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HDC is a division of the Agriculture and Horticulture Development Board (AHDB).

HNS Cold Storage - a Grower Guide

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How to successfully cold store hardy nursery stock

Foreword

HDC funded research work has been undertaken to determine the current uses of cold storage in the hardy nursery stock industry and to assess its feasibility as a scheduling aid. From this, it became apparent that some growers were discouraged from using cold storage because of perceived high costs, whilst others had limited knowledge of its potential uses or how to manage it.

As a result, the HDC Hardy Nursery Stock panel commissioned ADAS UK Ltd to undertake a study of how cold storage is being used by nursery stock growers both in the United Kingdom and abroad, which led to the production of this 'Best Practice' Guide for growers. It incorporates a detailed section on how to use cold storage and explains about the different types of cold stores, their construction, acquisition, layout, energy efficiency, environmental control and capital costs.

The HDC is grateful to ADAS Horticultural consultant Andrew Hewson for leading this work so enthusiastically and providing such a comprehensive guide for the industry. The HDC would also like to thank all the growers who have contributed to the guide, especially those who have participated in the case studies; their practical experience and technical expertise has proved invaluable during the writing of this publication.

Nick Dunn

Chairman, Hardy Nursery Stock Panel

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Summary

- When considering building new stores, understand the costs, have a clear idea of what your requirements are and seek the advice of a specialist engineer before starting.
- Consider shared investment with other growers, particularly those who require cold storage at different times of the year.
- Build the biggest cold store you can afford. Think carefully about its location on the nursery and how it will integrate with other resources to minimise handling, for example when removing plant material from the store for orders, or when sorting through plant material prior to storage.
- Ensure there is good access around the outside of the cold store and provide plenty of safe working space for staff and machinery, including delivery vehicles. Also, ensure that the surrounding area is kept clear, clean and in good condition, particularly with Danish trolleys or palletised handling systems.
- Ensure there is adequate lighting for easy access and safe working in and around the cold store, and that lighting units are sealed to prevent moisture ingress. Use energy efficient lamps.
- When considering the layout of the cold store, aim to optimise its storage capacity but leave plenty of room to allow staff to work safely and sufficient space to accommodate vehicles such as fork-lifts.
- Install safety barriers alongside the internal and external walls of the cold store to prevent damage from machinery and equipment or stacked boxes/crates.
- Ensure plants are handled carefully in order to minimise physical damage and subsequent deterioration in store. Only healthy plant material should be cold stored, and if plant material is to be stored well into the spring, it should enter cold storage at peak dormancy.
- Don't leave plants in the store for too long, otherwise they will quickly deteriorate. Evergreen subjects are not ideally suited to cold storage, particularly long-term storage.
- Keep storage times as short as possible, and moisture levels to the minimum needed to prevent desiccation. Monitor the store environment regularly to ensure it is correct. Accurate control of temperature and humidity levels is an important part of good store management, and essential for successful long term storage of nursery stock. Evaporation equipment should be designed to de-humidify the air to a minimum.
- Optimise the energy efficiency of the cold store by a) using energy efficient equipment, b) ensuring the store is well insulated and well sealed, c) good housekeeping and environmental control and d) regular equipment maintenance; ensure cold stores are serviced annually.
- Be prepared to spend generously on insulation and make sure the cooler units of the cold store are sufficiently large.
- Cold stores need to be well utilised to be cost-effective. Think carefully about what they're to be used for and what sort of capacity you'll require – both now and in the future. Insufficient storage capacity during peak periods can be a particularly limiting factor.
- Limited knowledge of cold storage and over-reliance on the technique can result in poor quality plants, so ensure nursery staff are well briefed in the use and management of cold stores.
- Avoid using fruit or vegetable stores to cold store nursery stock, for example in rented situations as ethylene residues may cause damage. If there is no alternative, ensure the store is well vented prior to use and check stored plant material regularly.
- For successful seed storage, the seed must be mature and have a stable food reserve. Generally, seeds with a high fat content don't store well. Seed should be processed and stored as quickly as possible following collection, so that initial viability is high and the rate of deterioration in store is decreased.
- Cold storage or chilling of soft, summer cutting material collected during hot conditions maintains cutting quality and improves rootability through the removal of field heat. Usually, two hours cold storage at 1-3°C following collection will suffice.
- Ensure container grown nursery stock that is going into cold storage is adequately watered and not dry,
- Mature, hardened-off plant material always stores much better than soft material, where *Botrytis* can be a particular problem (e.g. roses).
- Ensure that plants are in peak condition when they go into cold store, for example by lifting field grown nursery stock when it is fully dormant.

1.0 Introduction

Cold storage technology enables hardy nursery stock growers to do things that would otherwise be difficult if not impossible. When used to full advantage, it is a powerful crop management tool which reduces wastage, increases efficiency and delivers greater flexibility of supply. It may also help to manage the effects of climate change on future crop production. Many UK growers now use improved methods of cold storage to exploit these benefits for commercial advantage.

A previous HDC funded project completed in 2006 (HNS 140) identified the main commercial uses of cold storage facilities amongst UK growers. Primarily, it is used as a nursery management tool to hold and schedule stock for sales, transplanting or potting. It is also widely used for the storage of propagation material. The study also highlighted the following benefits:

- Improved accuracy of scheduling to meet customer requirements
- Reduced wastage and hence financial losses during storage periods
- Increased flexibility to meet and maximise sales opportunities
- Greater opportunity to produce niche crops and compete with imports
- Improved efficiency in propagation, planting and despatch operations

Other advantages include improved hardiness of plants and reduced labour inputs for growth control (trimming & 'holding' plants).

However, HNS 140 also found that there was limited knowledge of cold storage technology amongst some growers, particularly in respect of acquiring facilities, environmental control, energy management and general storage considerations. Also, some growers were more familiar with the benefits of using cold storage than others.

The aim of this publication is therefore to provide nursery stock growers with the guidance they need to take full advantage of cold storage technology. A number of leading industry figures have contributed by sharing their knowledge and experience. As rising costs continue to squeeze margins, it is particularly important that growers recognise and exploit the benefits of modern technology. Whilst cold storage alone will not transform an ailing business, it can help growers to improve their supply chain efficiency and be more competitive.

2.0
Using cold storage

Cold storage technology is used in a number of different ways for the production and marketing of hardy nursery stock. This section explains the following uses:

- Storage of propagation material (seeds and cuttings)
- Manipulation of production scheduling
- Manipulation of market scheduling and other uses
- Storage of finished plants

2.1 Propagation

For propagation purposes, cold storage is primarily used for the storage of seeds and cutting material until it is convenient to handle them, and to maintain quality. It is also used for the storage of budwood and scion material to keep it fresh and in good condition, enabling budding and grafting to be scheduled more easily and undertaken when required. Similarly, hardwood cutting material used to propagate subjects such as *Cornus, Malus, Prunus, Platanus, Populus* and *Salix* in winter, can be cold stored until convenient to handle, before transfer to rooting bins, or lining out in the field.

Perhaps surprisingly, cold storage is still only used in this way by a relatively small number of growers in the UK, often through the use of low cost (typically, <£4K) refrigerated units during the summer period, yet there is considerable potential to use it more widely. This is particularly so during the busy summer period for example, when it can be difficult to process large volumes of soft cutting material quickly, whilst it is still fresh and in good condition. The convenience and flexibility offered by controlled temperature cold storage is a considerable advantage.

Seed storage and treatment

Cold storage or chilling of seeds is a common way of overcoming dormancy and maintaining seed viability during the period between harvesting and sowing. In effect, seed storage may be regarded as a period in which the embryo is maintained in a quiescent state while the environmental factors affecting germination are reduced to an acceptable level. For successful storage, the seed must be mature, with a developed and quiescent embryo and have a stable food reserve. Generally, seeds with a high fat content don't store well. Seed should be processed and stored as quickly as possible following collection so that initial viability is high and the rate of deterioration in store is decreased. Some nurseries still use cold storage as a means of breaking seed dormancy, although many in the UK buy in their seed requirements from commercial seed-houses. Usually, the seed arrives pre-treated and ready to sow when conditions are right.

Controlled temperature

The principal advantage of using controlled temperature storage is that cold treatments can be given at any time of year if necessary. Cold stores are usually set at 0-5°C although just below 3°C is usually the optimum level. However, some nurseries have experienced good results at 1-2°C, which also reduces the likelihood of seeds starting to germinate during the chilling period.

Choice of store

A domestic fridge that can be adjusted down to 3°C is ideal for small seed lots, whilst a nursery cold store facility is required for larger quantities. The use of a converted or purpose built store is the most common method of cold stratifying seed to overcome physiological dormancy. This type of dormancy is imposed by an underdeveloped embryo (e.g. *Fraxinus excelsior* and *Ilex* spp.), or bio-chemical factors which limit the mobilisation of food reserves to the developing embryo (e.g. *Betula* spp, *Rosa* spp. and *Sorbus aucuparia*).

Optimum storage conditions

To maintain seed viability, storage conditions must immobilise certain essential enzymes, and slow down respiration thereby slowing the deterioration of stored food reserves, without injuring the embryo. Reduced moisture content of the seed, reduced storage temperature and modification of the storage environment are the key parameters required.

The temperature-moisture relationship is critical. Fluctuations in seed moisture during storage reduce viability, with many kinds of short-lived seeds losing viability completely if the moisture content becomes low. Conversely, various storage problems arise with increasing seed moisture, most notably pests and fungal diseases, so it is important to strike the right balance. Generally, reduced temperatures lengthen the storage life of seeds, and can offset the adverse effects of high moisture content.

Be aware that ambient storage can be used for many kinds of commercial seeds for at least a year, for example to hold seeds from one year to the next. The seeds of some species will in fact retain their viability for longer except under the most adverse conditions. However, longevity is usually enhanced by reduced temperature storage under controlled conditions and this is generally best for those seeds which are to be held for longer than one year.

Species preferences

Whilst the ability of seed to germinate following storage is linked to its initial viability at harvest, it also requires provision of the right storage conditions, primarily the correct levels of temperature and humidity. Take note that some species, particularly certain spring-ripening seeds of temperate zone trees such as *Alnus, Ulmus, Magnolia, Populus, Salix* and some of the *Acer* spp, are short-lived if they are not allowed to germinate immediately, for example in their natural environment. Similarly, the seeds of many tropical plants grown under high temperature and humidity conditions are usually short-lived. By contrast, the medium-lived seed of some woody species (most conifers for example) can remain viable for several years if stored correctly, i.e. low humidity and, preferably, at low temperatures. Seeds which are long-lived can remain viable for up to 20 years providing the seed coat, which is usually hard and impermeable to water, remains undamaged.

Case study 1

Forestart Ltd in Shropshire are specialist seed suppliers who use cold storage to keep seed in optimum condition for sale and, to break seed dormancy (cold, moist stratification). Five cold stores are used, most of which were purchased second hand because they were cheaper than new installations – although they are more costly to maintain. However, a new purpose built cold store was constructed several years ago to provide more capacity and improve efficiency. All of the cold stores contain racking, shelves, boxes and bags for storage *(Figures 1 and 2)*. A small mobile cold store is used when seed collecting *(Figure 3)*.

© Forestart Ltd

Fig 1 Sealed bags are used to maintain the optimum moisture content

© Forestart Ltd

Fig 2 All of the cold stores contain racking, shelves, boxes and bags for storage

© Forestart Ltd

Fig 3 A small mobile cold store is used when seed collecting

Case study 1 *continued*

Temperature is thermostatically controlled and linked to an alarmed monitor which checks and records temperature values twice daily during the week and daily at weekends. An alarm is triggered if temperatures are not correct. Different species have different optimum temperature requirements for stratification and so various storage temperatures (-8°C to +2°C) are used to enable these requirements to be met. Maintaining the optimum moisture content is important for each species and this is regularly laboratory tested. If the moisture content needs to be reduced, the seeds are placed in a kiln and stored in sealed plastic bags to maintain the desired level *(Figure 1 - P9)*. On the rare occasions that the moisture content needs to be increased, seeds are soaked in water. Moisture content is not controlled in individual cold stores, as many different species with different requirements may be stored in each temperature range. Therefore, moisture is controlled within the sealed bags. Strip lights are used to enable staff to see clearly and work safely when in the store.

Each of the five cold stores are insulated to varying degrees - energy efficiency specifications are less advanced with the older stores but were taken into account with the new store, in consultation with a local engineer.

A combination of manual handling, fork-lifts and pallets are used. One of the newer stores is designed for fork-lift access. The newest store was split into two, and there is direct access from the (seed) weighing room to each compartment. Stackable boxes are also used to make maximum use of space.

Although rats and mice are only occasionally encountered, they have the potential to do the most damage. Traps are used and are frequently checked to ensure swift eradication. Oak seed is heat treated prior to storage to control *Ciboria batsohiare* (fungal disease), although this is not a major problem. Sessile oak is sometimes sprayed to control *Septoria.*

Helen Richardson of Forestart explains more about successful seed storage; *"Successful seed storage is largely dependent on managing the moisture content of the seed. If you get that right, most species will store okay although there are several that do not store well, for example Salix, Cedrus and some Abies species – the latter two due to the high oil content of the seed. Moisture content is influenced markedly by the conditions prevailing when the seed is harvested. Imported seed is tested for moisture content on arrival, as it can change and will be adjusted for optimum storage.*

Crucial to success is cleanliness, routine monitoring, maintaining the optimum moisture content and understanding the storage requirements of each species (some like to be kept well aerated during storage whilst others don't, and are kept tightly sealed in polythene bags). Regular seed testing to ensure the seed is viable and in good condition for storage is also very important. Our experience indicates that there's no significant difference in seed storage requirements between species from either the northern or southern hemisphere, providing the moisture content is right.

Our most frequently occurring problem is break down of cold stores, so we've installed extra alarms and monitors. This is also a condition of our insurance policy. We also have a number of procedures in place that ensure such incidents do not occur. A manual thermometer is fixed in each store to cross-check the actual temperature with the required temperature, whenever staff are in the store. Procedures for strict daily checks are also in place. In the event of a problem, the local engineer can be called out immediately. An agreement is in place with a large cold store operator to store stock if a complete failure was to occur. A maintenance contract has also been implemented to minimise the risk of a breakdown occurring (Figure 4).

