Grower Summary

PE/PO 013

Refrigeration-based dehumidification: energy performance and cropping effect on commercial nurseries

Final 2014

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

If you would like a copy of this report, please email the HDC office (hdc@hdc.ahdb.org.uk), quoting your HDC number, alternatively contact the HDC at the address below.

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Project Number:	PE/PO 013
Project Title:	Refrigeration-based dehumidification: energy performance and cropping effect on commercial nurseries
Project Leader:	Tim Pratt, Farm Energy Centre
Contractor:	Farm Energy Centre
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GROWER SUMMARY

Headline

Protected edible crops

Refrigerant based dehumidifiers trialled on a tomato nursery in 2013 delivered heat savings of 91kWh/m^2 (24%) compared to a conventional heating system. This was offset by electricity use of 19kWh/m^2 and a 1kg/m^2 reduction in yield. Being a single year of trials with no replicates work in 2014 aims to investigate this yield loss.

Protected ornamental crops

Extrapolation of data from the trial to cover high energy ornamental crops grown at 16^{o}C or higher indicates that quicker paybacks may be possible (less than four years) due to a reduced dehumidification capacity requirement (lower capital cost). Nurseries that use gas oil for heating should get a faster payback but this is often offset by the fact that such nurseries use relatively little heat.

Background

Controlling the humidity in greenhouses is a vital part of growing high-yielding, quality crops with the minimum use of crop protection chemicals. Traditional methods of controlling humidity involve venting warm, humid air from the greenhouse whilst replacing this with colder, outside air which carries less moisture. The consequential drop in temperature (loss of energy) is supported using heat to maintain the required greenhouse temperature. We estimate that 20% to 40% of a nursery's annual energy consumption is for humidity control.

An alternative approach is to remove the water vapour using a dehumidifier. There are a number of basic designs of dehumidifier; the most common being the refrigerant-based heat pump which has been used in this project. The heat pump design is well proven and has found many applications, e.g. grain drying and wood kilning for instance, and trials have also been carried out in greenhouses e.g. by ADAS at Stockbridge house (Bartlett D.;1991). Early investigation of the technique failed to result in significant commercial penetration but advances in the technology and increased energy costs warranted this renewed investigation.

Summary

Edible crop trials

Trial set up

Four dehumidifiers (supplied by DryGair Ltd), with a combined water removal capacity of 180 litres/hour were installed in a 6,120m^2 greenhouse at Red Roofs Nursery Ltd in East Yorkshire. Over a growing season, energy and crop performance were compared to an adjacent, conventionally heated and ventilated greenhouse compartment.

The dehumidifiers were positioned half-way along the crop rows and straddled the rows as shown in the photograph below.

