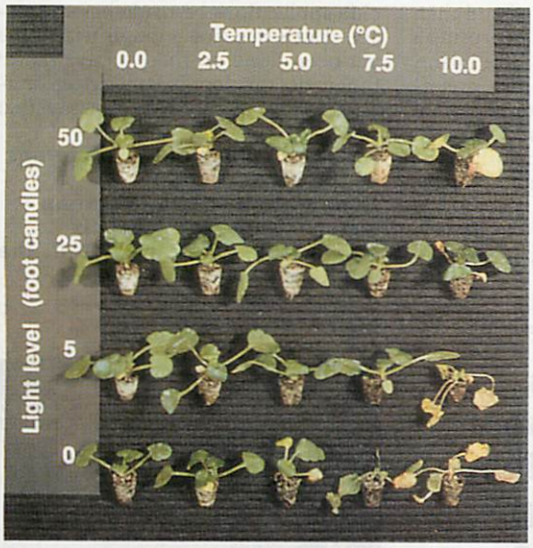
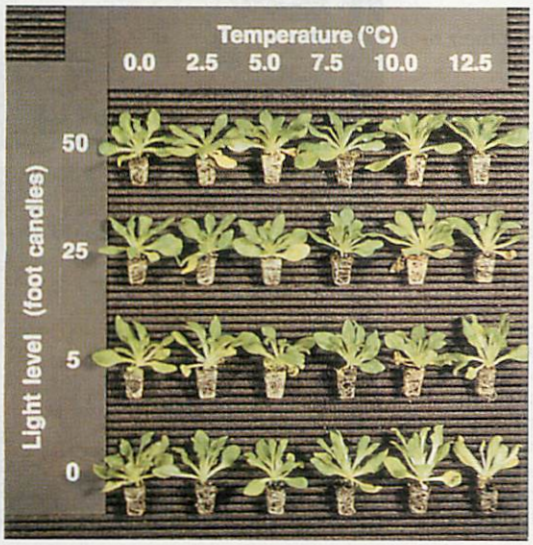
A cool answer to crop management

Delaying plug growth through the use of cold storage can be a useful tool in managing cropping programmes



The pansies satisfactorily tolerated 16 weeks of storage at 0 and 2.5°C at all light levels, including darkness. Satisfactory storage time in the dark decreased as the temperature increased



Petunia plugs stored satisfactorily at temperatures ranging from 0 to 5°C in darkness. The addition of five foot candless of light increased the satisfactory temperature for six weeks of storage to 12.5°C

Plug seedlings are often ready for transplanting before growers are ready to transplant them. When this happens, growth must either be slowed or delayed in some way, or they must be transplanted no matter how inconvenient it might be.

Several methods of slowing or delaying growth have been tried and are used with some success, including water and nutrient stress and the use of growth regulators. But these have the potential for a knock-on effect on growth after transplanting. And if the plugs are held in a greenhouse, valuable space is taken up, reducing overall production and profits.

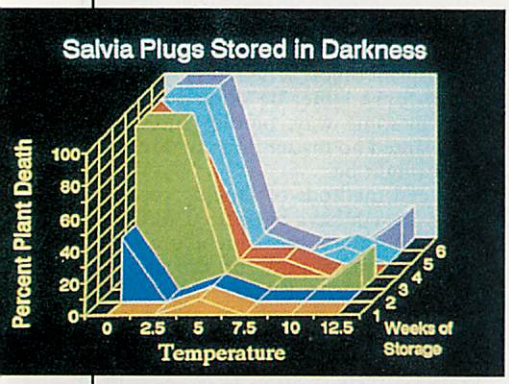
An alternative, storing the plugs at low temperature, has been tested over the last two years by researchers at Michigan State University in the USA, led by Dr Royal Heins. This storage can take place in cold greenhouses, walkways, the headhouse or coolers. It is important to understand how the different light and temperature conditions that can be encountered in these different situations will affect the growth of seedlings after transplanting.

