Horticultural Development Company

Grower summary

PC 278

The development and commercial demonstration of ducted air systems for glasshouse environmental control

Annual Report 2008

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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 the full report, please email the HDC office (hdc@hdc.org.uk), quoting your HDC number, alternatively contact the HDC at the address below.

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Headline

- The design and installation of a ducted air heating and ventilation system in a commercial greenhouse in the UK has been successfully completed.

Background and expected deliverables

This report summarises the findings of the first year's work of a three year project to investigate the performance of a ducted heating and ventilation system installed in a 1Ha tomato production greenhouse in the UK. The work is being carried out to investigate a technology which can potentially address grower concerns that high energy costs and greater awareness of climate change issues are threatening the viability of glasshouse horticultural production in the UK.

The project follows on from the recently completed PC 256 which examined the potential for using closed glasshouse technology in the UK. The main conclusion of this work was that the closed glasshouse concept could not be used in its entirety because of technical and financial constraints. However, the project indentified that the application of one key feature of the design, the ducted air heating and ventilation system, to conventionally designed glasshouses offered significant advantages including:

- Reduced energy consumption.
- Improved crop yield.
- Reduced pest and disease problems.

One of the major advantages of a ducted air system is that it allows lower temperature water to be used for glasshouse heating. For example, 50°C water can satisfy all the heating requirements of a greenhouse. This has the potential to reduce losses in the hot water distribution system, increase boiler efficiency and increase the working capacity of heat storage systems. In addition, the opportunities to use alternative energy sources such

as low grade heat from CHP, heat pumps and waste heat sources also increase significantly.

It is also common to use some minimum pipe heat even when the greenhouse temperature and humidity are at acceptable levels. Ducted air systems reduce the need for minimum pipe heat because they can respond much more quickly to a sudden increase in heat demand.

The improved air movement created by a well engineered ducted air system will lead to a more homogenous environment in the glasshouse. This will reduce energy use through more accurate temperature and humidity control.

Objectives

The overall aims of the project are to:

- Reduce energy use in heated glasshouses.
- Reduce CO_2 emissions associated with glasshouse production.
- Expand the opportunities for glasshouse businesses to use alternative heat sources.
- Improve yield and quality.

Reduce disease incidence and therefore the use of crop protection chemicals.

Summary of the project and main conclusions

Materials and methods

The project comprises three parts:

1. Research, development and design of a commercially acceptable ducted air heating and ventilation system for the trial greenhouse at a commercial nursery in the UK.
2. Installation of the selected system at the trials site.
3. Experiments to investigate system performance and crop response.

The project is being carried out at Mill Nursery Ltd in East Yorkshire. This report details the work carried out to complete items 1 and 2 of the above list.

Staff from FEC Services Ltd and representatives of Mill Nursery worked alongside a number of potential equipment suppliers prior to appointing the following companies as contractors/project partners:

