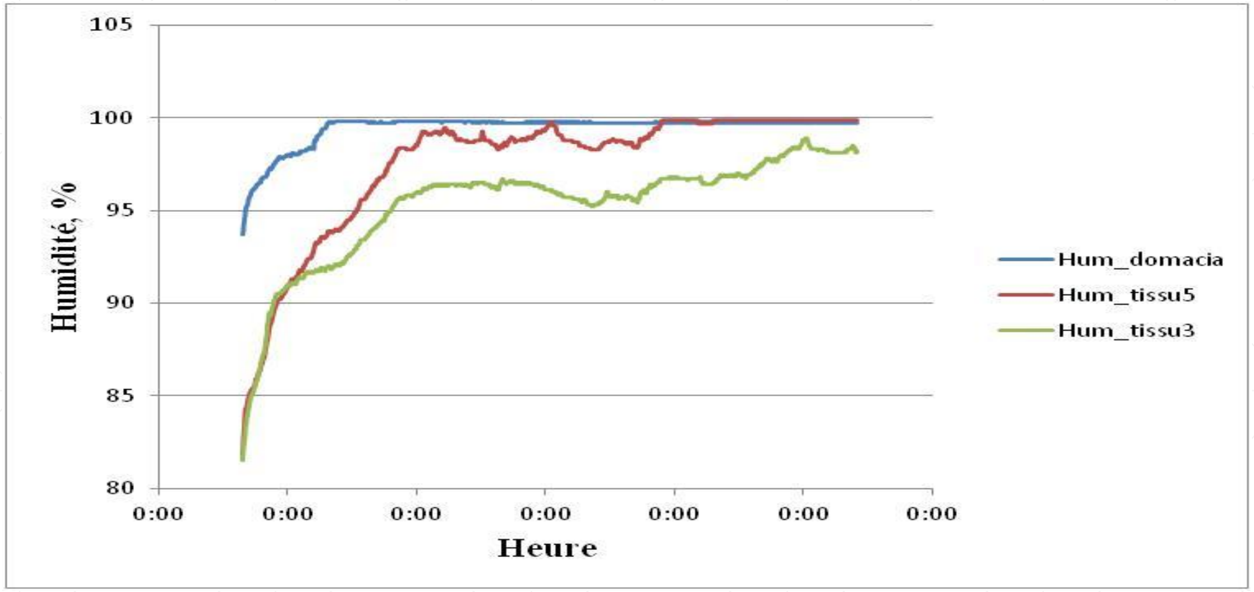
Polyester polar

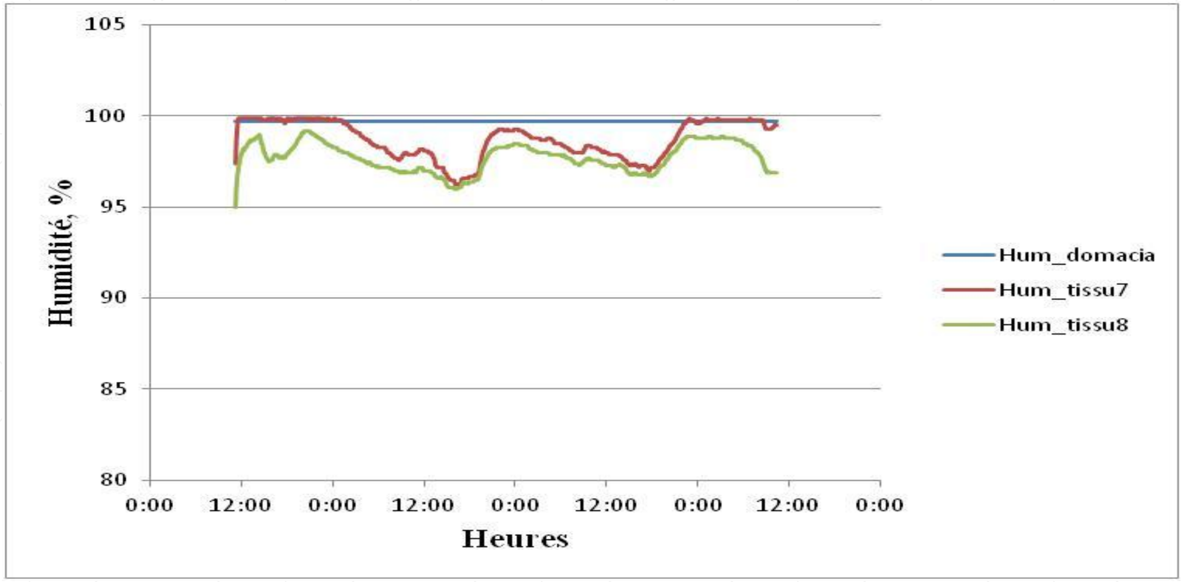
Temperature and humidity measurments in domacia

