Horticultural
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Air Movement in Glasshouses

A grower guide

This guide provides information for growers to give them to better understanding of the benefits of well designed air movement systems and help them select an air movement system that best meets their individual needs.

Foreword

Achieving good air movement in the glasshouse is a complex issue that is influenced by crop type, heating system design, ventilation system design and the configuration of fan systems.

Although most growers are aware of some of the potential advantages of air movement systems, many do not fully appreciate the full benefits of a well designed system. Also, the design and selection of fan ventilation systems is often viewed as a 'black art'. The end result is that growers often use inappropriate or poorly selected systems that ultimately do not live up to their expectations.

This guide has been complied to de-mystify an intricate and complex area and growers following the information it contains will have a better understanding of how to achieve satisfactory and beneficiary air movement conditions in their glasshouse.

The information in the guide has been compiled from past research and development work together with other best practice sources. Because of the intricate nature of the subject some gaps in the knowledge still exist. Therefore, to provide definitive answers to some of the more complex questions, more work will undoubtedly be needed.

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Action Points for Growers

1 Natural air movement inside the glasshouse will be at its lowest when:

- The vents are closed or are only slightly open.
- The heating system is either off or operating at low output.
- A thermal screen is drawn closed.

At these times it may be of benefit to use a fan based air circulation system to boost air movement.

2 Using a well designed and installed fan air circulation system is an efficient way to achieve a uniform glasshouse environment. Fans positioned to promote horizontal circulatory air movement are commercially proven to be an effective solution.

3 Alternative layouts can be used but they are less likely to be as effective.

4 Floor level ducted air systems offer the potential to provide uniform airflow – particularly in vine crops like tomato, cucumber and pepper – however they are not proven at the moment and more development work is needed.

5 Research has shown that a single fan is capable of creating effective air movement in an area of up to 1,000m^2. However recommendations from commercial suppliers are that one fan per 500m^2 - 750m^2 should be installed.

6 Fans specifically designed for air circulation in glasshouses should be used. Equipment should also be selected on the basis of an energy efficiency ratio (EER). The EER quantifies the amount of air movement per unit of electricity used (m^3/h/W). The most efficient fans have an EER up to twice that of the poorest performers.

7 Controls should be used to ensure that the fans operate whenever the glasshouse vents are closed (or are only slightly open) or when a screen is drawn closed over the glasshouse. For optimised operation and minimum running costs fan air circulation systems should be automatically controlled. This can be done by linking the system to the glasshouse climate control computer.

The Need for Air Movement

Although most growers are aware of some of the potential advantages of air movement systems, many do not fully appreciate the full benefits of a well designed system. Also, the design and selection of fan ventilation systems is often viewed as a 'black art'. The end result is that growers often use inappropriate or poorly selected systems that ultimately do not live up to their expectations.

This guide aims to provide information for growers which will enable them to better understand the benefits of well designed air movement systems and help them select a system that best meets their individual needs and circumstances. The information has been compiled from past R&D work plus other 'best practice' sources. However, some gaps in the knowledge still exist and for more definitive answers, undoubtedly more work will be needed.

A uniform glasshouse environment is important because:

1. Variations in the glasshouse environment may lead to uneven plant growth and development and disease problems.
2. Energy waste can occur because the conditions measured by the glasshouse climate control sensors will not be representative of those throughout the glasshouse.

Although glasshouse heating and ventilation systems are designed to create uniform conditions in the region of the crop, non-uniform conditions often occur. For example, in still air conditions in summer, maximum horizontal temperature variations of up to 7°C have been measured in a tomato crop. CO_2 concentration varied by 150vpm.

Variations can be overcome by establishing good air circulation in the glasshouse. This is most commonly done by using circulation fans. When using air circulation fans in the conditions outlined above, the variations in temperature and CO_2 concentration reduced to 1.6°C and 20vpm respectively.

Using fans consumes energy - so it is important to use the most efficient equipment arranged in the most effective way. This involves selecting a system that provides the minimum airspeed to consistently achieve the desired results.

"Using fans consumes energy - so it is important to use the most efficient equipment arranged in the most effective way."

The Benefits of Good Air Movement

"Good air movement helps minimise the incidence and development of disease."

Improved disease control

High humidity conditions in the boundary layer around the plant leaf can lead to the development of diseases such as botrytis. Therefore, if these high humidity zones can be eliminated, improvements in disease control will result.

For example the process of radiant cooling means that, on a clear night in a glasshouse without thermal screens, plant temperature may be significantly cooler than the surrounding air temperature. Under these conditions the humidity adjacent to the plant will be higher than indicated by the control system sensors. In the worst case dew point may be reached and condensation will occur. Under these conditions disease problems are much more likely to occur.

Again providing good air circulation can overcome these problems by helping to even out temperature differences between the plant and the air surrounding it.

Effective CO_2 use

During daylight hours photosynthesis depletes the CO_2 content of the air in the boundary layer around the leaf. If there is good air movement in the plant canopy, this CO_2 depleted air is replaced and plant growth is promoted.

