Title:	Bedding Plants: The use of low temperature storage as a scheduling aid in bedding plant production (autumn pansy and primrose)
Project number:	PC 196a
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Contents

Grower Summary

Headline

- Primrose, pansy and viola plugs can be held in cold storage at 3-4°C for several weeks. Primrose plugs still produced marketable plants even after cold storage for up to 16 weeks. Although the pansy and viola plugs stored well for 4 weeks under these temperatures, they appear to require a different environment for longer term storage.

- In terms of plant scheduling, the 16 week plug storage period (transplanting plugs every 4 weeks) produced a sequential marketing period for finished primroses from mid January 2004 to the end of April 2004. The marketing period achieved for finished pansy and viola plants however, was more limited.

- Low temperature storage of plugs will prove a useful tool in the development of plant scheduling programmes, although further research on the effect of day length, light integral and temperature on plant material pre-storage and post transplanting will be required before precise marketing windows can be targeted.

Background and expected deliverables

Accurate plant scheduling has become a critical requirement of successful bedding plant production in recent years. Customers increasingly demand more numerous batches of plants of varying species and varieties, delivered on a range of dates in order to satisfy fluid market demands. This applies as much to plant propagators supplying young plants as it does to growers supplying finished plant material.

The HDC funded trial PC 196 showed the potential of low temperature storage to hold a range of summer bedding plant plugs for a relatively short period of time, 7-14 days, before sale as commercial plugs (as an aid to managing peak demand periods experienced by commercial propagation companies) and for as long as 3 weeks if they were then to be grown on (as an aid to managing peak transplanting periods experienced by producers of finished plant material). This trial was developed as an extension to PC196 to find out if important autumn and winter bedding plant species (primrose, pansy and viola) could be held as plugs in cold storage (to ease short term demand or production peaks) and to also examine the possibility of holding the plug material for a longer time period in an attempt to schedule the production of finished plant material.

As part of PC196a it was envisaged that if seedlings could be allowed to develop under autumn growing conditions into plug plants of sufficient size this would then possibly permit them to initiate flower whilst still in the plug tray. Such plug material could then be cold stored and removed sequentially from storage over a period of time to target specific marketing periods for the finished plants. The prevailing weather conditions post transplanting would then only determine the speed of flower development as opposed to flower initiation.

The project was designed to generate data relevant to both propagators and growers of finished plants, with expected deliverables that include:

- Quantitative information concerning the responses of primrose, pansy and viola plugs to storage at 3-4°C for up to 16 weeks, from September 2003 to January 2004.
- Information on the effects of cold storage on plug and final plant quality and flowering response.
- Identification of effective scheduling regimes for primrose, pansy and viola plugs, using low-cost cold storage facilities.
- The possibility of using low temperature storage to schedule the production of finished plant material.

The information generated should allow plug producers and growers to develop plug storage regimes appropriate to their own specific circumstances. The data should also indicate if scheduling finished plant material is achievable via the use of cold storage alone.

Summary of the project and main conclusions

The trial was designed to evaluate the commercial effectiveness of storing primrose, pansy and viola plugs at 3-4°C for up to 16 weeks, prior to transplanting in an attempt to target key marketing periods for the finished plants. Three varieties of primrose ('Quantum', 'Danova' and 'Alaska'), two varieties of pansy ('Ultima' and 'Dynamite') and one viola variety ('Penny') grown in both 264 and 405 plug trays, were stored at 3-4°C in a refrigerated cargo container for up to 16 weeks, with continuous light from tungsten bulbs producing 5.97 $\mu mol\ m^{-2}\ s^{-1}$ at the plant tray surface. The storage regime began on 22 September 2003 and plugs were removed for transplanting after 4, 8, 12 and 16 weeks of storage, the final batch of plugs coming out of store on 12 January 2004. Control batches of plugs that had not been cold stored were transplanted on the 22 September and 26 November 2003.

Two batches of control plug plants were used in attempt to compare the marketing periods achievable for the finished plants both with and without the use of cold storage.

Treatment and transplanting date for the plugs used in the trial

Treatment	Material transplanted	Transplanting date
No storage (control, batch 1)	Control plugs only, batch 1	22nd September, 2003
4 weeks storage	Cold stored plugs	20th October, 2003
8 weeks storage	Cold stored plugs	17th November, 2003
No storage (control, batch 2)	Control plugs only, batch 2	26th November, 2003
12 weeks storage	Cold stored plugs	15th December, 2003
16 weeks storage	Cold stored plugs	12th January, 2004

After each appropriate period of storage, 108 plugs from each variety and plug tray size were transplanted into double six polystyrene packs using a commercial growing medium. Plug quality and survival rates, final plant quality and survival rates, days to first flower and percentage of plants in flower (including percentage blindness in the case of primrose) were recorded. Marketing periods for each batch of plants were then calculated based on the percentage of plants in flower over time.

Plug quality and survival during storage

Plug quality during storage was assessed every 4 weeks and scored from 0-4, with '4' representing the highest quality and '0' the poorest. Plug habit, height and leaf colour each contributed to the quality score recorded. Comments on plug quality were also made.
The commercially raised plugs used in the trial were, overall, of good quality. However, the viola 'Penny' and some of the pansy 'Ultima' plugs delivered for use in the trial were distorted in growth resulting in many of the plants failing to develop or flower and a percentage died prematurely. As sufficient quantities of replacement plug material were not available, it was decided to continue the trial with the plugs supplied.

The primrose plugs held well in store, all the plugs were acceptable as commercially raised plug plants after 4-8 weeks in cold storage and in many cases the remaining plugs were still suitable for growing on (nursery own use) even after 16 weeks in cold storage. The main problem noted was plug death due to desiccation. The primrose plugs in the 405 trays appeared most prone to this, with losses up to 21.5% noted. The degree of plug loss can be minimised by correct store choice and management, ensuring the store is full (if the air flow is vigorous within the store) and regularly monitoring / irrigating the plug plants (at least weekly). Other factors that influenced overall plug quality was a loss of leaf colour intensity with increased storage period and leaf petiole etiolation, noted towards the end of the trial.

The pansy and viola plugs did not store as well in the long term. Many of the plugs held well for 4 weeks, then the quality scores declined, a result of leaf petiole stretching, lower leaf yellowing, leaf senescence and a general loss of leaf colour. Temperatures below 3-4°C and a different light source to tungsten bulbs may be required for longer term storage. Plug loss during storage, however, was minimal and desiccation was not a real issue as losses never exceeded 4%.

Plant quality and survival post transplanting

Plants were assessed for final plant quality when the double six packs had attained the finished product specification (two to three plants in full flower with further visible flower bud per pack). Final plant quality was assessed using the same scoring procedures and parameters as those used to assess plug plant quality. Comments were also recorded.

Most of the primrose plugs produced good quality finished plants, except for a variable level of plant blindness and the occasional polyanthus stem symptom, no plant abnormalities were recorded. Variations in plant height and habit were noted and towards the end of the trial a high level of leaf extension was noted in response to the improving weather conditions. The variations in height and habit and the leaf extension growth could have been controlled commercially via the use of growth regulators. Only three plant losses were noted post transplanting.

The pansy and viola final quality scores were poor in comparison to the primrose quality scores. The plants struggled to grow away from the distortion noted in the plugs at delivery, resulting in plants that were deformed, uneven, in some cases chlorotic and reluctant to flower. However, a distinct improvement was noted in the quality of the plants that had been stored as plugs for 12-16 weeks. It is not clear why the symptoms disappeared towards the end of the trial, it may have been a reflection of the improving growing conditions following transplanting permitting the plug to recover and grow away. Plant losses were also related to the distortion, following transplanting affected plugs did not particularly grow or establish and quite often died prematurely. Losses were generally around 3-4%, but in one instance reached 14.8%.

Time to first flower and marketable product following transplanting

The time taken for the first plant from each plug storage treatment to flower (irrespective of whether any further flower subsequently followed) and the time taken to attain finished product specification were recorded for each variety from each treatment.

In the case of the primrose varieties, as the trial progressed from autumn into winter the 'Quantum' and 'Danova' plugs took progressively longer to reach first flower post transplanting (September, October and November transplanting dates). The time to first flower then declined for the plugs transplanted later in the trial (December and January). In the case of time to market specification, the time taken remained approximately static through September, October and November and then declined from the December transplanting date onwards. The difference in production times noted corresponded well with changes in day length, light levels and temperature through the period of the trial, those plugs transplanted later, responding to improving weather conditions through late winter / early spring. The data recorded for 'Alaska' was slightly different, on average the time to first flower and market specification decreased as the trial progressed, there was no apparent response to decreasing and then increasing day length and light levels throughout the period of the trial. Effects of plant variety and plug size were also recorded.

The incidence of recorded plant blindness increased to levels of 5-27% as the trial progressed, even though all the plugs that were placed into cold storage were sown in week 32.

In the case of the pansy and viola varieties, as the trial progressed into the winter months all the varieties took progressively longer to reach first flower, as recorded for the plugs transplanted in September, October and November. However, as the day length, light levels and temperatures increased through late winter and early spring, the number of days to first flower declined, as recorded for the plugs transplanted in December and January. The time taken to reach market specification declined for all the varieties from the second transplanting date in October onwards. As with the primroses, effects of variety and plug size were also recorded.

Percentage of plants in flower and potential marketing periods

The percentage of plants in flower was calculated for all treatments from the point of first flower to the attainment of market specification. The information generated for the primroses, pansies and violas enforced the trends reported in the previous section. However, the calculation of percentage levels of flowering over time allowed a more accurate picture of crop development to be built up and it also permitted marketing periods for each variety from each treatment to be calculated.

The start of the marketing periods was represented by at least 10% of the plants in any treatment showing open flower, the end of the period was deemed to be the date when all the plants in any treatment were deemed to be fully marketable or when 50% of the plants in any treatment attained open flower (whichever was recorded first).

The first control treatment and subsequent four cold storage treatments produced a continuous potential marketing period for flowering primroses that stretched from mid January 2004 to the end of April 2004. The three longest storage treatments (8, 12 and 16 weeks) ensured that flowering primroses were available through March and April 2004 covering both Mothers Day and Easter.

In the case of the pansy and viola varieties the marketing period achieved was more limited, irrespective of the number of days the plugs spent in cold storage the marketing period for most of the plants was centered around the month of March 2004. There was limited flower production between late November 2003 and late February 2004.

Conclusions

The results show that primrose, pansy and viola plugs can be effectively held at low temperatures for several weeks. In the case of primrose plugs, temperatures of 3-4°C appeared ideal and permitted the storage of plugs for up to 16 weeks. However, with pansy and viola plugs, storage temperatures below 3-4°C and a light source other than tungsten bulbs may be required if storage exceeds 4 weeks.

The results emphasize how crucial the correct storage environment is for successful storage at low temperatures. Although the good levels of air movement achieved in store throughout the trial effectively limited the incidence of foliar diseases, they also caused desiccation of the primrose plugs, especially those grown in the 405 plug tray.

The trial also showed the potential of low temperature storage as an effective tool when it comes to scheduling production. Low temperature plug storage would permit nurseries to hold plugs back to meet demand peaks during particular production weeks, to expand the time period over which plug material could be made available and used, or to target general marketing periods with finished plant material.

However, cold storage treatments alone appear insufficient to permit growers to target specific marketing dates for all plant species. In the case of primrose, the cold storage treatments worked well producing sequential batches of flowering plants from January 2004 to April 2004, covering two important periods of demand - Mother’s Day and Easter. However, the pansy and viola marketing period attained through the use of the cold storage treatments was altogether more limited. Even though plugs were transplanted over the same 16 week period, most of the plants achieved finished product specification during the month of March 2004, whilst there was insignificant levels of flowering product available through December 2003, January and early February 2004.

Further research work is still required to understand the exact effects of day length, light integral and temperature on flower initiation and development post transplanting. It was envisaged that if plugs could be initiated prior to cold storage, then conditions post transplanting would only affect the development rate of the flowers as opposed to actually determining the precise point of initiation. However, the environmental conditions post transplanting not only had an effect on flower development but also on initiation and, in the case of primroses, on the level of blindness recorded. If accurate plant scheduling is to be achieved for all the important bedding plant species, commercially viable methods of plant manipulation, pre-storage and post transplanting, will have to be explored to permit specific marketing periods to be targeted.

Financial benefits

A cost benefit analysis on the use of cold stores was undertaken as part of PC 196, it highlighted a positive benefit from using cold stores in the following areas: -

- *Reducing wastage* – depending upon the size of the store and the number of plug trays stored, cold stores can actually show a benefit if they reduce plug wastage by as little as 2.5%.

- *Holding crops prior to transplanting* – when hold ups occur during production it can be more cost effective to hold plugs in certain stores for a short while (1-2 days) prior to transplanting than it is to unload and then reload Danish trolleys.

- *Substitution for glasshouse space* – cold stores can be cost effectively used as a substitute for glasshouse space, depending upon the plug tray stack height on the trolley in the cold store.

- *Use of the cold store for seed germination and dormant plant storage* – increases in the germination level of primrose by only 7% was shown to recoup the cost of using a cold store for this purpose in seed cost alone.

Further benefits could be accrued if cold stores are used to help schedule the production of finished plant material to meet marketing targets. In the case of primrose production, demand variations and product availability are often both controlled by the prevailing weather conditions through late winter and early spring. The wholesale price can often drop by over 30% during periods of over supply through February, whilst during late March product may be scarce and a premium offered. Effective scheduling techniques will permit growers to target periods of under production and avoid market gluts. When the techniques become precise enough they may also permit the grower to target specific dates such as Mother's Day and Easter. Scheduling techniques may also open up new market opportunities, for instance if flowering pansies can be programmed for availability during December and January.

Action points for growers

Cold stores capable of maintaining 3-4°C can be used to hold primrose, pansy and viola plugs for at least 4 weeks, longer in the case of primroses if scheduling of finished plant material is to be attempted. The storage facilities do not need to be sophisticated, the trial highlighted that a refrigerated lorry back can provide acceptable storage facilities for this purpose.

- **Cold storage facilities**

  Lorry backs provide efficient air circulation but this, coupled with the expansion cooling system they employ, can lead to the rapid desiccation of plugs, necessitating a frequent irrigation programme.

- **Store temperature and light source**

  Temperatures of 3-4°C were adequate for the long term storage of primrose plugs and for the storage of pansy and viola plugs up to 4 weeks, however lower temperatures may be required for the longer term storage of pansy and viola plugs. The use of tungsten light bulbs in store may have exacerbated the degree of leaf petiole and plant stretch recorded and in the case of longer term storage regimes a light source generated from tubular fluorescent bulbs may be more suitable.

- **Store management**

  Frequent checks on plugs in store are needed to monitor quality levels and assess potential disease problems. Good store hygiene is essential to minimise disease carry over between crops in store.