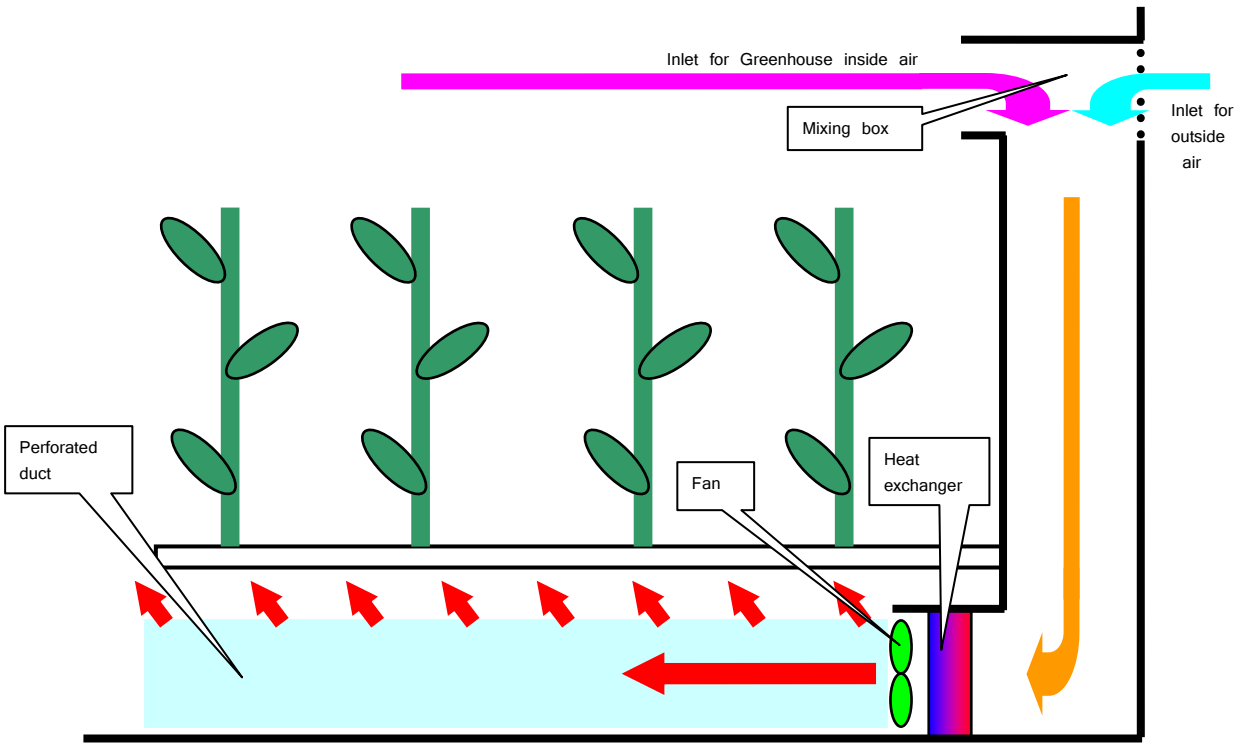
- Priva UK Ltd – responsible for the design, manufacture and installation of the fan and duct assemblies, instrumentation and control software.
- Cambridge HOK Ltd – responsible for the design and installation of a separate heating system to supply the fan and duct assemblies.

The greenhouse used for the project is split into two 1Ha blocks. This arrangement allowed a fan and duct system to be installed in one block whilst an otherwise identical 'conventional system' was retained in the adjacent block. This layout allows side by side performance comparisons of the two systems to be carried out throughout the three years of the project.

Technology overview - ducted air heating and ventilation

Figure 1 below is a schematic showing a single air handling unit of the type installed at Mill Nursery.

Figure 1 – Air handling unit schematic



The system includes the following major components:

- Fan – to circulate air around the greenhouse.
- Perforated duct – this is a polythene tube with holes punched along its length. It is used to distribute the air evenly throughout the greenhouse.
- Mixing box - automatically operated louvers are fitted on both the greenhouse side and outside air side. These allow the proportion of inside and outside air to be varied according to the desired greenhouse environment.
- Heat exchanger - this allows the air to be heated to the desired temperature. It is a radiator unit that is connected to the nursery's boiler and combined heat and power (CHP) system.

Collectively these components are called an Air Handling Unit (AHU).

Although the above diagram shows the system installed in a greenhouse with hanging gutters it is equally applicable to raised benches. In practice the location of all the key components can be changed to accommodate various crop layouts and greenhouse designs.

Basic system requirements/specification

Three criteria had to be specified for the system that was installed at the trial site. These were:

1. Heating capacity.
2. Total airflow.
3. Uniformity of airflow and heat distribution.

In practice the specification of the system considered practical and commercial limitations (e.g. physical size of the equipment, capital costs and running costs) before settling on a solution that provided an acceptable compromise. In developing this solution the following performance related considerations were made.

Heating capacity

The peak heat demand of individual greenhouses varies widely depending on location, desired cropping temperature, quality of construction etc. The following describes the factors taken into consideration for the installation at Mill Nursery. These factors are also considered to be the ones that are relevant to the majority of growers in the UK.