Glasshouse cooling

When solar radiation levels are high the surface temperature of the plant leaves can be significantly higher than the air temperature. Good air movement helps to replace the high temperature air adjacent to the plant with cooler air. This subsequently cools the plant and helps to reduce water demand and plant stress.

Having an understanding of the energy flows and energy transfer processes that take place in a glasshouse allows us to recognise what causes air movement.

Energy Flows & Air Movement

Energy transfer in the glasshouse

Energy radiating from the sun is transmitted through the glasshouse cladding where it then falls on to the surface of the objects inside (plants, growing media, equipment etc). Whilst some of this radiant energy is lost due to reflection, most of it is absorbed by the surface of the objects it falls on and the temperature increases as a result.

So far the air in the house has played no part in the heat exchange process; indeed radiation passes through - but does not heat - the air.

As the temperature of objects rises above that of the surrounding air, heat is transferred to the air by convection. Heat transferred by convection from a hot object results in an increase in the temperature of the air surrounding it. This is called sensible heat transfer.

In the case of objects with a wet surface, heating usually causes the evaporation of moisture from their surface. This evaporated moisture is then absorbed by the surrounding air and its moisture content increases.

The heating energy required to evaporate water is known as the latent heat of evaporation. This heat comes from the wet object, thus reducing its temperature. At the same time the surrounding air gains energy in the form of evaporated moisture and, during this process, the energy and moisture contents of the air increase without a rise in air temperature. This process explains why the presence of a crop has a marked influence on the internal environment of a glasshouse.

Anyone who has walked into a glasshouse containing plants on a summer's day will know that the plants induce a cooling effect, and that the temperature is significantly lower than if the glasshouse were empty. This is because when the sun shines on a glasshouse containing healthy plants the leaves act as objects with wet surfaces and, unlike most other objects with a wet surface, they do not dry out. Only when the transpiration mechanism cannot cope with the demand, and the plant subsequently wilts, do the plants dry out and act like normal objects.

Heating system effects and air movement

Although the energy transfer processes described above have only considered solar radiation, the same mechanisms also occur when other heating methods are used.

For example, when a pipe heating system is used, heat is both radiated from the high temperature surface of the pipes and the air is heated by convection. Similarly, if space heaters are used the air is heated by convection which then transfers energy to the plants.

In both of these cases the convective heat transfer process is important when considering air movement. This is because when the air is heated air movement currents are set up as the buoyant warm air rises in the glasshouse.

Space heaters (either of the suspended or cabinet design) can also affect air movement as they often have a fan unit as an integral part of their design. Both the air movement induced by the fan and the natural buoyancy of the heated air can influence internal air movement.

In practice the problem with space heaters is that they place heat at a high level in the glasshouse – often well above crop level. If this is the case then the buoyant warm air quickly rises into the glasshouse roof space where it has little influence on conditions adjacent to the crop. Similarly problems can also arise if heating pipes are placed too high in the glasshouse.

"The heating energy required to evaporate water is known as the latent heat of evaporation."

"Space heaters can also affect air movement as they often have a fan unit as an integral part of their design."

Energy Flows & Air Movement

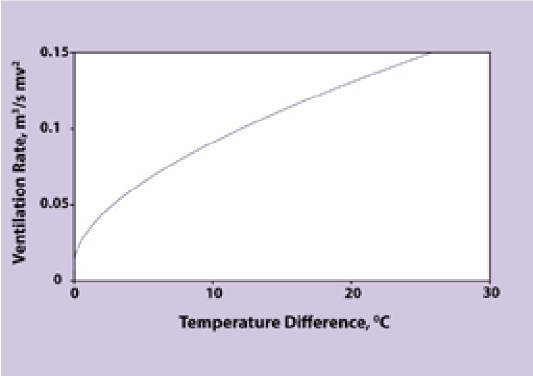

Figure 1
The effect of the difference between internal and external temperature on ventilator air flow

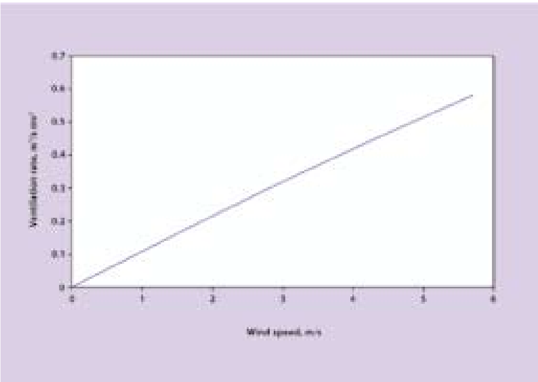

Figure 2
The effect of wind speed on ventilator airflow

Ventilation

The main function of the glasshouse ventilation system is to provide cooling and prevent the internal temperature from becoming too high. This is done by exchanging the warm internal air with cooler air from outside. In addition to this primary function, the ventilation system is also important for removing the water vapour transpired by plants and for replenishing the CO_2 used in photosynthesis. By implication therefore, the ventilation system is also a key factor affecting air movement in the glasshouse.

Mechanical Ventilation

Mechanical ventilation systems give predicable rates of air exchange (and air movement). They can also be accurately controlled.

Mechanical systems typically use fans mounted along one glasshouse wall to extract internal air. This is then replaced by external air entering through openings in the opposite wall.