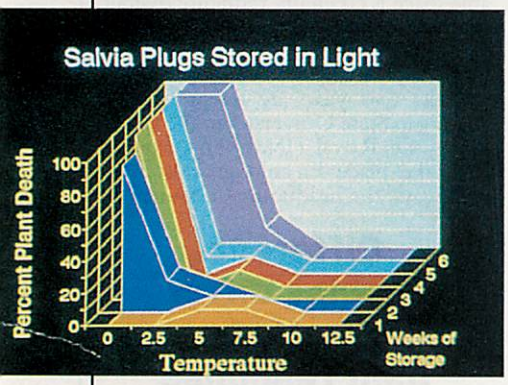
Different species differ greatly in their response to cold storage

The option of suitable coolers offers great scope for control, and therefore better scheduling and management. A grower may want to hold some plugs for just a few days, and store others for several weeks. For each, there is an optimum combination of temperature and light. Equally, using the wrong combination could destroy a crop.

There are other management factors to be taken into account too. Growers may want to store different species with different storage requirements in the same facility, in which case a compromise is necessary. Also, a warmer temperature than the optimum might be more cost-effective if only short-term storage is wanted.

It is therefore important to understand how holding plugs of different species under a wide range of different temperature and light conditions will affect subsequent plant growth. ▷





◁ The Michigan State researchers are performing systematic tests on a range of plants to find out just such information. Since February 1990, impatiens, pansies, geraniums, petunias, salvias, ageratums, marigolds and begonias have been looked at. A total of 25 plug sheets (size 406) of each species was obtained from a commercial grower when they were at a transplantable stage. They were then held in a greenhouse for a week before starting the storage treatments in order to eliminate possible side-effects from shipping.

The trays were then placed at different light and temperature combinations. The light levels used were darkness, 50, 250 and 500 lux. The highest level was dropped when no significant differences were noted between that and 250 lux. All the plugs were sub-irrigated as needed with clear water during storage. (The plants' nutritional needs are minimal at low temperatures). The frequency of irrigation varied from two to 10 days, depending on the temperature treatment and relative humidity of each cooler.

Ten representative plants were removed from each plug sheet of each temperature/light combination after each week up to six weeks.

Salvias should not be stored at less than 5°C. Temperatures from 5 to 12.5°C were satisfactorily tolerated for up to four weeks in the dark, but the plants elongated and the leaves abscised as the temperature increased. The acceptable storage period increased to six weeks when light was added

There were a few variations from this. 'Majestic Yellow' pansies were removed from storage at two week intervals up to 16 weeks.

A representative plant from each treatment was photographed and then all were potted up in 10cm pots using a commercial soilless mix. The plants were forced into flower in a greenhouse with a minimum temperature of 20°C. The storage treatments were then rated as satisfactory or unsatisfactory. Satisfactory treatments had no more than one out of 10 plants die and the plants did not show a delay in flowering of more than five days compared to control plants, which had been potted directly without any storage.

The results showed clearly that different species differ greatly in their response to the treatment.

Botrytis proved to be a major problem in storing impatiens

Impatiens

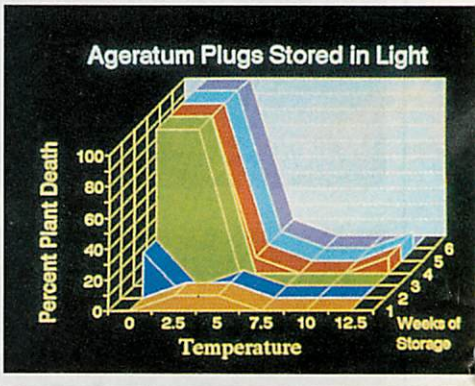
'Accent Orange' impatiens were sensitive to chilling injury at temperatures below 7.5°C. Storing impatiens plugs at 0°C for even a week killed all the plants. Storing impatiens at 2.5°C for more than two weeks or at 5°C for more than three weeks resulted in severe chilling injury and subsequent death, regardless of light levels.

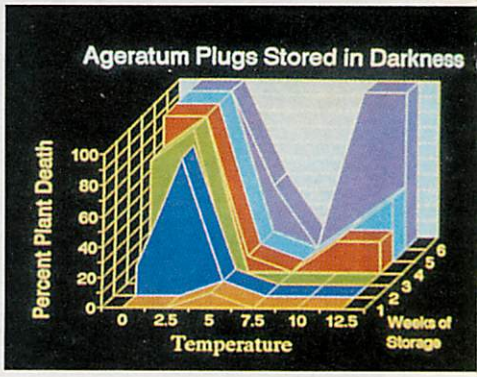
The coldest temperature the impatiens could tolerate for more than three weeks without chilling injury was 7.5°C. Impatiens satisfactorily tolerated this temperature for six weeks at all light levels, including darkness. The longest impatiens could be stored in the dark satisfactorily at 10 and 12.5°C was five and four weeks respectively. Storage at 12.5°C for more than four weeks in the dark delayed flowering.