- **Plant care prior to storage and post storage**

  Any plug material must be of high quality prior to storage. Plugs should be watered before storage, but foliage must be dry before the plugs are placed into store.

- **Plant scheduling**

  The use of cold stores to target marketing periods or to extend the season for plant material is achievable, especially in the case of primroses. Cold stores can be used to halt plug development permitting propagators to store and then offer more plugs during demand peaks or offer plugs outside the usual marketing periods, for example in the case of primroses beyond week 40. In the case of growers of finished plant material, the process would permit growers to place bought in plug material into store either to alleviate logistical problems during periods of peak transplanting or to delay transplanting (with minimal loss of plug quality) to target later marketing periods, for example late March and April with a flowering pot grown primrose crop.

Science Section

Introduction

Attempts at plant scheduling via the cold storage of plugs were demonstrated for bedding plants by work undertaken in the USA (Heins et al., 1992 and 1995; Kaczperski and Armitage, 1992) and, latterly, confirmed by studies relevant to the UK bedding plant industry on a range of summer bedding plant species (Brough, Taylor and Grout, 2004). This latter work (PC 196) showed that effective storage for up to four weeks could be achieved for a range of bedding plants (Table 1) and indicated that there was significant potential for expanding the range of plant species for which the technique might have commercial application.

Table 1. Recommended maximum cold storage periods for a range of bedding plant plugs (Brough, Taylor and Grout, 2004).

	4°C storage		**8°C storage**	
	Commercial plug quality*	***Acceptable quality plug●***	***Commercial plug quality****	***Acceptable quality plug●***
Alyssum	7 days	14 days	7 days	7-14 days
Antirrhinum	14 days	21-28 days	7-14 days	21-28 days
Begonia	14 days	21-28 days	7-14 days	21-28 days
Dahlia ∇	7 days	21 days	7 days	14-21 days
Geranium	7-14 days	28 days	7 days	21 days
Impatiens ∇	0-7 days	0-7 days	0-7 days	0-7 days
Lobelia	14 days	28 days	7-14 days	21-28 days
Marigold	14 days	21-28 days	14 days	21-28 days
Nemesia ∇	7 days	14 days	7 days	14 days
Petunia	7-14 days	21 days	7 days	21-28 days
Salvia ∇	7 days	21 days	7 days	14-21 days
Verbena	7-14 days	21 days	7 days	14-21 days

∇ Severe to moderate chilling injury noted with these subjects.
* plugs for direct sale
• plugs held prior to transplanting

PC 196a was designed to build on the work from these previous trials and to extend the evaluation of cold storage treatments to cover the important autumn and winter bedding plant crops – primrose, pansy and viola. The main objectives of the study were threefold: -

- To investigate low temperature responses of pansy, viola and primrose plugs
- To examine the effects of low temperature storage on plug and final plant quality and flowering times
- To evaluate the low temperature storage of plug plants over a much longer period of time (16 weeks) as a method of scheduling the production of finished autumn primrose, pansy and viola crops.

In this particular trial, cold storage treatments were not only examined for their suitability to hold bedding plant plugs in the short term, but to also investigate whether the plugs could be held over a much longer period of time in an attempt to target important marketing dates with the finished plant material.

Work by Karlsson, 2002, Pearson et al., 1996, Maslen, 2002 and Pearson et al., 1998 indicated at the commercial possibility of scheduling primrose and pansy plants. It was envisaged that if plug plants could initiate flower whilst still in plug trays, then the plugs could be held in cold storage and removed and transplanted at set periods throughout the autumn to produce batches of flowering plants to meet specific marketing dates. Weather conditions post transplanting would then only determine the rate of flower development as opposed to the actual time of flower initiation.

As with the previous low temperature storage trial (PC 196), this study was designed to be observational with no statistical analysis of data.

Material and Methods

Three varieties of primrose (an early, mid-season and late series), two varieties of pansy (a large and a medium flower sized series) and one viola variety were used in the trial. All the plants were supplied as commercially raised plugs in two tray sizes – 405 and 264 plug trays. Two batches of control plants were used to compare the level of scheduling achievable using two transplanting dates as opposed to cold storing one set of plugs over a 16 week time period and transplanting a batch of plugs every 4 weeks.

Table 2. Primrose, pansy and viola plug material used in the trial.

Primrose			Pansy / Viola		
Variety	***Type***	***Plug age on delivery***	***Variety***	***Type***	***Plug age on delivery***
Quantum (blue)	Early	*405 – 6 wks 264 – 6 wks	Ultima (‘Orange Blotch’)	Medium flower	*405 – 5 wks 264 – 6 wks
		•405 – 9 wks 264 – 10 wks			•405 – 8 wks 264 – 9 wks
Danova (blue)	Mid-season	405 – 6 wks 264 – 6 wks	Dynamite (orange)	Large flower	405 – 4 wks 264 – 6 wks
		405 – 8 wks 264 – 8 wks			405 – 8 wks 264 – 9 wks
Alaska (yellow)	Late	405 – 6 wks 264 – 6 wks	Penny (‘Orange Sunrise’)	Viola	405 – 5 wks 264 – 6 wks
		405 – 9 wks 264 – 10 wks			405 – 8 wks 264 – 9 wks

* The plug age for the first 405 and 264 trays for each variety relate to those delivered on the 18 September 2003 (control batch 1 and all the cold stored treatments).
• The plug age for the second 405 and 264 trays for each treatment relate to those delivered on the 21 November 2003 (control batch 2).

The plugs were produced by Roundstone Nurseries and delivered to the trial site (Writtle College) on 18 September 2003. Upon delivery the plants were placed on a bench in a single span glasshouse and watered. The plugs were held in the glasshouse until the 22 September 2003 to allow the plugs to recover from any transport stress before being placed into cold storage.

Wayne Brough, ADAS Horticultural Consultant, and Robyn Taylor, Writtle College Trials Officer inspected the plugs for quality on the 19 September. The primrose plugs were of good commercial quality. However, there was very little difference in actual plant size between the plugs in the 405 tray and the 264 tray (a result of similar sowing times). ‘Quantum yellow’ was substantially smaller than the two other primrose varieties in both tray sizes. In general most of the pansy and viola plugs were of good commercial quality. However, it was noted that viola ‘Penny Orange Sunrise’ in the 264 trays suffered from a distortion of the growing point, with 50–60 % of the plugs in the tray being affected. To a lesser extent, similar symptoms were also observed on the pansy ‘Ultima Orange Blotch’, again primarily in the 264 plug tray. The growing point appeared scarred and deformed, with a lack of new growth (Appendix 1). As insufficient replacement plant material was available these plugs were used in the trial.

All the trays were watered on the 22 September and left for 2-3 hours to ensure the foliage was dry. All the trays (except the control plugs which were transplanted by hand on the same day) were then placed onto Danish trolleys prior to transfer to the cold store. The storage facility used was a low specification refrigerated cargo container, with a low output interior tungsten lighting (Plate 1) providing a continuous light source 24 hours a day. The target storage temperature was 4°C and the mean light level generated by the tungsten lights in store was 5.97 μmol m^{-2} s^{-1} (as measured at the mid height of a plug in the centre of a plug tray). The plug trays were watered as necessary (typically every 7 days). The Danish trolleys were removed from the store when irrigation was required, and replaced after free water had drained through the tray and the foliage had dried to reduce the risk of *Botrytis* infection.

Plate 1. Refrigerated cargo container used for storing the plugs during the trial.

Plugs were inspected for disease and quality at monthly intervals over the 16 week storage period and any comments were recorded. Photographs were taken of the plug trays at regular intervals. The cold store temperature was continuously recorded using a data logger placed on the surface of a plug tray (Figure 1). No fungicide treatments were necessary whilst the plugs were in store.

The second batch of control plugs (identical plant series) was received on the 21 November 2003. These were handled in an identical fashion to the first batch of control plants and remained in the glasshouse before transplanting into trays on the 26 November 2003. Once again a degree of distortion was noted on the second batch of pansy and viola plugs.

Plugs for transplanting were taken as continuous rows from the appropriate plug trays. Plugs in cold storage were transplanted every 4 weeks over the 16 storage period on the dates presented in Table 3.

Table 3. Treatment and transplanting date for the plugs.

Treatment	Material transplanted	Transplanting date
No storage (control, batch 1)	Control plugs only, batch 1	22nd September, 2003
4 weeks storage	Cold stored plugs	20th October, 2003
8 weeks storage	Cold stored plugs	17th November, 2003
No storage (control, batch 2)	Control plugs only, batch 2	26th November, 2003
12 weeks storage	Cold stored plugs	15th December, 2003
16 weeks storage	Cold stored plugs	12th January, 2004

108 plugs of each plant variety from each plug tray size were transplanted into 9 double six polystyrene packs at each transplanting date (1,296 plugs were transplanted on each date). Transplanting was by hand into SHL proprietary Pot and Bedding Compost. Following transplanting the double six packs were placed on the glasshouse floor.

The glasshouse used in the trial was a single span structure with automatic vents, set to vent at 13 °C. The pipe heating system was set at frost protection (creating a minimum night temperature of 3°C). Glasshouse temperatures were recorded using a data logger place in a sheltered position out of direct sunlight (Appendix 2). Humidity records were not maintained. The plants were placed on beds consisting of upturned polystyrene trays (to ensure drainage and to lift the bed level with the paths), covered with capillary matting and then Mypex. Plants were hand-watered using a lance and fed with Sangral 3:1:3 liquid fertiliser (diluted at 1:200) after 4 weeks, and then subsequently at every watering to the point of marketing.

Data recorded during the trial included: plug and plant survival, quality of stored plugs and finished plants (a 0-4 quality scoring system along with written comments), days to first flower, percentage of plants in flower and days to marketable product (the specification being a minimum of two to three open flowers and visible flower bud in each tray). Colour photographs were taken of the plugs following transplanting and again when all the plants within a treatment had reached a marketable stage.

To determine plug survival during storage, the number of dead plants in a tray was counted every 4 weeks. Plant survival was determined at regular intervals (weekly) after transplanting by counting the number of dead plants that occurred in each treatment.

The plug and plant quality score was based on a qualitative scoring system where '4' represented the highest quality plug / plant and '0' a plug / plant of the poorest quality. The scoring system assessed leaf colour, plant habit and height as separate assessment criteria. The scoring system used for height reflected the general size and height of the plant and also the uniformity of plug / plant height within a tray / pack. Each plant species was assessed independently as to the general appearance and growth habit. Plug quality during storage was assessed every 4 weeks. Final plant quality was assessed when all the double six packs in a particular treatment had reached the marketable stage.

Assessment for first flower and percentage flowering were performed at regular intervals through out the growing period. The day on which the first open flower was seen in any of the 108 plants in a particular treatment represented the time to first flower. On a number of occasions, especially in the case of the pansy and viola varieties, odd plants would come into flower well in advance of the rest of the other plants. This was still recorded as time to first flower, even though in a number of cases further flower was not immediately produced by the remaining plants. The number of open flowers were counted per treatment so that the percentage of plants in flower could be calculated, this produced a better indication of flower development within a treatment.

Days to marketable product was taken as the time between the day of transplanting and the day when the treatment as a whole reached the marketable stage.

Due to a problem noted on the pansies and violas which was first noted on the plugs at delivery but also affected the plants post transplanting (primarily plant distortion, stunting, leaf yellowing and premature plant death) growing media and leaf tissue samples were sent away for analysis to try and determine the cause. The results are presented in Appendix 3. Unfortunately the exact cause of the problem was never determined.

During early March an isolated aphid outbreak occurred on the plants in the glasshouse and an application of Aphox (pirimicarb) was made on the 12 March 2004. The aphid population was then subsequently controlled using a single application of the aphid parasite *Aphidius colemani* (Aphiline C), applied a week after application of the Aphox treatment.

Results and Discussion

Cold store performance

The cold storage facility used in the trial was a re-commissioned refrigerated cargo container that had been refitted to include an interior door handle, panic button with alarm, and interior lighting. A temperature gauge had also been fitted to the front of the container along with an access ramp and lockable security bar (Plate 1). The cold store temperature air supply was set at 3°C with the aim of maintaining an average store temperature of no more than 4°C. Store temperature was recorded hourly throughout the storage period using a data logger placed on a plug tray to obtain the temperature range the plugs were exposed to (Figure 1).

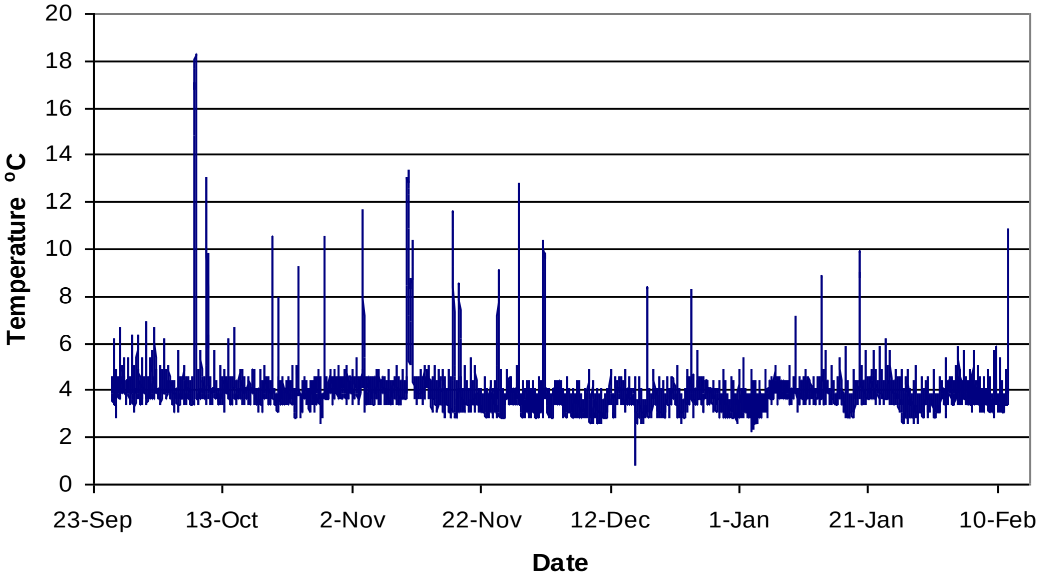


Figure 1. Temperature records during the plug low temperature storage period.

Peaks in the temperature correspond to when plugs trays were removed from the store and remained outside in the prevailing climatic conditions while assessments and irrigation were undertaken. The average store temperature for the storage period was 3.9°C, with slight drops in temperature occurring during the winter months of December and January when outside temperatures during this period were lower than the actual store temperature. This demonstrates that relatively inexpensive, low specification storage facilities can be used with confidence to provide relatively accurate low temperature storage conditions.