Systems of this type are currently unpopular in the UK because of the electricity costs associated with the operation of the fans. For example, to achieve the air change rates needed in the UK the total fan power needed is around 100kW/Ha. The running costs for a system of this size would typically be £2.75/m^2/year (based on current electricity prices).

Natural Ventilation Systems

Most glasshouses in the UK have natural ventilation systems. These systems use windows or ventilators that open in either the roof or sidewalls. With this arrangement air exchange is dependent on the:

- external windspeed.
- difference in temperature between inside and outside air.
- area of open ventilators.

It is normal to quote the total area of the ventilators as a percentage of the glasshouse floor area and this provides a convenient method of comparing the ventilation potential of different facilities. Values of the ventilator area typically range between 10% and 25%. For example, the ventilator area of a typical Venlo glasshouse is usually in the range 15% to 20%.

Glasshouses with larger ventilator areas will have a higher cooling potential and the ability to create more natural air movement. Opening roof glasshouses maximises this air movement by having a ventilator area of 90%.

Natural Ventilation Rate - Temperature difference

In sunny conditions the temperature inside the glasshouse is normally higher than outside and air exchange and movement can be created by opening the ventilators. The warm internal air is less dense than the cooler outside air and so it has more buoyancy. This creates the exchange of air through the ventilator and warm air leaves through the upper portion of the opening whilst cool air enters through the lower part.

The rate of air exchange depends on the difference between the inside and outside temperature (see Figure 1). It should be noted that the rate of air exchange is not linear – for example the rate of air movement does not double if the temperature difference doubles. In fact the rate of air exchange depends on the square root of the temperature difference. This means that when the temperature differences are small, a small change will create a greater change in air flow than when the temperature difference is large.

Wind Speed

Wind contributes to ventilation by creating pressure differences over the glasshouse surface. This causes air to flow in through the ventilators in high pressure areas and out of ventilators at low pressure areas. Ventilation rate is proportional to the mean windspeed (see Figure 2).

In practice the wind does not blow at a constant speed – it is more normal that gusts occur and the speeds fluctuate over time. These speed changes cause pressure changes at individual ventilators, thereby affecting the rate and direction of airflow within an individual vent.

In practice it is found that if the average windspeed doubles, then the rate of air exchange also doubles.

Energy Flows & Air Movement

Combined Effects – Temperature & Wind

In reality both wind and temperature differences contribute to the actual air exchange.

R&D has shown that when the temperature difference between inside and outside is typically 2-3°C, wind will be the main driver for air exchange – that is so long as the windspeed is 1.5m/s or greater. Therefore, during the summer, wind is the main influencing factor on air exchange.

On the other hand, during the winter when temperature differences between inside and outside can be as high as 15°C, temperature difference is the major factor which influences air exchange.

Ventilation Effects on Internal Air Movement

The internal air circulation that occurs during natural ventilation depends on which ventilators are open. In a glasshouse with continuous ventilators open along both sides of the ridge and the wind direction at 90° to the ridge, there is an inward flow through the windside vent and outward flow through the leeside vent. Whilst some air will be deflected downwards, most of it will short circuit and go out of the glasshouse as soon as it enters. In these circumstances internal airflow depends on the currents that are set up by the incoming flow (see Figure 3).

When the wind direction is at an oblique angle to the ridge, complex and irregular airflow patterns can be set up in the glasshouse.

Whilst they are not common on glasshouses in the UK, sidewall ventilators may be used when high ventilation rates are required (eg in countries where high summer temperatures are common). This configuration is also found on some polytunnels.

Again, if the sidewall ventilators are open on both sides of the glasshouse and the wind direction is at 90° to the glasshouse ridge, most of the air will travel straight through the glasshouse as shown in Figure 4. In a similar fashion to the situation with roof ventilators, secondary currents will be set up which will cause air movement throughout the house. Whilst sidewall ventilators can potentially give better air movement at low level, care must be taken at times when outside temperatures are low otherwise plants may be chilled by the influx of cold air.

"In practice it is found that if the average windspeed doubles, then the rate of air exchange also doubles."

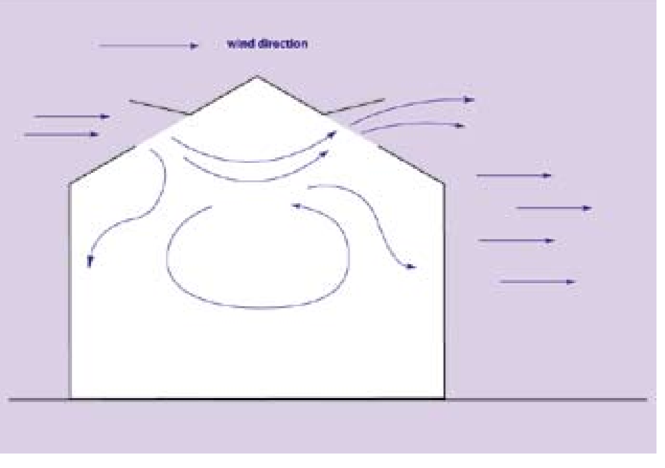

Figure 3
Potential short circuiting of airflow with ridge ventilation of a glasshouse

