Energy saving in poinsettia production

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Spiralling energy costs pose a serious threat to the commercial viability of poinsettia production for the Christmas season. This factsheet brings together the findings of past and current research projects on energy saving in poinsettia production, and outlines how growers could apply these findings to reduce their energy costs.

Action points

- Adopt good housekeeping practices. Implement energy-management practices, ensure regular equipment maintenance and make essential repairs without delay. Taking these steps can save up to 10% of energy with little or no capital outlay.

- Consider cool-growing regimes. A **NEW** energy-use Table indicates the substantial energy savings to be made. Lowering the set-point at ‘pinching’ to 15^{o}C and retaining this to marketing has been shown to save up to 30% of energy. However, to retain quality, potting has to be at least three weeks earlier than usual. Alternatively, adopt cool-temperature finishing (dropping the temperature only from around week 43). This is a generally preferred option since potting has only to be 7-10 days earlier and energy saving can still be as high as 17%. Ensure that the minimum temperature prior to marketing does not fall below 15^{o}C and take particular care over disease control and growth regulation. Consider switching to cultivars recommended for cool growing.

- Consider using temperature integration (TI). Exploiting solar gain by raising the vent temperature setting and compensating by dropping the temperature at other times can save around 12% energy in commercial practice, without reducing the average temperature. **TI should combine very well with cool-temperature finishing.**

- Consider raising poinsettias off an unheated floor and on to benches. This will incur a capital cost but will allow lower temperature set-points to be run, saving energy without loss of quality. Alternatively, provide floor-grown poinsettias with low-level heating. This is more energy efficient than high-level heating and avoids crop shading.

- Consider installing or upgrading energy-saving screens. When drawn across, efficient screens can reduce the heat loss of a greenhouse by 30-60%. Blackout screens can additionally be used with poinsettia for photoperiod control to give season extension.

- Up to weeks 43-46, allow the greenhouse air temperature to fall for several hours at dawn, or when screens are removed (DROP). This will save energy and reduce

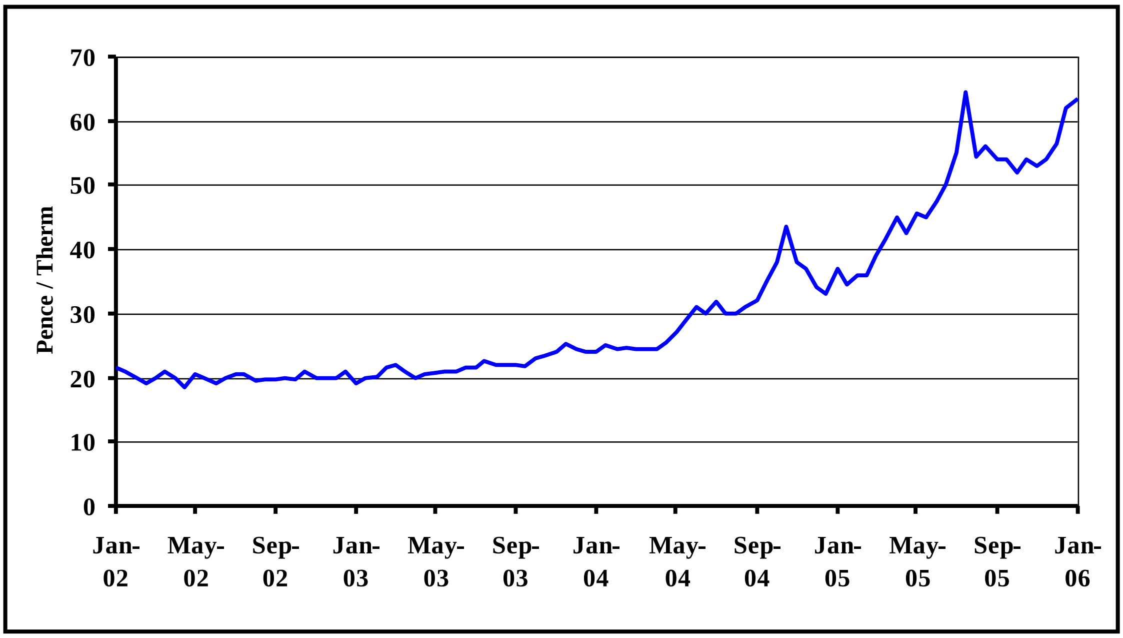
PGR use. This is a specialised form of TI and temperatures will need to be raised at other times to maintain the target average temperature.

- Consider whether retail quality could be achieved at closer spacing. Increasing the output in this way reduces the energy used per pot. Closer spacing could be especially useful in association with cool-growing or less vigorous varieties.