The direct expansion cooling unit found in this type of cold store did have a high rate of air circulation which led to plug desiccation and death. This was a potential problem especially with the smaller plug tray (405). However, the drying effect of the air was reduced somewhat when a greater number of Danish trolleys were placed into store. The increased number of trolleys helped to break up much of the direct air movement across the shelves containing the plug trays. One major benefit of the high rate of air movement was the negligible disease levels noted on the plugs, only low levels of *Botrytis cinerea* occurred towards the end of the trial. No fungicide applications were required during the 16 week low temperature storage period.

Growing environment

After the appropriate period of storage, the plug plants were transplanted into polystyrene packs and placed in a single span glasshouse with minimal pipe heating to provide frost protection. The glasshouse temperatures were recorded using a data logger and the average temperature in the glasshouse for the growing period of each treatment is shown in Table 4. The glasshouse temperature remained reasonably consistent throughout the trial period for all treatments. The average growing temperatures were slightly higher in the first and last treatments, while the lowest temperatures were recorded for those treatments exposed to the peak winter conditions.

Table 4. Average glasshouse temperature for the growing period of each treatment.

Treatment	Control, batch 1	4 weeks cold storage	8 weeks cold storage	Control, batch 2	12 weeks cold storage	16 weeks cold storage
Growing period	23 Sept 2003 – 3 Mar 2004 (Weeks 39-10)	21 Oct 2003 – 10 Apr 2004 (Weeks 43-15)	18 Nov 2003 – 11 Apr 2004 (Weeks 47-15)	27 Nov 2003 – 16 April 2004 (Weeks 48-16)	16 Dec 2003 – 24 April 2004 (Weeks 51-17)	13 Jan 2004 – 3 May 2004 (Weeks 03-19)
Average temperature	11.7°C	10.7°C	10.5°C	10.4°C	10.8°C	11.0°C

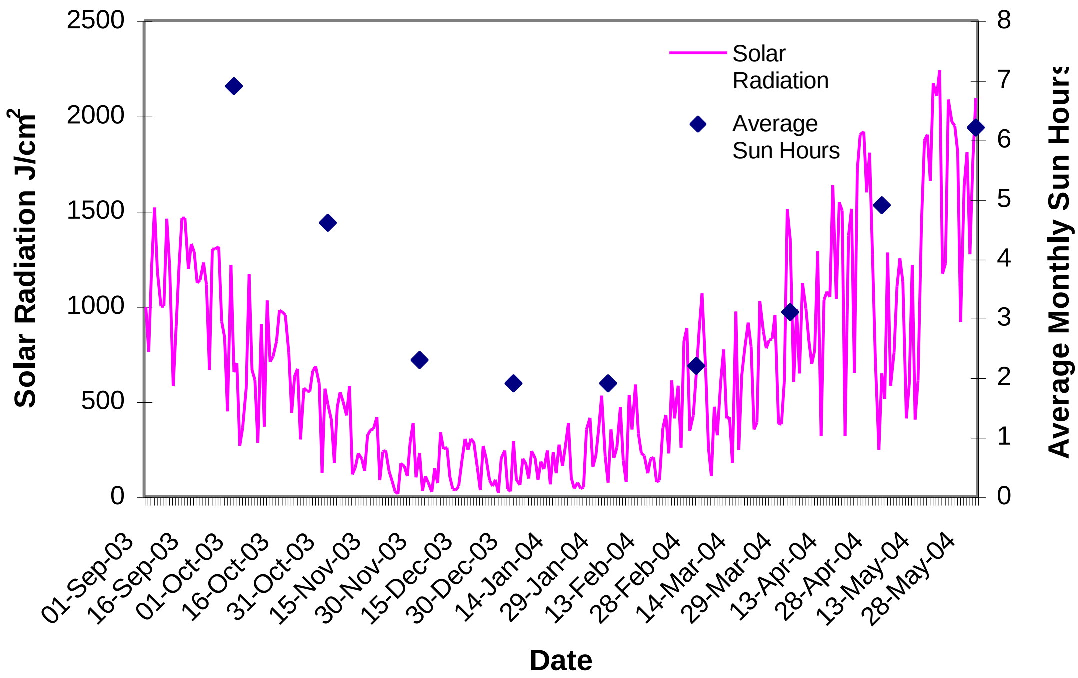


Figure 2. Daily solar radiation and monthly average sun hours during the trial period.

Weather records collected from the Writtle College meteorological station provide the daily solar radiation and average daily sun hours (Figure 2) for the growing periods of all the treatments. Daily solar radiation and average daily sun hours follow predictable patterns with both radiation and sun hours dropping during winter months. December had the lowest total monthly radiation of 4585 J/cm^2 and average daily sun hours of 1.9 hours.

Primrose Varieties

Plug survival during storage

The percentage of plug plants which died during storage was determined for each 4 week period of cold storage (Table 5). Actual plug losses were recorded for all the primrose varieties in the trial from week 4 of storage onwards. The percentage of plug plants lost was much higher in the 405 trays than in the 264 trays throughout the whole storage period.

Table 5. Percentage loss of primrose plug plants during storage.

Variety	4 weeks storage	8 weeks storage	12 weeks storage	16 weeks storage
Quantum 405	5.3	9.1	10.0	11.6
Quantum 264	0.5	1.4	2.0	2.5
Danova 405	11.7	21.5	21.5	21.5
Danova 264	1.0	1.0	1.0	1.1
Alaska 405	12.1	12.6	14.0	14.8
Alaska 264	0.3	0.5	0.5	0.5

Although low levels of *Botrytis cinerea* were noted developing on dead plugs and damaged foliage the primary cause of plug death was desiccation, a result of the relatively strong air flow through the cold store (Plate 2).

Plate 2. Plug desiccation and death in Primrose ‘Danova Blue’ (405 tray).

Plugs in the smaller cell size of the 405 tray proved more susceptible to the drying effects of the air movement within the store, a result of the smaller water reserve held within the growing media. Once dry, the growing medium in the cell also proved difficult to re-wet again. With a more frequent irrigation regime these losses could have been reduced, however the additional costs associated with removing the plugs from store and watering them on a more frequent basis needs to be balanced against the improved survival rate to be an economically viable exercise.

Plug loss during storage was less of a problem for the plugs grown in the larger 264 plug tray. The larger volume of growing medium, and therefore available water reserve, helped to support the plug against the drying effect of the air movement for a longer time period. However, the maximum number of plugs that can be held in any given storage area using 264 plug trays will be fewer relative to plugs held in 405 trays.

Plug quality during storage

The plugs were assessed for leaf colour, habit and height upon delivery and every 4 weeks whilst in cold storage. Each parameter was assigned a score from 0 to 4, with 0 representing poor quality and 4 excellent quality. The maximum total value achievable was therefore 12. ‘Control batch 1’ and ‘control batch 2’ received no cold storage treatment, and were assessed for quality on arrival at Writtle College. All the other treatments were assessed at the point of transplanting into polystyrene packs after their appropriate storage period (Table 6).

More detailed comments concerning plug plant quality were made over the cold storage period and are presented in Table 7. As can be seen from the scores and comments, plug quality remained at reasonable levels throughout the entire 16 week storage period of the trial. All the plugs were acceptable as commercially raised plug plants after 4-8 weeks in cold storage, whilst those in the 264 trays were still, in some, cases acceptable after 12 weeks storage (Plate 3).

Plate 3. Primrose ‘Quantum Blue’ (264 tray) after 12 weeks cold storage.

As a result of plug loss due to desiccation, the 405 trays were not acceptable from around 4 weeks onwards, although the remaining plugs were of good quality.

Table 6. Plug quality scores for the primrose varieties.

		Control, batch 1	4 weeks storage	8 weeks storage	Control, batch 2	12 weeks storage	16 weeks storage
Quantum 405	Colour	4	4	4	4	3	2
	Habit	4	4	4	4	3	3
	Height	3	3	3	4	3	3
	Total	**11**	**11**	**11**	**12**	**9**	**8**
Quantum 264	Colour	4	4	4	4	3	3
	Habit	4	4	4	4	4	3
	Height	3	3	3	4	3	3
	Total	**11**	**11**	**11**	**12**	**10**	**9**
Danova 405	Colour	4	4	3	4	3	2
	Habit	4	4	4	4	4	3
	Height	4	4	4	4	4	3
	Total	**12**	**12**	**11**	**12**	**10**	**8**
Danova 264	Colour	4	4	4	4	3	3
	Habit	4	4	4	4	4	3
	Height	4	4	4	4	3	3
	Total	**12**	**12**	**12**	**12**	**10**	**9**
Alaska 405	Colour	4	4	4	4	3	2
	Habit	4	4	4	4	3	3
	Height	4	4	4	4	4	3
	Total	**12**	**12**	**12**	**11**	**10**	**8**
Alaska 264	Colour	4	4	4	4	3	2
	Habit	4	4	3	4	3	3
	Height	4	4	4	4	4	3
	Total	**12**	**12**	**11**	**12**	**10**	**8**

(0 = Poor; 4 = Excellent)

Apart from losses due to desiccation, the main factor that influenced overall plug quality was a reduction in the intensity of leaf colour, the foliage on the plugs becoming paler with increased time in cold storage. This loss of colour was probably a result of the low light conditions (the light generated from tungsten bulbs is not particularly suitable as replacement lighting) in store leading to the degradation of chlorophyll within the leaf (and possibly nutrient deficiency). Etiolation of the leaf petioles also began to occur towards the end of the storage period, leading to a slight reduction in the plant habit and height quality scores attained. The plugs however were still suitable for growing on (nursery own use) even after 16 weeks in cold storage.

Due to the small size of the 'Quantum' plug plants at delivery, the quality score for height for all storage periods was slightly lower than the other two primrose varieties.

Table 7. Qualitative assessment of the primrose plugs during storage.

Variety	Storage treatment and comments
Quantum (blue) 405	Control batch 1 – Significantly smaller plugs compared to other two varieties with 2–3 expanded leaves. Uniform size with good leaf colour. Control batch 2 – Uniform plugs of good size and habit. Good foliage colour. 4 Weeks – Plugs still small (no development in store), some plugs (especially around edge of tray) stressed due to drying out. 8 Weeks – Plugs still small, beginning to pale in leaf colour, low level of lower leaf yellowing. First signs of *Botrytis* on desiccated plugs. 12 Weeks – More plug losses due to desiccation (10%), *Botrytis* developing on dead plugs. Foliage pale green. 16 Weeks – *Botrytis* still present on dead plugs. Foliage pale green, with lower leaf yellowing. Plugs still small.
Quantum (blue) 264	Control batch 1 – Plugs small compared to the other two varieties, no difference in plug size between the 405 and 264 cell sizes. Control batch 2 – Uniform plugs with good leaf colour. 4 Weeks – Plugs still small but with good leaf colour. 8 Weeks – Plugs still small, but leaf colour still good. 12 Weeks – Odd plug losses due to desiccation. Foliage still reasonable good colour. 16 Weeks – Plugs still small, but of reasonable colour, some stretching of leaf petioles.
Danova (blue) 405	Control batch 1 – Uniform plugs of good size and leaf colour with 3-4 expanded leaves. Control batch 2 – Uniform plugs of good size, habit and leaf colour. 4 Weeks – First signs of general paling in leaf colour. Some desiccation stress noted. 8 Weeks – Plugs beginning to pale in colour, with occasional yellow lower leaf. Losses due to desiccation noted (10-15%). 12 Weeks – 15-20% plug losses due to desiccation, no disease development. Foliage paler in colour. 16 Weeks – Pale foliage on plugs but no evidence of disease or leaf stretching.

Variety	Storage treatment and comments
Danova (blue) 264	Control batch 1 – Uniform plugs, although again no difference in size between 405 and 264 cell sizes. Control batch 2 – Uniform plugs of good size and leaf colour. 4 Weeks – First signs of general paling in leaf colour. 8 Weeks – Plugs beginning to look pale in colour, but no leaf yellowing evident. 12 Weeks – Odd plug losses due to desiccation. Foliage slightly pale. 16 Weeks – Leaf colour pale, but still reasonable. Leaf petiole stretching and a low level of lower leaf yellowing noted.
Alaska (yellow) 405	Control batch 1 – Uniform plugs of good size and leaf colour with 3-4 expanded leaves. Control batch 2 – Uniform plugs, relatively large compared to other two varieties. 4 Weeks – Very slight yellowing in first true leaves. Some plug desiccation noted. 8 Weeks – Plugs beginning to pale, lower leaf yellowing noted. Losses due to desiccation noted (10-15%). 12 Weeks – 15% losses due to desiccation. Plants pale in appearance, with lower leaf yellowing. 16 Weeks – Losses evident. Plugs pale in colour with yellowing and necrosis noted on lower leaves. *Botrytis* beginning to develop.
Alaska (yellow) 264	Control batch 1 – Good sized plugs (if a little variable) with good leaf colour. Control batch 2 – Uniform plugs, relatively large compared to other two varieties. 4 Weeks – A general paleness noted to leaf colour. 8 Weeks – Plugs beginning to pale with a low level of lower leaf yellowing. 12 Weeks – Odd plug loss due to desiccation. Plants slightly pale with some yellowing of old foliage. 16 Weeks – Leaf colour pale, with some yellowing of lower foliage. Leaf petiole stretching noted.

Plant survival post transplanting

Only three losses were recorded throughout the trial post transplanting, all were 8 week cold storage treatments. Two plants were 'Quantum' originally from a 264 plug tray and the third was 'Danova' from a 405 plug tray. The reason for the three plant losses was not determined.

Final plant quality

Plants were assessed for final plant quality when the double six packs had attained the finished product specification, which for the purposes of this trial were assumed to be at least two to three plants in full flower with further visible flower bud. Final plant quality was assessed as previously described for plug quality. Plant leaf colour, habit and height were assessed, and assigned a score of 0 to 4, with 0 being of poor quality and 4 excellent. A maximum score of 12 was therefore achievable (Table 8). A qualitative plant assessment was also undertaken (again when the finished product specification had been attained) and the comments are presented in Table 9.

Table 8. Final plant quality scores for the primrose varieties.

