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Novel control of humidity

A system which reduces relative humidity in the greenhouse and therefore brings about less disease, has also been designed to save energy.

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Control of two environmental factors, relative humidity and temperature in the greenhouse atmosphere are of great economical importance in cultivation.

The most known effect of sub-optimal humidity and condensation of moisture on plant organs is proliferation of moisture dependant diseases, in particular, *Botrytis cinerea* (grey-mould).

A new method of reducing the relative humidity in the greenhouse is by installing dehumidifiers known as Latent Heat Convertors (LHC) or AGAM units. Not only do they bring about a significant reduction in the extent of plant diseases which require high humidity conditions, there is also a reduction in energy required for heating the greenhouse. The reduction in energy consumption is due to the latent heat conversion of the greenhouse water vapour to sensible heat* of the condensed water.

Principles of LHC units - The principles of Latent Heat Convertors (LHC) are based upon direct contact of air with downward flowing hygroscopic

*Sensible Heat (or enthalpy) is defined as the heat energy absorbed or transmitted by a substance during a change of temperature which is not accompanied by a change of state



Latent Heat Convertors reduce relative humidity in the greenhouse and thereby reduce incidence of disease.

solution (brine). Each one of the units is composed of two separate heat exchangers, A and B. When the humid greenhouse air makes contact with the brine of exchanger A, the vapour is condensed on the brine.

The sensible heat of the condensation heats the brine and the warm brine heats the air which is introduced with a lower relative humidity (RH) back into the greenhouse.

The warm brine, which accumulates in the reservoir of exchanger A, is pumped to the top of exchanger B and is distributed downward on the exchanger. The warm brine of exchanger B exchanges heat with the cooler outdoor air, the temperature of the outdoor air increases and is also introduced into the greenhouse.

The brine, which is now cooler due to the exchange with the air, accumulates in the reservoir of exchanger B and is pumped on top of exchanger A. The diluted brine is concentrated in a brine evaporator heated with hot water from the greenhouse general boiler. Heat

from the brine evaporator is also introduced into the greenhouse.

Units on trial - To test the system, two neighbouring greenhouses, each 3600 m² (120m x 30m), with evaporative pads and clad with double polycarbonate sheets, were used in the experiments. Pipes for greenhouse heating were placed beneath the plant canopy and two lines with two circulation fans each line, were installed in each greenhouse to improve the air movement between the plants.

The number of plants, the cultivars as well as the methods of plant handling were similar in both greenhouses. Two models of LHC (AGAM) units were installed outside on the eastern wall of one of the greenhouses (greenhouse A). The second greenhouse (B) was used as a control.

The greenhouses were placed under the following conditions:

Greenhouse A:
1) LHC heating without addition of conventional hot-water heating.

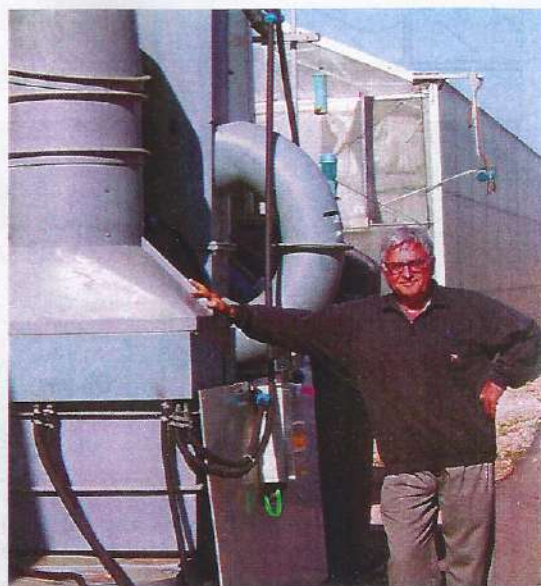
idity and heating

Table 1. Mean temperature (°C), mean relative humidity (%) and energy input (kWh) in greenhouse A with LHC heating and greenhouse B with continuous ventilation without heating during 12h of night period

Greenhouse conditions	Mean night temperature (°C)	Night relative humidity (%)	Energy input (kWh)
Continuous ventilation without heating	11.5	95	Fan operation only
LHC heating only	16.5	88	280 (for brine concentration)

Table 2. Mean temperature (°C), mean relative humidity (%) and energy input (kWh) in greenhouse A with LHC + conventional heating and greenhouse B with conventional heating and ventilation

Greenhouse conditions	Mean night temperature (°C)	Night relative humidity (%)	Energy input (kWh) in 12 hr period
Conventional heating and ventilation	18	90	1545
LHC and conventional heating	18	87	963



Gad Assaf with the Latent Heat Convecting pictured from the outside of the greenhouse.

- 2) LHC heating with conventional hot-water heating.
- Greenhouse B:
- 1) The greenhouse only ventilated without heating.
 - 2) Conventional heating and ventilation

LHC in operation - The efficiency of the AGAM units was examined twice during the spring of 2001, when the minimal ambient temperatures were 11.0°C-11.5°C and air humidity was 90%-95%.

The results (Table 1) show that at ambient temperature of 11.5°C the two AGAM units were able to raise the temperature in greenhouse A to 16.5°C compared with 11.5°C in greenhouse B. Furthermore, the air humidity in the control greenhouse remained at 95% similar to the outdoor humidity, while in the greenhouse heated with the AGAM units the humidity was reduced to 88%. The rise of 5°C over the outdoor temperature was a substantial donation to energy saving in the greenhouse, whereas the reduction of the humidity to 87% and 89% at 30m and 90m from the AGAM units respectively was suffi-

cient enough for prevention of grey-mould and other diseases requiring high humidity.

In the second experiment a minimum of 18°C was maintained in greenhouse B. For maintenance of this temperature during 12 hours at night, 1545 kWh of energy was required (Table 2). This amount of energy was not sufficient for dehumidification, nor a reduction of the relative humidity below 90% and hence not for a reduction in the level of grey-mould disease. On the other hand, maintaining a temperature of 18°C with two AGAM units in greenhouse A with the addition of conventional heating required only 963 kWh. This led to a mean decrease in RH to 87% and energy

savings of 3.64 kWh l⁻¹ of water (Table 3).

When the average temperature in the hot-water boiler is only 65°C, as it was during the experimental period, the condensation of water vapour is 8-12 l h⁻¹ per one AGAM unit. When the boiler water temperature is increased to 70°C the condensation of vapour is about 13 l h⁻¹. At 75°C the vapour condensation increases to 17 l h⁻¹ and to 20 l h⁻¹ per AGAM unit when the boiler water temperature is elevated to 85°C. With these conditions the RH in the greenhouse will be reduced to 85%, energy savings will be 6 kWh⁻¹ and they will provide a high level of protection against high humidity requiring diseases. □

Table 3. Efficiency of LHC operation with and without addition of conventional hot-water heating in comparison to conventionally heated and ventilated greenhouse

Greenhouse handling	Vapour condensation (l night ⁻¹)	Dehumidification (l night ⁻¹)	Coefficient of heat transfer (Wm ⁻² OC ⁻¹)	Energy saving (kWhl ⁻¹)
LHC heating only	280	560	1.30	
LHC and conventional heating	160	320	3.27	3.64
Conventional heating and ventilation	-	-	5.25	