'Freedom Red', a cultivar well-suited to cool-growing regimes in the UK (picture courtesy of Paul Ecke Ranch, Encinitas, California)

Background

Leading UK growers have estimated that energy in the 2006 season will probably account for up to 20-30% of the production costs of natural-season poinsettias grown for the Christmas market. This reflects a return to the high energy price levels of the mid 1970s, and a threefold increase on the prices of just a few years ago. Spiralling energy costs now pose a serious threat to the commercial viability of the crop. The UK is no longer self-sufficient for energy, and supply is subject to international competition and increasing global demand. It seems unlikely, therefore, that energy prices will fall substantially in the foreseeable future, and commercially successful poinsettia production will increasingly require efficient energy management.



Recent increases in wholesale gas prices – Elf Business Gas Ltd

Growers are also required to pay a Climate Change Levy (CCL), imposed by Government in 2001 as a means of encouraging businesses to become more energy-efficient and to help the UK meet its Kyoto Protocol commitments for the reduction of CO_2 emissions. Some relief was afforded to the greenhouse horticulture sector by the granting of a 50% rebate on the CCL, but this ended in March 2006. As a replacement, the Government is now offering a formal Climate Change Agreement (CCA) which gives an 80% rebate on CCL to those growers who sign up to it. The target that a grower has to commit to is a 12% improvement in energy efficiency by 2010, judged against 2004 as the base year. Improvement for growers who have poinsettias in their production schedule is most likely to be measured in annual energy use per unit greenhouse area. Typically, the 80% CCL rebate for poinsettia production is likely to be worth an annual £1,700 per hectare, assuming gas as the heating fuel. In addition, achieving the 12% energy reduction will itself give an annual saving approaching a further £5,000 per hectare (including electricity). The potential total annual saving once the 12% saving has been achieved is, therefore, around £6,700 per hectare. Energy saving has never been more important!

Good housekeeping

The starting point for energy saving in the greenhouse is good housekeeping. This includes the implementation of energy management practices, regular equipment maintenance and making essential repairs as soon as they are needed. FEC Services Ltd has estimated that good housekeeping can often save up to 10% of energy for little or no capital outlay. In particular:

- **Collect energy-use data at least once each week**. This will give a detailed insight into factors affecting energy use. Include all fuels - gas, electricity, oil etc – and aim to take meter readings and / or storage tank levels on the same day, and at the same time, every week. Compare energy use with similar periods in previous seasons. If possible, use the information to benchmark your performance against other growers. To be of most use, energy data should be compared alongside greenhouse climate (temperature and humidity), weather (temperature, windspeed and radiation) and cropping information. Used in this way, the data will give an understanding not only of where the energy is being used, but also of the factors leading to increases and decreases in consumption. Increases in energy use that cannot be accounted for by changes in growing conditions indicate a possible problem with the heating equipment, requiring immediate investigation and rectification.

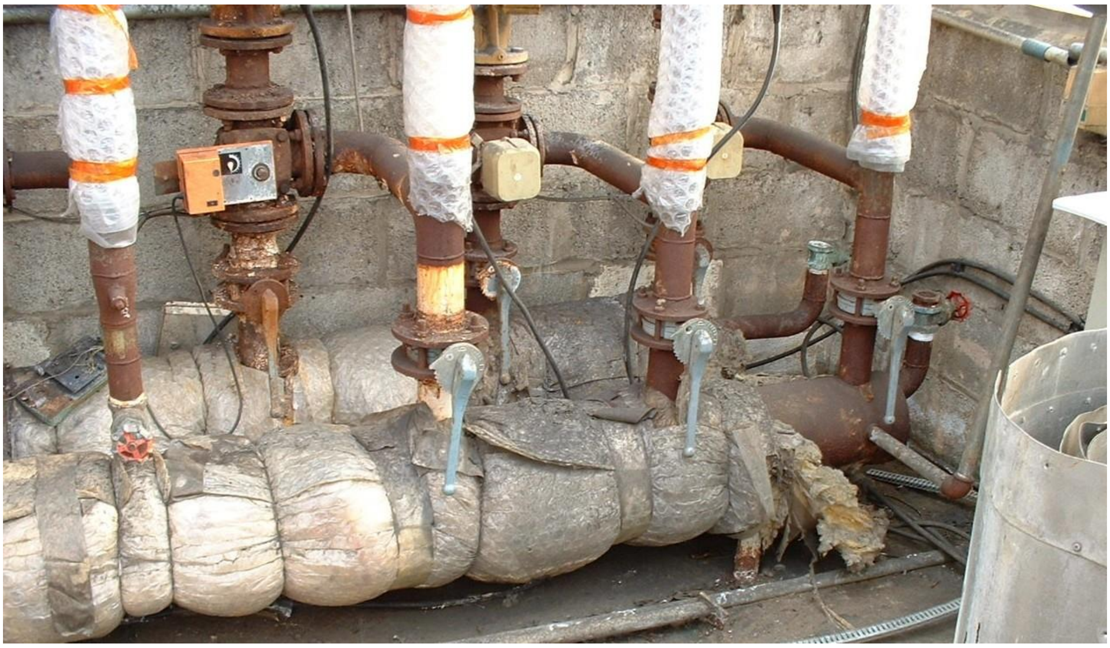
- **Ensure regular maintenance of the weather station and measuring box.** The measurements made by the weather station (i.e. radiation, outside temperature and windspeed) and the measuring box or screen (temperature and humidity) are the key variables used by the climate control system to maintain the greenhouse environment. This means that if the measurements taken are inaccurate, energy is probably being wasted. For example, if the greenhouse temperature sensor is measuring 1ºC low, then between 5-10% more heating energy than is needed will be used. All sensors should be regularly cleaned and checked. This is particularly important for the measuring box where the water supply should be topped up at least weekly. Electronic sensors should be calibrated regularly.