		Control batch 1	4 weeks storage	8 weeks storage	Control batch 2	12 weeks storage	16 weeks storage
Quantum 405	Colour	4	4	4	4	4	4
	Habit	4	3	4	4	4	4
	Height	4	3	4	4	3	4
	Total	**12**	**10**	**12**	**12**	**11**	**12**
Quantum 264	Colour	4	4	4	4	4	4
	Habit	4	4	4	3	4	3
	Height	4	3	4	2	2	3
	Total	**12**	**11**	**12**	**9**	**10**	**10**
Danova 405	Colour	4	4	4	4	4	4
	Habit	4	4	4	3	4	4
	Height	4	4	4	3	3	4
	Total	**12**	**12**	**12**	**10**	**11**	**12**
Danova 264	Colour	4	4	4	4	4	4
	Habit	4	3	3	4	4	4
	Height	4	3	4	2	3	4
	Total	**12**	**10**	**11**	**10**	**11**	**12**
Alaska 405	Colour	4	4	4	4	4	4
	Habit	4	4	4	4	3	3
	Height	4	3	3	4	3	3
	Total	**12**	**11**	**11**	**12**	**10**	**10**
Alaska 264	Colour	4	4	4	4	4	4
	Habit	4	3	4	4	3	3
	Height	4	3	4	4	3	3
	Total	**12**	**10**	**12**	**12**	**10**	**10**

(0 = Poor; 4 = Excellent)

Most of the plugs produced good quality finished plants (Plate 4). Except for a variable level of plant blindness (see section on plant blindness) and the occasional polyanthus stem symptom, no plant abnormalities were recorded. Some variation in height, habit and flowering response was occasionally noted with some varieties, but chemical plant growth regulators were not applied to the plants at any point in the trial to avoid masking any treatment effects on plant habit and development.


Control batch 1


4 weeks storage


8 weeks storage


Control batch 2


12 weeks storage


16 weeks storage

Plate 4. Packs of Primrose 'Quantum Blue' grown from '405 plugs' (plug storage dates indicated under each picture).

Table 9. Qualitative assessment of the finished primrose plants at marketing.

Variety	Storage treatment and comment
Quantum (blue) 405	Control batch 1 – Leafy plants of uniform size. Some variation in flowering response. Control batch 2 – High quality plants of good height, habit and colour. Some variation in flowering. 4 Weeks – Good leaf colour, but some variation in height and habit. Some variation in flowering response, some plants still in tight bud. 8 Weeks – Good quality plants of uniform height, habit and colour. Although variable flowering response. 12 Weeks – Plants of good habit, with good foliage and flower colour. Some variation in flowering response, with some plants still in bud. 16 Weeks – High quality uniform compact plants, with good flowering.
Quantum (blue) 264	Control batch 1 – Leafy plants of uniform size, with reasonably uniform flowering. Control batch 2 – Good leaf colour, however height and habit variable. Variability in flower response, buds in some plants barely visible. 4 Weeks – Good leaf colour, with some variation in plant height, some small plants. 8 Weeks – Good compact plants of uniform height and habit. Some variation in flowering. 12 Weeks – Good foliage colour, good habit, although plants slightly small with some variability in height. Reasonable even flowering. 16 Weeks – Plants of uniform height and habit, with good flowering response.
Danova (blue) 405	Control batch 1 – Leafy plants of uniform size. Good uniform flowering throughout the treatment block. Control batch 2 – Very large leafy plants, although uniform in height and habit. Reasonably uniform flowering throughout. 4 Weeks – Good quality plants of uniform height, habit and flowering response. 8 Weeks – High quality marketable plants. Uniform height, habit and flowering response. 12 Weeks – Very large leafy plants, with good uniformity and foliage colour. 16 Weeks – High quality marketable plants of uniform height, habit and colour. Good uniform flowering throughout.

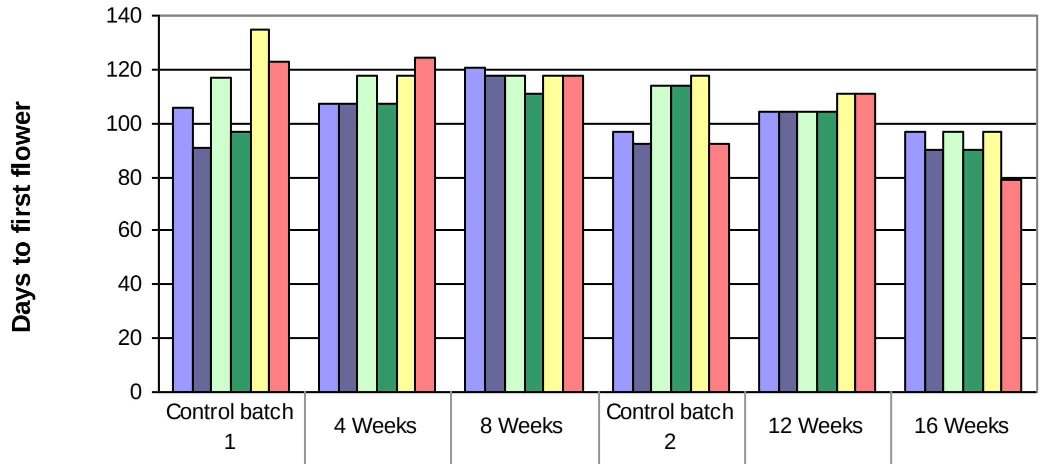
Variety	Storage treatment and comment
Danova (blue) 264	Control batch 1 – Leafy plants of uniform size. Good uniform flowering throughout. Control batch 2 – Good foliage and flower colour. Good compact habit and height, with some small plants. 4 Weeks – Good leaf colour, with some variation in plant height and flowering. 8 Weeks – Large leafy plants of uniform height and habit. Some plants still in tight bud. 12 Weeks – Large leafy plants of uniform height and habit. Some variability in flowering response, with some plants in tight bud. 16 Weeks – High quality marketable plants of uniform height, habit and colour.
Alaska (yellow) 405	Control batch 1 – High quality plants, with uniform habit and height. Control batch 2 – High quality marketable plants. Large leafy uniform plants. 4 Weeks – Good quality plants with uniform flowering. Good uniform height and habit, apart from some smaller plants on pack edges. 8 Weeks –Large leafy plants with minor variation in plant size. Reasonably good uniform flowering. 12 Weeks – Large leafy plants, with good flower and foliage colour. Uniform height and habit. Flowering response not uniform. 16 Weeks – Plants large and leafy, but uniform in height and habit. Slight variation in flowering response.
Alaska (yellow) 264	Control batch 1 – Good quality plants. Uniform height and habit, with uniform flowering. Control – High quality marketable plants. Large leafy uniform plants. 4 Weeks – Good flower and foliage colour. Some variation in height and habit, with some plants being very large and leafy. 8 Weeks – Good quality plants although large and leafy, with a good uniform flowering response. 12 Weeks – Large leafy plants, with good flower and foliage colour. Uniform height and habit. 16 Weeks – Plants large and leafy, but uniform in height and habit. Uniform flowering throughout.

Two of the varieties, 'Danova' and 'Alaska', tended to be generally leafy in habit and towards the end of the trial (12 and 16 week storage treatments) there was a prominent level of leaf extension in response to the prevailing weather conditions post transplanting. If the crops were being grown commercially, a growth regulator spray programme would have been applied to improve plant habit and restrict leaf extension. In contrast the variety 'Quantum' remained compact for most of the period of the trial.

The aphid outbreak towards the end of the trial did affect the vigour of some plants, notably the control batch 2 - 'Danova' from the 264 plug tray and 'Quantum' from the 264 plug tray. Some of the plants within these treatments were a little stunted at the point of assessment as a result of the aphids feeding in the growing points of the plants. The symptoms were hidden to an extent by the more vigorous healthy plants growing in the same pack.

Time to first flower

The number of days from transplanting to first flower for each treatment is presented in Figure 3. As the trial progressed into the winter months the 'Quantum' and 'Danova' plugs took progressively longer to reach first flower, post transplanting. Those transplanted during September (control batch 1), October (4 weeks storage treatment) and November (8 weeks storage treatment) taking on average 103, 110 and 117 days to first flower. However, plugs transplanted during December (12 weeks storage treatment) and January (16 weeks storage treatment) took on average 104 and 93 days to flower. This is the expected situation if flower initiation had occurred in the plug stage and the rate of flower development was being determined by changes in day length, light intensity and temperature post transplanting.



	Control batch 1	4 Weeks	8 Weeks	Control batch 2	12 Weeks	16 Weeks
Quantum 405	106	107	121	97	104	97
Quantum 264	91	107	118	92	104	90
Danova 405	117	118	118	114	104	97
Danova 264	97	107	111	114	104	90
Alaska 405	135	118	118	118	111	97
Alaska 264	123	124	118	92	111	79

Treatment

Figure 3. Days after transplanting to first flower for each storage treatment.

As noted in Figure 2, the average monthly sun hours and solar radiation levels recorded at Writtle College declined rapidly from October onwards, reaching their lowest levels during December and January. Average glasshouse temperatures also slightly declined over this period (Table 4).

The recorded levels then began to rapidly increase from mid February 2004 onwards. These differences in the prevailing environmental conditions led to the differences recorded in time to first flower. Plugs transplanted in January came into flower on average 21 days quicker relative to those transplanted in September.

Flowering times recorded for 'Alaska' were slightly different to those recorded for the other two varieties. On average, time to first flower decreased throughout the trial, there was no apparent response to decreasing and then increasing day length and light levels. This may be a result of the genetic characteristics of the variety. 'Alaska' being a late variety may perform better than the other two under the lower light levels and shorter days experienced during mid-winter.

The influence of photoperiod, light integral and temperature on the flowering of primrose was recorded by Karlsson in 2002. Work by Karlsson on 'Dania Lemon Yellow' indicated that flower initiation and development occurred faster when temperatures were maintained at 12°C or more, day length was 14-18 hours and light levels were at least 10-12 mol m^{-2} per day. Short days resulted in a longer period before flowering occurred. The results obtained from this trial broadly agree with Karlsson's findings, however as detailed environmental records were not maintained as part of the trial it is difficult use Karlsson's results to validate the trial results.

As expected, time to first flower was also related to primrose variety. The plugs potted early in the trial (no storage and 4 weeks storage treatment) came into flower as expected in order of season of the variety. 'Quantum' being an early variety flowered first, 'Danova' being an early – mid season variety flowered slightly later, whilst Alaska being a late variety came into flower last. The difference between flowering times may have also been exacerbated by flower colour. As reported by Pearson et al., 1996 and Maslen, 2002 time to first flower within a primrose series is often linked to flower colour, blue flowered varieties within a primrose series usually emerging ahead of other flower colours. Therefore the difference in time to first flower between the blue flowered 'Quantum' and 'Danova' varieties in comparison to the yellow flowered 'Alaska' may have been exaggerated slightly as a result of flower colour.

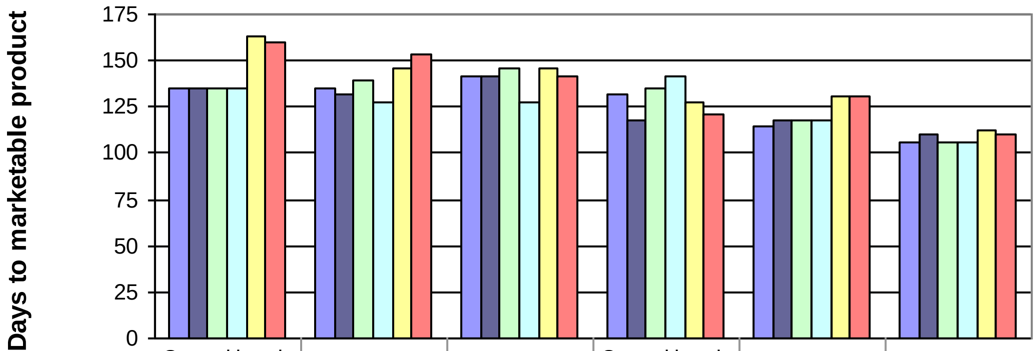
However, as can be seen from the results, any varietal differences in the time to first flower were reduced as the trial progressed, until by the final transplant date (16 weeks storage treatment) all three primrose varieties were coming into flower at approximately the same time irrespective of 'flowering season'. This may be a result of the extended cold storage treatment experienced by the plugs, however a more likely explanation is that the prevailing weather conditions following transplanting (increasing day length and improving light levels) were more influential than the genetical 'flowering season' of the variety in determining the time taken to flower during early spring.

Throughout the trial, the plug cell size had an influence on time to first flower for all three primrose varieties. For most transplanting dates, the plants which originated from 264 plugs came into flower before those that originated from 405 plugs. This difference was as great as 26 days in the case of ‘Alaska’, transplanted during November (control batch 2).

The results also appear to indicate a potential delay in the onset of flowering as a result of cold storage. This can be seen when comparing the second batch of control plants transplanted on 26 November (control batch 2) with plugs that had been cold stored for 8 weeks and transplanted 9 days prior on 17 November. All the ‘control batch 2’ plants except ‘Danova’ in the 264 plug tray and ‘Alaska’ in the 405 plug tray came into flower before those which had been cold stored. It is not known if this time difference is actually due to the effects of cold storage or the relative age of the plugs used in the trial. The primrose plugs that were placed into cold storage were 6 weeks old upon delivery and although they subsequently spent 8 weeks in cold storage they made little growth over this period. However, the plugs used for the second control batch were 8-10 weeks old upon delivery and the more rapid development of these plants may simply be the result of older starting material than any delay induced by long term cold storage.

Time to marketable product

As previously mentioned the finished product specification (per double six pack) was assumed to be at least two to three plants in full flower with further visible flower bud. The time taken to achieve this marketable product for *all* the packs in a particular treatment is presented in Figure 4.



	Control batch 1	4 Weeks	8 Weeks	Control batch 2	12 Weeks	16 Weeks
Quantum 405	135	135	142	132	114	106
Quantum 264	135	132	142	118	118	110
Danova 405	135	139	146	135	118	106
Danova 264	135	127	128	142	118	106
Alaska 405	163	146	146	128	131	112
Alaska 264	160	153	142	121	131	110

Treatment

Figure 4. Days after transplanting for each treatment to reach a marketable product.

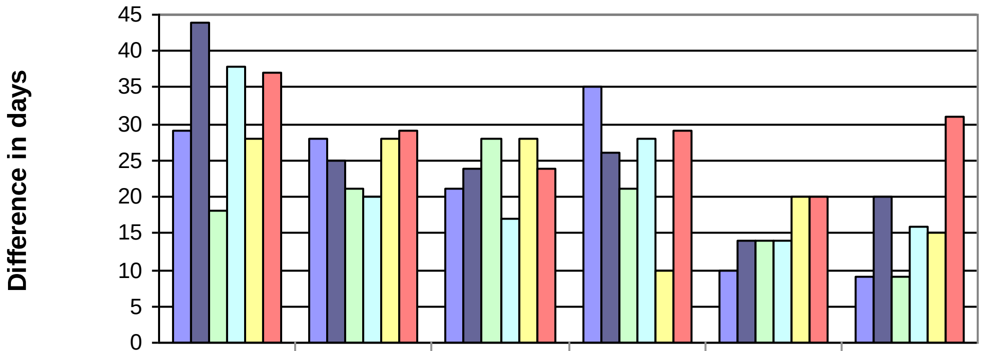
The time taken to achieve a marketable product follows similar trends to those recorded for time to first flower. In the case of ‘Quantum’ and ‘Danova’ the time taken to achieve a marketable product remained fairly static for the first part of the trial, around 135 days. However, from the 12 week cold storage treatment (December transplanting date) onwards the time taken to reach a marketable product rapidly declined, reflecting the increasing light levels and improving light quality through late winter / early spring.