The main advantage of cold storage for us is that seed from good harvests can be stored for several years to ensure continuity of supply. This is vitally important as not all species yield a sufficient number of seeds annually to meet demand. We simply couldn't function without cold stores, which enable us to maintain seed in optimum condition. They provide us with the control and flexibility we now need to meet market requirements and provide top quality seed, ready to sow if required. They also enable us to move and handle seed much more efficiently, using a pallet truck or forklift as required. Having several cold stores also reduces the risk of a catastrophic breakdown. Cold stores are however expensive, but in our case essential. We'd like to replace our older, inefficient stores with newer ones but it's difficult to justify the cost, particularly whilst we can still cope with the ones we have. Also, supermarkets with highly perishable products seem to have more influence when you need an engineer. This has been overcome by our developing a close working relationship with a local engineer."

Top tips – Helen Richardson advises *"Think carefully about handling and the internal layout of the cold store to enable efficient working. For example, our weighing room has direct access into the new cold store to save time. Also, we used to store seed in pits or on the floor of the cold stores, which meant the seed/stratification mix had to be bagged up to be moved (for example, to another store with a different temperature). Now, the seed is stored in boxes so it can simply be moved between the stores with a pallet truck or forklift, quickly and efficiently.*
Ensure the differing requirements of individual species are met, for example run different stores at different temperatures if necessary. Always have a thermometer in the cold store and monitor the condition of the seeds regularly."

Case study 2

Wyevale Transplants Ltd in Herefordshire are specialist producers of open ground seedlings / transplants *(Figure 5)* and use cold storage facilities for seed stratification and storage. Stored seed used to be gently frozen to hold it after stratification had been completed and dormancy broken, but Wyevale now tend to leave the more difficult spp. to seed specialists, who have the necessary expertise and storage facilities. Different species have different storage requirements *(Figure 6)*. *Fagus* for example, stratifies best if a limited amount of moisture is provided, but if too much is used the seed simply chits, hence particular skill is needed. However, *Fraxinus, Prunus spinosa* (blackthorn) and *Crataegus* (quickthorn) are relatively straightforward and so are stratified on the nursery.

Stored seed can attract various diseases including *Septoria,* a black fungal growth on acorns which causes the seed to collapse. If seed goes into store with this problem it is difficult to control, as it seems to thrive in damp conditions.

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Fig 4 It is imperative to set up a maintenance contract with a local refrigeration engineer to minimise the risk of breakdown occurring

© Wyevale Transplants Ltd

Fig 5 Overview of transplant beds

© Wyevale Transplants Ltd

Fig 6 Seeds of different spp. have different storage requirements and some, for example Cornus sanguinea, are bought in from specialist HNS seed suppliers

Case study 2 *continued*

Whilst recognising the value of cold storage, Steve Ashworth, Production Manager at Wyevale Transplants feels that cold stores *"can also be a real headache when they break down as we don't have ready access to a reliable cold storage engineer when problems arise"*. However, he also feels that *"cold stores are an essential tool that are worth their weight in gold, particularly to hold fresh seed on the premises so it can be sown when soil conditions allow. For us, one of the principal advantages of using cold stores is that orders can be prepared and stored ready for despatch in advance, making maximum use of labour resources. They are also important in helping to hold bare-root nursery stock back to enable spring planting (April). Old cold stores that were installed when energy was cheaper are now less efficient to use and run than newer, more modern stores."*

Top tips – Steve Ashworth says: *"Keep storage times as short as possible, and moisture levels to the minimum needed to prevent desiccation. Regular monitoring to ensure cold stores are functioning properly is time well spent, given the value of the stock within the store."*

Storage of cutting material

It is often useful to store cutting material prior to preparation and insertion. Where cutting material is collected during the pruning of nursery crops or stock plants for example, labour is not always immediately available to handle the cuttings, but cold storage enables it to be held in good condition until convenient. For the same reasons, it is also useful to be able to store cutting material when it is bought in from other nurseries – such consignments often arrive at the least convenient time and can quickly deteriorate unless stored correctly. Cold storage or chilling of soft, summer cutting material collected during hot conditions also helps to maintain cutting quality and improve rootability through the removal of field heat. Usually, two hours cold storage at 1-3°C following collection will restore turgidity and ensure cuttings are fresh before insertion.

Cold stores are used for this purpose in the UK during the soft and semi-ripe cutting months (spring and summer), typically from March to October. Some nurseries however, do run their cold stores throughout the year, albeit on a more limited basis in the winter months. In general, refrigerated units are used for this purpose and the target storage temperature is usually between 1-5°C. Humidity control is not usually necessary, as cutting material can be easily stored in polythene bags and damped down prior to storage.

Clear or black plastic bags should be avoided when collecting cuttings as they absorb more heat – white bags are ideal. Damp down the bags on the inside prior to collection and storage, to keep the cutting material cool and fresh.

Case study 3

New Place Nurseries Ltd in West Sussex specialise in pot liners *(Figure 7)* and container trees. They use a direct cooled refrigerated container body (7.0m x 2.5m) purchased several years ago for approximately £3,000 for cold storage *(Figure 8)*. Cuttings are stored at 6-7°C from April to October, rootstocks / bare-root nursery stock at 1°C from January to March. Humidity

© New Place Nurseries Ltd

Fig 7 Pot liners in production

© New Place Nurseries Ltd

Fig 8 Refrigerated container bodies are a low cost facility which are ideal for the short-term storage of seeds and cutting material

Case study 3 *continued*

control is not necessary as all material is wrapped in plastic prior to storage. Fluorescent lighting is provided for access purposes only. The store costs approximately £30 per week to run from April to October, when in full use.

Cutting material is stored in large plastic bags placed directly onto the floor of the store *(Figure 9)*. Rootstocks are stack-stored in apple bins lined with plastic and a fungicide is applied prior to cold storage. Usually, a fork-lift is used for loading / unloading. There may be fungal problems with rootstocks if temperatures fluctuate, for example *Botrytis*. This can be overcome if material is moist (not wet) when stored, wrapped correctly, treated with a suitable fungicide and temperatures remain constant.

Director John Hedger explains: *"This is a very basic, low cost facility that can be used by many nurseries. Plants are grouped into those that will be used immediately and those that will be left for longer. We try not to store southern hemisphere and soft plants for any length of time. In the past, we've considered renting storage space from fruit farms as is common in The Netherlands, but this is not a priority at the moment and so would just add cost to our products. So far, we have not found any species related problems.*

The cold store provides the nursery with an instant facility which has proved cost effective to purchase and run – elements of the cooler can be replaced providing the insulation remains in good condition. However, size can be a limiting factor, particularly during peak periods."

Top tips – John Hedger advises: *"In very hot weather conditions, minimise the storage time of cutting material to avoid temperature shock and subsequent deterioration. Also, if a fruit store is being used to store nursery stock, check and ensure that the ethylene levels are low. Buy the biggest cold store you can afford – you'll soon use the space."*

Case study 4

Fillip Willems Azaleas in Oost Eeklo, Belgium specialise in Azalea production and use a direct cooled facility to cold store cuttings for up to 6 weeks. They can also cold store finished plants for up to 3 months for crop scheduling, without any problems.

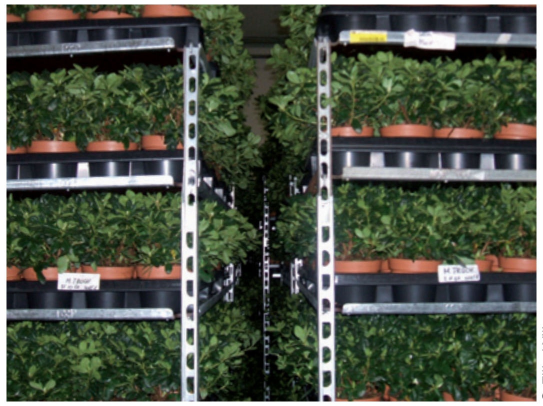
The cold store was installed several years ago and located near to the production glasshouse block and despatch area to ease and speed handling – the store itself was designed to minimise manual handling and allow ready access by forklift. It is well insulated (11cm deep to roof, 8cm to the side walls and 7cm thick polystyrene panels for floor insulation). Finished plants are initially stored at 6.5°C and then 2°C prior to despatch. Container stock is well watered before storage, and this usually provides sufficient moisture for the duration of the cold storage period. Doors are opened for a few hours each week in order to ventilate the store. Cuttings are stored on Danish trolleys, in plastic boxes lined with thin gauge white polythene to conserve moisture *(Figure 10)*. Finished plants are also stored on Danish trolleys, in plastic carrier trays *(Figure 11)*. Strip lights, sealed against moisture ingress provide necessary lighting for staff working in the store.

© New Place Nurseries Ltd

Fig 9 Cutting material collected in white plastic bags is stored directly on the floor

© Filip Willems

Fig 10 Cuttings are stored in plastic boxes lined with polythene to conserve moisture



© Filip Willems

Fig 11 Finished plants are cold stored on Danish trolleys

Top tips – Ensure container stock goes into store adequately watered and not dry, open doors periodically to vent and try to locate new cold stores close to production or despatch areas to minimise handling. Insulate the store well to reduce energy consumption – and costs.

Case study 5

Dutch grower **Gerard Van der Loo** based in Zundert specialises in the production and sale of rooted cuttings to the trade. A direct cooled store is used to hold cutting material before propagation and to store rooted cuttings in plug trays on Danish trolleys prior to despatch *(Figure 12)*. The store was purpose built 7 years ago and has 10-12cm of insulation in the walls and roof, 6cm in the floor. Experience has shown that wrapping the trolleys with foil *after* they have been cold stored for a few days (rather than prior to cold storage) provides the best results. Rooted cuttings usually go into cold storage during late November when they are dormant; the location of each variety or spp. is logged on a computer system to enable those picking orders to gain access to stock quickly, via one of 5 small doors that run alongside the store. Rooted cuttings are usually stored until late May-early June, after which any remaining plug trays are moved into nearby glasshouses, as it is uneconomical to run the store with small quantities of stock.

Top tips - All species need to be well rooted prior to cold storage. Plugs should be uniformly wet but the top growth of the cuttings dry prior to storage *(Figure 13)*. Fallen leaves should be removed promptly to minimise disease risks, most notably *Botrytis.*

© Gerard van der Loo

Fig 12 A direct cooled store is used to hold cutting material and to store rooted cuttings in plug trays prior to despatch

© Gerard van der Loo

Fig 13 Accurate irrigation is important, plugs should be uniformly wet prior to storage

2.2 Production scheduling

Cold storage technology has an increasingly important role to play in production scheduling to meet market demands for continuity of supply. This is particularly evident in the bedding plant sector, where there is interest in short-term low temperature storage of plug raised summer and autumn bedding plant species to delay growth and enable greater continuity of supply (ref HDC factsheet 09/05, *Low temperature storage of bedding plant plugs*). One of the advantages of this is that much less production space and labour is required to hold plugs back and maintain quality, as compared to other more traditional methods of growth control such as maintaining reduced watering / feeding regimes, pruning / pinching and the use of chemical growth regulators (to which, some ornamental plants may also be sensitive).

Labour and space benefits

Similarly, the ability to hold nursery stock plugs and pot liners in cold storage enables the development of scheduled potting regimes to meet market requirements, and provide greater flexibility when planning labour use and bed space. Using cold storage to control and manipulate vegetative growth in this way enables plants to be in the best condition at the right time and reduces the need for further trimming, feeding and handling, which may otherwise be necessary. Unlike finished plants, plugs and pot liners are quite small and so require less storage space. This means that large numbers can be accommodated cost effectively in relatively small stores. Liner producers can also use cold storage to manipulate the growth of stock plants to optimise propagation timing as well as to remove field heat from summer cutting material.

Findings from Project HNS 140

(Hardy Ornamentals: survey to determine current industry practice and future needs for the use of low temperature storage as a scheduling aid in nursery stock production)

HNS 140 found that around 40% of participants used cold storage to over-winter bare-root nursery stock for sale or potting, mainly between November and April. In some cases, cold storage was also being used during the summer period to hold material longer for potting, until labour and bed space became available. In such instances, the target storage environment was 1-2°C with humidity being maintained at 80-100% RH. Of those using cold storage for propagation material, around 50% were also storing transplant material to enable planting to be undertaken as and when labour resources and field conditions allowed. This included producers of containerised roses, herbaceous perennials (pot and bare-root), fruit nursery stock and ornamental trees.

The main benefit of cold storage for these growers was the flexibility it offered for scheduling their planting and propagation work, to allow for season extension and labour availability. Maintaining bare-root stock and propagation material in good condition was also considered to be a major benefit. Overall, few of the growers who participated in HNS 140 saw many limitations to using cold storage for production scheduling. However, one limitation was deterioration in store (e.g. disease infection or die-back), but this tended to be species dependent (one nursery noting that in their experience cold storage appeared to be detrimental to the root health of fine rooted subjects, most notably members of the beech family, *Fagaceae* - an important nursery stock and forestry group).

Manipulating flowering and market throughput

Cold storage can also be used to delay flowering and growth in a wide range of HNS, for example to meet the demands of garden centres and major retailers. A previous HDC project (HNS 113 – *The feasibility of using low temperature storage as a scheduling aid in nursery stock production*) completed in 2003, considered this in detail and provides an important reference point.

Cold storage of nursery stock subjects requiring a period of chilling to initiate flowering such as *Hydrangea* and certain herbaceous spp., also enables plants to be marketed in flower or in bud over a longer period, giving potential for higher returns and smoother cash flow. However, cold storage of finished plants in bud or flower requires particular care, as low temperatures at this stage can lead to premature flower drop or damage.

One of the main features of the present garden retail market is its requirement for relatively small volumes of product on a regular basis, and larger volumes during specific marketing periods throughout the year. In hardy plant production, several factors may conspire to make it difficult to meet this requirement, not least in the UK, adverse weather conditions during key periods. In turn, this often leads to considerable wastage and the grower usually bears the cost of this. Furthermore, an increasing amount of nursery stock is now grown under glass, which is costly and requires careful crop management to be cost effective. The use of cold storage as a scheduling tool can help to increase the throughput of such crops considerably and provide opportunities for season extension, enabling a greater return per m^2 of production area. Labour and transport resources can also be managed more effectively by removing some of the peaks and troughs of seasonal production.

Improved storage techniques for long distance shipping of nursery stock also lends itself well to the continued development of export opportunities for UK growers.

