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PRACTICAL SECTION FOR GROWERS

Scope of project and objectives

Sales of containerised roses continue to form an increasing share of the retail rose market. The market demand for roses in flower in spring and early summer has also continued to grow in recent years which complements, or partly substitutes, the market for bare root or containerised dormant plants for autumn sales. As with other horticultural products, retailers are looking for continuity of supply of roses at the optimum stage for sale over a selling period of two to three months or more.

This project looked at several techniques to achieve this but concentrated on using cold stores to hold back batches of plants, which were removed at intervals, to give a succession of crops in flower during the summer.

Over the two flowering seasons of the project, the main objectives were to:

1 Examine how different holding and growing environments such as cold stores, unheated glass, polythene tunnels and outdoor growing beds, could be used to achieve successional crops of containerised roses in an optimum flowering stage for summer sales.

2 Look at the use of dormant eye and started eye plants (lifted from the field at the end of the budding year) of mainly patio and dwarf floribunda cultivars, as a means of delaying maturity compared to the use of conventional 'finished bushes'.

3 To compare successional crops of roses from plants cold stored in containers, following autumn potting, with those held in store as bare root plants and potted sequentially on removal in late winter to early summer.

4 To gain experience of some of the factors which could influence how successfully plants stored and established, such as cold store environment, plant handling and pruning.

Summary of results

In the first year of the project, 1995, a well spaced sequence of crops ready for marketing from mid May until early August was achieved from containerised finished bushes. This involved the cultivars Indian Summer (HT), Trumpeter (floribunda), Sweet Dream (patio) and Pretty Polly (patio) grown from finished bushes containerised in November; pots were held under ambient conditions (polythene tunnel then outdoor bed), or held in a cold store and removed to the growing-on beds on 5 April, 15 May or 6 June. Dormant eye plants of these cultivars given the same storage treatments took much longer to become saleable. While dormant eyes could give a useful delay in

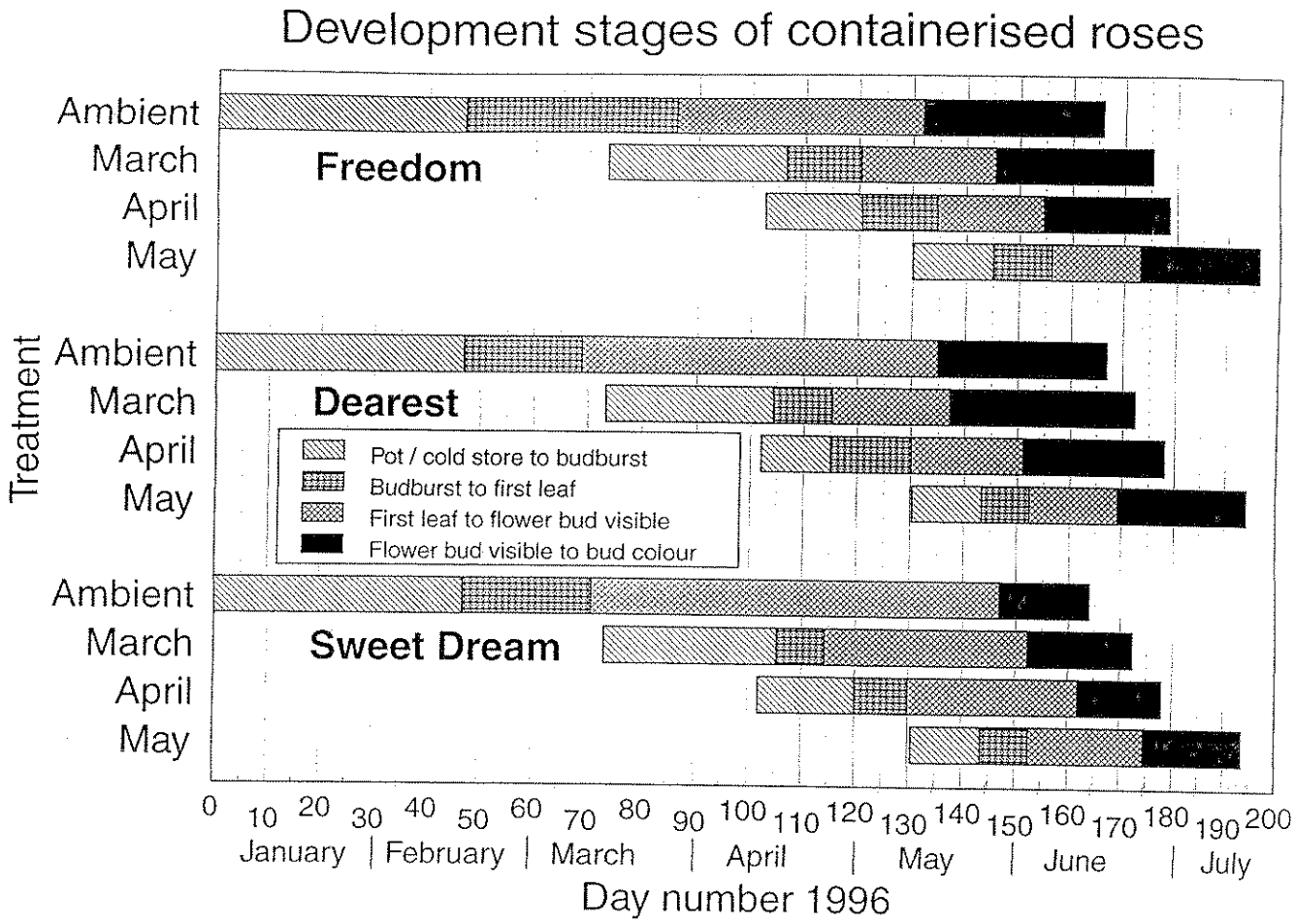
flowering, those removed from cold store in May and June were too late to make a good quality plant that season. Successive shoot pinching operations were required to encourage sufficient bushy growth before plants were allowed to develop to flower. Started eye plants used in the project's second year gave a better quality plant more quickly and required little pinching. Dormant eye and started eye techniques are best suited to patio cultivars which are inherently freely branching.