As noted in time taken to first flower, the variety ‘Alaska’ behaved slightly differently to the other two primrose varieties. The time taken to achieve a marketable product with this variety declined steadily throughout the trial, the control batch 1 (September transplanting) taking 50 days longer to achieve a marketable product following transplanting relative to the 16 week cold storage treatment (January transplanting).

Varietal differences were noted in the time taken to reach a marketable product. The earlier varieties (‘Quantum’ and ‘Danova’) reached a marketable stage quicker than ‘Alaska’ throughout the trial. Only a small difference was recorded in the time taken to reach a marketable product between ‘Quantum’ (early variety) and ‘Danova’ (early – mid-season variety). Although ‘Alaska’ reached a marketable stage after the other two varieties for almost every treatment, this time difference gradually diminished as the trial progressed.

Although plug size appeared to have an influence on time to first flower (the larger the plug the shorter the time to first flower), there was no consistently significant influence of plug size on time to attaining a finished marketable product.

As discussed in the time to first flower section, the control batch 2 plugs appeared to develop quicker following transplanting (with the exception of ‘Danova’ in 264 plugs) than the 8 week cold storage plugs even though the control plugs were transplanted 9 days after the stored plugs. As mentioned previously, it is not known if this time difference is actually due to the effects of cold storage or the relative age of the plugs used in the trial.



	Control batch 1	4 Weeks	8 Weeks	Control batch 2	12 Weeks	16 Weeks
Quantum 405	29	28	21	35	10	9
Quantum 264	44	25	24	26	14	20
Danova 405	18	21	28	21	14	9
Danova 264	38	20	17	28	14	16
Alaska 405	28	28	28	10	20	15
Alaska 264	37	29	24	29	20	31

Treatment

Figure 5. Number of days between first flower and marketable product for each treatment.

The time period between first flower and the attainment of product specification is presented in Figure 5. There is a trend for the time between first flower and attainment of finished product specification to lessen as the trial progresses. A clear example of this is the variety 'Quantum' in the 405 plug tray. However, for several of the other varieties the decrease in time is more irregular over the trial period.

Percentage of plants in flower

The percentage of plants in flower was calculated for all treatments from the point of first flower to the attainment of finished product specification (Table 10). This calculation gives another view of how the plants in each treatment developed and became marketable as opposed to recording a single date when all the plants in the treatment attained the required specification (permitting a marketing period to be calculated).

Table 10. Percentage of plants in flower over the production period for each treatment (days from the point of transplanting).

Control batch 1															
Days	**91**	**97**	**103**	**106**	**110**	**117**	**123**	**135**	**139**	**142**	**146**	**151**	**154**	**160**	**163**
Quantum 405				0.9	1.9	5.6	17.6	84.3							
Quantum 264	0.9	0.9	2.8	2.8	4.6	10.2	23.1	76.9							
Danova 405						1.9	3.7	51.9							
Danova 264		1.9	1.9	3.7	5.6	9.3	15.7	48.1							
Alaska 405								0.9	0.9	1.9	22.2	32.4	32.4	47.2	63.0
Alaska 264							1.9	3.7	8.3	11.1	16.7	17.6	40.7	58.3	
4 weeks storage															
Days	**107**	**111**	**114**	**118**	**124**	**127**	**132**	**135**	**139**	**142**	**146**	**149**	**153**		
Quantum 405	1.9	5.6	7.4	15.7	25.0	28.7	36.1	48.1							
Quantum 264	0.9	2.8	6.5	13.0	23.1	25.9	38.9								
Danova 405				3.7	6.5	8.3	8.3	18.5	58.3						
Danova 264	0.9	6.5	13.0	37.0	45.4	48.1									
Alaska 405				1.9	2.8	5.6	6.5	11.1	30.6	32.4	50.0				
Alaska 264					0.9	2.8	3.7	7.4	16.7	21.3	33.3	46.3	62.0		
8 weeks storage															
Days	**111**	**114**	**118**	**121**	**125**	**128**	**132**	**135**	**139**	**142**	**146**				
Quantum 405				3.7	9.3	10.2	20.4	27.8	49.1	56.5					
Quantum 264			2.8	13.0	21.3	25.0	34.3	44.4	57.4	56.5					
Danova 405			0.9	7.4	16.7	21.3	23.1	36.1	47.2	50.9	55.6				
Danova 264	1.9	1.9	6.5	15.7	38.0	43.5									
Alaska 405			0.9	0.9	6.5	14.8	28.7	36.1	47.2	57.4	58.3				
Alaska 264			0.9	1.9	8.3	14.8	23.1	33.3	48.1	55.6					
Control batch 2															
Days	**92**	**97**	**100**	**104**	**107**	**111**	**114**	**118**	**121**	**125**	**128**	**132**	**135**	**139**	**142**
Quantum 405		0.9	0.9	3.7	4.6	11.1	29.6	34.3	37.0	48.1	55.6	69.4			
Quantum 264	1.9	1.9	5.6	9.3	13.0	22.2	40.7	54.6							
Danova 405							7.4	15.7	24.1	26.9	34.3	45.4	57.4		
Danova 264							3.7	7.4	9.3	11.1	16.7	22.2	37.0	52.8	70.4
Alaska 405								5.6	20.4	38.9	45.4				
Alaska 264	0.9	0.9	0.9	2.8	2.8	9.3	16.7	37.0	59.3						

12 weeks storage															
Days	**104**	**107**	**111**	**114**	**118**	**121**	**125**	**127**	**131**						
Quantum 405	0.9	4.6	25.9	50.0											
Quantum 264	4.6	6.5	16.7	38.9	66.7										
Danova 405	0.9	6.5	24.1	45.4	69.4										
Danova 264	3.7	7.4	24.1	40.7	58.3										
Alaska 405			2.8	4.6	14.8	19.4	25.0	25.9	48.1						
Alaska 264			3.7	9.3	13.9	25.0	29.6	35.2	45.4						
16 weeks storage															
Days	**79**	**83**	**86**	**90**	**93**	**97**	**99**	**103**	**106**	**110**	**112**				
Quantum 405						2.8	11.1	40.7	57.4						
Quantum 264				3.7	14.8	23.1	37.0	48.1	53.7	60.2					
Danova 405						2.8	17.6	32.4	53.7						
Danova 264				0.9	3.7	5.6	28.7	55.6	62.0						
Alaska 405						0.9	2.8	15.7	27.8	50.0	53.7				
Alaska 264	1.9	1.9	1.9	1.9	2.8	2.8	11.1	24.1	34.3	42.6					

The data enforces the two previously mentioned trends, the production time for the plugs transplanted later in the trial becomes less and the time between first flower and the attainment of market specification for the plants in each treatment is compressed into a smaller time period.

Potential marketing periods

The potential marketing periods presented in Table 11 are extracted from data in Table 10 and Figure 4. The start of the marketing period is represented by at least 10% of the plants in any treatment showing open flower, the end of the period is the date when all the plants in any treatment were deemed to be fully marketable (the specification being two to three plants per pack in flower with further visible flower bud) or when 50% of the plants in any treatment attained open flower (whichever was recorded first). The marketing period presented assumes the plants are sold as they reach market specification.

The first control treatment and subsequent four cold storage treatments produced a continuous potential marketing period for flowering primroses that stretched from mid January 2004 to the end of April 2004. The three longest storage treatments (8, 12 and 16 weeks) ensured that flowering primroses would be available throughout March and April 2004 covering both Mothers Day and Easter.

In contrast the two control potting dates (22 September and 26 November) produced two potential marketing periods, one from mid January to late February 2004 and another from early / mid March to early April 2004. If a further control potting date had been added in October then a continuous potential marketing period may have been achieved.

The trial does show the potential to target set marketing periods using cold storage treatments (once the effects of day length and light quality are better understood) and to extend the season for finished primroses. Many propagators currently offer primrose plugs for sale up until weeks 38-40 (mid-late September), cold storage would also permit propagators to germinate, grow and then hold and offer plugs over a longer period of time and growers to purchase and hold plugs prior to transplanting freeing up production space.

Table 11. Potential marketing periods for the primrose varieties from each treatment (dates in brackets are the transplanting dates for each treatment).

Control batch 1 (22 Sept 03)		**4 weeks storage** (20 Oct 03)	
Quantum 405	19 January – 3 February	Quantum 405	11 February – 2 March
Quantum 264	16 January – 3 February	Quantum 264	11 February – 28 February
Danova 405	24 January – 3 February	Danova 405	28 February – 6 March
Danova 264	16 January – 3 February	Danova 264	10 February – 23 February
Alaska 405	12 February – 28 February	Alaska 405	2 March – 13 March
Alaska 264	8 February – 28 February	Alaska 264	3 March – 17 March
8 weeks storage (17 Nov 03)		**Control batch 2** (26 Nov 03)	
Quantum 405	22 March – 29 March	Quantum 405	15 March – 29 March
Quantum 264	15 March – 26 March	Quantum 264	8 March – 22 March
Danova 405	16 March – 2 April	Danova 405	19 March – 6 April
Danova 264	13 March – 22 March	Danova 264	25 March – 12 April
Alaska 405	20 March – 2 April	Alaska 405	23 March – 1 April
Alaska 264	20 March – 29 March	Alaska 264	15 March – 25 March
12 weeks storage (15 Dec 03)		**16 weeks storage** (12 Jan 04)	
Quantum 405	31 March – 6 April	Quantum 405	19 April – 26 April
Quantum 264	31 March – 7 April	Quantum 264	12 April – 26 April
Danova 405	31 March – 7 April	Danova 405	18 April – 26 April
Danova 264	31 March – 7 April	Danova 264	18 April – 23 April
Alaska 405	7 April – 23 April	Alaska 405	21 April – 30 April
Alaska 264	6 April – 23 April	Alaska 264	19 April – 30 April

Plant blindness

The incidence of plant blindness was initially not considered within the scope of the trial, however as the trial progressed evidence of blindness within the treatments became noticeable. Therefore any plants that did not produce buds and showed no sign of bud formation at the end of the assessment period were counted and the percentage blindness determined and presented in Table 12.

Table 12. Percentage of blind primrose plants for each treatment.

Variety	Control batch 1	4 weeks storage	8 weeks storage	Control batch 2	12 weeks storage	16 weeks storage
Quantum 405	-	0	0.9	0	3.7	6.5
Quantum 264	-	-	3.7	Present	1.9	11.1
Danova 405	-	4.6	12.0	4.6	9.3	11.1
Danova 264	-	-	-	9.3	4.6	4.6
Alaska 405	0	0	18.5	Present	10.2	10.2
Alaska 264	0	4.6	14.8	-	8.3	26.9

The data set are not complete as earlier flowering treatments and varieties were not assessed for blindness, and are marked accordingly. Where blindness was noted, but data were not collected a note of 'present' was recorded in the table.

All the primrose varieties used in control batch 1 and all those placed into cold storage were sown in week 32. The sowing week number for the primrose plugs used in control batch 2 are presented in Table 13.

Table 13. Sowing week of the primrose plugs used in 'control batch 2'.

Control batch 2	
Sowing week	***Varieties and tray size***
Week 37	Quantum 264, Alaska 264
Week 38	Quantum 405, Alaska 405
Week 39	Danova 405 and 264

Blindness has been a common problem noted on primroses sown between weeks 33 and 38 (Pearson et al., 1996). It was hoped that by using plugs sown in week 32 the risk of blindness could be minimized. However, as can be seen from Table 12 not only was blindness an increasing problem as the trial progressed for the cold stored plugs, but levels of blindness recorded in control batch 2 (sown much later in weeks 37-39) were relatively low. Pearson et al., 1996 concluded that blindness was a failure of the plant to initiate flowers as opposed to flower abortion. By using plugs sown in week 32 it was envisaged that the plugs would have been large enough to have initiated flower bud prior to storage thereby reducing the risk of blindness irrespective of the weather conditions post transplanting. However, the results appear not to support this theory. Although the data for time to first flower and marketable plant suggest that initiation could have occurred at the plug stage, the increasing degree of blindness throughout the trial indicates this was not the case, because if blindness is the result of failure to initiate flower rather than flower abortion, then flower initiation must have been determined post transplanting. Work by Karlsson, 2002 has shown there is no correlation between plant size and flower initiation and at the time of flower initiation he found leaf number varied from 6 to 26. It therefore looks unlikely that flower initiation can be guaranteed to occur at the plug stage even in plugs sown prior to week 33. The prevailing weather / growing conditions post transplanting appear to influence initiation and as a consequence determine the level of blindness.

Pansy and Viola Varieties

Due to many of the pansy and viola plugs suffering from a growth distortion (Appendix 1), the results in this section should be treated with caution. Although plant material and growing media samples were sent away for analysis, no exact cause for the distortion was found (Appendix 3). The majority of affected plants did not grow out of this deformity, and as a result many failed to develop and flower, a percentage dying prematurely.

Plug survival during storage

The percentage of plug plants that died during storage was determined for each 4 week period of cold storage and is presented in Table 14. The actual number of plugs lost during in storage was relatively low. Unlike the primrose plugs, the pansy and viola plugs appeared less prone to desiccation, although the few losses recorded were the result of excessive water loss. This may be due to the fact that the pansy / viola plugs had a relatively smaller leaf area per plug from which to loose water or possibly that the leaves of pansy / viola as a species are more efficient at minimizing water loss than the leaves of primroses. There was much less of a difference in the numbers of plug plants lost between the 405 plug tray and the 264 plug tray compared to the primrose plugs.

Table 14. Percentage loss of pansy and viola plug plants during storage.

Variety	4 weeks storage	8 weeks storage	12 weeks storage	16 weeks storage
Ultima 405	0.5	0.0	0.7	1.2
Ultima 264	0.5	0.7	1.2	1.2
Dynamite 405	1.0	2.8	2.8	3.1
Dynamite 264	0.3	0.4	0.8	1.1
Penny 405	0.4	0.9	3.3	3.8
Penny 264	2.0	1.9	2.1	4.0

Plug quality during storage

The pansy plugs were assessed in an identical manner to the primrose plugs. Plugs were assessed for leaf colour, habit and height upon delivery and every 4 weeks whilst in cold storage. A score was assigned from 0 to 4, with 0 representing poor quality and 4 excellent quality. The maximum total value achievable was therefore 12. ‘Control batch 1’ and ‘control batch 2’ received no cold storage treatment and were assessed for quality on arrival at Writtle College. All the other treatments were assessed at the point of transplanting into polystyrene packs after their appropriate storage period (Table 15). More detailed comments concerning plug plant quality were made over the cold storage period and are presented in Table 16.