Limiting factors

Limiting factors in the use of cold storage as a nursery management tool are likely to be the knowledge and skill level of staff when using it; limited knowledge and over-reliance on the technique can result in poor quality plants. In HNS 140, having sufficient storage capacity during peak periods was considered to be particularly challenging, and on occasions a limiting factor.

Case study 6

Whartons Nurseries Ltd grow roses and herbaceous perennials on 90 ha of land in Norfolk, primarily for the garden centre market. This includes field production as well as container grown nursery stock and the company uses cold storage as a crop scheduling tool *(Figure 14)* to help meet customer requirements for continuity of supply – weekly deliveries of potted roses are provided throughout the spring and summer period. Bare-root roses are cold stored to retain dormancy, retard flowering and aid scheduling of the potting process. They are cold stored for winter sale as bare-root products, potted for sale as dormant plants, or in summer as flowering plants.

Four 'new build' cold stores are used, each of which are direct cooled using mist atomisers. Warm air produced by the cooling system is channelled into the working area at night to keep the building warm, whilst waste heat is directed outside. Each store is insulated with 120mm polystyrene and the walls are vacuum sealed as a fire precaution. An internal steel barrier (300-600mm high) is used to protect the walls from damage by forklifts. The biggest cold store is used between September and May, a period considered to be too long (and costly) for store rental.

Bare-root woody nursery stock is held at 1°C to maintain dormancy whilst softer plant material and cutting material is usually cold stored at 4-5°C to remove field heat and keep it in good condition. Bare-root roses are stored fresh from the field, starting in September at 6°C when soft, reducing to 3°C in mid October when 'ripe' and 1°C from early December through to April-May in order to maintain dormancy. Roses are lifted from early-mid September through to March. Mist atomisers are used to maintain humidity at 98% to help ensure stock does not become dehydrated whilst in store. Lighting is used to facilitate safe access and working for nursery staff.

Stackable stillage pallets moved by fork lifts are the main handling system used. Plants are placed in these whilst being lifted from the field and taken into cold storage. They are then graded and trimmed before either being returned to cold storage, potted or despatched to customers as bare-root plants. Propagation material is wrapped in plastic whilst rootstocks are kept open and misted to prevent dehydration. Prior to storage, mud is washed off the roots and the plants are thoroughly watered whilst in the field pallets.

Running costs are currently around £5/day but vary and depend on weather conditions. No separate electricity is used for the cold stores. Routine fungicide treatments are used once a week for general disease control and particularly *Botrytis*.

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Fig 14 Cold storage is used for several purposes and crops, including the scheduling of roses for garden centre sales

Case study 6 *continued*

Director Robert Wharton shares his experiences of using cold storage: *"Our cold stores enable us to hold and maintain bare-root roses in good condition for several months and this helps us enormously with product scheduling for customers, who increasingly seek continuity of supply, particularly the major retailers. However, cold stores are not cheap and need to be well utilised to be cost-effective. So, think carefully about what they're to be used for and what sort of capacity you'll require – both now and in the future. The cooling fans we use are noisy, which can be a nuisance and distracting.*

Some rose varieties don't store well. Mature, hardened-off plant material always stores much better than soft material, where Botrytis can be a problem. Our methods work well for us but we must monitor temperature and humidity carefully to ensure optimum storage conditions are maintained – if the plant material becomes too wet, it simply rots-off, whilst if it becomes too dry it perishes. We try to check twice weekly for dry spots.

We moved to our new packhouse and storage buildings four years ago and updated our system. Total cost for the two new cold stores which can each hold more than 300,000 roses was around £55K, excluding the outer insulated building. We considered using fogger units for humidification but visibility is difficult in the store and they create an unhealthy atmosphere for staff to work in. The Hygrofan misters we use help overcome this (Figure 15), although they can be noisy. We mist according to plant need, which is usually no more than hourly or half-hourly, otherwise over-watering could become a problem."

Top tips – Robert Wharton recommends: *"Check temperatures and humidity regularly – the more moisture is in the store the more it costs to cool it down. Also, use the best insulation you can afford - and keep the doors of the cold store shut!"*

© Whartons Nurseries Ltd

Fig 15 Mist atomisers provide direct cooling and unlike fogging units, enable clear vision when working

Case study 7

Oakover Nurseries Ltd based near Ashford in Kent are large scale (120 ha) specialist producers of native seedlings and transplants for the trade and amenity landscape market *(Figure 16).* They use seed collected from local sources for best provenance. Understocks are also grown for budding or grafting. They use cold storage to hold nursery stock until planting out when field / weather conditions are suitable and labour resources are available, and to hold finished plants for marketing purposes. The real benefit of cold storage for them is the added flexibility it provides in production planning.

A direct cooled store fitted with an ice-bank humidifier forms the main cold store. This is partitioned, with spray foam insulation: one side being used for finished plants and the other to hold planting material. The store is kept at 1-2°C to maintain dormancy without freezing, with a humidity of >95%. An ice bank humidifier which draws air over a bank of chilled water is used to ensure stock is kept adequately hydrated. The temperature is set to run at 1-2°C and thermostatically controlled. Low and high pressure sodium lamps are used to enable staff to see and work safely when in the cold store. A converted lorry-back container is also used, to store seeds and transplants.

© Oakover Nurseries Ltd

Fig 16 Overviews of production beds; cold storage enables the planting and sales seasons to be extended, making it an invaluable crop management tool

Case study 7 *continued*

A concrete road is used for access to and from the main cold store, which is insulated with foam on the inside to improve energy efficiency. A separate shed with no additional insulation is used for ambient storage; this is inadequate for summer cold storage but is satisfactory during the winter. Most of the handling is mechanised, using stillages, pallet boxes and fork-lifts.

Botrytis is the main concern, and is controlled by routine checking of stored stock and by removing infected material promptly. Fungicides are not used routinely in the store, but are sometimes applied to seedlings in long-term storage.

Manager John Wood shares some of his thoughts on cold storage: *"Having cold storage facilities has several advantages; stock is readily available for despatch yet can be held if there are delays, for example with landscape work. It also enables the planting season to be extended and there is less plant wastage, as stock can be held in store and so the sales window extended. Stock can be lifted and graded in advance too, making it easier to reconcile what you have available for sale with forward orders. It also enables us to respond quickly to the market and customer requirements. Running costs can be significant, but these are usually outweighed by the many advantages, not least avoiding the need to heel in lifted stock, which can be laborious and time consuming.*

Some nursery stock species don't store well for any length of time, most notably Fagus, Quercus and legumes such as Laburnum and Robinia, so we limit the time they're kept in store. Drying out has been a particular issue too, but the ice-bank humidifier has helped a lot and enables us to maintain humidity at >90%. Stored stock is still watered, but less frequently now the humidifier has been installed. Whilst fogging is another way of boosting humidity, it may also produce heat, which means greater workload for the store plant, as the two elements compete."

Top tips – John Wood advises: *"Ensure that plants are in peak condition when they go into cold store, by lifting them when they are in the right condition, i.e. fully dormant."*

2.3 Market scheduling and other uses

Low temperature storage can be used to manipulate growth and flowering in order to meet sales requirements, exploit promotional opportunities such as trade events or flower shows (e.g. Chelsea) and create new market opportunities, for example through season extension. Garden retailers in particular are increasingly seeking continuity of supply. They demand smaller volumes of container stock that 'looks good' on a more frequent basis, whilst larger volumes timed for specific marketing periods are also required. Cold storage can help to manage demand and meet customer expectations.

Many nurseries also encounter difficulties finding sufficient space to hold and maintain nursery stock under protection during the winter period, particularly for early spring sales and cold storage offers another way of doing this, in a controlled environment.

Scheduling flowering for the market

Cold storage can help promote flowering in some spp., for example those with a chilling requirement such as *Hydrangea.* Research with Hebe varieties has also shown that low temperature storage can increase flower production, as compared to plants stored at higher temperatures. Also, the ability to hold plants at the flower bud stage to delay flowering enables the marketing period to be extended to maximise sales potential. This is particularly advantageous with crops normally sold in bud or flower such as *Azalea* and *Camellia,* for which cold storage can also be used to protect budded plants against adverse weather.

Scheduling plant quality for the market

Cold storage is also useful to maintain plant quality in plants loaded and ready for despatch *(Figure 17),* thus enabling orders to be made up further in advance of the despatch date. Plants held in cold store can be hardier and stress tolerant – a useful advantage for growers supplying garden centres and landscapers, where delays in plant handling and adverse storage areas on site are not uncommon.

Sales targets

Sales targets invariably dictate production planning and are used to devise propagation, planting and potting schedules. Nurseries supplying major retail groups often have clearly defined target sales weeks *(Figure 18),* whilst those dealing mainly with independent garden centres usually have less defined sales targets or 'windows' and schedule crops according to sales forecasts. Unlike the bedding plant sector, scheduling aids such as plant growth regulators, crop trimming and temperature regimes such as 'DIF' or 'DROP' are not widely used by nursery stock growers, largely because of the wide range of subjects grown and their variable response to such techniques (e.g. *Clematis* varieties vary considerably in their responsiveness to chemical growth regulators). Also, a considerable volume of nursery stock is grown outdoors, where there is less scope for growth control. In such situations, using cold storage to control growth and schedule crops may be a more feasible alternative, providing market returns enable it to be cost effective (HNS 140 found that the perceived high costs of cold storage - capital costs, running costs and additional plant handling costs, were the main reasons why nursery stock growers did not use it more widely).

Global warming and dormancy

If mild winters become the norm and global warming increases as appears likely, then the need to induce and maintain dormancy in plants may gain momentum, and bring with it a sharper focus on using cold storage as a management tool to facilitate this. Being able to hold plants in bud, advancing winter colour and delaying the flushing of certain species (e.g. *Pieris*) may also offer clear marketing advantages that could be exploited by using cold storage. However, there is also a need for research into the effects of this on shelf-life and 'after sales' garden performance.

© Rik Dhaese Azaleas

Fig 17 Azaleas in cold store ready for despatch

Fig 18 It is important to schedule plants to meet target sales periods, in this case following National Conifer Week

Case study 8

Frank P Mathews Ltd based in Worcestershire grow ornamental trees and fruit nursery stock for garden centre sales, mail order markets and to the trade *(Figure 19).* The nursery owns several cold stores, which are used between November and May to hold finished plants and bare-root plant material to be transplanted / potted and grown on. They also use cold storage to hold scion material for bench grafting, rootstocks for transplanting and in some cases, to delay flowering of finished plant material.

One jacketed and several newer, direct cooled cold stores are used by the nursery, the former to store graft-wood (January-March). The latter are steel framed, block filled buildings. The temperature is set to run at 2°C in the direct cooled stores and 1°C in the jacketed store, measured and set by experience, whilst 90% RH is achieved by a Pendred Tru-fog crop hydration system *(Figure 20).* Sodium vapour lighting is used for access; this is energy efficient and gives minimal heat output, compared to fluorescent lighting.

All stock is palletised and diesel fork-lifts are used to move plant material in the cold store. A build up of ethylene from the fork-lifts is unlikely as any gas usually escapes when the doors are regularly opened for moving stock in and out. Gas fork-lifts were used in the past, but the exhaust fumes were unpleasant – and unhealthy for staff to work in. Nursery stock in the cold store is also dormant, and so less susceptible to ethylene damage. Access to the newer stores is by electrically operated rolling doors. Pallets are laid out in double rows with access gaps in-between and stacked up to the eaves of the store with a small gap between the pallets and the wall.

Earlier stores had 75mm wall insulation whilst the later ones have 100mm and the roofs have 110mm sprayed polyurethane. The floors of the newer stores are constructed from 150mm reinforced concrete, and are insulated with around 75mm styrofoam. *Botrytis* (most notably on *Ligustrum* spp.) and canker can be a problem. The cold stores are disinfected regularly to help control these problems.

Nursery Manager Dale Swash comments: *"Having cold storage enables late planting in spring, waiting until soil conditions are favourable. Bare-root stock can also be maintained in high quality condition and it is a useful scheduling tool for potted nursery stock. It also saves time over the busy winter period as grading is done as stock is sorted for storage (more efficient materials handling). However costs, and in particular running costs (electricity) are a concern, although the stores are not used in summer, when such costs would be higher, even uneconomical. We have also encountered problems with the evaporators in the direct cooled stores, leading to low temperature differentials and stock freezing. Motors breaking down due to their (old) age and constant exposure to high humidity have also been a problem.*

The fogging units have proved very useful in maintaining humidity and reducing the time previously spent wetting down bare-root stock – for example, the nursery used to have to pre-wrap 'Colt' cherry rootstocks, but no longer need to do this. We've also seen a 20% increase in rooting of 'Colt' but found that cherries and pears can be difficult to store long-term as they have a tendency to break dormancy and start growing. We've also encountered some problems when trying to hold containerised flowering shrubs such as ornamental Malus and Prunus."

© Frank P Mathews Ltd

Fig 19 Cold storage is used to hold finished plants, and bare-root plant material for transplanting or potting

© Frank P Mathews Ltd

Fig 20 High humidity is achieved by a Pendred Tru-fog hydration system

Top tips - Dale Swash advises: *"Aim for the best cold store specification and quality that your budget will allow, as it will pay dividends in the long term. Also, build the biggest cold store you can and ensure it is well insulated."*

Case study 9

Ludemann Pflanzen based near Hamburg in Germany grow landscape shrubs, 2 year seedlings and various transplants including conifers for forestry purposes. They use 3 jacketed cold stores for the scheduling of production and marketing operations. Three million spruce are shipped to Sweden each year. These are lifted, graded, packed into waxed paper sacks and frozen in the cold stores prior to despatch. Seed of various forestry spp. is also cold stored. The most recent direct cooled cold store was completed in 2007 and was purpose built *(Figure 21).* It is located in the despatch building to ease and speed handling; concrete curbs were also installed to prevent damage by fork lifts and stacked boxes/crates.

Plant material is usually stored at -0.5°C, whilst all seed is kept at -6°C *(Figure 22)* (except oak, which is stored at -3.5°C). RH is maintained at 98-99%. Conifer transplants are the main crop and full beds are lifted as orders arrive; surpluses are then cold stored for future sales, but usually no longer than 6-8 weeks. Cold storage usually runs until the end of May.

2.4 Finished Plants

Holding finished plants in cold stores to meet sales demand is a popular activity (46% of growers interviewed for HNS 140 use cold storage in this way).

