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Performance aspects of a seawater greenhouse

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Performance aspects of a seawater greenhouse



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THERE ARE SEVERAL regions on earth which have inhospitable climatic conditions and have only brackish water sources. In such places freshwater has to be provided not only for domestic use, but also for agricultural needs. The function of this greenhouse is to produce normal greenhouse crops and also to provide water for irrigation. It is intended for use in hot arid coastal regions which have steady winds from a predominant direction to create an air flow through the greenhouse for ventilation. The incoming air is evaporatively cooled in a pad wetted with seawater and the humid air leaves the greenhouse via a seawater cooled condenser which condenses water from the air stream. A second evaporating pad was placed before the condenser. The wind also induced an air flow through the space between two roof layers over seawater flowing on the lower roof surface (Figure 1).

The planting scheme in the greenhouse consisted of 50 per cent lettuces and 50 per cent French beans to demonstrate the efficiency of the evaporative cooling process creating a cool and humid environment particularly suitable for these crops which are at the same time important and expensive to produce in the Canary Islands.

Simulation

The simulation model [Chalabi et al, 1991] consisted of energy and mass balances which enable variations in the state variables of air, plant, greenhouse roof and soil

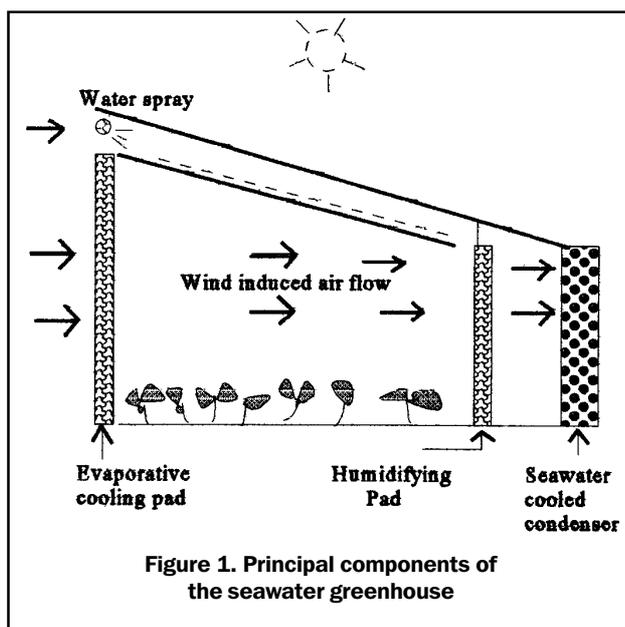


Figure 1. Principal components of the seawater greenhouse

temperatures, absolute humidity and carbon dioxide concentration to be predicted in response to changes in external weather conditions. The model was extended to include the sensible and latent heat exchanges occurring in the two greenhouse evaporation pads and in the roof cavity. (Raoueche et al.).

The model was used to predict the contribution of each element of the system in adding vapour to the air passing through the greenhouse and the roof cavity. Also calculated was the rate of water evaporated/condensed per m² of ground floor area of a seawater greenhouse in the Canary islands (Spain). Meteorological data recorded during the months of December 1994 and June 1995 in Tenerife were used to generate a consistent set of hourly average values of solar radiation, ambient temperature, clouds and moisture content.

Results and discussion

The contribution of each element of the system in adding vapour to the air passing through the greenhouse and the roof cavity was assessed.

