Grower Summary

PE 013a

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

Final 2015

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Project number:	PE 013a
Project leader:	Tim Pratt, Farm Energy Centre
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Date project commenced:	1st December 2012
Date project completed	31st March 2015

GROWER SUMMARY

Headlines

Protected edible crops

- A final year heat saving of 118kWh/m^2 (32%) was achieved with a refrigerant based dehumidifier trialled in a commercial tomato crop.
- This was offset by electricity use of 16 kWh/m^2 and an average yield reduction of 1.6 kg/m^2. The cause of the yield reduction remains unproven.

Protected ornamental crops

- Extrapolation of data from the tomato trial to high energy ornamental crops grown at 16^{o}C or higher indicates potential for use and should payback on capital of around six years.
- Nurseries using gas oil for heating may get a faster payback as oil is a more expensive fuel than gas.

Background

Controlling humidity is a vital part of growing high-yielding, quality crops, whilst also minimising the use of crop protection chemicals. Normally humidity is controlled by venting warm, humid air from the greenhouse and replacing this with colder, air from outside. This air carries less moisture and is warmed to restore the correct growing temperature. We estimate that 20% to 40% of a nursery's annual energy consumption is used in humidity control.

An alternative approach to reduce humidity is to directly remove water from the air 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. It has in the past been trialled in greenhouses e.g. by ADAS at Stockbridge House (Bartlett, 1991). Early investigation of the technique failed to show significant commercial advantage and subsequent uptake was low. Improvements in the technology and increased energy costs have led to this reinvestigation of the technique.

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. Energy and crop performance were compared to an adjacent, conventionally heated and ventilated greenhouse compartment over two growing seasons.

The dehumidifiers were positioned half-way along the crop rows and straddled the rows as shown in Figure 1 below.

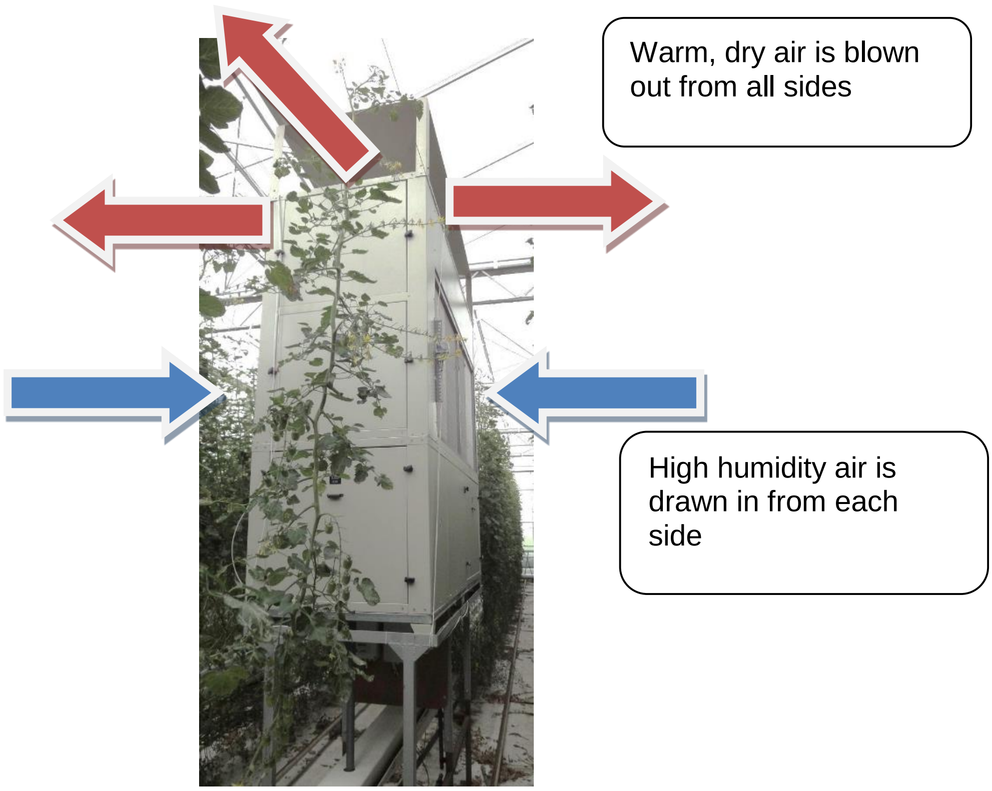

Figure 1. Dehumidifier in situ at Red Roofs Nursery

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 operational. 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 during the summer and early autumn.

Figure 2 below shows the heat saving achieved in each of the 2 years.