But impatiens could be stored for up to six weeks without delay in flowering if they were exposed to as little as 50 lux (five foot candles) of light during storage.

Botrytis proved to be a major problem in storing impatiens. Botrytis can be limited by maintaining low relative humidity during storage. However, low humidity causes the plugs to dry out quickly, which means that they will have to be irrigated during storage. The Michigan State researchers are currently recommending that appropriate fungicide applications be made before storage. But since not enough trials have yet been done on the effectiveness of fungicides on plugs in cool storage situations, the researchers also say that

Ageratum plugs are not tolerant of the dark. The only temperature where ageratum successfully stored for six weeks in the dark was 7.5°C. The addition of light, however, dramatically increased the plants' chances of survival





impatiens should be stored under low humidity conditions.

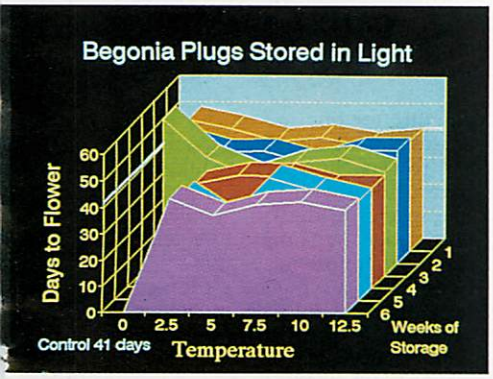
Moving the plugs from cool storage to a warm greenhouse with high light levels did not prove a problem as long as the plugs were moist when they were placed in the warm environment.

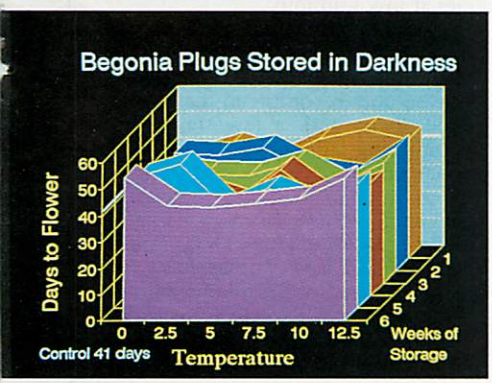
Pansy

The 'Majestic Yellow' pansy plugs proved more tolerant to temperatures below 7.5°C than impatiens. The pansies satisfactorily tolerated 16 weeks storage at 0 and 2.5°C at all light levels, including darkness. Satisfactory storage time in the dark decreased to 14, 10 and six weeks as the temperatures increased to 5, 7.5 and 10°C. Pansies were successfully stored for 16 weeks without delay in flowering with light levels of 50 lux at 5 and 7.5°C and 250 lux at 10°C.

Botrytis was a major problem in storing impatiens plugs at cool temperatures, but it did not affect the pansies.

The optimum temperature range for begonia is 5 to 7.5°C, but the range widens when the duration of storage is four weeks or less and when light is added





The optimum temperature for marigolds is 5°C, but even at the optimum, their limit in the dark is three weeks

Petunia

'Ultimate Red' petunia plugs stored satisfactorily for six weeks at temperatures ranging from 0 to 5°C in darkness. The addition of 50 lux of light increased the satisfactory temperature for six weeks of storage to 12.5°C.

Geranium

'Pinto Red' geranium plugs elongated quickly in the dark at temperatures above 7.5°C. The addition of 50 lux of light increased the satisfactory temperature range for four weeks of storage up to 12.5°C. Despite this relatively wide tolerance by both species, Heins and his colleagues concluded that the optimum temperature for both petunia and geranium plugs was around 3°C. Although both geranium and petunia plugs tolerated 0°C, this is not recommended for storage.