Pruning back batches of plants following their first flush of flower gave a second flush of flower from mid August to mid October. Indian Summer and Trumpeter, with their more open habit, had a more attractive appearance than the patio cultivars where a lot of the dense older foliage at the base of the plants had become discoloured or diseased.

Sequential pottings of bare root plants from cold store gave as good results as removing batches of ready containerised plants from store in trials, in 1996, the second year of the project with the cultivars Freedom (HT), Dearest (floribunda) and Sweet Dream (patio). The times taken to flower, numbers of flowers per plant and the final root development were very similar between bare root and containerised storage methods. Following nil storage (ambient) and cold storage until 13 March, 11 April, 9 May, these timings, coupled with a cool May that year, gave a more compressed spread of maturity dates in 1996 than in the 1995 trial, particularly between the earlier three batches. All batches were of good quality and of similar size even though the latest crops had between half and two thirds the number of flowers and buds present at marketing as the earliest ones.

Clearly defined key stages of plant development have been identified and can help in determining how long before batches are likely to be ready for marketing and whether management action is needed to help keep cropping schedules to plan.

A trial using the cultivar L'Aimant (floribunda) in the second year of the project compared root and shoot pruning treatments prior to cold storage. Some plants were stored hard pruned to 20 cm root and 13 cm shoot ready for containerising, while others were stored as lifted from the field following the normal root undercutting and light shoot trimming and hard pruned when potted in April. There were no significant differences in establishment or subsequent summer growth and flowering between treatments.



Action points for growers

- In order to get an evenly spaced sequence of crops in flower, longer intervals between successive potting dates up to about mid April are required than for later pottings, as plant development is largely dependant on temperature. A model for containerised rose growth is being developed which will enable growers to predict potting dates and manage crops more accurately to help them meet targeted marketing dates.

- Ensure temperatures in cold stores are maintained below 1 °C to keep plants dormant if they are to be held for an extended period for spring and summer potting. Check plants regularly for signs of desiccation; cover with polythene and damp down as required.

- Most cultivars can be safely root and shoot pruned ready for potting prior to cold storage. However some, such as Sweet Dream, may be susceptible to progressive shoot blackening and dieback from the tip while in storage. If in doubt about a cultivar, leave longer shoots that can be re-pruned when potted.

- Plants left unsold after the first flush of flower can be hard pruned back and will flower again some 35 - 60 days later depending on the cultivar and time of year. This gives a second opportunity for sales, although it is often difficult to keep old foliage healthy and attractive at that time of year. Consider using longer term cold storage to target plant batches for late summer sales.

Practical and financial benefits from the study

Being able to provide successional batches of containerised roses at the optimum stage for marketing in early flower will extend the effective selling season and should stimulate overall demand. The improved matching of supply and demand between nurseryman and retailer, improvements in product quality and reductions in plant wastage should also help boost retailers' and end consumers' confidence in the product. It is also possible that a demand for late summer flowering roses can be stimulated by these techniques.

The use of cold storage techniques offers flexibility of plant handling, labour use and more efficient use of growing areas for the nurseryman. It is hoped that the predictive crop scheduling model for containerised roses currently being developed will enable growers to manage their batches of plants and marketing schedules more precisely.

EXPERIMENTAL SECTION

INTRODUCTION

Background

Containerised roses continue to take an increasing share of the retail market for this crop compared to sales of bare root, sleeved or root wrapped plants. Garden centre outlets, in particular, now require a continuity of supply over a long selling season starting as early as September for 'dormant' plant sales, and from late April through to July or beyond for container plants in flower.

For plants sold in flower, the nurseryman is becoming more involved in promoting his product by providing a succession of stock in peak condition for sale. Experience has shown that the retailer is increasingly unable or unwilling to manage and tend plants over a long period. Roses remaining unsold after the first flush of flower will rarely be pruned back and kept sprayed against pests and diseases for later sale. Straggly plants with starved, diseased and damaged foliage will often remain at the end of the season, which does little to promote the product.