Case study 10

Rik Dhaese Azaleas in Oost Eeklo, Belgium specialise in the production of evergreen azaleas for the garden centre and export markets. Whilst most stock is marketed prior to flowering, some of the plants are also forced for sale as flowering plants. Most stock is taken into cold store on Danish trolleys during August and sold by mid December, except for those batches destined for Mothers Day sales, which remain in cold storage until the end of February, prior to forcing.

Best results are achieved by cold storing the plants initially at 6-7°C (August-September) and then gradually reducing the temperature to 4°C *(Figure 23).* Plants which are to be sold in flower, are usually removed from cold storage for forcing, 2-3 weeks prior to despatch. Forcing is usually carried out between September and December, resuming in March for Mothers Day sales, until natural flowering time. The stores are direct cooled and some use is made of rented cold store facilities 15km away when additional capacity is required, although this represents an extra handling cost. Constant air circulation during storage is considered essential.

Unrooted cuttings are also cold stored; thereafter 4-6 cuttings are direct stuck for sale as 2 litre plants.

© Ralf Ludemann

Fig 21 A new direct cooled store located in the despatch building to ease handling. It has storage racks to maximise space usage

© Ralf Ludemann

Fig 22 Seed is stored in crates and kept at -6°C (oak at -3.5°C)

© Rik Dhaese Azaleas

Fig 23 Cold stores are direct cooled, initially at 6-7°C and then 4°C. Good air movement is essential to maintain plant quality

Case study 11

John Richards Nurseries Ltd in Worcestershire produce a wide range of hardy nursery stock for garden centres. Specialities include *Clematis,* heathers, and many grafted subjects. A purpose built direct-cooled store was built in 2000 *(Figure 24)* and is used along with 3 small ex-lorry-mounted direct-cooled stores. In one, graft wood is winter stored at 1-2°C. The other two are used for winter storage of *Clematis* rooted cuttings, which are held at a similar temperature. The aim is to maintain temperature as close to 1°C as possible, although it can creep up to 3-4°C in early summer. Humidity is maintained at around 90%, mainly by watering pot-grown stock well as it is brought in and topping up this water as required. Floors are also damped down as necessary. Moisture resistant fluorescent tubes are used to enable staff to see what they are doing. It is believed that this is of a sufficiently low intensity – and duration, as to be photosynthetically neutral and have no photoperiodic effect.

Although forklift access to the large store is possible, most stock is held on Danish trolleys which are arranged in double rows. In the small cold stores, graft-wood is held in plastic bins and *Clematis* rooted cuttings are on Danish trolleys. The large store is well insulated with 100mm on the roof, 6cm on the walls and 4cm on the framework. In construction, 4 tonnes of polyurethane was sprayed on the inside. A 5cm layer of insulation was laid beneath the 15cm concrete floor. *Botrytis* can be a problem with subjects like *Acer, Azalea japonica* varieties and *Clematis.* Accurate humidity control linked to good air circulation is important to help reduce this problem. Fungicides are also used. Aphids and sooty mould have been a problem with *Photinia* in cold storage, which also tends to shoot quite readily. Leaf browning and necrosis can also be a problem with *Photinia*. Tortrix moth caterpillars can survive and become active in cold stores, damaging *Ilex* varieties.

Director John Richards outlines his thoughts on cold storage: *"We would find it hard to do without our cold store facilities. However, about £120,000 went into our main store (470m^2) and this is money tied up all the year round for a facility which lies empty for half the year. We invested in the large cold store to enable us to provide frost protection for root-tender container-grown stock, in particular evergreen subjects. Traditionally, such subjects would have been over-wintered in a polythene tunnel, resulting in a rise in temperature causing stock to break dormancy and become tender above ground level. Because we serve customers over much of the U.K. including northern England, it is essential that we are able to despatch stock with confidence during frosty spring weather. Furthermore, to enable us to control bud burst, stimulate vigorous subsequent growth and free up production space, multiple layers of rooted cuttings and liners are stored within this facility. Other benefits include the ability to schedule despatch of flowering plants, such as Clematis montana varieties, and even achieve a degree of induced hardiness within soft-leaved young Pieris plants. The third week of November sees us busily stocking our cold store after its summer shut down. It is essential that any stock to be held in a dormant state, is introduced before any bud swelling takes place. For some reason, Cordyline (which we no longer grow) and Pittosporum (also a southern hemisphere genus) do not like the cold store, neither does Choisya 'Sundance', whilst the green-leaved parent seems quite happy."*

© John Richards Nurseries

Fig 24 A purpose built direct-cooled store was constructed to provide frost protection for root-tender container grown nursery stock

Top tips – John Richards advises: *"Be prepared to spend generously on insulation and make sure the cooler units are sufficiently large. If, unlike ourselves, you are tempted to use composite insulated panels, do consult your insurers and your local fire control officer beforehand."*

3.0 Types of cold storage facilities

Successful long term cold storage requires a combination of low temperatures and high relative humidity. As a general guide, the recommended temperature for most nursery stock subjects is around 0°C, with a relative humidity approaching 100% in order to prevent drying out.

Maintaining the required temperature is relatively straightforward, providing the cold store is properly constructed and equipped. However, achieving high levels of relative humidity is more difficult and drying out rather than poor temperature control is the usual cause of damaged plants in a cold store.

HNS 140 *(Hardy ornamentals: Survey to determine current industry practice and future needs for the use of low temperature storage as a scheduling aid)* found that the type of cold storage used, and the investment levels made by UK growers varied considerably, depending on what the cold storage facility was to be used for. Field producers appeared to spend more, to hold and schedule bare-root / root-balled nursery stock for sales or transplanting. However, such facilities are also widely used to store propagation material, for example budwood in summer and hardwood cuttings during the winter months.

There are four types of cold storage facilities for nursery stock; ambient cooled, direct cooled, wet air cooled and jacketed cold stores.

3.1 Ambient cooling

Nursery stock can be cold stored for short periods in winter without refrigeration by ventilating the store with cold air from the outside. With good equipment, it is usually possible to hold the temperature at 0-1°C during the mid-winter period and below 5°C in November and late March, depending on seasonal conditions. However, for early lifted bare-root nursery stock some form of controlled cooling will usually be required.

In an ambient cold store, it is essential to provide good insulation and an efficient, well controlled fan. Ideally, the building should be insulated to the same extent as a refrigerated store but this is not always feasible or cost effective; in some situations, temporary stores made from straw bales may suffice and can be successful in mid-winter if well constructed. However, to be an efficient insulator, straw must be kept dry. A wall made from straw bales is also porous to air leakage. Both problems can be overcome by sheeting over the compound.

As a guide, ambient stores fitted with cooling fans should have an output equivalent to 30 room volumes per hour *(Figure 25).* With the inlet and outlet vents designed for an air speed of 5 metres per second, it need only develop around 100 Pa pressure. A fan chosen for maximum efficiency should not raise the air temperature by more than 0.5°C.

A 'differential thermostat' which compares temperatures inside and outside the cold store should be used to control the fan. When the outside air is at its coolest, the fan will run, provided it is not below freezing (a frost override controller then operates). With the specified fan output, the running time to

© SVH

Fig 25 Cooling fans in ambient stores require an output equivalent to 30 room volumes per hour achieve cooling will be short, so small volumes of cool air can be used and any reduction in relative humidity will be minimal and short-lived.

Many growers of field grown nursery stock including roses and herbaceous perennials still use ambient cooling successfully for short spells during the mid-winter period, reserving more costly, controlled temperature facilities for long-term storage and holding propagation material.

3.2 Direct expansion refrigerated cooling

Most conventional cold stores use direct cooling, by which the air in the store is in direct contact with a refrigeration coil. This type of cold store is relatively cheap to install and is the most usual type of cold store available for renting. However, the drying effect of the refrigeration coil is a disadvantage. The moisture removal from the store air is affected by the temperature difference of the store air as it passes through the refrigeration coil. A high temperature difference results in a drier store. The larger the surface area of the cooling coil the lower the temperature difference needs to be for the same level of heat removal. This can only be influenced at the design stage. Large coils are more expensive, so better storage comes at a higher cost.

Direct expansion stores can be used successfully if the plant material held within it is wrapped in plastic film to prevent moisture loss *(Figure 26).* Container bodies in particular are designed for light weight and maximum volume, and so by necessity have small refrigeration coils and higher temperature differences, resulting in a drier store environment. The wrap can either be placed around individual plant bundles or a complete pallet cage / trolley. Unwrapped nursery stock can be held in direct cooled stores but only for very short periods (i.e. overnight or at most for a few days).

Direct cooled cold stores are very flexible and enable temperatures of -2 to +5°C and humidities of 95 to 100% to be maintained, with care. This type of store is best suited to applications at the higher end of each of these ranges. It can be used for short-term storage (e.g. to maintain plant quality for a few days during periods of peak production or slow sales) or long-term storage (e.g. to facilitate crop scheduling over a period of weeks or several months). In the case of the latter, only good quality, undamaged plant material should be considered for storage over several months, otherwise wastage will occur.

3.3 Wet air cooling

With this system, the air in the cold store is cooled by direct contact with chilled water. By using water as the cooling medium, the store air does not lose moisture. It is impossible to cool the store below freezing, so frost sensitive subjects have an added safeguard. In practice, the store will normally operate at around 1°C and so some species may not be fully dormant. If this is a concern, the problem can be overcome by slightly reducing the freezing point of the water using specific salts such as sodium carbonate. Conventional 'anti-freeze' products such as those based on glycol compounds are totally unsuitable.

With wet air cooling, the store air is drawn through and cooled in a heat exchanger; typically this is a tower filled with a honeycomb material to break the flow of chilled water, so exposing the maximum water surface area to the air. The fans used in this type of cold store can produce one of two patterns of air flow: counter flow, whereby the air flows upwards against the direction of water, and cross-flow, where the air flows across the tower.


© CLTV Winkel

Fig 26 Plant material in direct cooled stores should be well wrapped in plastic film

For nursery stock, the former type is better, as the existing air is in contact with the coldest water.

In either flow pattern, the fan must be on the upstream (warm) side of the tower, so that the heat it produces is absorbed by the cooling water. Placing the fan downstream can add sufficient heat to the store air to significantly lower its relative humidity. If some of the air is not fully chilled in its passage through the tower (a problem more likely in cross-flow patterns), the relative humidity of the discharge air can be reduced sufficiently to cause desiccation of plant material in storage.

The chilled water is produced either by an ice bank or by sprayed coil units *(Figure 27).* The former consists of a water tank with refrigeration plates onto which some of the water freezes. The resultant ice block creates the 'bank' which can be drawn on when the cooling load exceeds the capacity of the refrigeration plant. Although this reserve is not so essential for long term nursery stock storage, it does allow the refrigeration compressor to run only during periods of the cheapest electricity tariffs.

In the case of sprayed coil units, the air cooling water is chilled by spraying it directly onto the refrigeration coils of the store.

Ice bank coolers are a relatively modern development capable of providing very high humidities, low temperatures and rapid cooling *(Figure 28).* However, as the costs of an ice bank will be higher than those of a sprayed coil, and its operating efficiency lower, the ice bank cooler may be less attractive when used solely for the cold storage of nursery stock.

The addition of moisture directly to the air in a cold store can also be provided by using fogging units, which also reduce water losses from the stored plant material. These can be effective for short periods, but the additional moisture often forms as ice on the refrigeration coil unless the evaporation temperature of the refrigerant is relatively high (as is the case with large refrigeration coils). This then results in more defrost cycles that require more heat input into the store and so more running time for the refrigeration plant, which in turn dries out the air in the store; there is no substitute for a well selected and designed store.

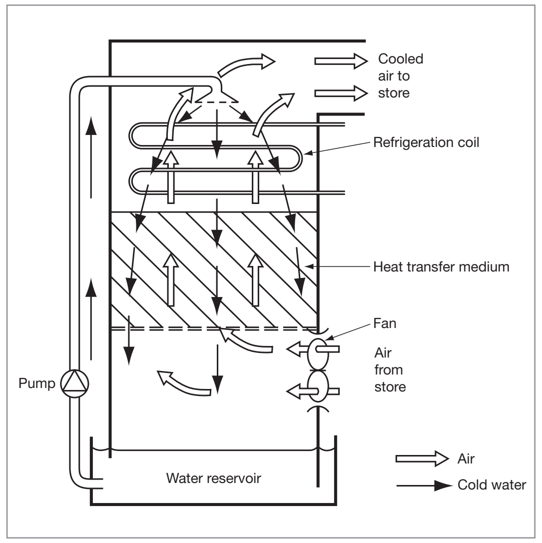

Fig 27 Spray chill cooler construction

3.4 Jacketed cold stores

This is a popular type of cold store that can be used for the long term storage of seeds, cuttings, forestry transplants and a wide range of other nursery stock. In it the plants are separated from the refrigeration coils by a waterproof membrane, so any drying effect of the evaporator coil cannot be transferred to the stored plant material.

The store consists of a conventionally insulated outer shell and a metal-walled inner shell, constructed so that the air from the cooler can circulate in the space (jacket) between them. Fans are used to circulate this air around the store and over the evaporator coil. Whilst these remove moisture from the air and reduce its relative humidity, a high humidity can be maintained within the store itself because the two air spaces are kept completely separate. Heat build-up from inside the store is removed by the cold air in the jacket, via its thermally conductive inner wall. As the air speed inside the store and temperature gradient across the inner jacket is low, the rate of heat transfer from the store is correspondingly low. So, to obtain the maximum cooling efficiency, a large surface area is required and this is achieved by circulating the air in the jacket completely around the store.