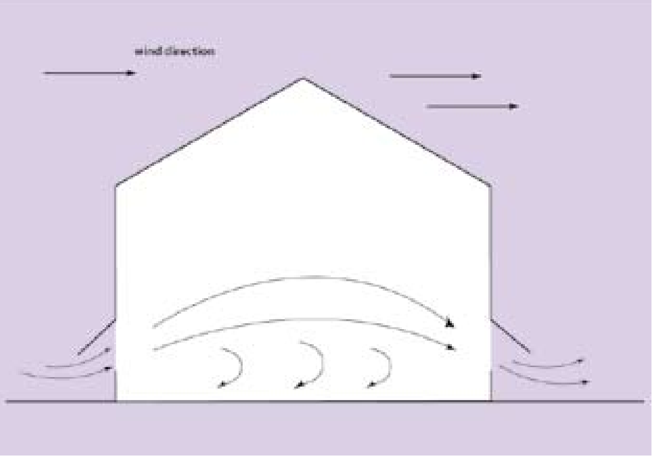

Figure 4
Potential short circuiting of airflow with sidewall ventilation of a glasshouse

> ***"Humidity levels under a closed screen tend to be higher than in an unscreened house."***

Crop Effects

The nature of the crop has a marked effect on how ventilation influences the air movement inside the glasshouse.

When a short plant is being grown on the floor or on benches, then the influence is likely to be small. However when tall crops such as tomatoes, cucumbers etc are being grown the crop effect can be very significant. Figure 5 shows how ventilator configuration and crop row direction affects the airspeed inside the glasshouse. It also shows the most common arrangement for tall crops in the UK and highlights that the airspeed is typically only 12% of the external wind speed.

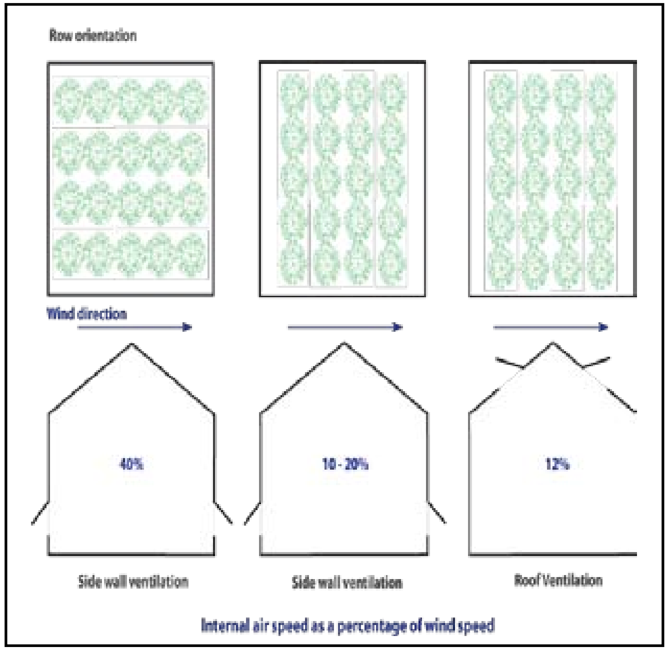

Figure 5
The effect of crop row direction on the speed of internal airflow

The effect of screens

Screens – either for energy saving, blackout or shading purposes – are used by many growers. These may take the form of either temporary screens or permanent retractable screens. Whatever the primary purpose for their use, all screens have a significant effect on internal air movement when they are closed.

The ways in which a closed screen can affect air movement are as follows:

- A closed screen reduces the heat demand for the glasshouse. This leads to reduced pipe temperatures (for a boiler system) or reduced heater operation. The effect is reduced air movement as described earlier.
- There is less natural air leakage into the glasshouse when the screen is closed. This reduces natural air movement and air exchange.
- The effect of the glasshouse ventilation system on air movement in the glasshouse can be significantly altered. This is particularly the case with temporary screens where opening the vents over the screen has little effect on air movement.

Screens also have the effect of increasing the importance of good air movement in the glasshouse and the need for homogenous environmental conditions. For example, humidity levels under a closed screen tend to be higher than in an unscreened house. Because of these factors any variations in the environment can more readily lead to conditions which are conducive to disease formation. Supplementary air movement systems using fans are therefore more likely to be a necessity when screens are installed.

Air Circulation Fans

In the earlier sections of this guide we have examined how heating and ventilation systems can induce air movement in the glasshouse. As previously highlighted however, the unpredictable and variable air movement patterns developed by these mechanisms often means that the internal glasshouse conditions are not optimised. The net result is an uneven glasshouse environment and potential problems with plant growth, disease and increased energy consumption.

To overcome these problems fan systems can be used. Fans can be used as the primary method of glasshouse ventilation - with the end result being a predictable and controllable air flow. However, these systems are not widely used in the UK because of running cost considerations.

A more common approach is to integrate air circulation fans to help overcome the inherent problems associated with the heating and natural ventilation systems in common use. This involves using supplementary air circulation fans mounted in the glasshouse roofspace.