Project Objectives

The overall objective of this project was to develop techniques to enable a successional supply of containerised bush roses of a range of cultivars to be made available for marketing over a spring and summer period from May onwards. This would have the following benefits:

i) Extend the effective selling season for roses and possibly stimulate new demand by extending the flowering season.
ii) Significantly improve the quality of the later season product for the retailer.
iii) Enable producers and retailers to match supply and demand more effectively, and reduce the problems from holding large quantities of unsold stock on both the nursery and garden centre.
iv) Reduce wastage from plants deteriorating in the sales area and, hopefully, stimulate sales by maintaining product quality.
v) Flexibility for handling, potting and despatching plants, and smoothing the labour profile for key operations.
vi) Increase output from both the nursery production and point of sale areas by sequentially potting batches of plants.

In the first year, experience was gained in the use of cold storage, polythene tunnels and glasshouse environments to manipulate crop development. Also, a range of cultivars were containerised as both 'dormant eyes' (ie lifted at the end of the budding year), and finished bushes (ie lifted at the

end of the bush production year), and flowering times and quality were compared. The detailed results of this work were presented in the interim project report (February 1996), and the key relevant findings are referred to in this report.

Second year work objectives

i) To compare roses cold stored for varying lengths of time in containers following autumn potting (as done in Year 1), with the more economic option of holding bare root plants in cold store, and potting sequential batches in late winter - early summer.

ii) To collect further data on development times in a different season.

Two other smaller experiments were also carried out:

iii) Obtain preliminary indications of the importance of the timing of root and shoot pruning in conjunction with the use of cold storage, either following autumn potting or before spring potting.

iv) Compare the performance of dormant eye with 'started eye' plants of patio cultivars potted sequentially from cold store.

MATERIALS AND METHODS

Trial A - Cold storage of containerised vs. bare root finished plants - HT, floribunda and patio cultivars

Treatments

	Containerised at lifting or stored bare rooted	*Cold stored until*
1	Containerised	Ambient (no cold storage - potted 1/12/95 and held in polythene tunnel until spring)
2	Containerised	March (13/3/96)
3	Containerised	April (11/4/96)
4	Containerised	May (9/5/96)
5	Bare root	March (13/3/96) then potted
6	Bare root	April (11/4/96) then potted
7	Bare root	May (9/5/96) then potted

Cultivars

Freedom	(HT)	on Laxa rootstock
Dearest	(Fl)	on Laxa rootstock
Sweet Dream	(Patio)	on Laxa rootstock

Design and layout

7 storage/timing treatments (2 storage methods x 3 timings + 1 ambient control) x 3 cultivars = total 21 treatments.
4 replicates of 5 plants per plot.

Arranged on outdoor growing-on beds as split-plot design with timings from cold store as main plots to minimise shading effects between contrasting treatments (see layout plan Appendix I, p 28).

Trial B - Severity of pruning for cold storage of bare rooted and containerised plants

Treatments

	Pruning at lifting	*Containerised at lifting or stored bare rooted*	*Cold stored until*
A	Hard prune top + root	Containerised	Ambient (no cold storage)
B	Light prune top + hard prune root	Containerised	Ambient (reprune top in spring)
C	Hard prune top + root	Containerised	April
D	Light prune top + hard prune root	Containerised	April, (reprune top)
E	Hard prune top + root	Bare root	April, then potted
F	Light prune top + root	Bare root	April, top + roots pruned at potting

Pruning definitions:	***Measurements made from bud union:***
Light pruning	Shoots about 25-30 cm; eg as trimmed in field before lifting Roots not pruned; ie. as lifted after J-blade Damcon undercut
Hard pruning	Shoots about 13 cm as for potting Roots about 20 cm as for potting

Cultivar
L'Aimant (Floribunda) on Inermis rootstock

Design and layout

6 pruning / storage treatments in total
4 replicates of 5 plants per plot.

Arranged on outdoor growing-on beds as randomised block design, (see layout plan Appendix II, p 29).

Trial C - Sequential flowering of patio cultivars - Dormant eye vs. Started eye plants

Treatments

Plant type	*x*	*Cold Storage until*
Started eyes		Ambient (no cold storage - held in polythene tunnel until spring)
Dormant eyes		March (week 11) then potted
		April (week 15) then potted
		May (week 19) then potted

Cultivars

Sweet Dream	(on Laxa rootstocks)
Cider Cup	(on Laxa rootstocks)

Design and layout

2 plant types x 4 cold storage treatments x 2 cultivars = total of 16 treatments
4 replicates of 5 plants per plot.

Containers were arranged on outdoor growing-on beds as a split-plot design with timings from cold store as main plots to minimise shading effects between contrasting treatments (see layout plan Appendix III, p 30).