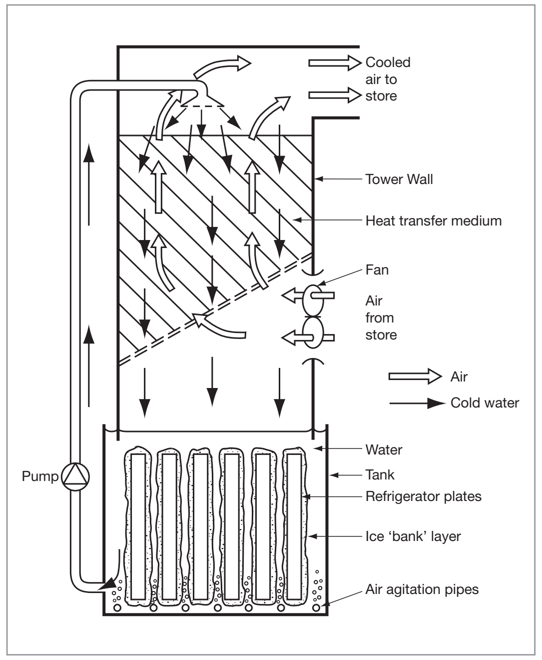

Fig 28 Ice bank cooler construction

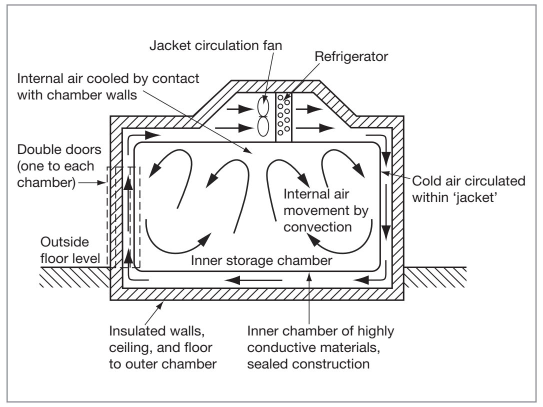

Fig 29 Jacketed cold store construction

Fig 30 Cooling chamber above storage space of jacketed store. A thin aluminium sheet separates the cooling system from the store, so preventing desiccation. Low temperatures pass through the aluminium sheet into the store beneath.

In a well constructed jacketed store *(Figure 29),* the floor is also made of metal, with a jacket airspace between it and the building floor. The doorway of the cold store is arranged to connect through both sets of walls, so that the airspace is sealed. The cooling unit and circulation fans are sited within the jacket airspace *(Figure 30)*, along with controls to maintain the correct storage temperature. Heat is conducted from the stored plants in the inner shell through metal walls to the jacket; the only air circulation within the shell being provided by convective currents. Because the plants are separated from the cooler unit, the refrigeration plant can be chosen for maximum efficiency, rather than for minimum relative humidity loss. Also, as the cooling does not involve water as a transfer medium, the store can be run below 0°C. Typical operating temperatures are -1°C to +1°C, depending on the type of plant material being stored.

This type of cold store has several advantages. Through its high surface areas for heat transfer that enable the maintenance of a high relative humidity in the store (95%), dehydration of the stored plant material can be minimised. The slow movement of the air inside the store also helps reduce the risks of fungal spores and in turn diseases spreading between the stored plants. Jacketed cold stores are more expensive however than a similarly sized direct cooled store, due largely to the additional inner shell and its support structure, although the cost is likely to be similar to a wet air cold store. The inner shell can also suffer from uneven cooling and localised freezing if the air distribution around the store is poor. This problem will increase if any part of the jacket becomes blocked by, for example, detached insulation material or a build-up of ice. Problems with air distribution can be difficult to rectify, as access into the jacket is usually limited.

Jacketed cold stores are unsuitable for storing plant material that requires cooling (e.g. the removal of field heat) or for material which is producing heat by respiration, as the heat cannot be removed rapidly from within this type of store. For this reason, some growers use them alongside other types of cold stores, for example direct cooled refrigerated container bodies for the rapid cooling and storage of summer cuttings.

4.0 Construction of cold storage facilities

To ensure that plant material in cold stores does not dry out and that running costs are kept to a minimum, the load on the cooling unit must be kept low. Natural heat gains through the walls, ceiling and to a degree the floor of the cold store need to be controlled with good quality insulation. Insulation materials are commonly specified by their heat transmission properties, which are usually referred to as 'U values'. The lower the figure the better the insulation. For a refrigerated cold store, a U value of 0.3 Watts/m^2 °C or better is required for optimum performance.

Fig 31 Typical insulation foam used in cold store

Insulation materials

A range of insulation materials can be considered for cold stores including polystyrene slabs, foams *(Figure 31)* and various flexible quilt products. Whilst it is important to accurately compare their insulation values, other factors such as physical strength, ability to achieve a seal, costs and resistance to heat, moisture and pests should also be considered. When comparing costs, it is important that they are calculated for the total structure of the wall or ceiling and based on equivalent U values, not necessarily equal insulation thickness.

Position of insulation

To be fully effective, insulation needs to be correctly positioned, otherwise unnecessary heat gain and humidity loss will occur as 'thermal bridges' are created through structural membranes in direct contact with both inside and outside air. To avoid such 'bridging', the insulation materials which are used should completely isolate the structural members by being positioned between the outer cladding and sheeting rails, or above roof purlins and below the roof sheeting. Insulated floors must also be built from a sound base.

Maintaining the structure and insulation

One of the biggest challenges in relation to the construction and use of a cold store is to keep both the structure and the insulation in good condition. With relative humidity levels needing to be kept near to 100%, any moisture ingress into the insulating material will reduce its effectiveness, so enabling the store temperature and humidity to fluctuate. Dampness from rain, snow, crop moisture and added humidity can be prevented by careful design.

However, the migration of water vapour into the insulation as a result of temperature differences between the outside and inside of the cold store can be a particular problem, as moisture moves from the warmer to the colder side of the insulation. Such moisture ingress can be kept to a minimum by the provision of a vapour barrier or 'check' which remains continuous and unbroken throughout. In some forms of construction for example, where metal clad composite panels are used, the cladding itself forms an effective vapour check. Other types however will require metal foils, polythene sheet and bitumen based compounds / coatings.

Vapour checks

Vapour checks must be positioned on the 'warm side' of the insulation although this will vary with the time of year and so there are two options. One is to provide a vapour check on both sides of the insulation but this must be totally vapour-proof to avoid trapping moisture within the structure. The other option is to provide the check on the side of the insulation that is warmest for the longest period of time, allowing the other side to 'breathe' naturally.

Where insulating materials are joined, it is virtually impossible to seal them effectively against either moisture or air movement, particularly the junction of walls with the floor or ceiling, and at door and ventilator openings. Reducing the number of doors and vent openings as much as is practical will help to offset this, as will reducing the number of different components used in the construction. Fully vapour-sealed composite panels whilst costly, can be assembled into a cold storage structure using airtight joints and will in the long term result in better efficiency and lower store operating costs.

Doors

Doors can be a major source of heat ingress and moisture loss, especially when air gaps are caused by poor construction methods or materials. To reduce the worst effects, doors and vents should be insulated to the same standard as the rest of the cold store, and if possible have the same internal finish. Draught excluders made for example from flexible nylon brushes or synthetic rubber gaskets can also help seal unnecessary air gaps. Nursery staff should be briefed to keep the doors shut as much as possible.

Proprietary factory made doors, which usually provide a high degree of insulation and air tightness can be used, and some sliding doors have a positive sealing action by slightly dropping onto gaskets when in the closed position *(Figure 32)*.

All doors should be as small as possible but large enough to enable handling equipment and machinery to enter and leave the cold store. Diligent store management and monitoring inevitably leads to the frequent opening of doors, and to minimise heat ingress and moisture loss, small personnel doors which are insulated and sealed to the same standard, should be located within the main door structure.

Floors provide another route for heat loss, so it is vital that these too are well insulated. *Figure 33* illustrates how floors should be constructed.

Design of jacketed cold stores

Jacketed cold stores, which are probably the most common type of store used for nursery stock, can either be built inside or as an extension to an existing building or as an alternative purpose built free standing structure. The outer wall of the cooling jacket is insulated, for example with 100mm polystyrene, to minimise the quantity of heat gained externally, and the resulting increased load on the refrigeration unit. The recommended U value of this is 0.3 Watts/m^2/°C. If the insulating material is not itself sealed, then a vapour barrier should be incorporated on the warm side of the insulating layer. Doors need to be insulated to the same standard with airtight seals around the edges and be large enough for fork lift trucks or pallet handlers where required. The inner walls of the jacket can be made from galvanised sheet steel which is impervious to water vapour and has a high thermal conductivity, although care needs to be exercised to adequately seal the joints.

The design of the air jacket is critical, as it is essential to obtain a uniform distribution of the cooling air around the store. This can be achieved by using the jacket above the ceiling as a pressurised plenum chamber with a baffle between it and the wall jackets, leaving a typical air gap of 30mm. Returning air can be collected from the wall cavity or in some cases a hollow floor might be more appropriate. One advantage of eliminating the suspended floor is the lower construction cost; the main disadvantage is the increase in heat gain from the ground, but this can be minimised by using adequate insulation.

The size of a jacketed cold store will depend on the quantity of plant material to be stored, but due to the inherent lack of positive air movement within the store, the maximum width advisable is usually 8-9m. If large volumes of nursery stock are to be stored, the construction of more than one chamber should therefore be considered – this would also enable a degree of energy saving during periods when a lower storage capacity is required. If plant material is densely stacked in the store, then large temperature variations can occur; to avoid this and to make optimum use of the height available, the plant material should be loosely stacked on a simple racking system.

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Fig 32 Some sliding doors have a positive sealing action

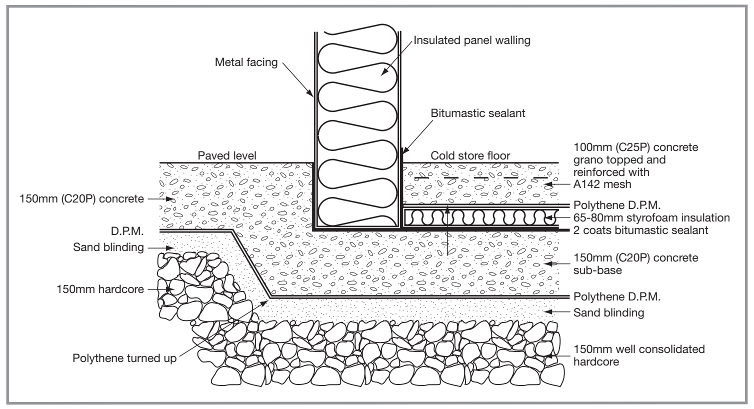

Fig 33 Floor construction and panel bottom

5.0 Environmental Control

The key to successful cold storage is to ensure that the correct environmental conditions are provided for an appropriate length of time, and that the plants are in optimum condition for storage, particularly if they are to be stored for several weeks or, in some cases, months. This means for example, taking particular care over lifting dates with field grown nursery stock and not leaving plants in the store for too long, otherwise they will quickly deteriorate. It also means ensuring that only healthy, good quality plant material is taken into store and taking care to avoid or at least minimise any potential physical damage which could be incurred during handling.

Successful long term storage relies on the correct combination of low temperatures and high relative humidity (RH). For example, with bare-root plants the temperature must be low enough to maintain dormancy whilst humidity needs to be high enough to prevent root desiccation; setting the temperature at 0°C and RH approaching 100% is one recommended way of achieving this. For container grown plants, the parameters are less critical as the growing medium acts as a buffer for the roots, which can be particularly sensitive to cold temperatures. (ref. HNS 113, *The feasibility of using low temperature storage as a scheduling aid in nursery stock production*).

5.1 Temperature

It is important to avoid chilling injury during storage, and plants vary in their sensitivity to cold. Bare-root roses for example can be maintained at 0°C to maintain dormancy – at this temperature ice crystals don't form, minimising damage to the stock. Survey work undertaken as part of HNS 140 found that in general the following temperatures are used successfully by UK nursery stock growers:

- -4 to 2°C for bare-root material
- 0 to 2°C for finished plant storage
- 1 to 5°C for cutting material storage

In the Netherlands, it is not uncommon for growers to freeze some nursery stock subjects (including the seed of some spp.) during long-term cold storage, primarily to reduce the risk of plants breaking dormancy and so enabling it to be stored for several months. Pest and disease problems are also reduced. To do this successfully, the store temperature is reduced gradually, for example from an initial 3°C down to -3°C. 'Defrosting' also needs to be done gradually and away from direct sunlight. Subjects which are not frozen, are usually stored at between 0.5°C (short-term storage) and 4°C (longer-term storage, i.e. several months, summer storage and for long distance exports to maintain dormancy for as long as possible).

Optimum temperatures

The optimum storage temperature range for individual nursery stock subjects varies, as highlighted by *Table 1* on the next page, but in practice, the temperature used will be the one that suits the majority of plant species in store and this may differ between nurseries, depending on which species are grown. For species that have not previously been subjected to cold storage, it is advisable to carry out small scale trials.

Table1.
Optimum storage temperatures for a range of HNS species

1°C	1-2 °C	1-3 °C	5-6°C	Unsuccessful
Garrya	*Azaleas*	*Amelanchier*	*Dicentra*	*Erica*
Choisya	*Philadelphus*	*Clematis*	*Euphorbia*	*lusitanica*
Daphne	*Hydrangea*	*Hamamelis*	*Hosta*	*Cordyline*
Escallonia	*Pieris*	*Rhododendron*	*Polygonatum*	
Eleagnus	*Cytisus*	*Camellia*	*Brunnia*	
Viburnum		*Forsythia*	*Ceanothus*	
Clematis		*Laburnum*	*Viburnum*	
Skimmia		*Malus*	*Deutzia*	
Japanese		*Viburnum*	*Spirea*	
Acer		*Dicentra*	*Pieris*	
Magnolia		*Brunnia*	*Terria*	
Cypressus		*Polygonatum*	*Amelanchier*	
Decrus			*Clematis*	
Prunus			*montana*	
Actinidia			*Acer*	
Erica			*Magnolia*	
'Albert's			*Prunus*	
Gold'			*Malus*	
			Wisteria	
			Solanum	
			'Glas nevin'	

Ref: HDC project HNS 113 *(The feasibility of using low temperature storage as a scheduling aid in nursery stock production).*

Establishing storage temperatures

When a cold store is initially filled with plants, it may have to be run at a lower temperature than the planned storage temperature in order to remove field heat from the plant material. In ambient cold stores, naturally cool air from outside the store can be utilised for this to save energy costs, by drawing it into the store via the ventilators.

Temperature control

Accurate temperature control of a direct cooled or jacketed cold store is essential to avoid frost damage. In jacketed cold stores, the response to temperature changes within the storage chamber is usually slow, and it should be controlled by monitoring the jacket air temperature rather than that of the chamber itself.

Stores cooled by wet air systems cannot run below the freezing temperature of the water used. With ice bank coolers, the refrigeration plant is controlled by an ice thickness sensor and on the sprayed coil, by the expansion valve setting. In the latter case, there may be an override sensor to detect any large accumulations of ice on the coils.