Peak heat demand - a modern greenhouse with thermal screens typically needs 1.25MW/Ha to maintain a greenhouse temperature of 20°C when the outside temperature is -5°C. Calculations showed that installing equipment to satisfy the peak heat demand was not commercially viable. Therefore, as the greenhouse at Mill Nursery already had an existing pipe rail heating system, it was decided that this would be retained and used during periods of high heat demand.

Heat requirements for humidity control - with a conventional heating system a pipe temperature of 50°C emits 400kW/Ha and satisfies the majority of the humidity control needs for a tomato crop.

It was therefore concluded that the heating capacity of the system should be at least 400kW/Ha.

Airflow

The size of a ventilation system is typically sized according to the number of times per hour that the air held within the greenhouse is either circulated or replaced with outside air. This is known as the air change rate.

The required air change rate for greenhouses is difficult to assess as there is currently little experience with ventilation systems of this type. However, the air change rates used in closed and semi-closed greenhouses in the Netherlands are:

- The Themato/Innogrow fully closed greenhouse – 20 air changes/hour.
- Semi-closed greenhouses – 10 to 12 air changes/hour.

If the lowest figure of 10 air changes/hour used in the Netherlands was installed at the trial site, the total power requirement of the fans would be 120kW. It was concluded that this was not practical in terms of capital and running costs and was therefore discounted.

Tests with a small scale system at Mill Nursery revealed that 2.3 air changes/hr gave acceptable air movement. Similar trials carried out by a leading tomato grower and Priva BV in the Netherlands at the same time showed that 1.4 air changes/hr gave acceptable results.

Based on these findings it was decided that the system should be specified to have a minimum air change rate of 2.0 air changes/hour.

Uniformity of airflow and heat distribution

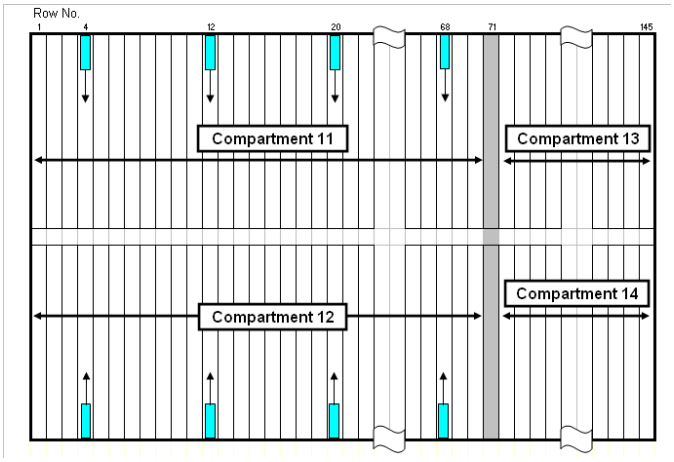
The use of hanging gutters and bench systems in greenhouses has recently become popular and this increases the opportunities for installing ducted air systems. The space under the gutter or bench can be used to house the fans and ducts, but careful consideration still needs to be given to the uniformity of airflow and heat distribution throughout the greenhouse. Areas which need specific consideration are:

- Along the duct – a perforated duct is used to ensure that air is distributed along its length. However, in a poorly designed system the holes closest to the fan can have more air leaving them than the holes at the far end. Under these circumstances the air movement and heat delivery close to the fan will be much higher than at the end of the duct.
- Between adjacent ducts – for the best air distribution a large number of ducts should be used, with the ideal arrangement being one underneath every hanging gutter. However, this arrangement is costly. Therefore, to reduce the cost the greatest possible distance between adjacent ducts was explored. Smoke tests with a small scale installation showed that one duct per 12.8m (8 rows of tomatoes) still delivered good air distribution.

The installation at Mill Nursery

Based on the specification detailed above, the installation at the trial site uses 18 x AHU's arranged as shown in Figure 2 below. Each AHU covers a floor area of 563.2m^2 (8 rows x 1.6m x 44m).