Culture

Lifting from the field

Roses were undercut in the field with a J-blade Damcon undercutter and winch in October 1995. Dates of lifting from the field, followed by potting and / or cold storage of plants depending on treatment, were as follows:

Trial A	28/11 - 1/12/95
Trial B	4/12/95
Trial C	11/12 - 12/12/95

Cold storage

Plants were stored in a conventionally refrigerated jacketed cold store (not ice-bank cooler) at about 0 - 1 °C. All bare root cold stored plants in Trials A & C were given the same hard pruning treatment of roots and shoots as used in Trial B prior to being tied in bundles and placed in polythene sacks. Plants were checked regularly and damped with water when required. A spray drench of prochloraz manganese (as Octave at 1 g/litre) was applied over the bundles on 26/1/93 and 9/2/96 to help protect against the development of pathogens from decaying leaves present, and in an attempt to check stem blackening (dieback) that was affecting cv. Sweet Dream in particular.

Containerised plants in cold store were stood on the floor spaced pot thick. They were kept moist but not wet, and required very little attention.

Growing media

Plants were potted into the following growing media:

100%	Premium Grade (medium / coarse) Shamrock Irish Moss Peat
2.4 kg/m^3	Magnesian limestone
3.0 kg/m^3	Ficote 140 TE controlled release fertiliser (for plants potted in autumn / winter)
	or
4.0 kg/m^3	Ficote 140 TE controlled release fertiliser (for plants potted from March onwards)

The rates of CRF used here as recommended by Fisons, represented a safe option for experimental purposes. The use of a '140 day' longevity product at these rates minimised the risk of 'flash release' under warm conditions in a polythene tunnel, or when potting in summer for example. The lower rate for the autumn / winter potting reflected the need to limit the build up of salts until growth commenced in spring. A 140 day CRF also enabled plants to be held until the autumn or following spring without the need for supplementary feeding, as the need for trial assessments meant plants could not be actually sold during the spring / summer 1996 marketing period. Many commercial nurseries, however, use shorter longevity (one season) products at lower rates for containerised roses for spring sales to reduce costs.

Potting and standing out

4 litre deep black Optipot 17RX containers were used. The Ambient treatments in each Trial were potted in late November - early December 1995 and set out on permeable ground covered sand beds in a ventilated side polythene tunnel, and spaced pot thick. Thorough waterings were given initially, but thereafter little additional water was required until about mid February.

They remained in the tunnel to protect them from excessive winter rainfall and waterlogging before moving them to permeable ground cover beds outside, on 13 March 1996, at the same time as the March treatments from Trials A and C were potted or moved out from the cold store. Plants were set out on these beds at their final spacing with 5 plant plots at 270 mm centres across the bed and an in-row spacing of 300 mm centres down the bed. This spacing was wider than that used in the 1995 trial, and was sufficient to avoid having to re-space plants again later to prevent overcrowding.

Most irrigation outside was given via drippers (one per pot) apart from some hand-watering necessary to compensate for differential water use by treatments at different growth stages.

Pesticides

The residual herbicide, oxadiazon, was applied as Ronstar 2G granules at 20 g/m^2, over the pots on 15 March 1996 to the Ambient, March and April treatments, and on 9 May to the May treatments.

A routine disease spray programme against powdery mildew, black spot and rust, was applied at about 2 week intervals from late April to the end of September. Rotations of the following chemicals were used:

Carbendazim as Bavistin at 0.5 g / litre + dodemorph as F238 at 1.25 mls / litre

Myclobutanil as Systhane Flo at 1.0 mls / litre

Bupirimate as Nimrod T at 3.2 mls / litre

One of the following insecticides, mainly for aphid control, were added to sprays as required:

Pirimicarb as Pirimor at 0.5 g / litre

Dimethoate as Dimethoate 60 at 0.85 mls / litre

Deltamethrin as Decis at 0.7 mls / litre

Nicotine as Nicosoap at 6.6 mls / litre

Heptenophos as Hostaquick at 0.75 mls / litre

Records

Growth stages

From experience in 1995, a set of easily identified key stages of growth were recognised. It was important that the stages were of short duration so that the date could be recorded reasonably accurately, and that the stages could also be readily identified by growers in a commercial situation for the project to be of practical application.

The date when about 50% of the plot (or 50% of main shoots in the plot) were at the following stages were recorded on a whole plot basis.

Bud burst:	When terminal buds on the shoot framework had elongated, and the leaflets were unfurling at the bud tip, but had not yet opened out.
First expanded leaf:	When the first true leaflet had expanded and opened out flat.

First flower bud: When 2+ small green flower buds per plant could be seen developing in the apex of the main shoots (on hybrid teas and floribundas), or 4+ buds per plant amongst the many shoot tips (on patio cultivars).

Flower bud colour: When the flower bud calyces were beginning to split and petal colour could be seen.

Final 'marketing stage' record

When the flower bud colour stage had been reached for a treatment, general quality parameters were recorded for each plant:

Overall plant height from growing media to base of the flower on the tallest shoot.

Spread at widest point and perpendicular to the widest point.

Flower count, both of those at flower bud colour stage and beyond (including 'blown' blooms), and immature green flower buds.

A root cover score for the out-turned potball on a 1 (low) to 5 (high) scale.

A root colour score from 1 (mainly brown root) to 3 (a high proportion of fresh white root).

New root score from predominantly very fine (1) to thick and vigorous (2).