Principles of operation

The use of air circulation fans is based on the principle that air moving in a predictable pattern in a glasshouse only needs enough energy to overcome friction losses and turbulence to keep it moving. Persistence of air movement rather than creating a high air speed is the key if a uniform environment is to be achieved. For example, work at SRI concluded that the air speed only needs to be in the range of 0.2 to 0.4m/s to ensure satisfactory air movement. In fact, the work at Silsoe also concluded that an airspeed in excess of 0.5m/s could actually cause plant damage.

By creating air movement with a fan, secondary air currents are set up in the glasshouse. Therefore, the area over which a single fan can influence air movement extends far beyond the extent of the air jet produced by the fan.

Air is heavy – for example the air in a typical 1Ha glasshouse weighs approximately 40 tonnes. Therefore, once the air is moving it has significant momentum and it will keep moving. This is another reason why air circulation in the glasshouse can be achieved efficiently using a relatively small number of low powered fans.

Fans tend to create non-uniform air movement. Slow air approaches the fan inlet and very high speed air is ejected at the outlet. If this high speed air is directed straight onto plants it can have a detrimental effect. Also high speed air directed onto the glasshouse structure can increase local heat loss. A fan based air circulation system must therefore incorporate a method which evens out these variations in air speed before the air reaches the plants. This can be done by either using the airspace above the crop or by using a ducting system.

"Persistence of air movement rather than creating a high air speed is the key if a uniform environment is to be achieved."

Air Circulation Fans

> ***"Horizontally mounted paddle fans are commonly used in other commercial applications and they can be used to move air vertically in the glasshouse."***

Methods of creating air circulation

The common method of creating air movement is to use fans mounted in the space between the top of the crop and the glasshouse roof. The fans are arranged so that they create horizontal air flow.

Alternative arrangements of fans can be used, but work carried out at Silsoe Research Institute by Bernard Bailey showed that they are generally less effective than using the arrangement described above. For example horizontally mounted paddle fans are commonly used in other commercial applications and they can be used to move air vertically in the glasshouse. The problem with this approach is that fans of this type produce a conical zone of air movement and a large number of fans are required. Also, the fact that the fan blades are not shrouded means that the air flow is multi-directional and unpredictable in its flow. Because of these characteristics, fans of this type are less effective than ones creating horizontal air flow.

Data from a leading manufacturer of paddle fans recommends that 170 fans/Ha mounted at a minimum height of 3.5m above the crop are needed to produce suitable air movement. This contrasts with recommendations for horizontally mounted shrouded axial flow fans where the typical recommendation is for 20 fans/Ha. In this case the paddle fan system would have a total installed electrical load of 8.5kW/Ha whereas the axial flow fan system would have an electrical load of 4.8kW/Ha. This means that both the running and installation costs would be lower for the system based on shrouded axial flow fans.

Another alternative is to use fans connected to horizontal perforated plastic ducts. If mounted at floor level this arrangement emits jets of air which then entrain air and create a slow vertical circulation. Work by Bailey concluded that the air circulation created with equipment of this type is better able to penetrate the plant canopy and therefore has a more uniform effect on the plants. One potential problem with this approach is that it may not even out horizontal variations in the glasshouse environment as effectively as a horizontal air movement system. In practice this is not likely to be a problem in a well designed modern greenhouse where air leakage rates are low and the heating system has been well designed.

Systems using perforated polythene ducts are not currently in common commercial use. This is because, until recently, the layout of commercial glasshouses has not permitted their installation. However, as perforated benches and hanging gutters have become more common, there is now space to install the ducts under the crop. In fact, recent closed glasshouse installations in the Netherlands use systems of this type to distribute air (for both heating and cooling) throughout the glasshouse. Further work will be needed to develop these systems so that they can be practically accommodated in a wide range of situations, but it is likely that installations of this type will become more common in the future.

Selecting & Installing a System

As previously highlighted, the most common and effective fan arrangement in commercial use is a horizontal air movement system.This section will deal with practical aspects of selecting and installing a system of this type.

Fan selection

Use fans that have been specifically designed for air circulation. In contrast to general purpose extractor fans, fans of this type are designed to operate against zero static pressure. This optimises the air flow and energy efficiency.

Because of the long operating hours, fans should be as energy efficient as possible. Energy efficiency is dependent upon a wide range of parameters including blade design, housing design and motor configuration. To ensure that the best design is being used for your particular application you should compare different designs on the basis of their energy efficiency ratio (EER). The EER gives a measure of the amount of air moved by the fan per unit of energy consumed (m^3/hr/W).

Fan manufacturers do not normally provide EER information - so in many cases it will need to be calculated for the fans that are being considered. The following example shows how to calculate the EER.

A 420mm diameter air circulation fan operates at 1400rpm and delivers an air flow 4500m^3/h. It has an energy consumption of 150W.

The EER is

$$\frac{4500}{150} = 30\,m^3/h/W$$

This information can then be used to make a comparison with an alternative fan.

For example, a second fan is 500mm diameter and operates at 900rpm. This fan delivers 5000m^3/h and has an energy consumption of 200W.

The EER for this fan is

$$\frac{5000}{200} = 25\,m^3/h/W$$

In this case the first fan is more efficient and, provided that other performance parameters are the same, it should be chosen in preference to the second model.