Figure 2 – AHU layout



Each AHU delivers 6,000m^3/hr of air and has a heat output of 25kW.

This gives a total heating capacity of 450kW and an air change rate of 2.0 air changes/hour (108,000m^3/hr).

The photographs below show key parts of the installation at Mill Nursery.

Figure 3 – Fan box

Figure 4 – Fan box with side removed

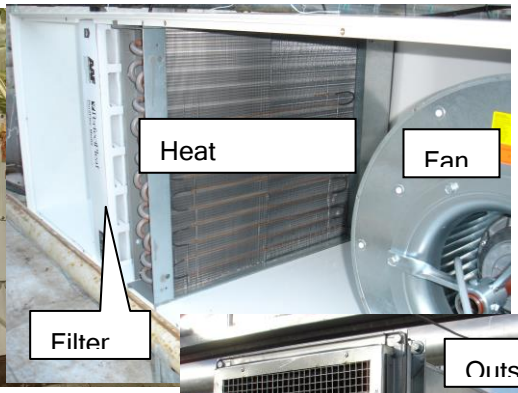


Figure 5 – Mixing box

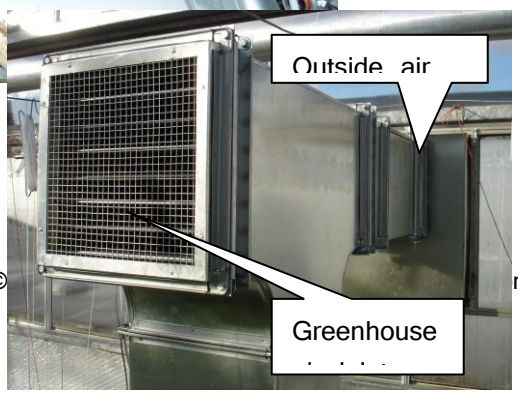
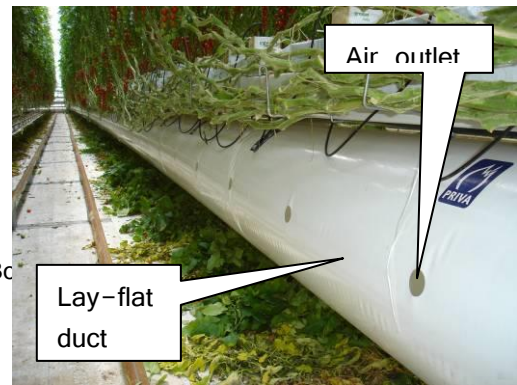


Figure 6 – Air distribution duct



Financial benefits

Costs

The total installed cost of the installation at Mill Nursery was equal to £159,000 (£15.90/m^2). However, it should be noted that this is unlikely to be an accurate indication of the cost of a commercial installation in the future because:

- Some of the features installed at the project site (e.g. variable speed drive for the fan units and high levels of instrumentation) are likely to be proven to be unnecessary for commercial installations following experience gained during this work.
- More cost effective ways of delivering the same effect may become apparent.
- The layout of the trial greenhouse (particularly row length) had a significant impact on the cost.
- Economies of scale in the manufacture of the equipment will reduce costs if/when more systems of this type are sold.

At this early stage in the project the financial benefits have yet to be determined.

Conclusions

A fan and duct based heating and ventilation system has been successfully installed and commissioned in a 1Ha commercial tomato greenhouse at Mill Nurseries, Keyingham, East Yorkshire. The outline specification of the system is as follows:

Heating capacity	450kW/Ha
Ventilation capacity	108,000m^3/hr
Air change rate	2.0 air changes/hour

This specification is considered to be a compromise which meets technical and economic constraints which are acceptable to growers in the UK.

Action points for growers

Because this is an interim report further information is needed by growers before the system can be commercially adopted. This specifically relates to the energy saving and crop performance that is achieved when using the system. Growers should therefore wait for the results of the next two years work on this project when data relating to energy use, crop performance and pest and disease levels will be available.