- **Minimize air leakage from the greenhouse.** A well-sealed greenhouse in good condition can use up to 25% less energy than an old, poorly maintained structure. With this in mind:
  Replace broken or slipped panes of glass.
  Make sure doors are kept closed.
  Ensure that vents close properly.
  Fit brush seals around poorly fitting doors and vents.
  Seal around pipes where they enter the greenhouse.

- **Consider installing windbreaks.** These minimize the airspeed over the greenhouse surface and can greatly reduce heat loss, particularly under windy conditions and when internal energy screens are not in use. Plastic screen materials such as "Tensar" are available for the purpose, but it is important to ensure that the siting of windbreaks does not result in crop shading since this can more than negate the benefits of energy saving.

- **Keep the glass clean – inside and out.** Dirty glass reduces the solar energy entering the greenhouse and increases the need for heating to maintain greenhouse temperatures. Regular glass cleaning will ensure that plant growth and energy efficiency are optimised. Ensure that any whitewash applied to the glass in summer is completely removed by week 36.

- **Insulate pipes.** An un-insulated external pipe loses 8 times the energy of an equivalent one that is insulated with 50 mm of good quality, dry insulation material. As a result 10 m of 100 mm diameter un-insulated pipe can be costing over £500 per year in wasted energy. Ensure that all damaged or missing insulation on external pipes is replaced with insulation conforming to BS5422 (2001). Also, remember that wet insulation is next to useless; effective weatherproofing must be fitted. All valves should also be fitted with insulating jackets.



Poor insulation costs energy

Cool-growing regimes

Growing at lower temperatures is a means of saving energy that can be employed by all natural-season poinsettia growers. It is not dependent on the quality of the grower's glasshouse or on how up-to-date are the environmental control systems. The savings to be made can be deduced from a NEW Energy-Use Table constructed by FEC Services Ltd. This gives estimates of the energy required to maintain given day / night temperature combinations, as a percentage of that needed to maintain 18°C day / 18°C night in November (100%). The calculations are based on indices of heat loss from the greenhouse, taking account of temperatures outside and inside. Being in percentage form, it is as valid for use on the S. Coast as in Lincolnshire, the Midlands or Yorkshire. However, it should be used with caution since it takes no account of factors such as solar gain, outside wind speed or use of energy screens. Percentage changes at night will be over-estimated if screens are being used. Nevertheless, the percentages are indicative of the relationship between the temperature set-point of the greenhouse and energy use through the life of the poinsettia crop for a given set-point target. The percentages translate directly into

Day	Night	Aug	Sep	Oct	Nov	Dec
20°	**20°**	30%	55%	88%	120%	153%
	18°	23%	46%	76%	107%	139%
	16°	17%	37%	65%	95%	125%
	14°	13%	29%	54%	82%	112%
18°	**18°**	16%	36%	67%	**100%**	133%
	16°	11%	27%	56%	88%	119%
	14°	7%	19%	45%	75%	105%
16°	**16°**	7%	20%	47%	80%	112%
	14°	4%	13%	36%	68%	99%
14°	**14°**	2%	9%	29%	61%	92%

Percentage energy use, relative to 18° day / 18° night in November, given by changing day and night temperature set-points financial costs, but the conversions depend on location, the specific characteristics of the greenhouse and on energy prices.