Propagation material

Propagation material is more susceptible to damage from low temperatures, duration of cold treatment and desiccation than either bare root or containerised plants. Maintaining the temperature at or above 2 to 3°C is usually necessary to prevent the leaves becoming frosted. The maximum storage time without causing damage is dependent on plant species. For example, cutting material of those subjects which have thinner, softer leaves (e.g. *Cornus* spp.) should be used quickly and ideally on the same day as they are taken, as they are more susceptible to damage than thicker leaved subjects such as *Hydrangea,* which can be stored for longer periods. As a general guide, propagation material should be used as quickly as possible, and ideally should be stored for no longer than two weeks, particularly soft cutting material for spring-summer propagation.

Production scheduling

Temperatures between -2°C and 2°C are traditionally used for nursery stock subjects and widely considered to be a compromise between maintaining dormancy, preventing temperature-induced damage to plant material and inhibiting the growth of fungal pathogens (e.g. *Fusarium* spp. and *Penicillium* spp.) Dutch growers tend to use low temperatures, typically -2°C for bare root stock whereas in the UK, temperatures below freezing are less common.

When using cold storage as an aid to production scheduling, it is particularly important to create a cooling programme that can be tolerated by the species grown on individual nurseries, and this should involve a gradual cooling process to minimise plant damage, particularly if the aim is to reduce the temperature below freezing. For example, bare-root nursery stock for transplanting can be stored below freezing, usually until June, using the following programme:

- Once dormant, lift and store at 2 to 3°C until December.
- Grade the stock and gradually reduce the temperature to 1°C.
- Gradually reduce the temperature further, to freezing (-3 to -4°C).
- Defrost slowly by removing plants from the store and spreading on the floor of a shed, out of direct sunlight.
- Water 2 to 3 times throughout the day to achieve a gradual thaw.
- Plant out.

Stock that is held above freezing can be treated as follows:

- Initially store at 3 to 4°C.
- Lower the temperature to 2°C by November or December.
- Lower the temperature further to 0.5°C by February.

Ref. Boomkwekerijen and Gerb

The Forestry Commission produces and cold stores a range of conifers including Sitka spruce and Japanese larch. These species are either stored for short periods at higher temperatures or longer periods at lower temperatures, until they are marketed or conditions are suitable for planting out. Plants are lifted when fully dormant and stored as follows:

- Short term storage with an initial temperature of 4°C until mid December, and then at a reduced temperature of 2°C.
- Longer term storage at -2°C.

Herbaceous perennials

Cold storage can also have other effects on plants which need to be taken into consideration, including the flowering of some herbaceous perennials. For example, cooling can induce flowering in most cultivars of *Aquilegia x hybrida* (8 wks) *(Figure 34)*, inhibits flowering in *Astilbe x arendsii,* (9 wks, 5°C) and promotes flowering in *Catanache caerulea*. However, cooling is unnecessary to regulate flowering in many modern cultivars, which are often selected for their precocious flowering ability; the effect of cold storage on flowering can also be dependent on the plant's developmental stage.

Fig 34 Cooling can induce flowering in most cultivars of *Aquilegia x hybrida*

Late field harvest (November-December) is recommended for optimum storage quality of herbaceous perennials, and research has suggested that a critical soil temperature of 10°C is required for field harvesting and subsequent storage of some species; this effect cannot be simulated by chilling bare-root plants that were harvested earlier. Other seasonal effects may also play a part, for example daylength, frost intensity and air temperature cycles (Hancheck 1995).

Broadleaved trees

The effect of lifting date on trees such as *Betula pendula* and *Quercus robur* is considered to be similar to herbaceous perennials. If they are lifted too early (e.g. mid-September), there is a detrimental effect on plant vitality, whilst subsequent longer periods of cold storage can have a further negative effect. For trees, the critical temperature so far as improved stress tolerance during cold storage is concerned is around 5°C, so by lifting after mid-October, when enough 'cold days' should have accumulated, growers can have greater confidence in the plants ability to survive cold storage without a detrimental effect on re-growth (Lindquist, 2001). However, seasons do vary and recent autumn months have been relatively mild, so this should be regarded as a guide only.

Seeds

Seeds are all stored for several reasons: general storage, maintaining freshness, as part of the stratification process to break dormancy and to provide the correct conditions for germination. For storage and stratification, seeds are usually stored in sealed plastic bags, often mixed with some growing media to prevent them from drying out, in temperatures ranging between -6°C and 2°C. Higher temperatures (>15°C depending on spp.) are sometimes required for seed germination post-storage. For example, conifer seeds can be stored at temperatures as low as -6°C, but oak acorns should not be stored below -4°C, otherwise damage to the embryo will occur and germination rates will suffer. It is therefore important to be aware of the preferred storage temperatures for the spp. in question.

Table 2 summarises cold storage temperatures currently used by UK growers for a range of plant material including seeds.

Table 2.
Summary of cold storage temperatures currently used by UK growers

Purpose	Plant material	Temperature °C
General storage	Seeds (storage)	-5 to 2
Germination	Seeds (germination)	15
Vernalisation	Seeds (stratification)	-6 to 1
Market scheduling	Herbaceous perennials	5
Market scheduling	Bare root shrubs / trees	5
Production scheduling	Cutting material	4 to 7
Production scheduling	Bare root shrubs, trees	-3 to 2
Production scheduling	BRS roses	2
Short term storage for immediate sale (early season)	trees / rootstocks	2
Storage until April	trees / rootstocks	0
Long term storage 0 to April then -3	trees / rootstocks	-3

Ref. HNS 140 *(Hardy ornamentals: a survey to determine current industry practice and future needs for the use of low temperature storage as a scheduling aid in nursery stock production).*
Section 2.1 provides more detailed guidance on seed storage.

Temperature monitoring and record keeping

Regular monitoring and accurate control of the temperature within a cold store are an essential part of good store management; most stores are now thermostatically controlled and these sometimes feed-back to office computers *(Figure 35)* or even mobile phones, so that problems can be quickly spotted and rectified. Similarly, a display panel giving a read-out from temperature probes in the store can be located outside the cold store. Cold store temperatures should be monitored daily, using probes *(Figure 36)* or thermometers placed throughout the store, suspended from the roof and lodged within plant material; note the position of the thermometer(s) in a logbook or computer. Keep detailed records of:

- The date when material is placed in the store
- The temperature
- The dates of any temperature changes
- Any problems that have occurred with the store or material
- Incidence of disease

Most benefit will come from using several temperature probes placed around the store in order to indicate any unevenness. Probes or thermometers used in this way should be 'slugged' with plasticine or placed in jars of water, to show an average rather than momentary temperature. Digital thermometers are now widely used and are usually reliable but it is good practice to use these alongside mercury thermometers as a comparison. It is also a good idea to check the temperature of bagged plant material periodically, as this can also generate heat and in turn deteriorate.

5.2 Relative humidity

Humidity is a measure of the amount of water vapour held in the air, usually expressed as relative humidity (RH). Relative humidity compares the maximum amount of water vapour in the air to the amount of water the air could hold at the same temperature. Humidity can also give an indication of the evaporation potential (and therefore transpiration potential) of plants, with less evaporation occurring when humidity levels are high as there is a lower differential between the air humidity and the humidity found within plant cells. The desiccation potential of plant material stored uncovered is therefore reduced when humidity levels are high, however the likelihood of fungal infection is increased.

In-store humidity levels depend on several factors. They are mainly determined by the air temperature difference across the refrigeration coil, but also the humidity of the outside air and how full the store is, as plants themselves will provide a degree of humidity. The more plants there are in the cold store the greater the humidity and less effort is required to maintain the optimum level. Individual stores will differ and it is important to be aware of the initial humidity of a store - for example, if it maintains high humidity or tends to be dry. Arid stores will need a system to prevent desiccation of plant material, others may not. Due to the high specific heat capacity of water, the more moisture held within the store, the greater the amount of energy that will be required to cool it down.

Fig 35 In most modern stores, thermostatic controls are installed which are linked to office computers

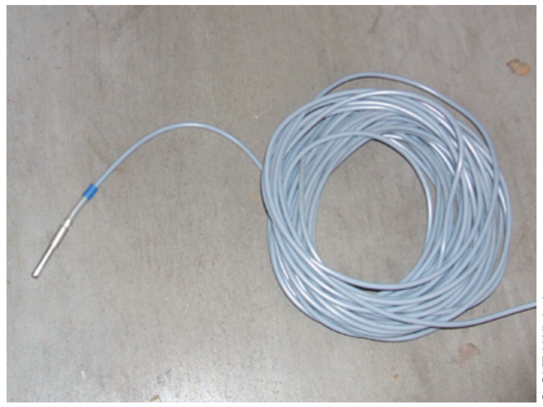

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Fig 36 Typical temperature probe used to monitor temperature of air or produce within a cold store

Relative humidity levels

The relative humidity (RH) level of air brought into a cold store from the outside will affect the amount of energy needed to maintain the required level inside it (usually, 95-100%). If this air is relatively cool, minimal energy is required as the RH will already be quite high (c95%). However, increasing the RH of the store above 98% will require greater energy inputs and so is more costly. Keeping humidity at the lower level also aids disease management by preventing fungal and mould development. For example, the spore germination of *Botrytis cinerea* on cyclamen leaves at 10-20°C rapidly increases when the relative humidity rises above 93% *(Figure 37).*

Leaf wetness can also increase opportunities for symptomless disease infections to become active and then apparent. Whilst the effects of the influence of humidity on infection of nursery stock at very low temperatures are still largely unknown, the number of new infections can be minimised by maintaining the relative humidity below 85% where possible and keeping leaf surfaces dry. Air movement within the store using fans will also help to keep disease levels low (ref. HNS 113). Temperature is also a factor. For example, *Botrytis cinerea* remains active at 0°C, and once temperatures reach 4-5°C there is a greater risk of infection. Fungal respiration and growth reduce at lower temperatures.

Dutch growers try to avoid cold storing species prone to *Phytophthora* or *Pythium* as cold damage can weaken the roots, making them more susceptible to infection on leaving the store. Usually, Dutch growers aim for humidity levels of 90-95% in cold stores.

Humidity monitoring and control

Humidity monitoring and control is not always necessary during cold storage. For example, if propagation material is stored correctly for a short time, desiccation is not usually a problem. However, for longer term cold storage and where humidity control is necessary, there are a number of options available:

- **Damping down** - Bare-root nursery stock can be maintained with no wrapping if the floors are damped down with water at the start of the season, on a weekly basis or as required. However, application of water will cause the cold store to warm up as mains water is usually 4 to 10°C.
- **Wrapped in plastic** - Plant material can be wrapped in plastic to prevent desiccation *(Figure 38),* for example in direct cooled stores. Other products can also be used; propagation material for example can be packed in deep trays, lined with fleece, damped down and covered.
- **Plants stored in pots** - These should be irrigated prior to storage, checked regularly and water applied if necessary (unlikely). Leaves need to be dry and the growing media not too wet when stored to reduce the risk of disease. Electronic monitoring is not essential.
- **Foggers** - These are used to maintain humidity and are usually set to run for short bursts on a cycle (e.g. 2-3 mins every 15 mins.). However, they can be difficult to set up correctly and those with an electronic control system that monitors relative humidity have thus far proved unreliable.

  Accurate measurement of relative humidity close to 100% with electronic detectors is difficult, so the accuracy should be checked with empirical systems such as a wet & dry bulb hygrometer. Other concerns include reduced visibility within the store due to the fog, which can pose a health & safety risk and create an unhealthy environment for nursery staff to work in. Avoid working in the store when the humidification system is operating.
- **Misters** - Humidification with misters can have a limited effect and so must be used with care. Such systems should avoid droplets of water landing on the plant material as this can create disease problems, detracting from the quality of the product. Fogging systems are preferable. Systems that use heat to evaporate water should be avoided.
- **Humidity equipment combined with the cooler** - The use of spray chillers and ice banks enable the store humidity to remain at high levels, since the moisture is used as the heat transfer medium and the temperature difference is small. The disadvantage is that operation at or below freezing is difficult, and the effect of reducing the rate of heat transfer from the product as the temperature approaches zero. The use of ethylene glycol to reduce temperature in the ice bank system is **not recommended.**

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Fig 37 Development of *Botrytis* on Cyclamen rapidly increases when the relative humidity rises above 93%

© Ralf Ludeman

Fig 38 Wrapping plant material in plastic helps to prevent desication

Several types of equipment are used to measure and check humidity levels in cold stores, including hand held humidity meters, dataloggers, humidistats, computers and humidity meters. Electronic capacitor based sensors work best at lower humidities and there is a loss of accuracy towards saturation (100% relative humidity - RH). Manufacturers quote ranges up to 98% RH. They do have the advantage of relatively low cost, speed and ease of use. Portable hand held versions are also available. Relative humidity is measured empirically by wet and dry bulb temperature difference, so even if there is a brand new electronic sensor on site, it must be checked under the store operating conditions of high humidity with a wet and dry bulb hygrometer.

5.3 Lighting

The main purpose of providing lighting in cold stores used for nursery stock is to help ensure safe access in and around the working area *(Figure 39).* As such, the quality of the lighting needs to be of a good standard for the general health and safety of staff members. As the main aim of storage is to delay plant growth and development (or, stratify seed), lighting and in particular light quality are not usually of primary importance for the plants being stored. Where the cold storage facility is small and typically housed within a larger lit unit, a lighting system may not be required as 'borrowed' light may be utilised.

When considering lighting installations, think about the purpose (i.e. what is it to be used for?), the costs (capital and running costs) and the energy efficiency of the equipment, to help keep running costs down. Also, in cold store situations, all fittings need to be waterproof and rustproof as they will be held in high humidity conditions. Sealed fluorescent light units are the most common form of lighting installed in cold storage facilities, whilst 250W high bay lighting is popular in some of the larger stores. To reduce heat gain from lighting, the control equipment and ballast for the lighting must be installed outside the envelope of the store. The lighting layout is important for inspection and safety, for example the height and layout of the lamps must be designed to provide a lighting intensity of at least 150 lux at the level of the storage racks.

© Gerard van der Loo

Fig 39 Lighting is required in cold stores to provide a safe working environment for staff

Types of lighting

General Lighting Service (GLS) filament lamps are the conventional light bulbs that we are all familiar with and consist of a glass envelope containing a tungsten filament and filled with an inert gas. The application of lamps in this group depends on the amount of light needed and the burning time of the lamp. The light output required is obtained by varying the power, by the design and use of reflectors and by use of transformers to adjust the voltage e.g. 12 Volt, 24 Volt or 240 Volt (halogen lamps).