The first batch of viola ‘Penny’ plugs delivered on 18 September 2003 were quite badly distorted, the leaves appeared brittle and the growing points contorted (Appendix 1). This was very noticeable on the plugs in the 264 tray where at least 40-50% of the plugs were affected, less so in the 405 tray. Similar symptoms were also noted on the pansy ‘Ultima’ plugs in the 264 tray, but to a lesser degree. Occasional symptoms were also noted on the other plugs.

The distortion persisted throughout the cold storage period (reducing the plug quality scores allocated) and affected plant quality post transplanting. Symptoms were also noted on the second batch of pansy / viola plugs which were delivered on 21 November 2003. Again the symptoms were most noticeable on the viola ‘Penny’ plugs and the pansy ‘Ultima’ plugs, however the symptoms were not as severe or widespread when compared to the first batch of plants. Growing media and plant samples were sent away for analysis post transplanting (Appendix 3) but the precise cause of the problem was never determined.

Table 15. Plug quality scores for the pansy and viola varieties.

Variety		Control batch 1	4 weeks storage	8 weeks storage	Control batch 2	12 weeks storage	16 weeks storage
Ultima 405	Colour	4	3	3	4	2	2
	Habit	4	4	3	4	3	2
	Height	4	4	3	4	3	2
	Total	**12**	**11**	**9**	**11**	**8**	**6**
Ultima 264	Colour	3	3	3	4	2	2
	Habit	3	3	3	4	3	2
	Height	4	4	3	4	3	1
	Total	**10**	**10**	**9**	**11**	**8**	**5**
Dynamite 405	Colour	4	3	3	4	2	2
	Habit	4	4	3	4	3	2
	Height	4	4	2	4	2	1
	Total	**12**	**11**	**8**	**12**	**7**	**5**
Dynamite 264	Colour	3	3	3	4	2	2
	Habit	4	4	3	4	3	2
	Height	4	4	2	4	2	1
	Total	**11**	**11**	**8**	**11**	**7**	**5**
Penny 405	Colour	4	4	3	4	3	2
	Habit	3	3	3	4	3	2
	Height	3	3	3	4	2	2
	Total	**10**	**10**	**9**	**11**	**8**	**6**
Penny 264	Colour	4	3	3	4	3	2
	Habit	2	2	2	4	2	2
	Height	3	3	3	4	2	1
	Total	**9**	**8**	**8**	**10**	**7**	**5**

(0 = Poor; 4 = Excellent)

Although many of the plugs held well for over 4 weeks in cold storage (Plate 5), by week 8 the plugs had started to stretch (primarily the leaf petioles) and lower leaf senescence had begun. The symptoms progressively worsened for all the plugs throughout the storage period and new growth was actually noted on some plugs. This is reflected in the progressive reduction in the quality scores for all the plugs as shown in Table 15. Many of the plugs at the end of the trial were unsuitable for commercial production and would not have been transplanted.

It appears the 3-4°C storage conditions were insufficient to prevent plug development long term (however leaf purpling, a cold response in pansy and viola, was noted on some varieties, Plates 6 and 7) and as the plugs tried to develop and grow in store, nutrients were drawn from the lower foliage leading to leaf yellowing and senescence. The sub-optimal long term storage temperature coupled with the fact that tungsten bulbs were used as the light source in store (these light bulbs are known to cause stem and shoot stretching) were probably the main reasons for the relatively high levels of leaf petiole and stem extension recorded later in the trial.

Table 16. Qualitative assessment of the pansy and viola plugs during storage.

Variety	Storage treatment and comments
Ultima ('Orange Blotch') 405	Control batch 1 – Good quality, plugs of comparable size to those in the 264 tray. Control batch 2 – Reasonable quality plugs of good quality, habit and leaf colour. 4 Weeks – Lower foliage yellowing, upper foliage greyish in appearance. 8 Weeks – Plugs now stretched, with yellow lower leaves. Plugs generally pale in colour. 12 Weeks – Plugs pale in appearance with yellow lower foliage. 16 Weeks – Plugs stretched, pale in colour with lower leaves yellow.
Ultima ('Orange Blotch') 264	Control batch 1 – Reasonable quality with some plugs showing signs of distortion and yellowing of older foliage. Control batch 2 – Plugs of good habit and leaf colour, again signs of growing point distortion noted. 4 Weeks – Lower foliage yellowing, upper foliage greyish in appearance. Distortion symptoms still present. 8 Weeks – Plugs now stretched, with yellow lower leaves. Plugs generally pale in colour. 12 Weeks – Plugs beginning to pale in appearance with yellow lower foliage. 16 Weeks – Plugs stretched (leaf petioles and new growth) with lower leaves yellow. Plugs pale in appearance.
Dynamite (orange) 405	Control batch 1 – Plugs appear slightly stretched, but of good quality. Control batch 2 – Good quality plugs with good leaf colour. 4 Weeks –Visible yellowing of older foliage, upper foliage greyish green in colour. 8 Weeks – Plugs stretched with yellow lower foliage. Plugs pale in colour. 12 Weeks – Plugs pale with some purpling, yellow lower leaves. 16 Weeks – Plugs pale and stretched with yellow lower leaves.

Variety	Storage treatment and comments
Dynamite (orange) 264	Control batch 1 – Plugs approximately 50% larger than 405 plugs, lower foliage pale and yellow. Control batch 2 – Good leaf colour and habit to plugs. 4 Weeks – Visible yellowing of older foliage, new foliage slightly grey in appearance. 8 Weeks – Plugs particularly stretched with yellow lower foliage. Plugs pale in colour. 12 Weeks – Plugs stretched with excessive lower leaf yellowing. Possibility of new growth in store. 16 Weeks – Plugs stretched, with yellow lower leaves.
Viola Penny ('Orange Sunrise') 405	Control batch 1 – Small plugs compared with other varieties. Plugs stretched in appearance, some plug distortion. Control batch 2 – Plugs of good leaf colour and habit, but with some distortion. 4 Weeks –Visible yellowing of older foliage, but younger leaves still good colour. Distortion still evident. 8 Weeks – Plugs a little stretched with some lower leaf yellowing. 12 Weeks – Upper foliage still dark green – purple, but lower foliage yellow. Plugs stretched. 16 Weeks – Plugs stretched, pale in colour with yellow lower foliage.
Viola Penny ('Orange Sunrise') 264	Control batch 1 – 40 – 50% of plugs suffering from distorted growing points. Small plugs compared with other varieties. Control batch 2 – Good leaf colour to plugs but distortion evident. 4 Weeks – Distortion of growing point and yellowing of older foliage noted. 8 Weeks – Plugs stretched with some lower leaf yellowing. Distortion still evident. 12 Weeks – Upper foliage purple - green, but lower foliage yellow, some dieback of lower foliage. Distortion still evident. 16 Weeks – Lower leaf yellowing and necrosis. Plugs beginning to pale generally. Plugs stretched and distortion still evident.

Plate 5. Pansy 'Dynamite Orange' (264 tray), after 4 weeks cold storage.

Plate 6. Pansy 'Dynamite Orange' (405 tray) after 12 weeks in cold storage.

Plate 7. Viola 'Penny Orange Sunrise' (405 tray) after 12 weeks in cold storage.

Plant survival post transplanting

Plant losses following transplanting were relatively minimal and were generally related to the distortion problem noted in the plug plants at delivery as opposed to any specific factor post transplanting. Following transplanting, affected plugs did not particularly grow or establish and quite often died prematurely in the pack. For some reason recorded plant losses appeared to lessen with increasing cold storage time as plugs (Table 17).

Table 17. Percentage pansy and viola losses following transplanting.

Variety	Control batch 1	4 weeks storage	8 weeks storage	Control batch 2	12 weeks storage	16 weeks storage
Ultima 405	0.0	0.9	0.0	0.0	0.0	0.0
Ultima 264	0.0	1.9	0.0	0.0	0.9	0.0
Dynamite 405	3.7	1.9	1.9	0.0	0.0	4.6
Dynamite 264	1.9	2.8	0.0	0.0	0.0	0.0
Penny 405	6.5	6.5	0.9	0.0	0.0	1.9
Penny 264	0.9	14.8	0.0	0.9	0.0	0.9

Final Plant Quality

Plants were assessed for final plant quality when the double six packs had attained the finished product specification, which was identical to the primrose specification – two to three plants in full flower with further visible flower bud. Plant leaf colour, habit and height were assessed and assigned a score of 0 to 4, with 0 being of poor quality and 4 excellent. A maximum score of 12 was therefore achievable (Table 18). A qualitative plant assessment was also undertaken and the comments are presented in Table 19.

Table 18. Final plant quality scores for the pansy and viola varieties.

		Control batch 1	4 weeks storage	8 weeks storage	Control batch 2	12 weeks storage	16 weeks storage
Ultima 405	Colour	2	2	2	3	2	2
	Habit	2	0	1	3	3	4
	Height	2	0	0	2	3	4
	Total	**6**	**2**	**3**	**8**	**8**	**10**
Ultima 264	Colour	2	2	3	3	2	4
	Habit	2	0	1	3	3	4
	Height	2	0	1	2	3	4
	Total	**6**	**2**	**5**	**8**	**8**	**12**
Dynamite 405	Colour	2	3	3	4	4	4
	Habit	1	1	0	4	4	4
	Height	1	1	0	3	4	4
	Total	**4**	**5**	**3**	**11**	**12**	**12**
Dynamite 264	Colour	2	3	4	4	4	4
	Habit	2	0	1	3	4	4
	Height	2	0	1	3	4	4
	Total	**2**	**3**	**6**	**10**	**12**	**12**
Penny 405	Colour	2	2	2	4	4	4
	Habit	2	0	1	1	4	4
	Height	1	0	1	1	3	4
	Total	**5**	**2**	**4**	**6**	**11**	**12**
Penny 264	Colour	2	2	3	4	4	4
	Habit	2	0	1	2	3	4
	Height	2	0	1	1	3	3
	Total	**6**	**2**	**5**	**7**	**10**	**11**

(0 = Poor; 4 = Excellent)

As can be seen from Table 18 the pansy and viola final quality scores were poor in comparison to the primrose quality scores. The plants struggled to grow away from the distortion noted in the plug plants at delivery, resulting in plants which were deformed, uneven, in some cases chlorotic and reluctant to flower (see Appendix 4). The symptoms were noted in the control plants (control batch 1) and those that were cold stored (4 and 8 weeks storage). Similar symptoms were also noted in some of the control batch 2 plants (pansy ‘Ultima’ and viola ‘Penny’).

However, a distinct improvement was noted in the final plant quality for the plugs that had been cold stored for 12 and 16 weeks. In the case of these plants there were few symptoms of distortion, the main problem was a leaf colour bleaching / variegation / total leaf and plant chlorosis (Appendix 5) noted in the pansy ‘Ultima’ which appeared to be possibly genetical in origin. It is not clear why the symptoms disappeared towards the end of the trial, it may simply be a reflection of the improving growing conditions permitting the plugs to recover sufficiently following transplanting to establish and develop into a higher quality plant. As the symptoms were both noted on the plug plants at delivery and expressed by plants that had not been cold stored as plugs, the cause of the distortion could not have been the process of cold storage itself. However, it is difficult to determine

Table 19. Qualitative assessment of the finished pansy and viola plants at marketing.

Variety	Storage treatments and comments
Ultima ('Orange Blotch') 405	Control batch 1 – Foliage pale, with some yellowing. Variation in plant height and habit. Control batch 2 – Reasonable quality plants. Some plants affected by deformity, affecting height and growth habit. 4 Weeks – Very poor quality unmarketable plants. Plants deformed and uneven with limited flower development. Slightly pale foliage, with yellowing and some senescence. 8 Weeks – Poor quality plants. Many plants with no flower development, and small, pale distorted foliage. Variable height and habit. 12 Weeks – Plants not affected by colour bleaching are of good quality, some purpling of foliage. 16 Weeks – Plants without bleaching symptoms are large uniform high quality marketable plants.
Ultima ('Orange Blotch') 264	Control batch 1 – Pale foliage and uneven growth and height. Minor *Botrytis* infection. Control batch 2 – Reasonable quality, with some plants affected by deformity, although height and habit reasonably uniform. 4 Weeks – Unmarketable. Plants deformed, stunted in habit. Pale foliage, with lower leaf yellowing and senescence. 8 Weeks – Some distortion of foliage, however most plants appear to be growing out of deformity. Variable height and habit, and poor flower development. 12 Weeks – Plants not affected by colour bleaching of good quality. 16 Weeks – Large good quality plants of uniform height and habit. Uniform flower development throughout.
Dynamite (orange) 405	Control batch 1 – Poor growth and habit on some plants, variability in plant height within treatment. *Botrytis* noted on some plants. Control batch 2 – Very good quality plants, uniform in habit and height. 4 Weeks – Majority of plants unmarketable. Poor quality, no uniformity in height or habit, with some plants showing deformity symptoms. 8 Weeks – Very poor quality unmarketable plants. Many plants showing symptoms of deformity, with small distorted leaves and stunted growth. Many plants showing no sign of flower development. 12 Weeks – High quality, marketable plants. Uniform growth and flowering. 16 Weeks – High quality, marketable plants. Good flower and foliage colour, with uniform flowering throughout.

Variety	Storage treatments and comments
Dynamite (orange) 264	Control batch 1 – Pale foliage, no uniformity of growth or height. *Botrytis* developing on old foliage. Control batch 2 – Good quality plants, a little uneven in height. 4 Weeks – Plants deformed in growth and habit. Yellow foliage, very poor quality plants, unmarketable. 8 Weeks – Only some packs of marketable quality. Many affected by deformity of growth. Poor uniformity in height and habit, although reasonable level of flowering. 12 Weeks – All plants of high quality, healthy and uniform in growth. 16 Weeks – High quality marketable plants, with good flowering.
Penny ('Orange Sunrise') 405	Control batch 1 – Poor foliage colour and variability in growth and habit. *Botrytis* present on old foliage. Control batch 2 – Many plants affected by deformity, resulting in height and habit variation. Some plants not developing flowers. Poor quality plants. 4 Weeks – Unmarketable plants of very poor quality. All plants showing signs of deformity. No uniformity in height or habit. Many with no signs of flower development. 8 Weeks – Unaffected plants of reasonable quality. Distorted plants small and stunted in habit, no uniformity in height. 12 Weeks – Good quality plants, uniform habit and height, reasonable flowering response. 16 Weeks – High quality marketable plants. Good levels of flowering, with no signs of deformity.
Penny ('Orange Sunrise') 264	Control batch 1 – Poor foliage colour and variability in growth and habit. Control batch 2 – Signs of deformity on many plants affecting height and habit. Although reasonable flower development. 4 Weeks – Unmarketable, poor quality plants. All plants showing signs of deformity. No uniformity in height or habit 8 Weeks – Unaffected plants of reasonable quality. Distorted plants small and stunted in habit, foliage pale in appearance with tip purpling. 12 Weeks – Reasonable quality. Some variation in height, with minor foliage purpling. 16 Weeks – Limited deformity of growth, and variation in height and habit. Overall good quality with healthy plants of marketable quality.

whether the cold storage treatments reduced or exacerbated the resulting symptoms recorded.