Appendix 1 shows the calculated EER values for a range of glasshouse air circulation fans that are available in the UK. All of these values have been calculated from manufacturer's catalogue data. The information is not based on independently measured data therefore should only be used as an indicative performance comparator. However, the information in the table clearly shows that the EER can vary considerably. The best fans performance fans can have up to twice the efficiency of the poorest designs.

Number of fans needed

Determining the number of fans needed for a particular project is a complex procedure. This is because it is dependent of a range of factors including glasshouse size and shape, the glasshouse design (i.e. Venlo, wide-span, poly-tunnel etc), glasshouse orientation, crop type and prevailing weather conditions. Therefore, the most accurate way to determine the number of fan units required is to carry out complex calculations using computational fluid dynamics (CFD) methods. This involves using computer based calculation methods. Some manufacturers will carry out these calculations for customers in order that specific designs can be provided.

If it is not possible to carry out CFD calculations some general rules can be applied. These give an indication of the number of fans needed.

- Silsoe Research Institute (SRI) tests concluded that one fan unit was sufficient to provide adequate airflow in a 426m^2 glasshouse.
- The same SRI study goes on to suggest that one fan per 1000 - 1500m^2 is adequate.
- Most fan manufacturers suggest one fan per 500 - 750m^2.

Based on these research results and recommendations, typically between 10 and 20 450mm diameter fans are needed per hectare.

"The EER gives a measure of the amount of air moved by the fan per unit of energy consumed (m^3/hr/W)."

> *"If the inlet side of the fan is placed too close to a glasshouse end wall the air flow will be restricted."*

Fan layout

Correct fan layout is very important as it can affect both the number of fans required and the overall results obtained.

Fans should be positioned to create a circulatory air movement pattern, and each fan should reinforce the motion that each creates. The application of this arrangement principle for a single fan in a small glasshouse is shown in Figure 6a below.

Most circulation fans that have been specifically designed for glasshouse use have a 'throw' in the range of 40 - 50m (i.e. this is the maximum distance from exit side of the fan where air movement is affected). This dictates the maximum distance between fans along the glasshouse. A typical layout for a multi-fan installation is shown in Figure 6b below.

When positioning fans it is also important not to place them too close to the glasshouse walls. If the inlet side of the fan is placed too close to a glasshouse end wall the air flow will be restricted. To ensure that this does not occur, a distance of at least 7.5m should be allowed between the end wall and the inlet side of the first fan.

Fan height should be sufficient to allow free air flow from the fan across the head space between the crop and the glasshouse roof. It is important that there are no obstructions in the path of the fan outlets, otherwise performance will be compromised. Airflow should be well clear of the top of the crop, glasshouse structural members or any other equipment.

Maintenance

Regular maintenance must be carried out so that a fan based air circulation system can continue to operate at its optimum efficiency. Dust and dirt must be removed from all of the fan components including the fan blades, housing (including any air straightening vanes etc), guards etc. Failure to carry out cleaning on a regular basis (at least annually) may result in reduced air flow and premature motor failure.

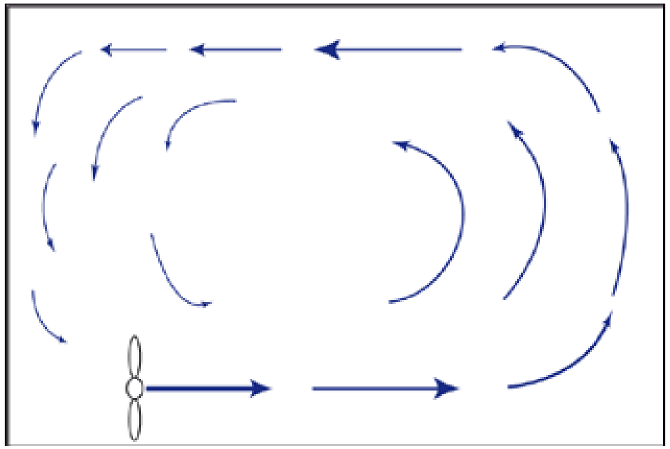

Figure 6a
Circulatory airflow pattern created by a single fan in a small glasshouse

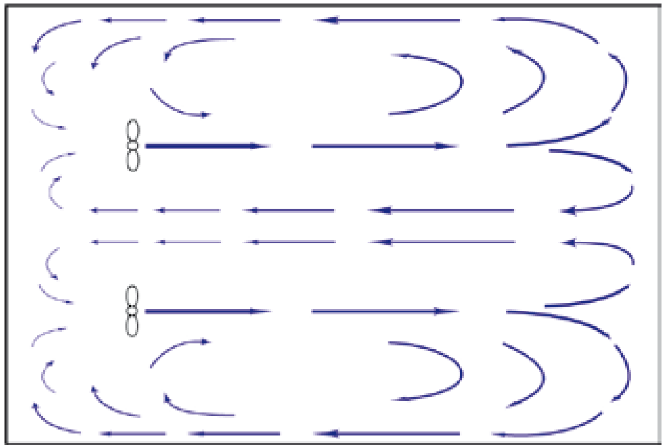

Figure 6b
Circulatory air movement created by multiple fans in a glasshouse

Cost/Benefit of Installing Internal Fans

One of the potential areas of benefit when considering air circulation fans is energy saving. As previously highlighted, if the environment is not uniform the temperature sensing point for the climate control system may not give a representative reading. As a result energy will be wasted due to unnecessary operation of the heating system and overheating of the glasshouse.