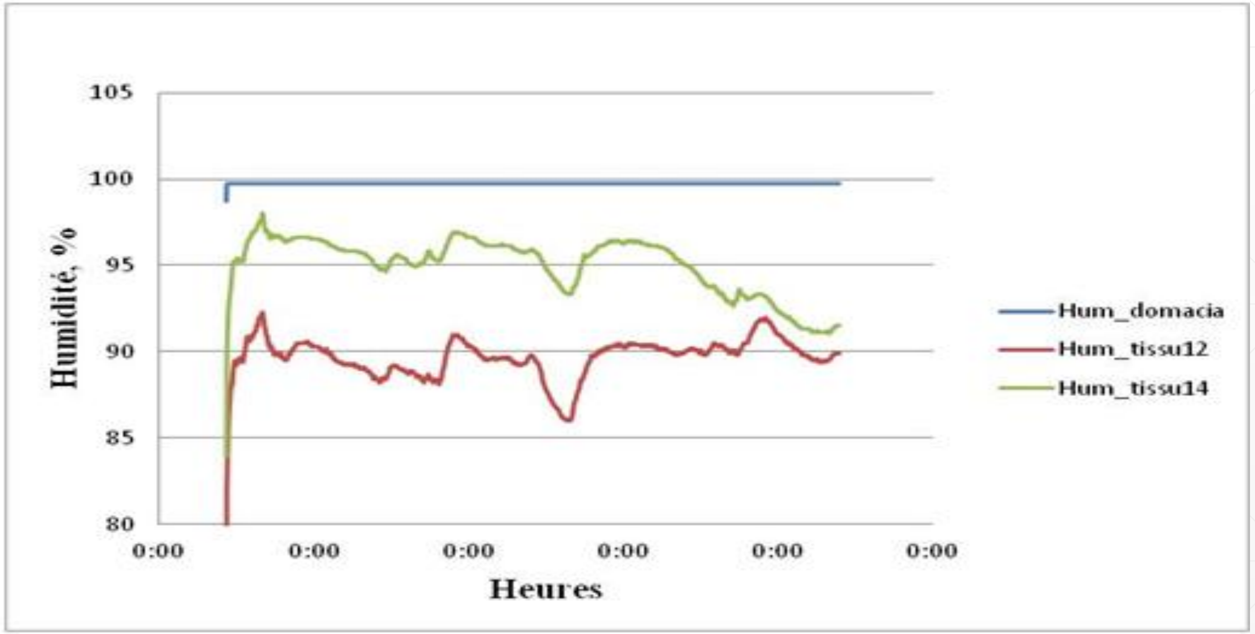


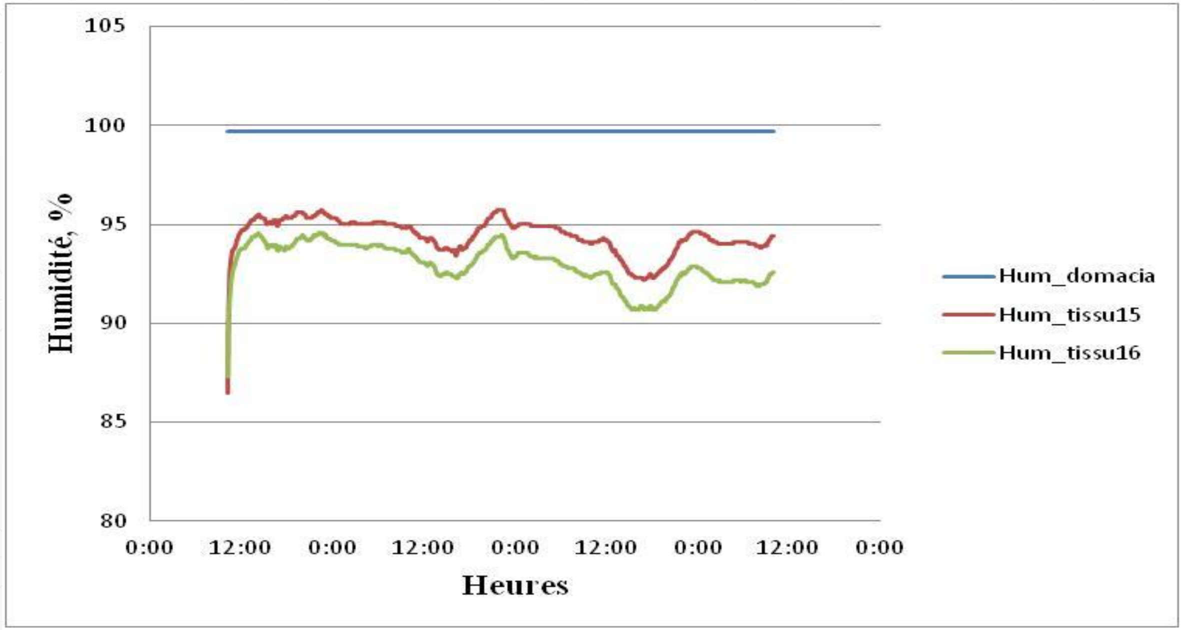
Temperature and humidity measurements in tissue

Comparison of the evolution of the humidity in domatia and several substitute materials « Tissues »









General Conclusion

- Simulation of the microclimate in greenhouse at different scales to develop management strategies to control pests.
- Heterogeneity of the microclimate in the boundary layer ecological niche of pests .
- Temperature and humidity conditions prevailing in the pests and predators habitat (BL) are strongly disconnected from the ambient greenhouse air.
- Determine climate preference of pests to derive climate control strategies allowing for a wiser control of greenhouse pest infestations.
- Using CFD facilities to study the strategies to control the local climate under the leaf to make it unfavorable for pests
- Integrate this control strategy of temperature and humidity in relation to the bioagent preference in greenhouses.

Thank you for your attention