4 weeks storage


8 weeks storage


12 weeks storage

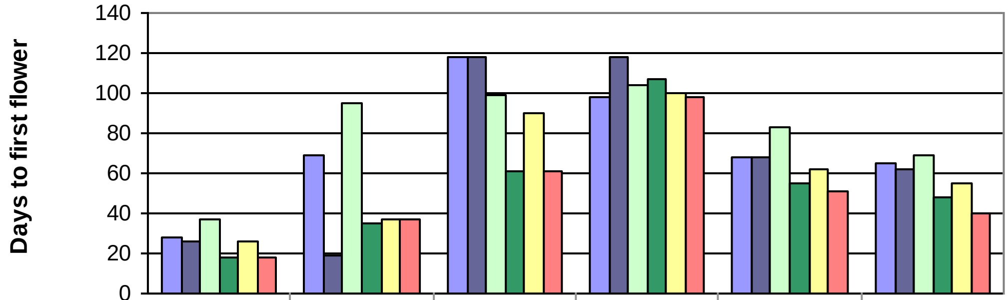

Control batch 2


16 weeks storage

Plate 8. Packs of Pansy 'Ultima Orange Blotch' grown from 264 plugs (plug storage dates indicated under each picture)

Time to first flower

The number of days from transplanting to first flower for each treatment is presented in Figure 6. As the trial progressed into the winter months both the pansy and viola varieties took progressively longer to reach first flower. Plugs transplanted during September (control batch 1), October (4 weeks storage) and November (8 weeks storage) taking on average 26, 49 and 91 days to first flower. However as the day length, light levels and temperatures increased through late winter and early spring the number of days to first flower declined. Plugs transplanted during December (12 weeks storage) and January (16 weeks storage) taking on average 65 and 57 days to flower.



	Control batch 1	4 Weeks	8 Weeks	Control batch 2	12 Weeks	16 Weeks
Ultima 405	28	69	118	98	68	65
Ultima 264	26	19	118	118	68	62
Dynamite 405	37	95	99	104	83	69
Dynamite 264	18	35	61	107	55	48
Penny 405	26	37	90	100	62	55
Penny 264	18	37	61	98	51	40

Treatment

Figure 6. Days after transplanting to first flower for each storage treatment.

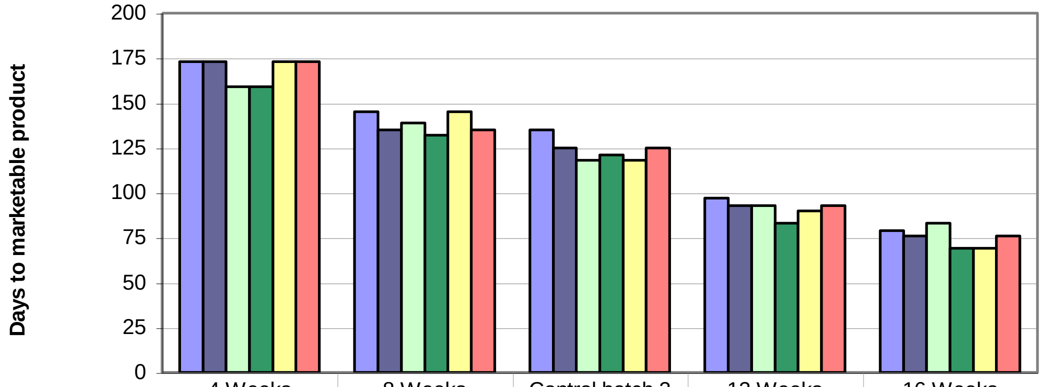
As previously discussed for primroses, there are also numerous environmental and production factors that influence the time taken to flower in the case of pansy and viola. Pearson et al., 1998 list temperature, photoperiod, light integral, the timing of light application, light source and variety as factors affecting the flowering of *Viola wittrockiana*. The data clearly indicates the reluctance of the pansy and viola varieties to flower during periods of low light intensity / short days, as can be seen from the dramatic increase in days to first flower for plugs transplanted during November (8 weeks storage and control batch 2). The distinct peak in time to first flower for these transplanting dates indicates that either flower initiation had not occurred in the plug stage or else the prevailing environmental conditions greatly extended the period of flower development.

From the results obtained it is difficult to state if the varieties were significantly different in their times to first flower. Most frequently the viola 'Penny' came into flower first and the pansy 'Ultima' came into flower last, but without statistical analysis it is difficult to say if the time differences recorded were significant. The situation was complicated somewhat by the fact that on a number of occasions an odd plant in a particular treatment would come into flower well in advance of the remaining plants. Pearson et al., 1998 made reference to work that showed that pansy varieties do have different photoperiodic sensitivities and that some are highly responsive to day length whereas others are only weakly responsive, therefore potential varietal effects cannot be discounted.

In terms of the effect of plug cell size on time to first flower from transplanting, with the exception of the odd result, plants that originated from the 264 plug tray came into flower anything from a few days to several weeks earlier than those which originated from the 405 plug trays. However, the 264 plugs were 1-2 weeks older than the 405 plugs, having been sown a week or fortnight prior.

Time to marketable product

The finished product specification (per double six pack) was assumed to be at least two to three plants in full flower with further visible flower bud (as for the primroses). The time taken to achieve this marketable product for *all* the packs in a particular treatment is presented in Figure 7.



	4 Weeks	8 Weeks	Control batch 2	12 Weeks	16 Weeks
Ultima 405	173	145	135	97	79
Ultima 264	173	135	125	93	76
Dynamite 405	159	139	118	93	83
Dynamite 264	159	132	121	83	69
Penny 405	173	145	118	90	69
Penny 264	173	135	125	93	76

Treatment

Figure 7. Days after transplanting for each treatment to reach a marketable product.

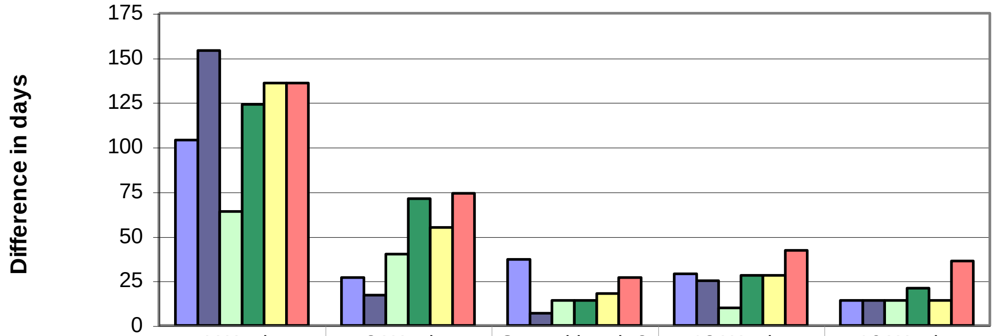
Due to the general level of distortion recorded on the control batch 1 plants, most of the packs never reached the stage where at least two to three open flowers and further flower bud were present per pack within each treatment, therefore no data is presented for this particular treatment.

The time taken to reach a marketable product was different in the overall trend to that recorded for time to first flower. The time taken for the plants to reach a marketable product declined for all the varieties from the 4 week storage treatment onwards. On average the plugs transplanted during October (4 week storage treatment) took 168 days to reach a marketable product, whilst those transplanted during January (16 week storage treatment) took 75 days, less than half the time. This contrasts with time to first flower, in that the plugs from the 4 week storage treatment came into flower in one of the shortest times, a result of the odd plant coming into flower early, whilst the majority of the remaining plants took considerably longer to come into flower. This may indicate that the prevailing light levels / day lengths during this period of the trial were not sufficient to initiate a full flowering response in the plants.

In terms of achieving finished product specification, the pansy variety 'Dynamite' appeared to take the shortest period of time in most cases.

As for the time to first flower, with the exception of a few odd results, plants that originated from the 264 plug tray attained the final product specification anything from a few days to over two weeks earlier relative to those which originated from the 405 plug trays. However, the relative ages of the plugs should be considered before drawing any definite conclusions.

The time period between first flower and the attainment of finished product specification is presented in Figure 8. The clear trend is for the time taken between first flower and attainment of product specification to decline as the trial progresses.



	4 Weeks	8 Weeks	Control batch 2	12 Weeks	16 Weeks
Ultima 405	104	27	37	29	14
Ultima 264	154	17	7	25	14
Dynamite 405	64	40	14	10	14
Dynamite 264	124	71	14	28	21
Penny 405	136	55	18	28	14
Penny 264	136	74	27	42	36

Treatment

Figure 8. Number of days between first flower and marketable product for each treatment.

Percentage of plants in flower

The percentage of plants in flower was calculated for all treatments from the point of first flower to the attainment of finished product specification (Table 20). This calculation gives another view of how the plants in each treatment developed and became marketable as opposed to recording a single date when all the plants in the treatment attained the required specification (permitting a marketing period to be calculated).

Discounting control batch 1 as finished product specification was not reached, the data confirms that as the trial progresses from the 4 week cold storage treatment onwards the trend is for the production time for each treatment and the time between first flower and the attainment of market specification to decline.

Table 20. Percentage of plants in flower over the production period for each treatment (days from the point of transplanting).

Control batch 1																				
Days	**18**	**26**	**28**	**33**	**35**	**37**	**40**	**42**	**47**	**51**	**54**	**56**	**58**	**61**	**63**	**65**	**68**	**72**	**75**	
Ultima 405			0.9	0.9	0.9	1.9	5.6	7.4	11.1	14.8	19.4	23.1	23.1	23.1	25.0	26.9	25.0	27.8	11.1	
Ultima 264		0.9	0.9	0.9	0.9	0.9	1.9	4.6	6.5	8.3	11.1	13.9	16.7	16.7	16.7	16.7	16.7	16.7	13.0	
Dynamite 405						0.9	0.9	1.9	9.3	12.0	13.0	15.7	15.7	14.8	14.8	14.8	10.2	7.4	7.4	
Dynamite 264	0.9	1.9	1.9	7.4	8.3	11.1	14.8	17.6	20.4	23.1	23.1	25.9								
Penny 405	0.0	0.9	0.9	3.7	3.7	3.7	6.5	7.4	13.5	13.5	13.5	14.6	14.6	14.6	14.6	14.6	9.8	4.2	2.1	
Penny 264	0.9	0.9	2.8	3.7	3.7	3.7	5.6	6.5	13.0	17.6	17.6	21.3	21.3	22.2	23.2	23.2	17.6	14.8	14.6	
4 weeks storage																				
Days	**19**	**23**	**26**	**33**	**35**	**37**	**40**	**44**	**47**	**51**	**55**	**62**	**69**	**75**	**78**	**82**	**89**	**95**	**107**	**111**
Ultima 405													0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Ultima 264	0.9	0.9	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dynamite 405																		1.9	1.9	1.9
Dynamite 264					1.9	1.9	2.8	3.7	6.5	7.4	10.2	11.1	12.0	11.1	10.2	11.1	12.0	8.3	4.6	3.7
Penny 405						0.9	0.0	1.9	2.8	2.8	2.8	2.8	1.9	1.9	0.9	0.9	0.0	0.0	0.9	1.9
Penny 264						0.9	0.0	0.9	1.9	2.8	2.8	4.6	4.6	3.7	1.9	1.9	0.9	0.0	0.0	0.0
4 weeks storage (continued)																				
Days	**114**	**118**	**124**	**127**	**132**	**135**	**139**	**141**	**145**	**148**	**152**	**155**	**159**	**162**	**166**	**169**	**173**			
Ultima 405	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.7	7.4	12.0	29.6	33.3	45.4	45.4	50.0			
Ultima 264	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	1.9	2.8	6.5	8.3	19.4	24.1	36.1	39.8	43.5			
Dynamite 405	1.9	1.9	0.9	2.8	2.8	3.7	6.5	6.5	9.3	10.2	23.1	27.8	46.3							
Dynamite 264	3.7	2.8	2.8	2.8	2.8	4.6	10.2	10.2	20.4	26.9	38.0	43.5	58.3							
Penny 405	1.9	3.7	3.7	4.6	4.6	8.3	8.3	8.3	13.0	17.6	27.8	37.0	45.4	51.0	56.5	58.3	66.7			
Penny 264	0.0	0.0	0.0	0.0	1.9	2.8	4.6	6.5	9.3	11.1	14.8	14.8	15.7	15.7	18.5	22.2	24.1			
8 weeks storage																				
Days	**61**	**67**	**79**	**86**	**90**	**96**	**99**	**104**	**107**	**111**	**114**	**118**	**121**	**125**	**128**	**132**	**135**	**139**	**141**	**145**
Ultima 405												0.9	1.9	6.5	11.1	14.8	26.9	34.3	44.4	48.1
Ultima 264												4.6	8.3	22.2	26.9	51.9	55.6			
Dynamite 405							0.9	0.9	0.9	0.9	0.9	1.9	8.3	23.1	28.7	44.4	48.1	58.3		
Dynamite 264	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.9	4.6	7.4	7.4	23.1	29.6	45.4	47.2	66.7				
Penny 405					0.9	1.9	1.9	3.7	4.6	4.6	5.6	8.3	12.0	15.7	30.6	54.6	60.2	65.7	72.2	75.0
Penny 264	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	3.7	5.6	13.0	16.7	30.6	50.0	71.3	80.6			

Control batch 2																				
Days	**98**	**100**	**104**	**107**	**111**	**114**	**118**	**121**	**125**	**128**	**132**	**135**								
Ultima 405	0.9	0.9	1.9	1.9	3.7	4.6	9.3	13.9	37.0	40.7	50.9	57.4								
Ultima 264							3.7	16.7	46.3											
Dynamite 405			3.7	6.5	19.4	33.3	50.0													
Dynamite 264				0.9	11.1	24.1	50.9	62.0												
Penny 405		1.9	3.7	5.6	14.8	18.5	38.0													
Penny 264	0.9	0.9	1.9	3.7	7.4	24.1	34.3	64.8	77.8											
12 weeks storage																				
Days	**51**	**55**	**58**	**62**	**68**	**71**	**76**	**79**	**83**	**86**	**90**	**93**	**97**							
Ultima 405					0.9	0.9	1.9	2.8	11.1	14.8	27.8	36.1	50.9							
Ultima 264					0.9	1.9	5.6	7.4	23.1	27.8	44.4	48.1								
Dynamite 405									5.6	9.3	39.8	54.6								
Dynamite 264		0.9	0.9	1.9	5.6	8.3	20.4	25.9	45.4											
Penny 405				0.9	0.9	2.8	13.9	24.1	41.7	42.6	66.7									
Penny 264	0.9	1.9	3.7	3.7	5.6	6.5	16.7	19.4	27.8	33.3	50.9	60.2								
16 weeks storage																				
Days	**40**	**43**	**48**	**51**	**55**	**58**	**62**	**65**	**69**	**72**	**76**	**79**	**83**							
Ultima 405								2.8	8.3	25.0	41.7	48.1								
Ultima 264							4.6	13.0	34.3	47.2	63.9									
Dynamite 405									3.7	10.2	38.9	44.4	53.7							
Dynamite 264			0.9	0.9	4.6	8.3	17.6	25.9	44.4											
Penny 405					0.9	0.9	17.6	30.6	48.1											
Penny 264	0.9	0.9	2.8	2.8	3.7	3.7	7.4	13.9	34.3	41.7	67.6									

Potential marketing periods

The potential marketing periods presented in Table 21 are extracted from data in Table 20 and Figure 7. The start of the marketing period is represented by at least 10% of the plants in any treatment showing open flower, the end of the period is the date when all the plants in any treatment were deemed to be fully marketable (the specification being two to three plants per pack in flower with further visible flower bud) or when 50% of the plants in any treatment attained open flower (which ever was recorded first). The marketing period assumes the plants are sold as they reach specification.