Temperature records

Tiny Talk data loggers were used to record cold store, polythene tunnel and outside air temperatures using a 1 hour recording interval. Temperature sensors for containerised plants were set at a height of about 400 mm from the ground, ie of a height applicable to shoot growth, This was to avoid any inconsistencies that might be caused by vertical temperature gradients than can occur near ground level.

RESULTS

TRIAL A - Cold storage of containerised vs. bare root finished plants

Plant health and survival

There were very few plant losses in this trial. Bare root plants of the cultivar Sweet Dream did, however, develop some blackening and dieback of the shoots while in cold store in April. The affected parts of the shoots of both the April potted batch and those remaining in cold store until May were trimmed back to healthy tissue, and most plants subsequently grew away well. No primary pathogen could be isolated from affected plants. The problem may have been physiological in origin, and it only affected Sweet Dream stored as bare root plants.

Rate of plant development

The key growth stages are shown graphically in Fig 1 p 14. The dates when the key development stages were reached are also given in Appendix IV, p 31. These dates are expressed as day number of the (leap) year to make comparisons between treatments easier. Appendix V, p 32 gives a conversion table for day number to calendar dates.

For all the key development stages, the effect of time of potting or removal from cold store (timing treatments) had the greatest effect on the date when stages were reached, although there was sometimes an interaction with cultivars (see Appx IV). Whether plants were cold stored ready containerised or as bare root plants potted after cold storage had little or no effect on the time taken to reach key development dates.

Plants which had received no cold storage (Ambient) broke bud early in mid February (day 47), almost two months before those potted in May, but under the prevailing cold temperatures further development was very slow. Differences between timing treatments became much less marked with the later stages of development, such that by the bud colour stage there was only about one month difference in maturity between the earliest (Ambient) and latest (May) treatments.

Budburst

There was a mean difference of 58 days between the date when the Ambient treatments broke bud, and the March timing. Budburst in the April and May timings, on average, followed 13 and 26 days later. Differences in budburst date between cultivars were usually small.