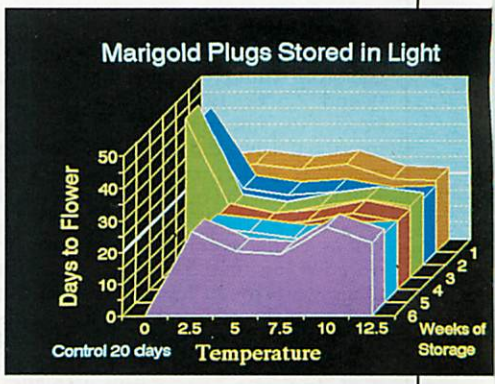
Botrytis was a major problem on both species, as with impatiens. The researchers recommend that they be stored under low humidity conditions, which means that irrigation will be necessary if storage is for longer than a week.

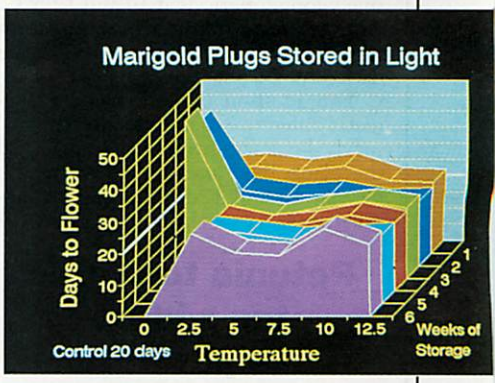
Light made a dramatic difference to the survival of ageratum

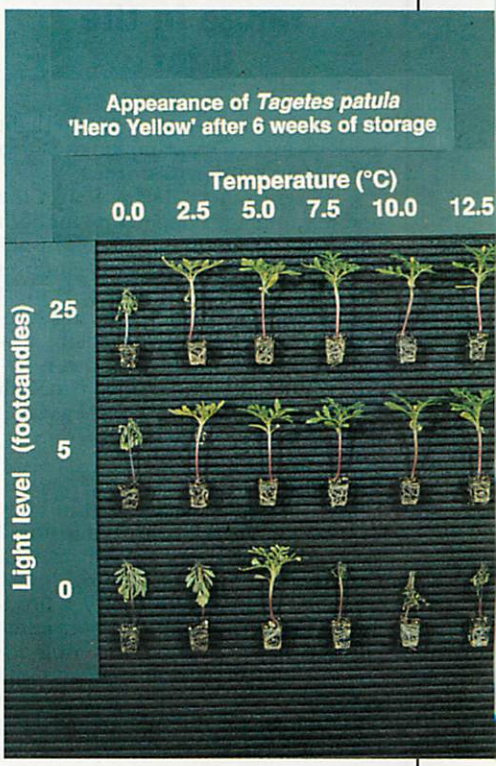
Salvia

'Red Hot Sally' salvia suffered chilling injury and death at 0 and 2.5°C, with the first evidence of chilling injury being delayed flowering. The results indicated that salvias should not be stored at less than 5°C. Temperatures from 5 to 12.5°C were satisfactorily tolerated for up to four weeks in the dark.

The plants elongated and the leaves abscised during storage as the temperature increased from 5 to 12.5°C. The possible period for acceptable storage increased to six weeks in the 5 to 12.5°C range when as little as 50 lux of light was added. Light was also reduced seedling elongation at all temperatures. ▷







◁ **Ageratum**
As with the salvias, the 'Blue Danube' ageratum suffered chilling and death at 0 and 2.5°C. But the storage time needed to cause injury was longer than for salvia. Salvia did not tolerate even a week at either temperature. The ageratum, on the other hand, tolerated a week at 0°C and two weeks at 2.5°C. But as a rule, ageratum should not be stored at less than 5°C. The ageratum plugs were much less tolerant of the dark than the salvias. Plants first elongated and then became chlorotic, and finally died when stored for progressively longer periods at 10 and 12.5°C. The only temperature where ageratum successfully stored for six weeks in the dark was 7.5°C.

The addition of light made a dramatic difference to the ageratum plants' survival chances from 5 to 12.5°C. All the plants died after six weeks in the dark at 10 and 12.5°C, while all survived after six weeks in the light at the same temperatures. Varying the light levels seemed to make no difference to subsequent plant performance.