Efford trials in the mid-1990s (PC 71c, 1995-1997)

Early energy-saving experiments, starting in the early 1980s at the Lee Valley Experimental Horticulture Station, and moving to Efford in the mid 1990s, looked at growing with a low heating set-point temperature throughout production. At Efford, the cool-growing regime began at ‘pinching’ when the set-point was reduced over the period of a week from 20°C to 15°C where it then remained through to marketing. This was compared with a standard ‘warm’ crop grown continuously with a day/night minimum temperature set-point of 20°C (venting at 22°C). It was found that:

- For cultivars ‘Freedom’, ‘Ria’ and ‘Red Sails’, cool-grown pots were of comparable commercial quality to control pots potted in Week 31 but, to achieve this, **potting of the cool-grown pots had to be at least three weeks earlier** (in Week 28). For ‘Sonora’, potting of the cool-grown pots would have had to be even earlier to have given pots of comparable quality. Shading treatments to simulate more-northerly locations indicated that potting there would also need to be earlier.

- Cool growing did not reduce bract star number, but it did tend to reduce bract size. Shoot extension growth was also reduced, but the longer growing duration of Week 28, cool-grown pots enabled these to match the height and diameter of control pots at marketing in all four cultivars. There was little difference in PGR use between Week 28, cool-grown pots and Week 31, ‘warm’ pots.

- Shelf life was not diminished by cool-growing.

Cool-grown ‘Freedom’, potted in Week 30 (centre) and Week 28 (right), contrasted with a standard Week 31 “warm” pot (left)

It was estimated that cool growing with potting in Week 28 will give an energy saving of around 30% compared to ‘warm’ growing and potting in Week 31 (regardless of geographic location or whether energy screens are used). However, the estimation of saving takes no account of energy used for active humidity control, or of the potential loss of production of other crops caused by a three-week earlier start. Venting was only 1-2°C above the heating set-point in this trial, and a higher vent setting would probably have saved more energy (by retaining solar gain), increased growth rate and may have reduced the need for such early potting.

Cool-temperature finishing (PC 71d, 1997-1998)

Relatively little energy is saved by lowering the heating set-point in the early stages of cropping (see Energy-Use Table) when plants are pot thick. Because of this, a generally preferred strategy is to encourage growth early in the season, when light levels are high, by retaining 'warm' growing conditions, and to lower the temperature set-point to 15°C much later in production. This was tested at Efford in the late 1990s with set-point reduction in Week 43. It was found that:

- Cool-temperature finishing gave pots of equal quality to control pots, and potting only needed to be 7-10 days earlier.

- Cool finishing gave much more brightly coloured bracts, but these were reduced in size by up to 30%. Because of this, naturally large-bracted cultivars appeared best-suited to the approach. Cyathia were less well developed at marketing.

- Cool-finished plants were compact and required fewer PGR applications. Less vigorous cultivars, such as Sonora, struggled to reach minimum height specifications.

- There were no deleterious effects on post-harvest performance. However, a subsequent trial (PC 156, year 3, 2000-2001) concluded that post-harvest life could be reduced if temperatures fell below 15°C in the final stages of production.

- The cool-finishing regime gave a potential energy saving of around 17%, using a similar estimation procedure as for PC 71c.

Good disease control is important when growing cool since higher humidities can increase the risk of damage caused by *Pythium* and *Botrytis*. Early PGR applications need to take into account the likelihood of reduced growth rates later in the production period when temperatures are lowered.

Cultivars suited to lower-temperature growing

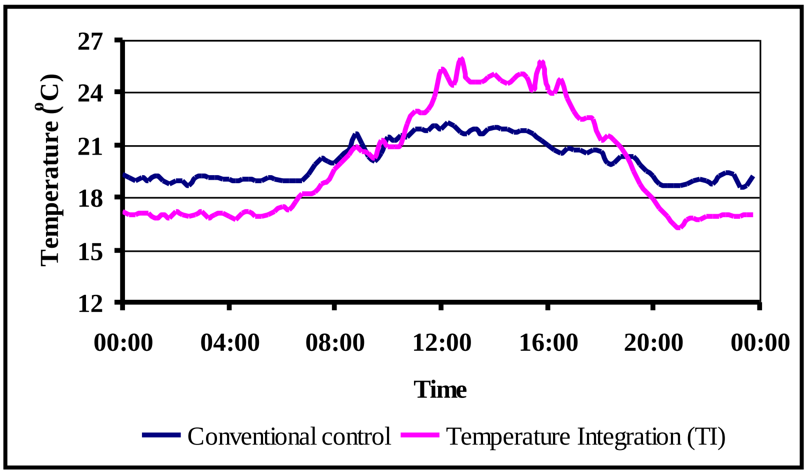
Cultivars suited to cool-growing regimes are likely to be vigorous with large bracts so as to withstand a general reduction in size without falling below minimum commercial specifications, and be quick to colour up so as to minimize marketing delays. Having these characteristics, 'Freedom' has always done well in UK, cool-growing regimes. **More recently introduced cultivars have not been objectively trialled in the UK under cool conditions, and caution needs to be taken with breeders' recommendations.** Cultivars claimed as suitable for cool growing might perform less well in the UK than to where they were bred. Climate and market requirements differ, and what suits one area of the UK may not suit another.