Fig 1 Development stages of containerised roses

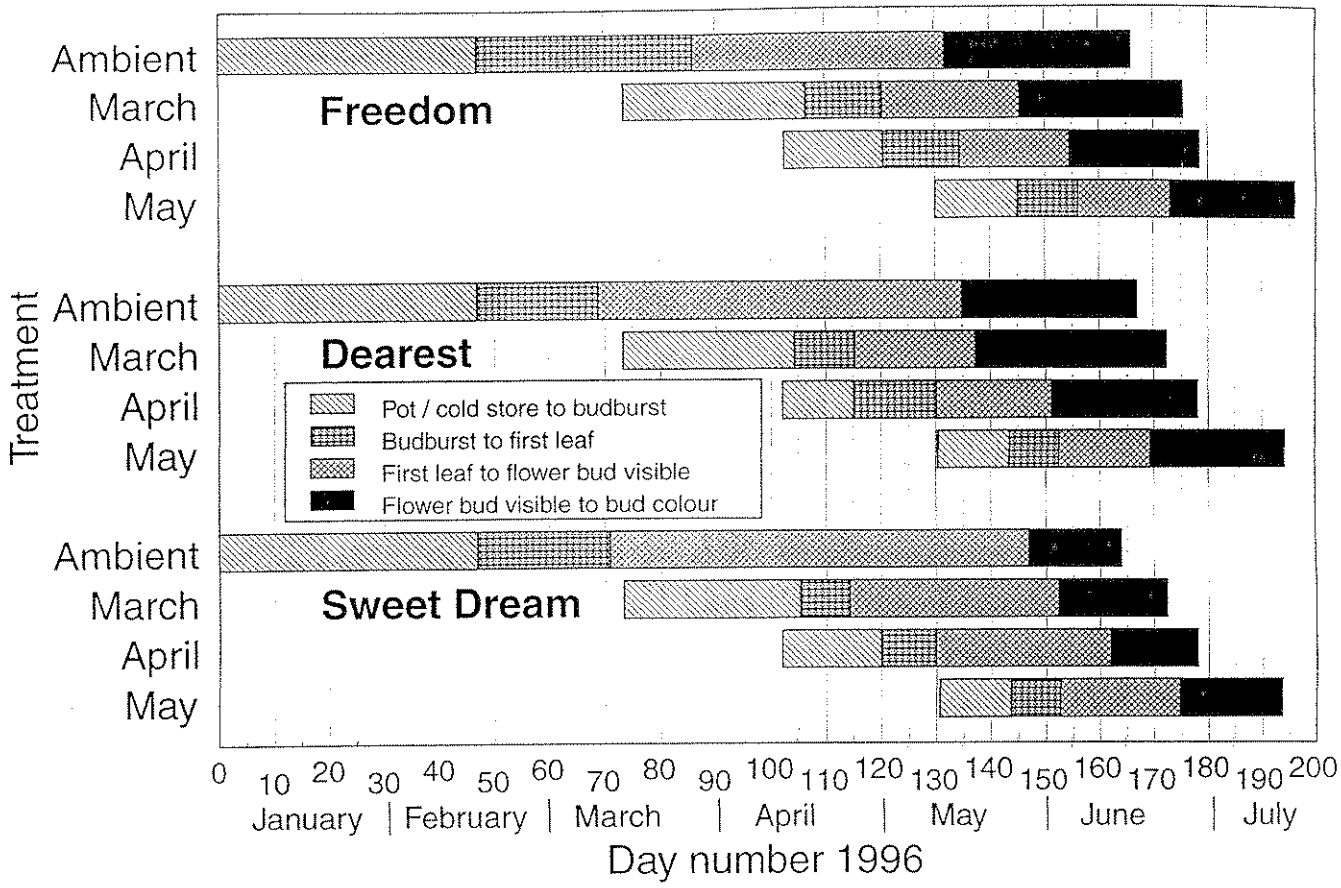
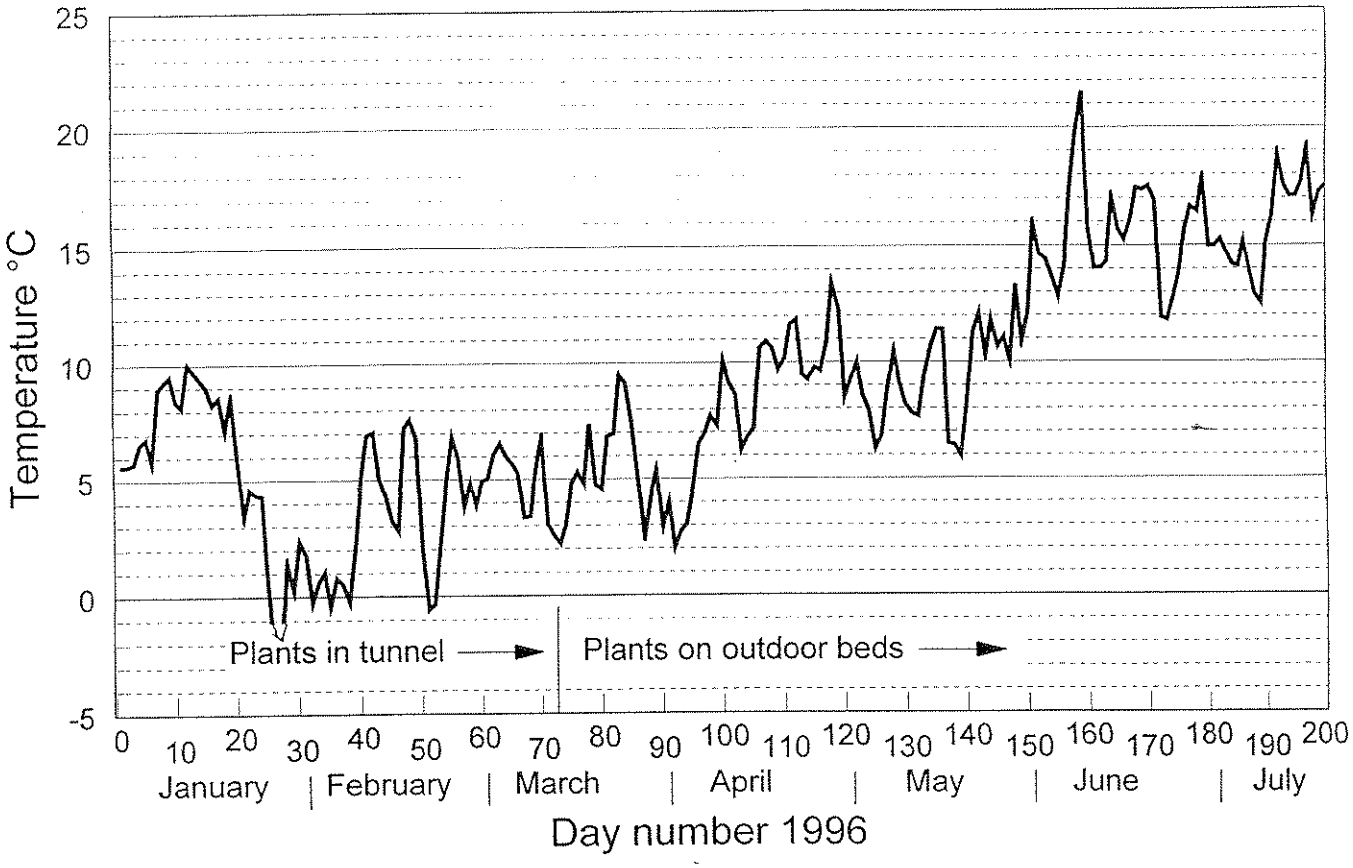


Fig 2 Daily Temperature (mean of hourly readings)



First expanded leaf

The first expanded leaf stage was reached later by Freedom than the other cultivars. This was most marked for the Ambient treatment where it was 16 days later than Sweet Dream and Dearest on average. Again, the difference between the March and April timings was relatively small.

Appearance of flower buds

Sweet Dream was 12 - 15 days later to show flower buds than the other two cultivars for the Ambient treatment, but only one to five days later for the May treatment. For Sweet Dream and Freedom, the interval between flower buds appearing in the Ambient and March treatments was short, about two to five days, compared to 13 days for Dearest. However there was a 12, 19 and 18 day interval respectively for Sweet Dream, Freedom and Dearest between the April and May timings.