Petunia tolerated the widest temperature range in the light

The researchers decided that the optimum storage temperature for both salvia and ageratum is 7.5°C. The acceptable temperature range increases when the duration of storage is short and when light is added during storage. The optimum long-term light storage temperature range for both is between 7.5 and 12.5°C. Even though ageratum could survive 0°C for a week, this is not recommended.

Begonia
Leaf spotting was evident within a few days on 'Vodka' begonia plugs stored at 0°C and, to a lesser extent, 2.5°C. Long-term effects of chilling injury were first manifested by delayed flowering, and as the length of storage increased, death. At 0°C, flowering delay was more pronounced and the percentage of dead plants increased when plugs were stored in the light rather than the dark.

The effects were not as severe at 2.5°C, but increased as the plugs were stored for longer periods.

The begonia seedlings elongated when held at 10 and 12.5°C. This was greater on plugs held in the dark but was not entirely prevented by the addition of light. Flowering was significantly delayed on plants stored in the dark at 12.5°C for any duration.

The begonia plugs tolerated storage in the dark for four weeks at 2.5°C, six weeks at 5°C, and five weeks at 7.5 and 10°C. Temperatures of 0 and 12.5°C were both unacceptable for dark storage.

When as little as 50 lux of light was added, however, the duration of acceptable storage increased to six weeks in the 2.5 to 10°C range. Even with 50 and 250 lux of light, acceptable storage duration was limited to four and five weeks at 12.5°C. The optimum temperature range for begonia is 5 to 7.5°C, but the temperature range widens to 2.5 to 10°C when the duration is four weeks or less and when light is added.

Marigold
'Hero Yellow' marigold plugs suffered chilling injury and death at 0 and 2.5°C. Flowering was delayed after just a week at 0°C and all plants were dead after four weeks. Most plants survived 5°C but flowering was delayed after three weeks of storage.

Marigolds did not store well in the dark as the temperature increased from 7.5 to 12.5°C. Maximum storage duration was two weeks at 10 to 12.5°C and three weeks at 7.5°C. Three weeks proved to be the maximum acceptable dark storage time.

Light improved the quality of stored seedlings at 5 to 7.5°C. Without light, all the plants died after six weeks at 10 and 12.5°C, while all survived six weeks at the same temperatures in the light. Variable flowering delay was, however, observed at these temperatures.

The optimum temperature for marigolds is 5°C, but even at the optimum temperature, their limit in the dark is three weeks. When stored in light, marigolds should not be stored for more than five weeks at 10°C or three weeks at 12.5°C.

General conclusions
In general then, plugs store better in the light than in the dark. The addition of as little as 50 lux can increase the acceptable temperature range for petunia, begonia, marigold, ageratum and impatiens by as much as 7°C.

Adding light, however, does not allow storage at temperatures below which dark-stored plants receive chilling injury. Petunia tolerated the widest storage-temperature range in the light (0 to 12.5°C), followed by pansy and geranium (0 to 10°C). Salvia and ageratum tolerated 5 to 12.5°C range. Impatiens had the narrowest range, from 7.5 to 12.5°C.

In the dark, petunia, pansy and geranium stored well from 0 to 7.5°C. Begonia stored between 2.5 to 10°C, while salvia could be kept between 5 and 12.5°C. Marigold and ageratum were the least tolerant to dark storage, performing well only from 5 to 7.5°C. Impatiens were also intolerant, with a range from 7.5 to 10°C.

The impact of storage on plugs varies according to the specific conditions, age, species, cultivar and physiological state of the plugs. The optimal temperature for one species, for instance, causes chilling and death in another.

The optimal conditions for one species can cause death in another

Growers, however, would usually have to deal with plugs of more than one species in the same cooler, and a knowledge of compromise temperatures is therefore necessary.

Botrytis can also be a problem on some species, especially impatiens, geranium and petunia. Use fungicides accordingly, and store susceptible species at low humidity.

Cool storage of plugs, Heins believes, does have the potential to become a viable management tool for growers. But he does recommend that growers experiment with a few trays before committing large qualities of plugs to cool storage.

This article was adapted from a series of four articles by Dr Royal Heins, Dr Will Carlson and Nathan Lange which appeared in the American magazine Greenhouse Grower. *The illustrations were kindly supplied by* Greenhouse Grower *and Dr Royal Heins.* □