Therefore, for a one hectare glasshouse fitted with 20 air circulation fans the following cost/benefits can be achieved.

Assumptions

Heating fuel price = 2p/kWh.

Electricity price = 8p/kWh.

Electricity rating of each circulation fan = 240W.

Total running hours for circulation fans = 2250 hours/annum.

Capital cost of installation = £7,000

Case 1 – Energy Intensive Salad Crop (tomato, cucumber etc)

In this case it is assumed that the annual heating energy consumption is 600kWh/m^2.

Fan Capital Costs

Assuming that the capital and installation costs are financed over 24 months at 6% interest rate.
Annual purchase cost = £3,723.00

Fan Operating Costs

Electricity for fan operation = 20 fans x 0.24kW x 2250hrs x £0.08p/kWh = £864
Annual maintenance = £100
Total = £964.00/year

Heating Costs

Annual heating costs = 600kWh/m^2 x 0.02p/kWh x 10,000m^2
= £120,000/Ha/year

Payback Assessment

In the first two years after installation, the total additional cost for the air movement system will be £3,723 + £964 = £4,687. To provide payback, this cost must be offset against energy savings that may be secured.

Therefore, an energy saving of £4,687/£120,000 = 3.9% must be achieved if payback is to be achieved inside two years.

Based on a growing temperature regime of 20°C day/18°C night and assuming typical UK weather conditions, it is commonly accepted that a 1°C error in temperature control is equivalent to 5% energy waste.

Elimination of a 1°C error in glasshouse temperature by using fan air circulation will therefore ensure a payback inside two years.

Cost/Benefit of Installing Internal Fans

Case 2 – Energy Extensive Ornamental Crop (eg pot & bedding)

In this case it is assumed that the annual heating energy consumption is 250kWh/m^2.

Fan Capital Costs

Assuming that the capital and installation costs are financed over 30 months at 6% interest rate

Annual purchase cost = £3,023

Fan Operating Costs

Electricity for fan operation = 20 fans x 0.24kW x 2250hrs x £0.08p/kWh = £864
Annual maintenance = £100
Total = £964/year

Heating Costs

Annual heating costs = 250kWh/m^2 x 0.02p/kWh x 10,000m^2
= £50,000/Ha/year

Payback Assessment

In the first two years after installation, the total additional cost for the air movement system will be £3,023 + £964 = £3,987. To provide payback, this cost must be offset against energy savings that may be secured.

Therefore, an energy saving of £3,987/£50,000 = 7.9% must be achieved if payback is to be achieved inside two years.

Based on a growing temperature regime of 15°C day/15°C night and assuming typical UK weather conditions, it is commonly accepted that a 1°C error in temperature control is equivalent to 8% energy waste.

Elimination of a 1°C error in glasshouse temperature by using fan air circulation will therefore ensure a payback inside two and a half years.

Cost/Benefit of Installing Internal Fans

Additional benefits

As highlighted earlier in this guide, other benefits that may be attributed to improved air circulation include:

- Lower humidity within the plant canopy, therefore helping to reduce disease development and associated costs for disease control e.g. pesticides and their application.
- Reduced condensation on leaf surfaces aiding disease prevention.
- Better CO_2 utilisation giving a greater potential to improve yield.
- Leaf temperatures which are much closer to the glasshouse air temperature enabling plant growth, yield, disease control, and water use to be optimised.
- Improved plant quality.

Within this analysis, none of these additional benefits have been considered. However, further savings may be achieved through areas such as reduced pesticide use.

As explained earlier in this guide, the effect of factors such as heating system operation and the use of natural ventilation systems can have a significant effect on the naturally occurring air movement in a glasshouse. Also, external weather effects including temperature, wind speed and wind direction can all affect the amount of natural air movement that occurs. Finally, the presence of a closed thermal screen can also significantly modify air movement rates and patterns.

All of these factors should therefore be taken into consideration when deciding when a fan based air circulation system should be operated.

In practice the above parameters mean that a fan circulation system needs to be operated when:

- The glasshouse vents are closed or are only slightly open (e.g. less than 2%).

  or

- The screen is closed over the glasshouse.

Manual control

Manual control has the advantage that it is cheap to install and operate. However, as it is unlikely that the glasshouse is attended 24hours a day, 365 days of the year, predictive decisions have to be made about turning fans on and off. The result is that fans will inevitably be left running when their operation is unnecessary. As a result electrical energy will be wasted and the running costs for the fans will be greater than necessary.

Automatic control

The preferred option is to use automatic control linked to the glasshouse climate control computer. This will then allow the running of the fans to be optimised.

The controls should be configured to turn the fans on/off in line with the vent and screen parameters stated above. Manual override can then also be provided to allow flexibility of operation at times when exceptional circumstances occur and an individual decision is made by the grower to switch the fans on or off.