As can be seen from the data, irrespective of the number of days the plugs spent in cold storage the marketing period for most of the plants was centred around the month of March 2004. Discounting control batch 1, the earliest marketing period was attained by plugs that had been stored for 12 weeks in cold storage. The December transplanting date appeared to be the latest date in 2003 when the plants benefited from the improved late winter / early spring weather conditions post transplanting, whilst still having the time advantage of being transplanted prior to Christmas.

Table 21. Potential marketing periods for the pansy and viola varieties from each treatment (dates in brackets are the transplanting dates for each treatment).

Control batch 1 (22 Sept 03)		**4 weeks storage** (20 Oct 03)	
Ultima 405	6 November – No data	Ultima 405	21 March – 9 April
Ultima 264	13 November – No data	Ultima 264	23 March – 9 April
Dynamite 405	6 November – No data	Dynamite 405	15 March – 26 March
Dynamite 264	28 October – No data	Dynamite 264	6 March – 26 March
Penny 405	4 November – No data	Penny 405	9 March – 29 March
Penny 264	1 November – No data	Penny 264	13 March – 9 April
8 weeks storage (17 Nov 03)		**Control batch 2** (26 Nov 03)	
Ultima 405	22 March – 9 April	Ultima 405	22 March – 4 April
Ultima 264	17 March – 27 March	Ultima 264	23 March – 28 March
Dynamite 405	17 March – 3 April	Dynamite 405	11 March – 21 March
Dynamite 264	10 March – 27 March	Dynamite 264	14 March – 21 March
Penny 405	14 March – 27 March	Penny 405	12 March – 21 March
Penny 264	11 March – 23 March	Penny 264	15 March – 24 March
12 weeks storage (15 Dec 03)		**16 weeks storage** (12 Jan 04)	
Ultima 405	6 March – 20 March	Ultima 405	20 March – 29 March
Ultima 264	3 March – 16 March	Ultima 264	14 March – 26 March
Dynamite 405	9 March – 16 March	Dynamite 405	22 March – 2 April
Dynamite 264	23 February – 6 March	Dynamite 264	10 March – 19 March
Penny 405	26 February – 13 March	Penny 405	11 March – 19 March
Penny 264	25 February – 13 March	Penny 264	14 March – 26 March

There was limited flower production between late November 2003 (when most of the first batch of control plants would have reached a marketable stage) and late February 2004, the earliest flower production attained during 2004. This is also the time period the bedding plant industry finds it difficult to supply flowering pansies. In the case of the pansy and viola varieties used, it appears the storage periods / transplanting dates examined in the trial were unsuitable to produce a flowering pansy during December 2003 - January 2004. The low light levels / short days experienced at this time of the year dictating flower initiation and development. Further research work is necessary to review the economically viable options to induce flowering in pansies and violas post transplanting at this time of the year. The treatments did however extend the marketing period achieved when compared to the control batch 2 plants, but only by 2-3 weeks.

Conclusions

The results show that primrose, pansy and viola plugs can be effectively held at low temperatures for several weeks. In the case of primrose plugs, temperatures of 3-4°C appeared ideal and permitted the storage of plugs for up to 16 weeks. However, with pansy and viola plugs, storage temperatures needed to be less than 3-4°C if storage exceeded 4 weeks. A light source generated from tubular fluorescent light bulbs may be more suitable than tungsten bulbs to limit the degree of leaf petiole and plant stretch induced during longer term cold storage.

The results emphasize how crucial the correct storage environment is for successful storage at low temperatures. Although the good levels of air movement achieved in store throughout the trial effectively limited the incidence of foliar diseases, they also caused desiccation in the primrose plugs, especially those grown in the 405 plug tray. The level of plug plant desiccation can be reduced by increasing the number of Danish trolleys placed into store, a store full of trolleys acts to break up much of the direct air movement across the trolley shelves. However, the plug plants should still be inspected on a regularly basis to monitor quality (at least weekly) and irrigated as necessary.

The trial also showed that low temperature storage of plugs could be an effective tool when it comes to scheduling production, to either increase plug availability during particular production weeks, to expand the time period over which plug material could be made available and used, or to target marketing periods with finished plant material. During peak periods of production, propagators could hold plugs in cold store rather than in glasshouses in the knowledge that the plants won't spoil in the short term. The process could also allow seed to be sown at the optimum time according to schedule and then cold storage used to halt plug development permitting propagators to store and then offer more plugs during demand peaks or offer plugs outside the usual marketing periods, for example in the case of primroses beyond week 40. In the case of growers of finished plant material, the process would permit growers the possibility of placing bought in plug material into store either to alleviate logistical problems during periods of peak transplanting or to delay transplanting (without loss of plug quality) to target later marketing periods with finished plant material.

Cold storage treatments alone though appear insufficient to permit growers to target specific marketing dates for all plant species. In the case of primrose, the cold storage treatments worked well producing sequential batches of flowering plants from January 2004 to April 2004, covering two important periods of demand - Mother's Day and Easter. However, the pansy and viola marketing period attained through the use of the cold storage treatments was altogether more limited. Even though plugs were transplanted over the same 16 week period, most of the plants achieved finished product specification during the month of March 2004, whilst there was insignificant levels of flowering product available through December 2003, January and early February 2004.

Further research work is still required to understand the exact effects of day length, light integral and temperature on flower initiation and development. As can be seen from the trial results for primrose, pansy and viola all these factors had an important influence on flowering post transplanting. It was envisaged that if plugs could be initiated prior to cold storage, then conditions post transplanting would only affect the development rate of the flowers as opposed to actually determining the precise point of initiation. However, as can be seen from the results the environmental conditions post transplanting not only had an effect on flower development but also on initiation and, in the case of primroses, on the level of blindness recorded. If accurate plant scheduling is to be achieved for all the important bedding plant species, commercially viable methods of plant manipulation, pre-storage and post transplanting, will have to be explored to permit specific marketing periods to be targeted.

Technology Transfer

The following technology transfer activities relate to the project: -

- The final report was submitted to the HDC October 2004.
- An article was prepared for the October 2004 issue of the HDC News summarising the results of the trial.
- An HDC Fact sheet was prepared during November 2004 summarising the results obtained from PC 196 and PC 196a.
- A short paper was presented at the BBPA / HDC Pansy and Viola Conference held at HRI Wellesbourne on 6 October 2004.

References

Brough, W., Taylor, R., and Grout, B. (2004) Bedding Plants: The use of low temperature storage as a scheduling aid. HDC Publication PC 196.

Heins, R.D., Kaczperski, M.P., Wallace, Jr., Lange, N.E., Carlson, W.H., and Flore, J.A. (1995) Low-temperature storage of bedding plant plugs. Acta Hort. 396: 285-296.

Heins, R.D., Lange, N. and Wallace, T.F. Jr. (1992) Low temperature storage of bedding plant plugs. P45-64. In: Kurata, K. and Kozai, T. (eds.) Transplant production systems. Kluwer Academic Publishers, The Netherlands.

Kaczperskia, M.P. and Armitage, A.M. (1992) Short term storage of plug grown bedding plant seedlings. HortScience. 27 (7): 798-800.

Karlsson, M.G. (2002) Flower formation in *Primula vulgaris* is affected by temperature, photoperiod and daily light integral. Scientia Horticulturae 95 (2002) 99-110

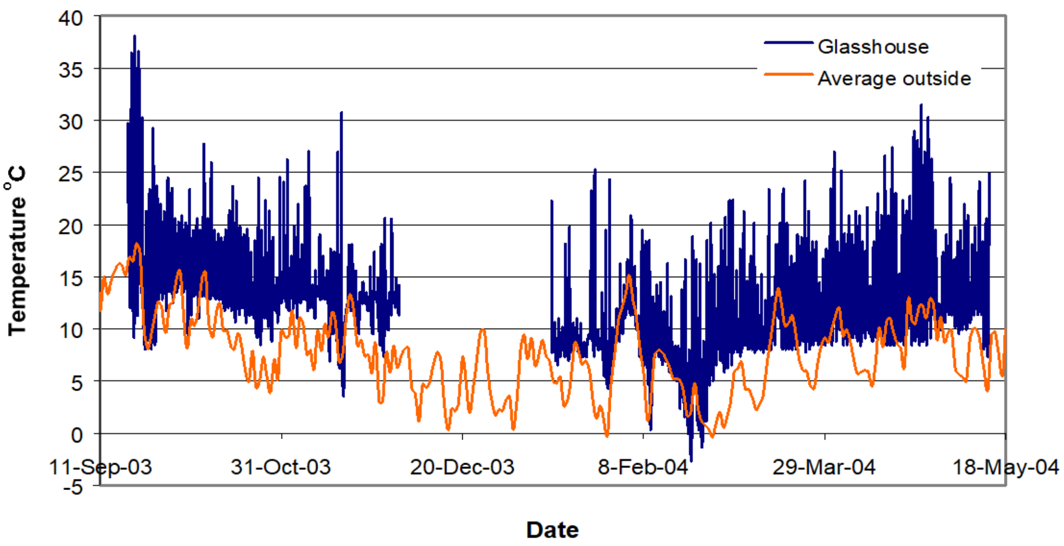
Maslen, L., Hadley, P., and Clarke, I. (2002) Primrose (*Primula vulgaris*): Factors affecting flowering and its variability. HDC Publication PC 154 (unpublished).

Pearson, S., Kitchener, H.M., Sach, L., and Fuller, A.K. (1996) An evaluation of the effect of container sizes, sowing dates and temperature on the development and blindness of *Primula vulgaris* cultivars, flowering from mid February to the end of April. HDC Publication PC 105.

Pearson, S., Smith, S., Coutts, S., and Adams, S. (1998) Manipulating the flowering of pansy (*Viola x wittockiana*). Reading University Technical Note for the BBPA.

Appendix 1. Viola 'Penny Orange Sunrise' showing growing point distortion. Note distorted plugs centre left.

Appendix 2. Glasshouse (top line) and average outside air temperature (bottom line).



As a result of a fault in the data logger, there are no precise daily glasshouse temperature records through December 2003 and early January 2004.

Appendix 3. Growing media and leaf tissue analysis results to determine the cause of the distortion symptoms in the pansy and viola plants.

1. Growing Media Analyses

	Fresh growing medium	**Used growing medium**
Determination	***Result (index)***	***Result (index)***
pH	6.4	6.5
Conductivity (µS @ 20°C)	186 (1)	151 (1)
Density (g/l)	318	410
Major Nutrients		
Phosphorus (mg/l)	84 (8)	57 (7)
Potassium (mg/l)	191 (4)	163 (3)
Magnesium (mg/l)	9 (1)	12 (2)
Mineral nitrogen (mg/l)	52	0
comprising		
Nitrate as N (mg/l)	7 (0)	<6 (0)
Ammonia as N (mg/l)	45 (1)	<1 (0)
Calcium (mg/l)	18	25
Sodium (mg/l)	17	57
Chloride (mg/l)	20	72
Sulphate (mg/l)	78.98	56.02
Trace Elements		
Boron (mg/l)	0.10	0.13
Copper (mg/l)	<0.15	<0.15
Manganese (mg/l)	0.2	0.1
Zinc (mg/l)	0.96	0.49
Iron (mg/l)	2.69	1.32

The analyses indicated there was little difference between the fresh and used growing media except that the used growing medium generally contained lower levels of each nutrient (as expected). The phosphorus levels were slightly high and the magnesium levels low in both the fresh and used media. Nitrogen levels were generally low, but the plants were being fed with a liquid feed to compensate this. The analyses showed a build up of sodium and chloride levels in the used growing medium, a result of accumulation from the mains water and liquid feeds used.

2. Leaf Tissue Analysis

Determination	Un-affected leaf	Affected leaf
Oven dry matter, % m/m	9.8	20.7
Total boron, mg/kg, 100% DM	65.2	24.2
Total nitrogen (Dumas), % m/m, 100% DM	3.83	2.90
Total sulphur, % m/m, 100% DM	0.31	0.29
Total calcium, % m/m, 100% DM	0.96	1.06
Total sodium, % m/m, 100% DM	0.19	0.15
Total potassium, % m/m, 100% DM	4.80	4.75
Total magnesium, % m/m, 100% DM	0.39	0.39
Total phosphorus, % m/m, 100% DM	0.80	0.82
Total iron, mg/kg, 100% DM	794	153
Total zinc, mg/kg, 100% DM	100	115
Total manganese, mg/kg, 100% DM	249	326
Total copper, mg/kg, 100% DM	22.4	8.53

The analysis did show up a number of differences between the un-affected leaf tissue and the affected leaf tissue. Levels of boron, iron and copper were considerably less in the affected tissue than in the un-affected tissue. However, in the case of iron and copper the levels in the affected leaf tissue were still within recommended parameters. The level of boron was slightly marginal though and the pH of the growing media (slightly alkaline) may have influenced the availability of the nutrient. Many of the symptoms recorded on the pansies and violas were similar to those associated with boron deficiency. However, it is confusing that in the case of plugs transplanted early in the trial the symptoms persisted until the end of the trial (even after transplanting the plugs into a fresh growing medium) and yet later batches of plugs (those stored for 12 and 16 weeks) emerged from the symptoms and made marketable plants. It possibly indicates that environmental conditions also influenced the level of symptoms expressed.

Appendix 4. Viola 'Penny Orange Sunrise' (control plants) at final assessment. Note distorted / stunted plants on left.

Appendix 5. Pansy 'Ultima Orange Blotch' (12 week plug storage period) at marketable product stage. Note plants with bleached symptoms.