Flower bud showing colour

There was a statistically significant interaction between timing and cultivar treatments, but this was small. The main treatment effect of timing can therefore be summarised as follows:

Timing	*Day no.*	*Date*
Ambient	166	14 June
March	173	21 June
April	178	26 June
May	194	12 July

On average, there was thus a seven day delay in maturity between the Ambient and March treatments, five days between March and April, and 16 days between the April and May treatments, giving a 28 day spread in maturity from the earliest to latest timing treatments.

The total number of days from potting or removal from cold storage to reach the flower bud colour or marketing stage for each of the four batches of plants is summarised in Table 1, p 16). The production time became progressively shorter as batches were started and grown on in increasingly warm conditions through the spring and summer. Although there were significant differences between the cultivars in the time to reach earlier stages of growth, differences were very small by the time they had reached flowering stage.

Temperature records

The temperature in April was warmer than usual, while temperatures in May were relatively cool, followed by a warm June. This had the effect of condensing the flowering dates of the first three batches of plants, particularly those potted in March and April, followed by a long gap until flowering of those potted in May. Fig 2, p 14 shows the mean daily temperature experienced by plants while on the growing-on beds both under the ventilated polythene tunnel and outdoors. Meterological maximum and minimum temperatures for Efford are shown in Appendix VI p 33.

Table 1 **Trial A: The main effect of the time (days) from date of potting or removal from cold store until appearance of flower bud colour for three rose cultivars. Mean of bare root / containerised cold storage for March - May treatments.**

Time of removal from cold store	Days from potting / removal from storage until flowering			
	Sweet Dream	Freedom	Dearest	Mean
Ambient (no storage)	195	197	198	197
March (13/3/96)	100	103	100	101
April (11/4/96)	77	77	77	77
May (9/5/96)	64	67	65	65

Quality of plants at marketing stage

There were no meaningful differences in the scores for root thickness and root colour, so these data are not presented here. Neither the type of plant (cold stored as bare root or containerised), nor the timing treatments had any significant effect on the height, mean spread or amount of root cover, so the main effect for the cultivars only is shown (Table 2).

Table 2 **Trial A: Main effect of cultivar treatments on quality of plants at marketing stage - size and root development. Mean of storage treatments.**

Cultivar	Mean height cm	Mean spread cm	Mean root cover Score 1-5
Sweet Dream	42	39	3.2
Freedom	53	56	4.4
Dearest	59	52	4.0
SED (51 df)	*1.11*	*0.76*	*0.14*
LSD (5%)	*2.0*	*1.6*	*0.3*

Height and spread

Characteristic of the cultivars, both Dearest and Freedom were taller and broader than the more compact patio Sweet Dream.

Root cover

Freedom and Dearest both had more root visible on the outside of the potball at the marketing stage than Sweet Dream, but nevertheless all cultivars, whether containerised prior to cold storage or potted from cold store, developed good root growth even from the latest pottings in May.

Flowering

The number of flower buds produced was very different for each cultivar, so they were analysed separately (Table 3). There was a clear trend for the later timings to have less flowers present at the time of marketing than the earlier ones, despite there being no apparent difference in overall plant size. Thus there were between a half and two thirds the number of flowers plus buds present on the May timing compared to the Ambient treatment. There was some evidence to suggest that those cold stored in containers showed a very small increase in the number of buds over those potted from cold store, but differences were small and not significant.

Table 3 **Trial A: The main effect of the time (days) from date of potting or removal from cold store on the quality of plants at marketing stage - flowering. Mean of bare root / containerised cold storage for March - May treatments.**

Time of removal from cold store	Total number of flowers per plant (all stages)		
	Sweet Dream	**Freedom**	**Dearest**
Ambient	70.6	5.25	19.65
March	62.7	4.37	13.15
April	54.1	4.45	14.31
May	41.5	3.57	10.77
SED (9 df)	*5.78*	*0.290*	*1.841*
LSD (5%)	*13.1*	*0.66*	*4.16*
except for comparisons including Ambient:			
SED (9 df)	*7.08*	*0.356*	*2.255*
LSD (5%)	*16.0*	*0.81*	*5.10*

TRIAL B - Severity of pruning for cold storage of bare rooted and containerised plants

Plant health and survival

There were no plant losses in any of the treatments in this trial on L'Aimant, and growth was strong and healthy from both plants that had been cold stored and those that had been potted in December and kept under ambient conditions. There was no indication that any treatments had caused any

stress or check to growth and flowering. Thus there was no evidence that cold storing the plants after the roots or shoots had been hard pruned, or as they were lifted from the field, made any difference to survival for this cultivar.

Rate of plant development

The Ambient and Containerised cold stored treatments were potted on 4/12/95, whereas those cold stored as bare root plants were potted from the store on 11/4/96. The Containerised Ambient with hard pruned shoots treatment (Trt A) reached budburst on 16/2/96. The Containerised Ambient with light pruned shoots treatment (Trt B) were pruned back to the same height as Trt A on 22/2/96, and subsequently the 'new' terminal buds burst on 3/3/96. Of the plants removed from cold store on 11 April, those that had shoots already hard pruned before storage (Trts C and E) reached bud burst on 25/4/96. Trts D and F were light pruned before storage and were re-pruned hard on removal from the cold store. They burst bud a little later; on 27/4/96 for those stored in containers and 30/4/96 for those stored as bare root plants.