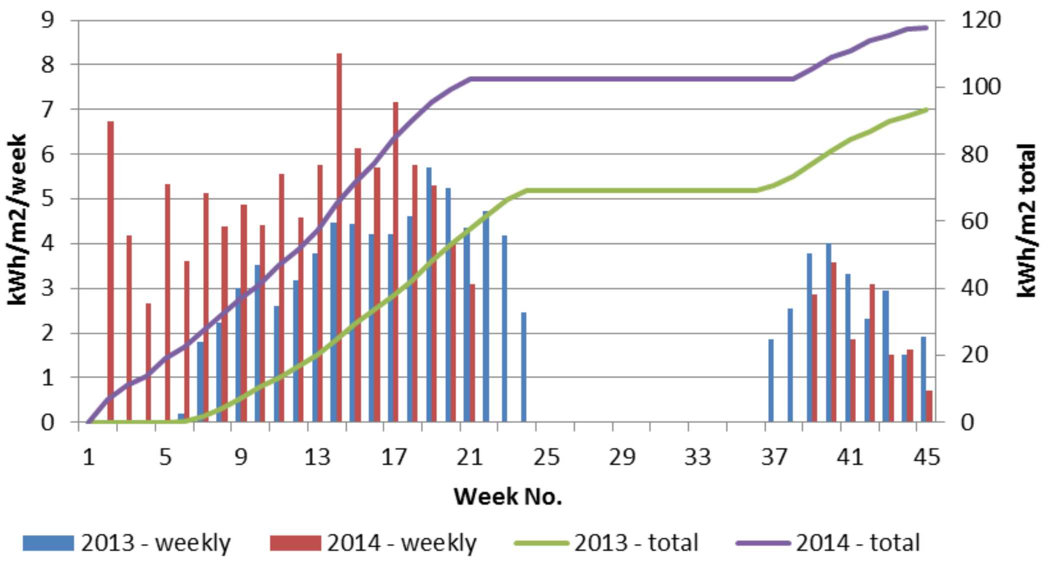

Figure 2. Weekly % and cumulative heat energy savings in 2014

Better performance in 2014 was achieved through a combination of improved dehumidifier efficiency, (a fault was identified in 2013), better control strategies and an earlier start in the season. This was offset to some extent by a longer off period during the summer.

2014 provided representative data for the likely savings going forwards. The greenhouse compartment with a conventional heating system used 367kWh/m^2 of heat whereas the compartment with dehumidifiers used 249kWh/m^2; a saving of 118kWh/m^2 (32%). This saving was of course offset by electricity used by the dehumidifiers (16kWh/m^2).

One area of possible 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.

In both years, the crop in the dehumidifier compartment yielded fewer tomatoes than the control (average 1.6kg/m^2 less), and was as a result of the plants becoming too vegetative around week 11. Although this was pre-empted in the 2014 growing season where the crop was steered more generatively from the start in a bid to prevent it, the affect was still noticeable and the yield was still less. Whether the yield reduction was wholly due to the dehumidifiers remains uncertain as anecdotal evidence from other trials suggests that this problem is not endemic.

Ornamental crop modelling

Data on environmental conditions and energy use was collected from the pot chrysanthemum greenhouse at Double H Nurseries, Hampshire in 2013 to allow the probable impact of dehumidifiers to be derived theoretically. 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

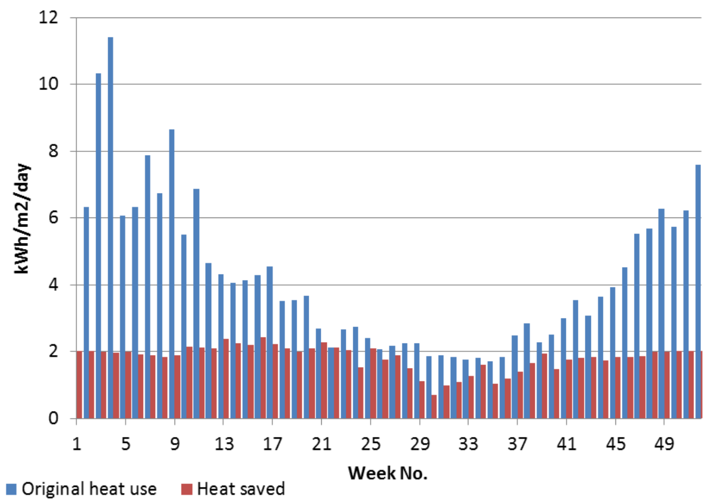

Figure 3. Ornamental crop: predicted heat saving

Consultation with ornamental plant growers suggests that a negative impact on plant growth / yield from the use of a dehumidifier system would be unlikely but this has not been tested.

Financial Benefits

Tomato trials

Focussing on energy saving alone, Figure 4 below shows the net energy saving based on the assumption that all heat saved would have been produced by a natural gas boiler.

As performance in the second year of operation was more representative of what could be achieved in practice (the equipment and control having been refined) second year figures are used in energy saving projections. Savings are illustrated in a family of curves representing a range of electricity and gas costs. Current gas costs are in the order of 60p per therm and electricity is around 8p per kWh (assuming a high proportion of cheap night rate use).