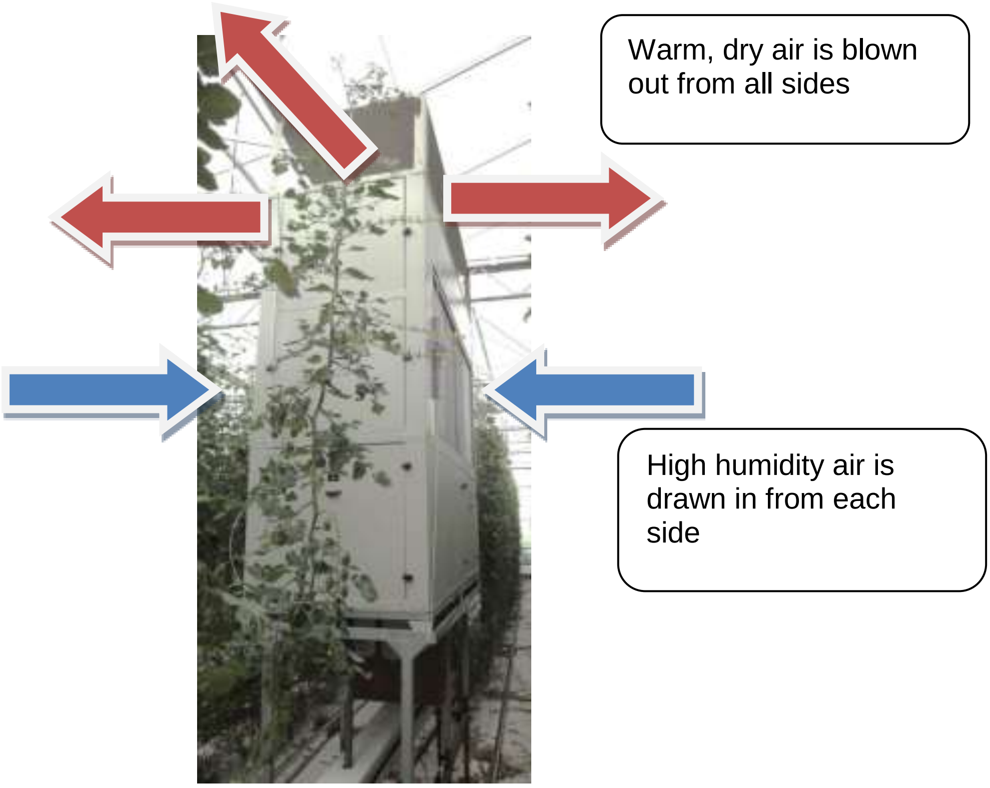

Figure 1. Dehumidifier in situ at Red Roofs Nursery

Results

After some initial problems with the dehumidifiers were resolved, they successfully performed close to specification extracting approximately 45 litres/hour of water for an energy input of 10kW of electricity i.e. 4.5 litres of water removed per kWh of electricity used. This figure is termed the Specific Moisture Extraction Rate (SMER) and is a key figure when comparing different manufacturer's equipment.

Although the original expectation was that they would only be used when the humidity was at its highest, it was soon evident that savings were possible in all but the lowest humidity conditions (<65%). Therefore as long as the RH was >65% and there was a heat demand in the greenhouse, the dehumidifiers were operated. The exception to this was when the heat produced as a by-product of CO_2 enrichment met all of the greenhouse heat demand. As a result, the dehumidifiers were not used from week 25 to week 36.

Figure 2 below shows the weekly heat saving achieved.

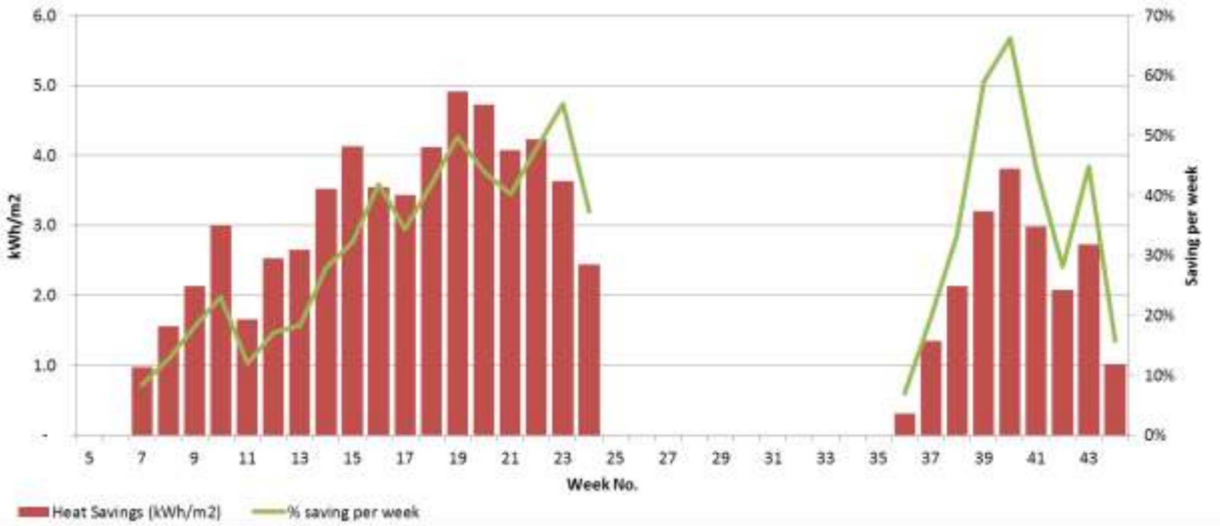

Figure 2. Absolute % (of total) weekly heat saving relating to use of dehumidifiers

Between weeks 1 to 44 inclusive, the control used 383kWh/m^2 of heat. The dehumidifier compartment used 91kWh/m^2 (24%) less and 19kWh/m^2 of electricity.

One area of concern was temperature uniformity. With the four dehumidifiers being, in effect, point heat sources compared to the distributed pipe heating source, one might have expected some degradation in uniformity. However, measurements showed there was actually a slight improvement in temperature uniformity, possibly as a result of the fact that dehumidifiers have internal fans to provide heat delivery and air mixing.

The crop in the dehumidifier compartment yielded fewer tomatoes than the control (1.0kg/m^2) as a result of the plants becoming too vegetative around week 11. Although the crop balance was corrected, the yield was not recovered. The nursery's crop advisor was confident that this could be avoided in the future. This remains to be proven in HDC funded trials in 2014 (PE 013a)

A major plus point relating to the crop is that no fungicide applications were required whereas the control crop needed two. Formal disease monitoring was not carried out.

Ornamental crop modelling

Data was collected from the pot chrysanthemum greenhouse at Double H Nurseries to allow the impact of dehumidifiers to be calculated. We measured the amount of time that heat was being used whilst the humidity was greater than 65%. Using this with the data recorded in the tomato trial we could determine the likely performance for ornamental crop.