High-intensity discharge lamps are the most efficient light sources, having a low thermal output and long life. They provide 5 fold more light than an equivalent incandescent lamp. Fluorescent lamps are economical to use, as they are energy efficient and have a long life. Several types of (energy efficient) high pressure lamps (e.g. HID) are produced, mainly for industrial and outdoor lighting. High-pressure sodium lamps are the most efficient and economical of these, producing 150 lumens/watt. They have a long life and high light output, still enabling the human eye to distinguish between colours. Their disadvantage lies in the time it takes for them to achieve full luminance from switch-on. Hence, they are more suited to the larger store. A separate lighting circuit with fluorescent tubes is recommended for immediate safety illumination around the doorway and walkways.

Mercury vapour lamps have a low capital cost but they also use more electricity than metal halide or high pressure sodium lamps. Their primary uses are for external and factory lighting. Their quick response is also suitable for passive infra-red automatic operation (PIR), which is useful to ensure that lighting is not left on unnecessarily.

LEDs consist of a small semiconductor (diode) which emits light when a small electrical current is passed through it; most of the energy produced is converted to light. LEDs have several advantages over other lamps including long lifetime, durability and low maintenance. Perhaps the main advantage is efficiency, making them extremely economical to use. They are currently still too expensive to buy for many applications, but as their popularity increases and the technology develops further, the price may reduce. The lifetime of an LED is thought to be approximately 100,000 hrs (e.g. 27 years if on continuously for 10 hours/day), as compared to incandescent bulbs (5,000 hrs) and compact fluorescent lamps (50,000 hrs).
(Sources: European Lamp Companies Federation www.elcfed.org, Osram.)

GLS bulbs can be replaced with efficient compact fluorescent units. As these are integrated units, the option of placing the ballast outside the store is not available.

In September 2007, Defra announced a voluntary initiative to phase out energy inefficient light bulbs between January 2008 and 31 December 2011. This process is supported by the European Lamp Companies Federation (ELC), major retailers and energy suppliers. The products affected are GLS (General Lighting Service) tungsten light bulbs, 'candle' and 'golfball' lamps. This has been available for the most inefficient (150W) lamps since January 2008. Further information can be found at http://www.defra.gov.uk/news.

Controls

In cold stores, the lights are predominately switched on manually, with the switch located close to the doorway. However, automatic lighting controls are also used, operating the light when the door is opened; the main advantages of this system are that it allows staff to enter the cold store without having to dismount from a forklift or put down their load, and it saves energy as lights are only switched on when an area is occupied. There is also a cost saving due to reduced energy usage following installation. Zoning of the lighting switches is recommended so that only the working areas of the store need to be illuminated, with a resultant saving in energy.

Automatic lighting controls can also use occupancy and light level sensing: Passive Infra-Red (PIR) devices can be used to detect when an area is occupied to turn lights on, with a built in time delay to ensure that lights remain on when the occupant is still. Photocells can also be used to ensure lights only come on when the ambient light level is too low for normal use. More detailed guidance can be found at http://www.cpelectronics.co.uk and http://www.greenlite.co.uk/switch.htm

5.4 Ethylene

Plants respond in various ways to the presence of ethylene. These responses include the stimulation of fruit ripening and in ornamental species premature flower abscission, which causes the flowers to drop (e.g. some herbaceous subjects). Ethylene levels are not generally monitored in cold stores used solely for nursery stock as they are unlikely to be a problem. However, vegetables and fruit at certain stages of ripeness do produce large quantities of ethylene and it is not advisable to store nursery stock with such produce as it can cause damage, particularly if the exposure time is quite lengthy (as may be the case in some situations - *Figure 40).* In fruit stores where ethylene is present, it also becomes absorbed into the fabric of the store and can be released over a period of time. It may also come from an adjacent fruit store compartment, a residue from a previous consignment of fresh produce, decaying plant material and the exhaust fumes of fork lift trucks, so beware. Research experience also suggests that ethylene levels appear to be linked to temperature, and are likely to be greater when the air temperature is higher.

To a large degree, 'danger levels' for nursery stock will depend on the type of plant material being stored and the exposure time - mature plants which are dormant and woody are likely to be more robust in this respect than liners or cuttings of an evergreen subject such as *Choisya* or *Eleagnus* for example. Similarly, softer active plant tissues such as developing flower buds and unlignified stems are more likely to release ethylene. As a guide, ethylene levels of 1-3ppm are unlikely to cause problems with established nursery stock in short-term cold storage but this will vary with species - and storage period. Certainly, ethylene levels approaching 5ppm for any length of time would be a concern and levels of 2-3ppm for sustained periods may cause injury in the long term, particularly with softer, less mature nursery stock including liners and cuttings.

Typical signs of ethylene damage include foliar yellowing and contorted growth once the plants have left cold storage - some species will be a lot more sensitive to this than others. If in doubt, check and where fruit or vegetable stores are used to hold nursery stock, for example in rented situations, take particular care to ensure the store is well vented prior to use.

© East Malling Research

Fig 40 Avoid storing nursery stock with fruit or vegetables as the large quantities of ethylene produced can severely damage growth

5.5 Management of the cold store environment

Simple management techniques can be used to maintain the optimum environment within the cold store:

Do

- Reduce air temperature gradually to mimic what occurs in nature.
- Site the temperature readout display outside the cold store.
- Choose a temperature that will suit the majority of plant species.
- Collect propagation material early in the morning to reduce the amount of field heat that needs to be removed.
- Stack pallets at least 10cm apart and allow 50cm vertical clearance between the top of the plants and the bottom of the next pallet, to ensure free air circulation and prevent pockets of warm air collecting.
- Monitor the temperature daily at a number of points within the store.
- Keep the entrance door closed when not in use to prevent humidity and temperature fluctuations. If this is not practical, consider installing a plastic curtain or porch, or use an automatic switch operated from the fork lift truck.
- Use a separate personnel door for stock inspections.

Don't

- Open the door unless essential, in order to avoid heat entry, fluctuating temperatures and increased energy inputs.
- Overfill bags of propagation material, as it will take longer to remove the heat from the centre and cuttings will deteriorate.

In summary, different species, and indeed varieties, often respond differently to changes in temperature, relative humidity and light. In addition, there are photoperiodic responses to be considered and whilst a considerable amount of research has been undertaken on the controlled atmosphere storage of fresh produce, there is relatively little research information available that specifically deals with nursery stock and in particular container grown plants. However, commercial experience to date suggests that only a limited number of hardy plants respond badly to cold storage, providing the timing and environmental conditions are right.

6.0 Energy efficiency

Various measures can be taken to optimise the energy efficiency of cold stores to reduce carbon emissions and running costs. These need not be expensive; energy savings of <20% for example can be achieved with refrigerated cooling through actions that require little or no investment, such as regular equipment checks and monitoring of the store environment. Improving the efficiency of cooling equipment and its workload, will also improve reliability and reduce the need for repairs. Essentially, optimising the energy efficiency of a cold store involves four basic measures;

- Using energy efficient equipment.
- Ensuring the store is well insulated and well sealed.
- Good housekeeping and environmental control.
- Regular equipment maintenance; ensure cold stores are serviced annually.

Consider the following to reduce energy costs:

Accurate temperature control - Use the optimum temperature for the job and ensure it is not set lower than necessary; overcooling wastes energy, increases the risk of equipment failure and does not improve the quality of the stored plant material. If the temperature of a refrigeration unit is set 1°C lower than necessary, the energy costs may increase by 2-4%.

Lighting control - Light adds heat to the cooled space and makes the cooling system work harder, thereby increasing energy costs. Although internal lighting for nursery stock is usually only used to facilitate access and working in the store, it may be on for long spells during busy periods of work. Ensure internal lights are switched off when not in use; this will save energy used by the lighting itself as well as that used to remove excess heat. Where lights are controlled by the opening and shutting of the door, ensure the switch works properly. Use energy efficient lamps.

Door seals - Faulty or poorly fitting door seals allow cool air to escape from the cold store and warm air to enter in its place, so making the cooling unit work harder, thus wasting energy in the process. Ensure the seals are in good condition and well fitted. Faulty door seals can increase energy consumption by up to 10%.

Storage capacity - Overfilling cold stores will reduce the air flow around the plant material, reducing the performance and efficiency of the cooling equipment, particularly refrigeration units. This leads to uneven temperatures and localised drying out.

Position of heat rejection components - Position the external heat rejection components of the cooling equipment carefully. The warmer the air around a condenser unit, the harder it has to work and the more energy it consumes. Avoid installing the unit near to sources of heat and direct sunlight. Also, ensure that the condenser has ample ventilation, so that the rejected heat can dissipate easily.

Over-cooling and over-filling

In general, good housekeeping in cold stores does not require special skills or equipment but with training and guidance, staff can substantially reduce energy consumption and costs. Over-cooling and over-filling are two of the most common causes of wasted energy. Over-cooling usually occurs because of concerns over equipment failure. It increases the probability of equipment failure as the units work beyond their normal capacity. Over-filling occurs due to work pressures during busy periods.

Store running efficiency

In refrigerated systems, ice will form on evaporators that operate below 0°C. As the ice builds-up, the evaporating temperature drops, causing the cooling system to work harder and so expend more energy. Its efficiency and capacity to run at the required temperature will also suffer. Regular defrosting is therefore essential to maintain optimum performance and efficiency levels; evaporators are usually fitted with automatic defrost systems to prevent ice build-up but this needs to be checked regularly to ensure it is working correctly. However, such systems also add to the heat load in the cold store, so they should run sufficiently to control the build-up of ice. Whilst more costly to install, de-frost on demand systems initiate defrost when needed rather than by a timer, and so are more energy efficient.

To optimise the efficiency of the evaporator, ensure that plant material is not stored directly under or in front of it as this will impede air flow around the cold store, leading to an increase in store temperature and energy consumption by the cooling system.

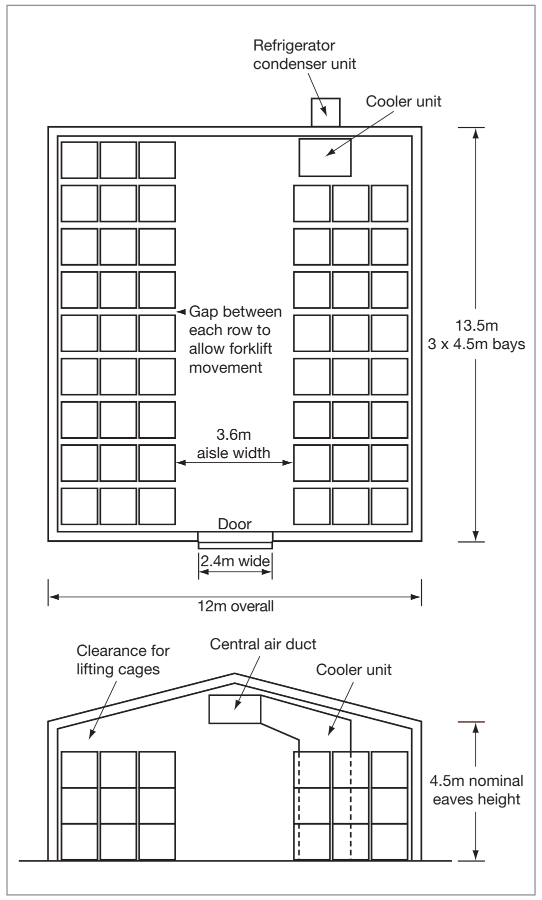

Fig 41 Example of cold store layout

Air movement in and out

Frequent air changes in cold stores can also lead to wasted energy, as cool air escapes and warm air enters. This can be minimised by ensuring that the doors are well fitted and remain closed as much as possible (consider fitting self-closing doors to help with this). Ice build-up on the floor and walls of a cold store is usually a good indication that a high level of air change is occurring. Its presence is also particularly dangerous and a ready cause of accidents. When a door is used regularly, install a strip curtain to prevent cool air escaping. Ensure it is well fitted and remains in good condition, replacing damaged strips when required. Identify any other places where warm air may infiltrate the store, for example damaged walls or gaps between panel sections, ports for conveyors or pipework, and ensure these are attended to promptly.

Heat gains from ancillary equipment in the cold store should also be minimised in order to optimise energy efficiency. The heat from evaporator fans for example can contribute up to 15% of the refrigeration load and lighting can account for a further 10%, due to the heat it generates. Consider replacing existing fan motors with lower power units. To ensure even temperature distribution throughout the cold store, some fans need to run continuously, although with a relatively simple modification to the control circuit, fans can be switched on and off in relation to the refrigeration needs of the store. Also, where evaporators have two or more fans, all fans do not need to be kept running all the time. Ballast for the discharge lighting that is used should be located outside the store.

Heat loads in cold stores can also be reduced by considering other additional items that also give off heat such as motors, fork-lifts and charging devices. People working in the store also give off heat; ensure that they wear adequate thermal clothing for their own comfort and safety, as well as helping to reduce energy costs.

Operating costs can be further reduced by maximising the refrigeration equipment operation using (cheaper) night-time electricity. This takes advantage of the fact that the well insulated and well sealed store warms up slowly, so the refrigeration equipment only needs to operate for a fraction of each day.

7.0 Store layout and materials handling

Whilst it is important to optimise storage capacity, it is also important to ensure there is enough space for nursery staff to work efficiently and safely in the cold store. Frequent access and plant handling are inevitable, particularly during the winter period, for example when collating orders.

If the internal layout of the store is poorly designed and becomes very crowded, considerable time can be wasted double handling stock. Handling adds nothing to the value of the product - only cost. The risks of stored plant material being damaged during the handling and storage process are greater too in very cramped and crowded store environments, where poor air movement can also trigger disease problems, most notably *Botrytis.*

7.1 Location of the cold store

Where possible, purpose built cold stores should be located near to work areas such as the despatch shed, to reduce handling time, for example when removing plant material from the store for orders, or when sorting / grading through plant material prior to storage. Ideally, grading should be done before plant material goes into the cold store, although work pressures sometimes preclude this, particularly during busy periods. On some nurseries, the cold store room or unit is contained within a larger working building used for potting, cuttings preparation and / or order collation and despatch. In the case of seed stores, it is a good idea to locate the cold store adjacent to the weighing room or the area where seeds are cleaned / prepared prior to storage or despatch to customers, to reduce handling time. Similarly, with cutting material, try to locate the cold store near to or within the area used for cuttings preparation and insertion; small converted lorry-back units, wracked out with shelves for additional storage lend themselves well to this.