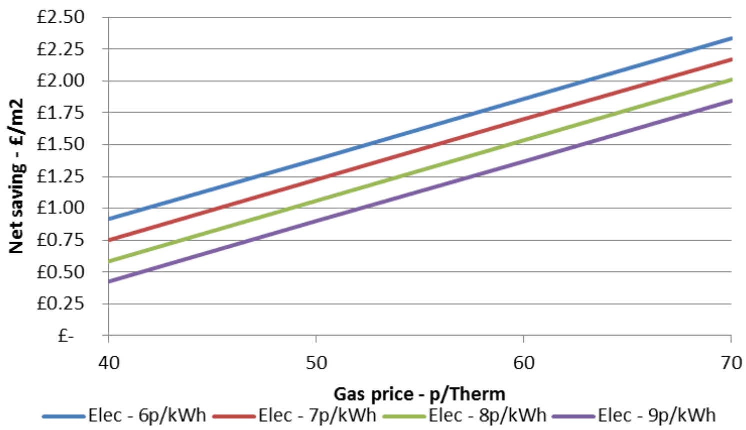

Figure 4. Energy cost savings from dehumidification at different gas and electricity rates

Nurseries that have CHP benefit from lower electricity costs than those using grid electricity so savings would be higher. The capital cost of an installation for an edible crop is in the order of £10/m^2 so a payback of between six and seven years is likely with current energy prices.

Ornamental crop modelling

Advice suggests that no impact on crop yield or quality is likely with ornamental crops as such crops are somewhat less sensitive to humidity conditions. Figures 5 and 6 below present the expected result for nurseries using natural gas and gas oil for heating.

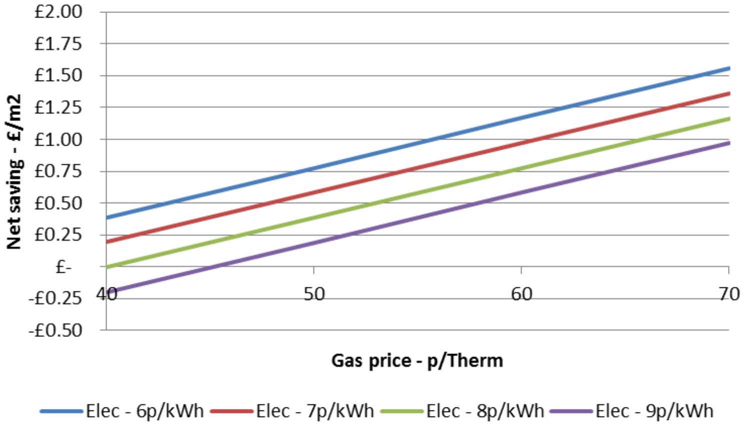

Figure 5. High energy ornamentals: net value of energy saving (natural gas)

Although net heating use and therefore saving is less for ornamentals, the capital cost of an installation for an ornamental crop is also lower (circa £5.50/m^2), as the transpiration and moisture load is reduced and less dehumidification 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 similar to edible crops (six to seven years) is possible.

We must also consider nurseries using gas oil as their heating fuel; as this is more expensive than gas the payback on dehumidifiers looks even better.

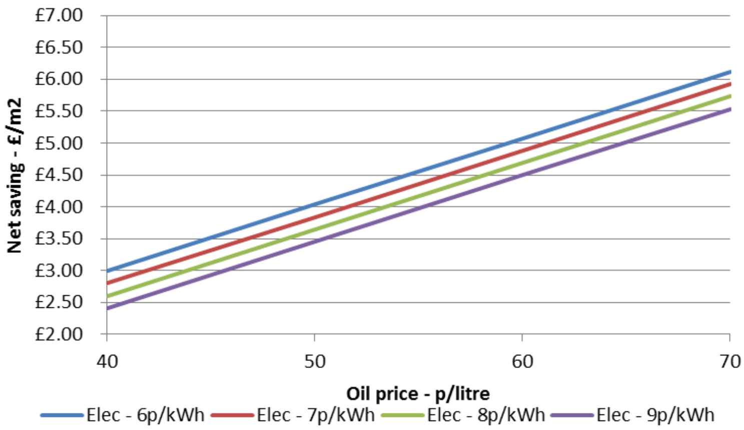

Figure 6. High energy ornamentals: net value of energy saving (gas oil)

Figure 6 assumes the same energy use as a 'high energy' natural gas fuelled ornamental crop. 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 consumption; offsetting the greater ‘per kWh saving’ that displacing gas oil brings. Taking the example of a grower who is using a 1/3 of the energy shown in the figure below, the return on investment might still be economically justifiable (four to five 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. This is site specific so hard to factor into a general economic model.

Action Points

Edible crops

- The energy economics of dehumidifiers are promising. However some doubt still exists over their ability to deliver the highest crop output. There should be no show-stopping technical reason to prevent this being overcome.
- The mechanism by which crop output is being held back needs to be identified and solved.

Ornamental crops

- Dehumidifiers represent a viable energy saving option in specific circumstances.
- Any growers using gas oil to grow crops at 16^{o}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 under five years.
- Growers using natural gas should investigate the capital cost, especially if a bigger electricity supply is required. Only those where the installation is relatively straightforward and therefore cheapest are likely to be a financially viable investment.