Figure 3 below shows the amount of heat used (no dehumidifiers) and the likely heat saving if they had been used. The key figures are:

- Original heat use – 261kWh/m^2
- Heat saving – 97kWh/m^2
- Electricity used – 19.5kWh/m^2

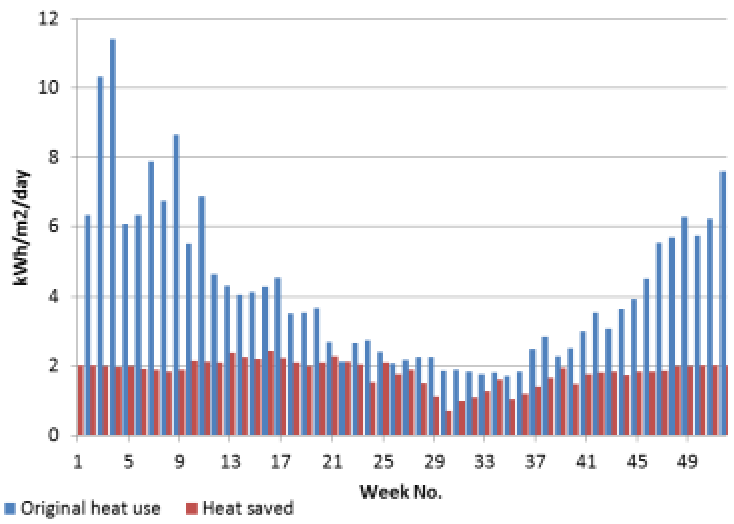

Figure 3. Ornamental crop: heat saving expected

Consultation with ornamental plant growers suggests that no negative impact on plant growth / yield is likely from the use of a dehumidifier system.

Financial Benefits

Tomato trials

Assuming, as advice suggests, the yield reduction experienced in 2013 could be avoided then it's fair to concentrate on the energy saving potential of the technique.

The figures in Table 1 below show energy savings/inputs and are based on the premises that :

- All heat saved would have been produced by a natural gas boiler (68p/Therm)
- All electricity used would have been imported from the grid (7.0p/kWh)

Nurseries that have CHP benefit from lower electricity costs which would increase the net saving by up to £0.40/m^2.

Table 1. Edible: energy saving cost breakdown

	kWh/m^2	£/m^2
Heat saving (kWh/m^2)	91	£2.48
Electricity used (kWh/m^2)	19	£1.33
Net energy cost saving		£1.14

The capital cost of an installation for an edible crop is in the order of £10/m^2 giving a return on investment in nine years. Allowing for the fact that one month of savings were missed in the figures above (equipment commissioning delays) and that simple optimisation of the control would increase performance, a return on investment in six years appears possible.

Ornamental crop modelling

Advice suggests that no impact on crop yield or quality is likely with ornamental crops. Table 2 below combines data collection from a year round high temperature ornamentals nursery with performance data from the tomato trial.

The figure in brackets is the cost of heat if gas oil is used (70p/litre).

Table 2. Ornamentals: energy saving cost breakdown

	kWh/m^2	£/m^2
Heat saving (kWh/m^2)	97	£2.65 (£7.36)
Electricity used (kWh/m^2)	19.5	£1.36
Net energy cost saving		£1.28 (£5.99)

Although net heating use is less for ornamentals, the capital cost of an installation for an ornamental crop is also lower, as the transpiration and moisture load is reduced and less dehumidifier equipment is needed per unit area. Also, with no availability of 'free' heat from a boiler which is being used to produce CO_2, the dehumidifier heat can be useful all year round. Taking these issues into account a return on investment in four years is possible (assuming natural gas as a fuel).

We must also consider here the use of the system for growers who are using gas oil as their heating fuel. As this is more expensive than gas, the payback on dehumidifiers look even better. However it's important to realise that growers who use gas oil are likely to be the ones growing lower temperature crops with lower net energy consumptions. But even taking this into account and taking the example of a grower who is using a 1/3 of the energy shown in the table above, the return on investment might still be reasonable (possibly three to four years). The only proviso to this is that our modelling has been done on a dehumidifier running in a higher temperature environment (>16^{o}C), and one would expect the dehumidifier to perform less efficiently at lower temperatures.

Capital cost is clearly a key element in the economics of a dehumidification system. As well as the hardware itself, the cost of providing sufficient electrical power to the greenhouse is often a significant issue. However, this is site specific so hard to factor into a general economic model.

Action Points

Edible crops

- The outcome of the 2014 trials will investigate if the 2013 yield reduction may be avoided. Growers are advised to delay adoption of the technology until such time as this is reported

Ornamental crops

- Dehumidifiers represent a viable energy saving option in specific circumstances.
- Any growers using gas oil to grow crops at 16°C or above should compare their energy use to that of the ornamental crop nursery monitored. Even if using 1/3 of the heat the return on investment is three years
- Growers using natural gas should make the same comparison as above. The impact of lower energy cost and therefore savings potential mean that dehumidifiers are only likely to be financially viable for high energy use crops.