7.2 Cold store design and layout

When considering the layout of the cold store, leave plenty of room to work in and sufficient to accommodate vehicles such as fork-lifts; as a guide, an industrial fork-lift usually requires a 3.6m aisle in which to turn and stack storage cages. *Figure 41* illustrates a simple store layout to accommodate typically sized 1.2m storage cages.

Whilst only 50% of the chilled area in this example is used (perhaps slightly less), the layout provides comfortable access for an industrial forklift to turn / stack storage cages. Any temptation to fill the aisle should be avoided otherwise access and handling will become inefficient, time consuming and a health & safety hazard. The maximum use of chilled space is only possible with a long, narrow store design and where access is restricted to entrance doors on one side wall only. As a guide, pallets, stillages, boxes or Danish trolleys should not be stored closer than 10cm to each other (more, where frequent access is required), or within 50cm of the roof, to ensure adequate air movement and obviate heat build-up.

Positioning of doors

Doors should be well fitted and remain closed as much as possible (consider fitting self-closing doors to help with this) to reduce air changes and conserve energy. Install a strip curtain to prevent cool air escaping from doors which are used regularly *(Figure 42).* In larger cold stores, use smaller access doors for staff in order to reduce air changes and wasted energy. This is also safer, by keeping staff on foot away from moving machinery as much as possible, and often more convenient. At least one door which can be opened from inside the store should be fitted, to enable any staff trapped inside to exit the store quickly and safely (in Germany, this is now a legal requirement). Fit reflective stickers to light switches and to the inside of the doors to enable anyone accidentally locked inside the store to find their way out quickly. Fit a safety alarm too, to assist anyone locked inside the store. Consider using hand held remote controlled units for opening / closing doors, for example by fork lift drivers to save time and minimise air changes / wasted energy.

It is good practice to install safety barriers along the internal walls of the cold store to prevent damage from machinery and equipment or stacked boxes/ crates *(Figure 43):* some nurseries also have similar protective measures in place around the outside of the store *(Figure 44).* Good access around the outside of the cold store is also important, so allow plenty of working / turning space for staff and machinery, including delivery vehicles. Ensure this is kept clear, clean and in good condition: smooth, level surfaces make plant

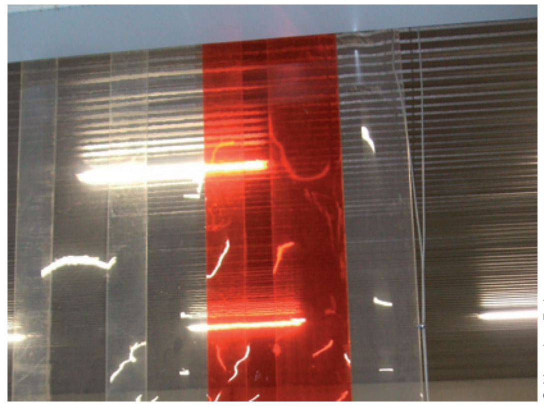
© Henning Pein
Fig 42 Plastic strip curtains prevent cool air from escaping


Fig 43 Safety barriers on internal walls help to prevent damage from machinery and crates


Fig 44 Safety barriers on external walls help prevent damage from forklift trucks and other machinery

handling much easier, quicker - and safer, particularly where Danish trolleys or palletised handling systems are used. Install a telephone inside the cold store for easy communication and as a safety back-up in the event of staff being locked inside the store. In the case of larger stores, several phone points are advisable – mobile phones may not work well inside a store.

7.3 Plant handling

Plant material should be handled with great care before and during storage, to minimise physical damage and subsequent deterioration. Only healthy plant material should be cold stored. Damaged plant tissue such as broken stems and bruised leaves should be removed before plants go into store. Plant material stored in stillages, crates and Danish trolleys (e.g. trays of plugs or pot liners) should not be packed too tightly, to permit air to circulate freely and avoid storage rots or disease pathogens such as *Botrytis* developing. Foliage should be dry to minimise leaf necrosis and attendant disease risks, most notably *Botrytis* and various leaf-spot pathogens.

Where necessary, ensure plant material including that on Danish trolleys is wrapped to prevent desiccation, for example in direct cooled cold stores. Root systems should be moist but not wet, and as much free moisture as possible should be removed in order to help keep stored material in good condition and avoid disease problems. Field grown nursery stock should be stored fresh from lifting, and lifted as late as possible, so that leaf abscission of deciduous subjects is well advanced *(Figure 45)* and plant material has had ample opportunity to 'harden off' prior to cold storage. For plant material in direct cooled stores in need of wrapping to prevent desiccation, ensuring leaf-fall is well advanced will help prevent heating-up and avoid storage rots. Where this not possible, deciduous material should be de-leafed as much as possible and net-wraps considered.


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Fig 45 Leaf abscission should be well advanced before deciduous material is lifted for storage

Some nurseries store bare-root material in metal cages ('stillages') with the roots facing outwards as they feel this helps prevent damage to adjacent plant material. Bags are usually tied to prevent water entering. Ensure all plant material is well labelled using weatherproof marker pens and labels. For reference, date the material when it enters storage.

In larger cold stores, log the location of each species / variety or order on the office computer system to ease and speed plant handling and order picking. Where there are several smaller, side access doors, this also enables staff to enter through the nearest one.

8.0 Acquiring cold storage facilities

Cold storage facilities can be acquired in a number of ways:

- Purpose built new installations
- Used or 'second-hand' cold store facilities
- Conversion or adaption of existing buildings such as a despatch shed, or other resources, for example a refrigerated lorry-back or shipping container
- Renting of cold store facilities off-site, for example from a neighbouring fruit farm or vegetable packhouse
- Sharing of cold storage facilities amongst a local group of growers

Cold stores for nursery stock usually need to be big and for growers without ready access to existing facilities, they are expensive to build. If considering building new facilities, it is important to understand the costs involved and the nursery's exact requirements before making such investments. For example, for nurseries with seasonal requirements, it may be more cost effective to rent or share storage space nearby, rather than spend large sums of money on a facility which is only used for a short period of the year. Such a facility is a 'year round' cost to the business in terms of insurance, occupied space and maintenance, unless it can be leased out on a seasonal basis.

Purpose built stores versus existing stores

New stores offer the distinct advantage of being tailored to the specific requirements of a particular business in terms of size, design, internal layout, location, mechanised handling, energy efficiency and environmental control. However, they are usually the most costly option. In contrast, inheriting or adapting existing facilities offers ready availability and significantly less capital outlay, although greater running and maintenance costs may be incurred, particularly with older, less energy efficient cold stores. The specification may also be quite dated and no longer meet the changing requirements of the nursery, thus requiring considerable modification. In such cases, a new purpose built store may prove to be a sounder long term investment. Older cold stores are invariably less energy efficient than new ones and mechanised handling systems can be difficult to accommodate.

Refrigerated containers

In terms of capital costs, refrigerated lorry-backs or shipping containers *(Figure 46)* are at the opposite end of the spectrum compared to newly built permanent constructions. They can easily be adapted for cold storage and are used quite widely by nursery stock growers for holding seeds or cutting material. They are relatively cheap (typically, £1,700 to £4,000) but usually quite small, and so have limited capacity. Plant handling is almost always manual due to the lack of space but they are a realistic, cost effective option for nurseries wishing to hold cuttings, budwood, seed or even plug plants. The condition of such stores can vary and should be checked, otherwise, costly repairs may ensue.

Renting and sharing

Renting or sharing cold store facilities has advantages too, particularly for those nurseries with very seasonal, short-term requirements, for example winter storage of bare-root nursery stock or summer storage of cuttings and budwood. This is also an option during busy periods where extra storage capacity is required to supplement existing 'in-house' facilities. Such short-term arrangements offer flexibility and opportunities to share costs (for example, with other growers who need access to cold storage at differing times of the year), without incurring the 'year round' expenses associated with new stores or the annual maintenance of older, less energy efficient stores. However, the availability of rented or shared space may be limited and the quality of such cold stores can also vary.

To be cost effective, rented facilities also need to be situated nearby as frequent travel is time consuming and costly. It follows, that there is usually less scope for quality control with off-site rented stores as compared to a nursery having ready access to its own facilities on site. Off-site security may also be a concern.

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Fig 46 Shipping containers can be easily adapted for cold storage

Case study 12

CLTV Winkel, Zundert, NL. Renting and sharing cold store facilities is quite common amongst growers in the Netherlands. CLTV Winkel in Zundert (a highly concentrated area of horticultural production) for example, is a co-operative through which local growers are able to book and rent space (obviating incurring long term storage costs themselves). Fresh produce, including strawberries and chicory, is usually stored until late December; thereafter the emphasis switches to nursery stock. The cold stores are also used for pot grown and bare-root strawberry plants.

CLTV write to growers (up to 400 use their facilities) each August inviting them to reserve space for the coming season. Stock for storage is usually delivered to CLTV by 15.30hrs on the scheduled day and removed by 10.00hrs on the day of sale or collection by the grower. Grower representatives are responsible for checking storage temperatures on a regular basis. All the stores are direct cooled, so the growers need to ensure stock is appropriately wrapped and prepared. *Skimmia* and *Pieris* are often cold stored for one month to facilitate scheduling and delivery requirements.

Points to consider when acquiring cold store facilities

- Do I need short–term seasonal storage or access to year round facilities?
- What do I need in terms of space, location and environmental control?
- Do my present facilities meet these needs?
- Will these needs change in the future?
- How much are my present cold store facilities costing (maintenance, repairs, insurance etc)?
- Are they cost effective and in good condition or should I consider building a new store?
- What specification do I need and how much will it cost?
- What is my budget?
- Am I flexible and prepared to rent / share cold store facilities?
- Are there suitable rented facilities available nearby and what condition are these in?
- Are they also used for fresh produce such as fruit?
- Are they suitable for my requirements?
- Are there other growers in the area prepared to share / rent?
- Is there a reliable service engineer in the area?

9.0 Costs of cold storage

The perceived high costs associated with cold storage facilities are usually the main reason why they are not used more widely by UK nursery stock growers, despite their many advantages. Indeed, 40% of growers who participated in HNS 140 cited concerns over costs as the reason why they were not using cold storage.

HNS 140 considered the cost-benefits of cold storage and found that purchase costs varied considerably (£40,000 to £125,000) depending on the intended use, and so in turn the type and size of cold store required. The age of the cold store facilities that were surveyed in the project varied markedly, and therefore made it difficult to compare capital costs accurately. Generally, refrigerated cold stores such as converted lorry-backs used for cutting material are relatively cheap (typically, £1,700 to £4,000) but usually quite small and so have limited capacity, particularly for larger grade nursery stock, for which cold stores need to be big and so are usually quite costly.

As a guide, the average annual cost to build and run a cold store is likely to be around £22/m^2 of storage area when spread over a ten year pay-back period, excluding the cost of any building that the store may be situated within. Over 50% of growers surveyed, used self-contained stores such as converted lorry-backs, existing barns or new steel framed buildings insulated to function as a cold store when required.

Ultimately, the economics of using a cold store depend on how well the space is used and to what extent the technology can be harnessed to improve saleable yield. For example, where low temperature storage is used to delay flowering or growth for marketing purposes, improved returns and reduced wastage can result, making it more cost-effective and attractive to growers.

One of the major advantages of using a cold store is that it can be used to over-winter woody nursery stock subjects and thereby save valuable glasshouse space (which, in turn, could be used for another crop). Plants can be stacked on trolleys in the store and kept there throughout the winter period. Assessing the cost benefit of this requires a simple comparison between the costs of cold storage compared to the cost of the equivalent glasshouse space that would be required. *Table 3* provides an illustration of this analysis.

Table 3:
*Direct area comparison between cold store (CS) and glasshouse**

Plants or pot size	No. of layers on trolley	Cost of CS area	Cost of glass area	Difference	% Difference
Large plants	2	£21.35	£9.12	-£12.23	-57.28
3Litre	4	£21.35	£18.24	- £3.11	-14.57
3 Litre	5	£21.35	£22.80	£1.45	6.79
9cm	7	£21.35	£31.92	£10.57	49.51
Plugs	9	£21.35	£41.04	£19.69	92.22

*HNS 113 – *The feasibility of using low temperature storage as a scheduling aid in nursery stock production.*

When five layers of plants or more are held in the cold storage area there is a clear cost-benefit, and this benefit becomes more significant when the store is used to improve 'saleable yield', as illustrated in *Table 4.*

Table 4:
*Break even yield for one crop per year**

Plants or pot size	No. of layers on trolley	Cost	Output per m^2	% break-even yield
Large plants	2	£21.35	£110.56	19.31
3 Litre	4	£21.35	£221.12	9.66
3 Litre	5	£21.35	£276.40	7.72
9cm	7	£21.35	£386.96	5.52
Plugs	9	£21.35	£497.52	4.29

*HNS 113 – *The feasibility of using low temperature storage as a scheduling aid in nursery stock production*

In this example, the cold store is used to delay flowering or growth to meet specific sales windows and so reduce wastage. If the store was used to hold just one crop of 3 litre nursery stock long enough to ensure that at least 10% or more of it could be sold (than if it had not been kept in a saleable condition), then the benefit exceeds the cost. This is particularly attractive for crops that have seasonal interest, for example those that flower over a short period, and when spells of poor weather arrive during peak sales periods. If the store can be used for two crops then the benefits are greater still: essentially, the greater the throughput the more worthwhile cold storage is.

Appendix 1

Further help and information

HDC project reports & factsheets

Project HNS 113 *(The feasibility of using low temperature storage as a scheduling aid in nursery stock production). 2001 – 2003*

Project HNS 140 *(Hardy ornamentals: Survey to determine current industry practice and future needs for the use of low temperature storage as a scheduling aid in nursery stock production). 2005-2006*

Project PC 196 *(Bedding plants: The use of low temperature storage as a scheduling aid). 2002 – 2003*

Factsheet 09/05 *(Low temperature storage of bedding plant plugs). 2005*

Organisations

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horticulture@adas.co.uk
www.adas.co.uk

Trade bodies associated with cold storage

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Companies offering cold storage services (construction/installation)

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