"The presence of a closed thermal screen can also significantly modify air movement rates and patterns."

Suppliers of Air Circulations Fans

Hotbox International Ltd
Unit 1, 236 Main Rd, Newport, Brough, East Yorkshire.
HU15 2RH.
Tel: 01430 444040
www.hotboxworld.com
Email: sales@hotboxworld.com

Holland Heater
Oud Camp 5, 3155 DL Maasland, Holland.
Tel: 0031 (0)174 - 516741
www.hollandheater.nl
Email: info@hollandheatr.nl

Priva UK Ltd
Bredon Road, Tewkesbury, Gloucestershire.
GL20 5BX
Tel: 0044 1684293081
www.priva.co.uk
Email: priva@priva.co.uk

HortiMaX Ltd
42 Stockbridge Road, Elloughton, Brough, East Yorkshire.
HU15 1HN.
Tel: 0044 (0) 1482-668676
www.hortimax.com
Email: info@hortimax.nl

Hydor Ltd
Unit 8, Parkers Close, Downton Business Centre, Downton,
Salisbury, Wiltshire.
SP5 3RB.
Tel: 01725 511422
www.hydor.co.uk
Email: info@hydor.co.uk

Vostermans Ventilation BV
PO Box 3025, 5902 RA Venlo, Holland
Tel: 0031 (0)77 389 32 32
www.vostermans.com
Email: ventilation@vostermans.com

Thermal Engineering Systems Ltd
Clay Lane, Uffculme, Cullompton, Devon.
EX15 3AJ.
Tel: 0044 (0) 1884 840 216
www.thermal-eng.co.uk
Email: sales@thermal-eng.co.uk

Further Help & Information

Sources of information

FEC Services Ltd
Stoneleigh Park, Kenilworth, Warwickshire. CV8 2LS
Tel: 024 7669 6512
www.fecservices.co.uk
Email: info@fecservices.co.uk

Hennock Consulting
5 The Dales, Nettleham, Lincolnshire. LN2 2SA
Tel: 01522 753600
www.hennock.co.uk

ADAS
Wolverhampton HQ, Woodthorne, Wergs Road,
Wolverhampton WV6 8TQ
Tel: 01902 754190
www.adas.co.uk

Further reading

Induced air movement to improve glasshouse climate.
HDC Project PC 47 Final Report.

Review of glasshouse design and technology for tomato and cucumber production.
HDC Project PC 68 Final Report.

A computational fluid dynamic (CFD) study of flow patterns, temperature distributions and CO_2 dispersal in a tomato glasshouse.
HDC Project PC 162 Final Report.

Glasshouse Climate Control – an integrated approach.
Wageningen Pers 1995.
Bakker J.C, Bot G.P.A, Challa H & Van de Braak N.J (Editors).
ISBN 90-74134-17-3.

The development and commercial demonstration of ducted air systems for glasshouse environmental control.
HDC Project PC 278 Annual Report 2008.

Appendix 1

Table of Energy Efficiency Ratio Values for Glasshouse Air Circulation Fans

Manufacturer	Model	Dia mm	Speed rpm	Volume m^3/h	Energy Consumption W	EER $m^3/h/W$
Hotbox	Mistraal 15	440	1400	4000	190	21.1
Hotbox	Mistraal 10	320	1300	1600	145	11.0
Hotbox	Mistraal 5	270	1275	900	85	10.6
Holland Heater	CF45LT	450	1000	3700	150	24.7
Holland Heater	CF40LT	400	1000	3100	140	22.1
Holland Heater	Low Energy Fan	450	1290	5700	260	21.9
Holland Heater	CF40	400	1500	3800	180	21.1
Holland Heater	CF45	450	1500	5600	320	17.5
Holland Heater	CF50LT	500	1000	5500	340	16.2
Holland Heater	CF50	500	1500	6800	460	14.8
Hortimax	MRVL	400	940	3290	120	27.4
Hortimax	MRVH	400	1430	4235	160	26.5
Hydor	HTS 24/6	630	900	10296	196	52.7
Hydor	HTS 16/4	400	1350	4572	156	29.2
Hydor	HTS 20/6	500	900	4932	196	25.2
Hydor	HTSS 20/6	500	900	4932	235	21.0
Hydor	HTS 18/6	450	900	4032	196	20.6
Hydor	HTS 18/4	450	1350	6120	313	19.6
Hydor	HTS 14/4	355	1350	3096	215	14.4
Hydor	HTS 16/6	400	900	3204	371	8.6
Multifan	TB4E404PP30Q	420	1400	4290	150	28.6
Multifan	TB4D40Q	420	1400	5050	210	24.0
Multifan	TB6E50Q	518	900	7060	300	23.5
Multifan	TB4E40Q	420	1400	5050	230	22.0
Multifan	TB6E40Q	420	900	3950	180	21.9
Multifan	TB4E50Q	518	1400	7760	390	19.9
Multifan	TB4D50Q	518	1400	7760	400	19.4
Priva	PCF					
Priva	Eco Fan	460	1225	4700	200	23.5
TES	Jet Fan	500	1290	6000	400	15.0

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