Ecke currently recommends 'Jester Red', 'Autumn Red' and 'Red Velveteen', whilst Fisher recommends 'Early Millennium', 'Cortez' and 'Mars'. Florema, in association with Agriom, has released three cultivars specifically for lower-temperature finishing (15°C from the equinox). These are the early / compact 'Alreddy Red' and the more vigorous and later cultivars, 'Stargazer Red' and 'Estrella Red'. Initial seedling selection in Agriom's breeding programme is at 17°C and particular attention is paid to final plant height and bract size, the two key components (along with speed) affected by lower temperatures. Dümmen takes the view that naturally compact cultivars are best because the growth of these will not be adversely affected by fluctuating temperatures later in production, and bract expansion will not be damaged by excessive PGR application. Cultivars especially recommended from the Dümmen range include the ‘Premium’ series and ‘EuroGlory’. The key to the use of compact cultivars is to achieve sufficient height at marketing and it is claimed that this can be done either by early potting (‘long and cool’ production), or by using high temperatures and an ‘aggressive’ nutritional regime in long days, possibly involving the use of ammonium fertiliser (‘quick and cool’ production). However, the applicability of this approach has yet to be validated under UK conditions.

Cultivars recommended by their breeders for cool-growing regimes: ‘Jester’ by Ecke (top left), ‘Early Millennium’ by Fisher (top right), ‘Alreddy Red’ from Florema (bottom left) and ‘Premium’ by Dümmen (bottom right)
(pictures courtesy of the respective breeders)

Temperature integration (TI)

TI regimes save energy without a reduction in overall average temperature. In this regard they differ from cool-growing regimes. TI makes use of solar gain, captured in the greenhouse by setting a high vent temperature, to run higher than usual day temperatures. This enables the heating set-point to be reduced at other times when the heating demand would conventionally have been high. The aim is to maintain a running average temperature over one or several days so that crop scheduling (largely determined by average temperature) is not seriously disrupted. The figure below shows typical temperature profiles over a 24-hour period for conventional and TI crops. The gain in temperature during the middle of the day in the TI greenhouse (from solar gain) is compensated for by running a lower heating set-point temperature than in the conventional house during the rest of the 24-hour period. Both profiles give the same average temperature, 20°C, but the requirement for greenhouse heating is less in the case of TI.



Typical daily temperature profiles for conventional and TI crops (PC 207)

Efford TI poinsettia trial (PC 190, 2002-2003)

Eleven cultivars were grown from a week 31 potting in both conventional (control) and TI temperature regimes. The set-point heating temperature in the control was gradually reduced during production from an initial 20°C to a final 16°C, with the vent temperature set at 2°C higher. The vent temperature in the TI treatment was 2°C higher still, raising average day temperatures, and these were compensated for by allowing temperatures to fall to as low as 18°C in the period up to the end of week 36, and to 14.5-15°C thereafter. Temperature averaging was over a running 3-day period. Any change to the temperature set-point in the control regime was matched by a change of settings in the TI regime. TI was ended one month before marketing and, thereafter, all plants were finished off in the control regime. Temperatures in the two regimes, averaged over the whole of the production period, differed by only 0.2°C at harvest. It was found that:

- Both regimes gave crops of excellent quality and there were no differences in time to marketing. However, on average, two extra Cycocel sprays (1,000 ppm active ingredient) were required for height control in the TI crop (range from no extra sprays in 'Premium' and 'Red Elf' to four extra sprays in 'Elegance Pink' and 'Elegance White'.

- Higher vent temperatures in the TI regime gave greater opportunities for CO_2 enrichment (using pure CO_2), and this was reflected in higher, final fresh and dry weights. However, this may not have applied had CO_2 been taken from the back of the boiler, because the boiler operated less frequently in the TI regime.

- Temperature fluctuations were greater in the TI regime than in the control, increasing the potential for high-humidity related, fungal disease. However, control of RH ensured that fungal disease was avoided.

