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Evaluation of a dehumidifier in a mild weather greenhouse

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HIGHLIGHTS

- The dehumidifier eliminated the risk of humidity damage in a mild weather greenhouse.
- The external and internal climate influenced the efficacy of the dehumidifier.
- The optimal climate was temperature of 15.0 °C and relative humidity between 84 and 88%.
- When the weather was cold and dry, the dehumidifier was not efficient.
- If the weather was cold and humid, the effect of HPD was not sufficient.

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ABSTRACT

The high humidity that surrounds crop plants, aggravated in mild weather greenhouses by high transpiration and lack of ventilation, encourages plant diseases and physiological disorders. A heat pump dehumidifier (HPD) has been installed in a mild weather greenhouse. Its development and the characteristics of the dehumidification process have been studied. The results indicate that the HPD reduced the risk of crop damage caused by humidity. Its effectiveness was related to the temperature value and the air humidity inside the greenhouse. HPD operation was not suitable under dry weather conditions. Conversely, when humidity was excessive, the HPD did not eliminate the risk of moisture damage. The appropiate conditions for using an HPD to eliminate humidity damage risk are relative humidity between 84% and 88%, and air temperature higher than 15.0 °C. Under these conditions, the condensed steam production value was 14.2 kg h^{-1}, the specific moisture extraction rate was 2.3 kg (kW h^{-1}), and the coefficient of performance was 2.5.

1. Introduction

In the horticultural sector in mild weather areas, most greenhouses are very simple constructions covered with a plastic film and with no active climate-control systems [1]. Environmental control is essentially achieved using ventilation techniques to control temperature (T) and humidity, which are, in most cases, far from ideal and strongly dependent on the outside conditions - thus resulting in relatively low yields [2,3]. Relative humidity (RH) tends to be high due to crop transpiration and low T, especially during the autumn-winter period [4]. Hand [5] showed that for a vapour pressure deficit (VPD) lower than 0.20 kPa, plant diseases are favoured and physiological disorders may occur. Nowadays, low-energy-demand, closed greenhouses are used to increase crop production by increasing the control of other variables - such as CO_2 or T - and are aimed at sustainable crop production; although they induce higher humidity levels [5,6,7]. In order to improve growing conditions and prevent the emergence of crop diseases, it is necessary to reduce the effects of low T and high humidity inside the greenhouse [8,9].

A proper dehumidification method must prevent the risk of humidity damage [10] while maintaining the greenhouse sealed; this is to ensure a homogeneous climate and high CO_2 levels when enrichment systems are installed. The most commonly used method to avoid moisture damage combines ventilation and heating [11]. Despite its low energy efficiency, this method is widely used because it only requires the ventilation and heating systems [12,13]. The use of vapour compression cycles to control humidity inside greenhouses has been investigated [14,15,16,17]. The method’s main advantages with regard to this application are (i) recovering the condensed water vapour’s latent heat and using it for heating and (ii) its effectiveness in controlling the humidity is independent of the external air conditions [18]. At present, there are numerous studies on other dehumidification

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Nomenclature

Abbreviations

RH	relative humidity, %
T	temperature, °C
VPD	vapour pressure deficit, kPa
p_{vs}	saturation vapour pressure at the air temperature, Pa
p_v	vapour pressure at the air temperature, Pa
ω	specific humidity, kgv kga^{-1}
h	enthalpy, J kg^{-1}
c	specific heat, J kg^{-1} °C^{-1}
L	latent heat, J kg^{-1}
W	mechanical energy transfer, J
P	power, W
PUC	power per unit of area, W m^{-2}
Q	heat transfer, J
q	heat transfer per unit of time and area, W m^{-2}
$m_{w,d}$	mass of condensed water vapour, kg
VCF	vapour condensed flow, g h^{-1} m^{-2}
CSP	condensed steam production, kg h^{-1}
$m_{a,d}$	mass of air treated in the heat pump dehumidifier, kg
AFT	air flow treated in the heat pump dehumidifier, m^3 s^{-1}
SMER	specific moisture extraction rate, kg (kW h)$^{-1}$
COP	coefficient of performance, -
m	mass, kg
tr	transpiration
E	energy of air, J