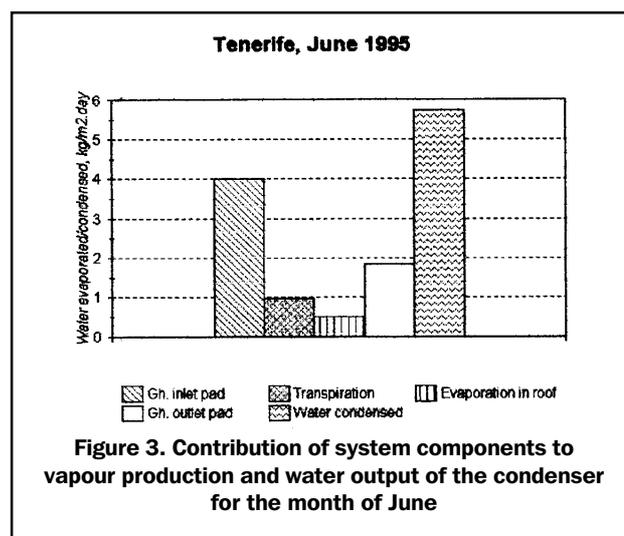
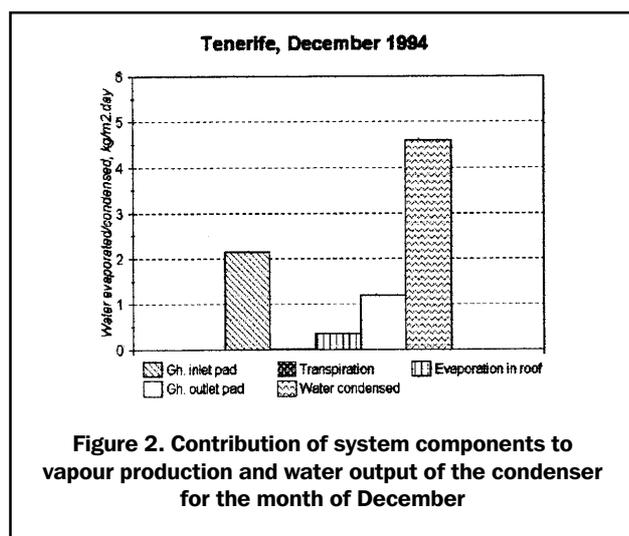
Evaporative cooling pad

The rate of evaporation of water from the cooling pad depends on the wet bulb temperature of the air entering the cooling pad, the pad efficiency and the rate of air flow, it is independent of the type of greenhouse and the extent of any crop.

The maximum reduction in temperature equals the wet bulb depression of the air approaching the cooler, so that the air leaving the cooler could be saturated. This is undesirable in greenhouses because transpiration is suppressed. Consequently, the efficiency of the evaporative coolers was fixed at 80 per cent. The maximum rates of water evaporation from the cooling pad in Tenerife for the months of December and June were 2.2 kg day⁻¹ and 1.85 kg day⁻¹ per square meter of greenhouse floor, respectively as shown in Figures 2 and 3. The evaporation from pad1 and pad2 represented 58 per cent and 32 per cent of the total evaporation rate respectively in December and 55 per cent and 25 per cent in June.

Greenhouse

Plant growth and development are directly related to water status, either in the form of liquid within plant tissue or in the form of vapour in the surrounding air. Transpiration plays a very important role in the hydraulic cycle of crops.



According to Rosenberg et al [1983], only 1 per cent of the available liquid water taken by the plants is actually involved in metabolic activities. Most of the water passes through the plants and is used to provide cooling through transpiration.

The ambient temperatures inside the greenhouse were reduced from 2 to 4°C compared with outdoor temperatures and the relative humidity was generally maintained at 85 per cent. This contributed to create an ideal environment for plant growth of a wide range of species and is of particular value in very dry and hot areas of the world where certain crops are only produced at a very high cost, if produced at all.

Figures 2 and 3 show the prediction of transpiration rate of the plant; as expected, most of the water was transpired during day time in proportion to solar radiation. The daily crop transpiration and water condensation was 0.2 kg m⁻² and 4.6 kg m⁻² respectively for the month of December and 0.96 kg m⁻² and 5.7 kg m⁻² respectively for June. The transpiration represented 0.5 per cent and 13 per cent of the total evaporation rate for the months of December and June respectively.

In December, the condensation is much lower than during June as expected, since transpiration by small plants during December does not supply much water to the greenhouse system. The transpiration rate is lower due to the higher relative humidity.

Roof cavity

The rate of water evaporation from the roof cavity was 0.35 kg m⁻² and 0.5 kg m⁻² per day for the months of December and June respectively (Figures 2 and 3). The evaporation in the roof cavity represented 9.5 per cent and 7 per cent of the total evaporation for the months of December and June respectively.

The thick film of water on the roof did not absorb a significant amount of solar radiation. This occurred because the heat removed by the water leaving the roof increased, thus the average roof temperature is lower and the saturated vapour pressure of the air leaving the cavity is reduced.

Conclusions

The Seawater Greenhouse represents a new approach to providing fresh water for growing crops. The prototype greenhouse was too small, and using a chiller (high consumption of electricity) to simulate the cold seawater cannot be used as the basis for an economical analysis. However, the Seawater Greenhouse was useful in providing the data needed for the design, modelling and the performance analysis of the different components of the system.

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