High quality plant of 'Elegance White' grown using TI at Efford (PC 190)

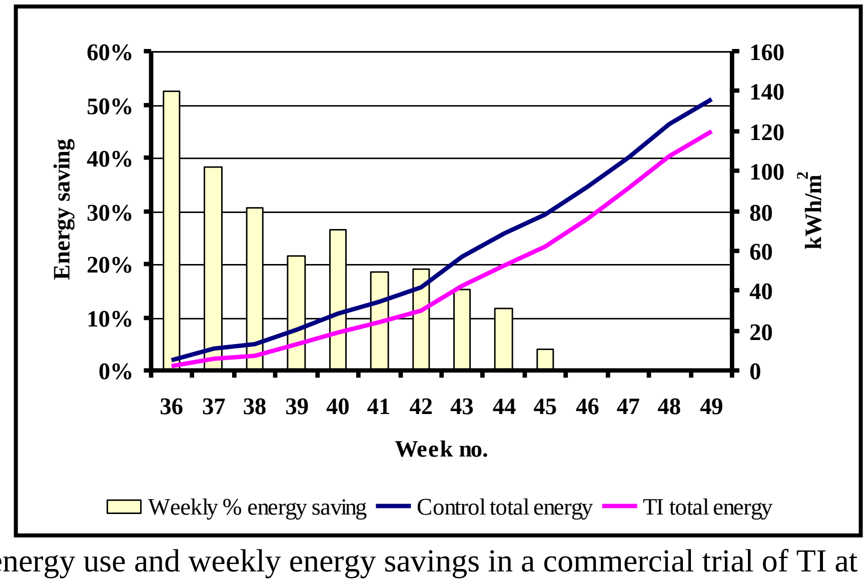
- By week 41, the TI regime had saved about 80% of the heating energy needed for the control crop. Thereafter, energy use in the two regimes was similar. This reflected reduced solar gain and the start of positive RH control. At marketing, energy saving due to TI was around 30%.

- Leaf and bract loss during shelf life was greater in TI plants than in control plants. However, this was probably not due to TI, but to higher, average temperatures being required for RH control in the TI crop compartment during the final three weeks after TI had been suspended.

Trials at Coletta & Tyson (PC 207, 2003-2005)
Conventional and TI regimes were compared in 2003 using 'Sonora' as the test cultivar at Coletta & Tyson Ltd., Millbeck Nursery, South Cave, East Yorkshire. Venlo greenhouses with a gutter height of 3 m were used, and each treatment occupied 0.45 hectares, so enabling a realistic estimate to be made of potential energy savings when TI is applied on a commercial scale. Poinsettias were grown on the floor on 'Mypex' matting, and there were no thermal screens and no CO_2 enrichment. TI settings were reviewed regularly to ensure that both regimes achieved the same average temperature. The maximum TI vent temperature was 26°C and the averaging period was 7 days. An identical, early morning, temperature DROP treatment was applied in each case. A 'vent then heat' strategy was adopted to ensure that the RH in each compartment did not exceed 88% for more than 30 minutes. It was concluded that:

- Both the conventional and TI crops met retail quality specifications at marketing, and there were no adverse effects of TI during subsequent shelf-life. *Botrytis* levels in the TI crop were no greater than in the conventional crop.

- TI gave weekly energy savings of 15% or more to week 43. Thereafter, energy use was similar in the two regimes and the overall final saving due to TI was 12%. The total energy used (as gas) in the TI regime was 120 kWh/m^2 (see graph).



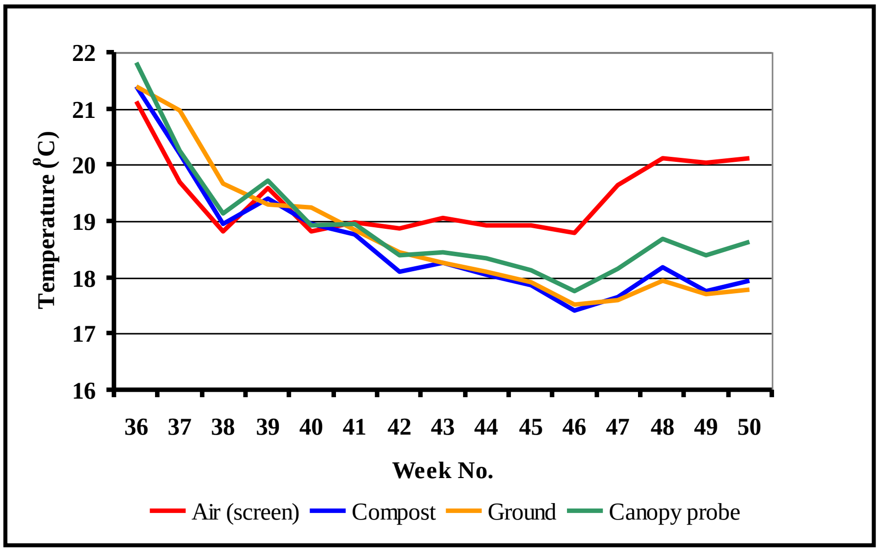
Total energy use and weekly energy savings in a commercial trial of TI at Coletta & Tyson (PC 207)