Subscript

g	greenhouse
e	entrance of the greenhouse
o	outlet of the greenhouse
t	At time t, s
t′	At time t′, s
tr	transpiration
i	initial state of the air
f	final state of the air
med	mean value
c	condensation of the water vapour
n	natural condensation in the greenhouse
d	due to the dehumidifier
w	condensed water
a	dry air
v	water vapour
l	latent
s	sensible

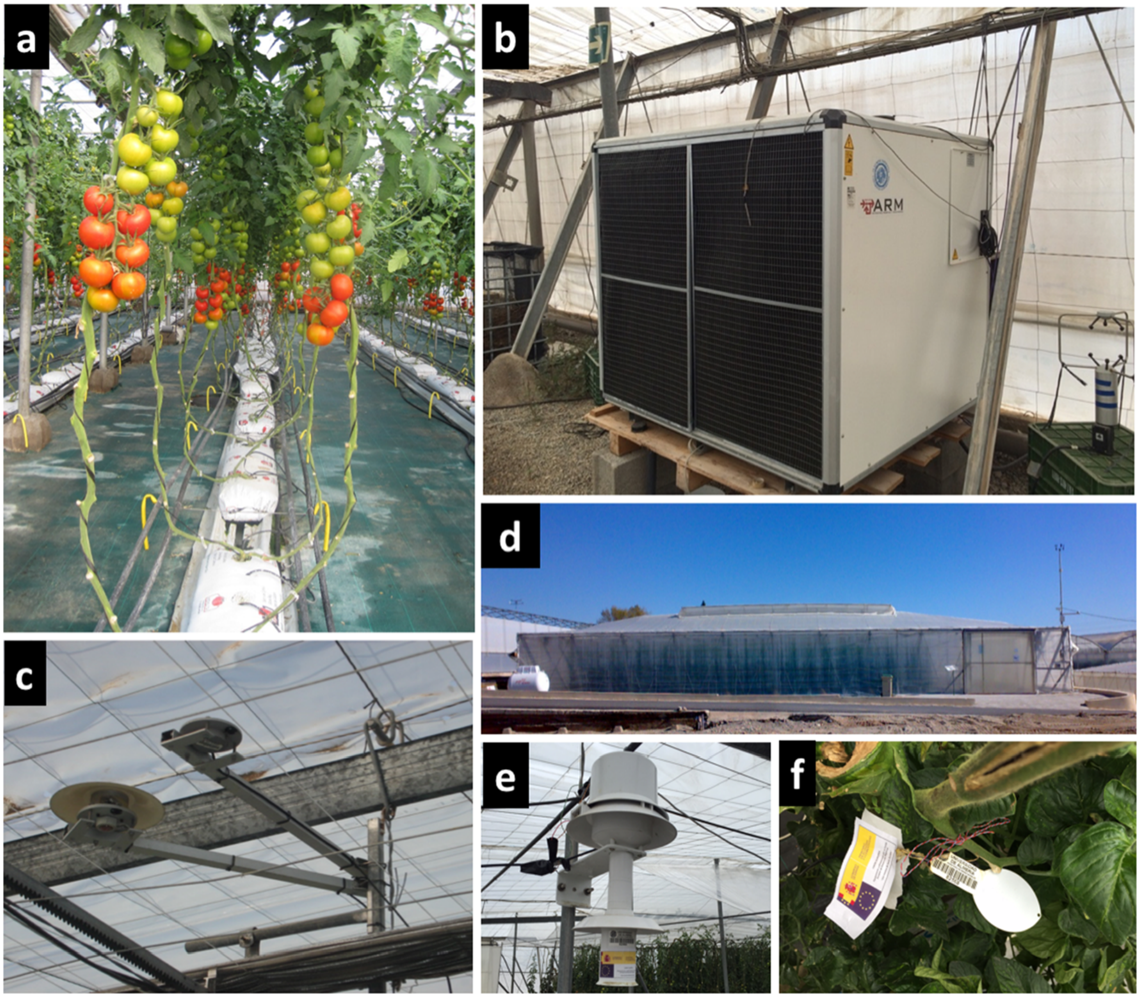

Fig. 1. Greenhouse facilities used for the experiments performed in this work: a. tomato plants, b. heat pump dehumidifier (HPD), c. radiation sensors, d. multispan greenhouse, e. temperature and humidity sensors, and f. leaf condensation sensor.

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