The successful production of two further crops at Coletta & Tyson Ltd. in 2004 confirmed that use of TI can achieve high quality poinsettia crops without increasing the risk of high-humidity fungal diseases. In particular, it was concluded that:

- TI control principles can be applied without specialist TI computer software, but energy savings are likely to be greater when specialist software is used. The likely payback time for TI software is 1-3 years, depending on existing computer hardware. Time needs to be set aside to implement and review new climate control settings, and for staff training.

TI should combine very well with cool-temperature finishing to achieve a greater energy saving than by either method in isolation. The two together ought to give minimal delay without compromising quality.

Growing on the floor? (PC 207, 2005)
It was noted in the Coletta & Tyson trials reported above that the temperature of the unheated floor was frequently 1-2°C below the air temperature during the final two months of cropping. This, in turn, routinely lowered the air temperature within the crop canopy of poinsettias growing on the floor by around 1°C (see temperature graph). It follows from this that it ought to be possible in such circumstances to produce poinsettias without any loss of quality, but with a lower air temperature setting, by raising the plants off the unheated floor and on to benches. Such a move will save energy, but a capital cost is involved. Alternatively, energy can be provided more efficiently to the floor-grown crop by the installation of low-level heating.



Average weekly temperatures for a commercial poinsettia crop growing on an unheated greenhouse floor (PC 207, 2005)

In general, low-level heating is more energy-efficient than high-level heating, since the former puts energy into the greenhouse where the plants are. Hot air rises, so high-level heating, whether from pipes or hot-air heaters, will always be second best. Heat will tend to go straight out of the vents, temperature stratification is more likely, and low-level heat distribution (where the crop is) can be very uneven. High-level pipes and heaters can also shade the crop, thereby reducing growth. Low-level heating can be achieved with above-ground heating pipes or by growing on heated floors. These range in sophistication from concrete floors with heating pipes running through them, to sand in which heating cables are buried. However constructed, a key element for energy conservation is to ensure that efficient insulation is provided below the floor to maximize heat transfer to the greenhouse and to avoid heating the underlying soil.

Screens and DROP

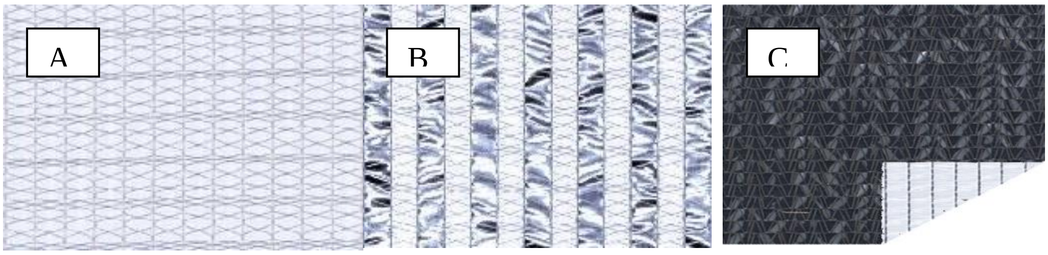
A well-designed and installed screen will, when drawn over a crop at night, reduce the instantaneous heat loss by between 30% and 60%. It makes sense, therefore, to consider screening any house in which Christmas poinsettias are to be grown. Such screens are likely to be used with other crops at other times of year, so care needs to be taken to determine which is the most appropriate of the three types of screen that are currently available.

Screen types

- **Energy-saving screens.** The need to achieve energy saving, whilst minimising shading, has led to screen manufacturers developing energy-saving materials that allow a high light transmission and pack away tightly when retracted. Typically, these materials (type A below) are made from polyester strips supported on a textile carrier. This construction allows the transmission of water vapour and can prevent excessive humidities building up under the screen. Instantaneous energy saving is around 30-40%. However, such screens are not ideal if crops requiring some summer shading are to be grown before poinsettias, and energy saving during the poinsettia season is far from optimized.

- **Shade screens.** These materials are designed to provide protection to plants that are vulnerable to damage by high solar radiation in summer. They are primarily constructed from foil-based materials (type B below) which can reflect incoming solar energy. Instantaneous energy saving can be up to 50%. These materials can also have ‘open’ strips that promote air movement across the screen. However, this reduces the energy-saving potential of the screen. Such screens can give a good compromise where crops requiring solar protection are grown in the summer and energy saving is important during the lower-light periods of the year when poinsettias are grown.

- **Blackout screens.** These materials are impermeable to light and are principally used in poinsettia production for the manipulation of photoperiod to give successional crops and season extension. The materials used tend to be of a heavy woven construction (type C below) and, as a result, they can give an instantaneous energy saving of up to 60%. However, these materials have poor breathability and can give humidity control problems. They also tend to be bulky and do not fold into small packs when drawn open.



Screens that can be used to save energy (see text)

DROP

There can be a considerable fall in greenhouse air temperature when screens are removed in the morning. This is because the warm air under the screen rises and is rapidly replaced by cold (unheated) air from above the screen. Preventing this temperature fall can take considerable heating energy and best practice is to let the temperature fall and to remain low for a period, then to gradually increase it, making full use of solar gain, so that a given, average 24-hour temperature is maintained. This is a specialised form of TI that can save up to 1.5 - 2% of energy and, by giving more compact plants, reduces the need for PGR sprays. This planned temperature reduction is generally known as DROP.

- Dropping the temperature during the first part of the day was shown to reduce poinsettia stem extension and to advance flowering and colouring (PC 41, Parts I and II, 1991-1994). The greater the magnitude of DROP, the greater the response. Paler-green leaves resulted when DROP treatments were given continuously, but leaves quickly regained their colour once treatment was suspended.

- Allowing the morning DROP temperature to fall by up to 8°C (without venting) resulted in fewer applications of PGR being needed to achieve height specifications (PC 155, 1998-1999 final). It was again shown that DROP advanced marketing (by around 7 days) and there were no deleterious effects on quality or post-harvest characters.

- A good commercial practice is to allow temperatures to start falling around one hour before the screens are removed. Typically, the temperature is allowed to fall to a minimum of around 14°C, and the duration of DROP (after screens are removed) is usually around 3 hours. DROP is generally ended around week 43-46 to avoid undesirable reductions in the size of coloured leaves and bracts, and is probably best suspended temporarily during periods when outside conditions are overcast and cool with minimal solar gain.

- The value of DROP for growth control and energy saving is such that the technique is commonly used at dawn on nurseries that have no energy screens.

Energy costs per pot

Although energy savings for CCL purposes are likely to be calculated on energy use per unit area, increasing the output of poinsettias without increasing the total amount of energy used, i.e. reducing the energy costs per pot, will still have highly beneficial effects on financial margin and the economics of production.

Spacing
The simplest way of reducing energy per pot is to grow at a higher plant density. This possibility was investigated in PC 71c (1996-1997), where final spacings were 10 pots/m^2 (standard) and 12 pots/m^2 (close) for 13 cm pots, and 22 pots/m^2 (standard) and 26 pots/m^2 (close) for 10 cm pots. It was found that:

- For 13 cm pots potted in Week 31 and grown 'warm', close spacing had a similar effect to shading in reducing overall, visual pot quality, mainly by increasing the proportion of smaller bract stars (< 200 mm diameter). However, the reduction was only significant in one cultivar, where plant diameter was also reduced, and there was little commercial detriment in three others (including 'Freedom').

- For 13 cm pots potted in Week 28 and grown "cool", close spacing had no detrimental effect on market quality. This was because the cool-grown pots tended to grow more slowly than the 'warm' pots, so close spacing gave less plant-to-plant shading. Any reduction in quality compared to the 'warm'-grown, standard-spaced control pots was due to cool growing rather than closer spacing.

- Close spacing gave no reduction in quality in 10 cm pots.

Most growers could probably increase pot density without significantly reducing marketable quality. However, this approach is likely to be most successful in conjunction with cool growing or with less vigorous cultivars or with cultivars having a more upright habit. Closer spacing could increase disease risk, so particular care will be needed to avoid this.

Final word

There is no one correct way to save energy in poinsettia production, and what is right for one grower will not necessarily be right for another. Much will depend on circumstances, type and standard of greenhouse, market requirements etc. It is also fairly certain that some growers will, already, be much more energy-efficient than others. Perhaps one of the most useful things that a grower can do is to determine where energy is being spent, and how energy costs compare with those of apparently similar growers. This is the starting point of good energy management and energy benchmarking. It is most probable that this will rapidly lead on to the identification of the most cost-effective, energy-saving solutions. One thing is certain; poinsettia prices paid to the grower are unlikely to rise in line with future energy costs, so energy saving will continue to be important into the future.