A similar pattern of timings applied to the first expanded leaf stage. However, by the time flowers developed, and particularly by the bud colour stage, differences between the pruning treatments were small and not statistically significant. Thus the two Ambient treatments reached bud colour on 13/6/96 and the April treatments 14 days later on 27/6/96.

Root development

In Trial B, a root development assessment was done on 5/6/96 rather than at the marketing stage, to see whether there was any early indication of treatment effects. The scoring system described above in Materials and Methods (p 12) was used.

Table 4 Trial B - Root development by 5 June 1996

Treatment	Mean root cover score (scale 1 - 5)	Mean root colour 1 = brown, 3 = white	Type 1 = thin 2 = thick
A Amb. / Hard prune / Container	3.9	1.3	1.0
B Amb / Light prune / Container	4.1	1.0	1.0
C April / Hard prune / Container	3.5	3.0	1.5
D April / Light prune / Container	3.2	3.0	2.0
E April / Hard prune / Bare root	2.7	2.8	2.0
F April / Light prune / Bare root	2.5	3.0	1.8

At this stage there was evidence that the Ambient treatments had a more developed, but older and more mature (suberised and brown), root system than the April treatments. Also those removed from the cold store already containerised had a little more root visible than those potted in April at this stage, although as shown in Trial A, differences were less apparent by the time plants had reached flowering. The April treatments showed a high proportion of fresh young and thick white root compared to the Ambient treatment. The effect of the severity of the initial shoot / root pruning treatments on root growth was small.

Quality of plants at marketing stage

There was no significant difference in plant height at marketing (mean 65 cm, $SED_{15\ df}$ 2.6). The Ambient treatments had a slightly greater spread (mean 50 cm) than the hard pruned April treatments (mean 45 cm) but this was not significantly different from the light pruned April treatments (mean 48 cm, $SED_{15\ df}$ 2.1). Differences in numbers of flower buds were not statistically significant (overall mean 9.3 buds per plant, $SED_{15\ df}$ 1.2).

TRIAL C - Sequential flowering of patio cultivars - Dormant eye vs. Started eye plants

The 'dormant eye' plants of cvs. Sweet Dream and Cider Cup for this trial were grown at Efford, whereas the 'started eye' plants were bought in from a commercial supplier. The started eye plants were of a similar age to the dormant eye ones, both having been budded onto Laxa rootstocks in summer 1995, but the rootstock top growth above the budshield was headed back (cut off) about 3 - 4 weeks after budding, once the bud had taken. A small framework of shoots was encouraged to develop during the remainder of the summer / early autumn by pinching the shoot which arose from the bud. Although these shoots were weak, and typically required trimming back to within about 50 mm of the rootstock at potting, they carried more buds than the single bud of a dormant eye plant, and thus offered a 'head start' for the plant in spring. The started eye plants also required little, if any, further pinching and shaping in spring in order to produce a bushy plant suitable for spring / summer sales.

Although plants established well from all potting dates in this trial, it proved very difficult to apply and monitor the shoot pinching operations frequently or accurately enough with the trial design and plot layout employed. This was compounded by the plant to plant variation in the amount and timing of pinching and plant shaping which was required within plots. Finally, flowering dates between treatments were further compressed by the pattern of temperatures that season. Consequently it was not appropriate to statistically analyse the plant development or plant quality data from this trial, and only broad indications of treatment effects could be drawn from it.

Rate of plant development

Recorded dates for flower bud colour were similar between cultivars for the April and May potting dates, but Sweet Dream was up to 10 days earlier than Cider Cup for the non-cold stored (Ambient) treatment. Over the range of potting dates, there was only a 17 day range in bud colour dates from 8 - 25 July (day 190 - 207). There was very little difference in recorded flowering dates from the dormant eye plants compared to started eyes, although normally dormant eye plants would be expected to flower later because of the more numerous shoot pinching operations required to build up a well branched plant. The Sweet Dream in this trial flowered later than the potted finished bush plants in Trial A by about 26 days for the Ambient potting to 13 days for the May potting.

Quality of plants at marketing stage

Plants from started eyes were larger (heights and spread) than from dormant eyes for the Ambient potted treatments, but there was little difference with the treatments potted later. However, started eye plants invariably produced better shaped and bushier growth, particularly when compared to dormant eye plants which had been insufficiently pinched. The extra bushiness from started eye plants was reflected in at least 25% and up to 75% more flowers at the marketing stage. Sweet Dream was more free flowering than Cider Cup. Comparing flower numbers of Sweet Dream in Trial C to those in Trial A; the started eye plants at marketing stage had slightly fewer flowers than the finished bush plants, whereas the dormant eye plants, particularly from the early batches, had as few as half the number of flowers.

DISCUSSION

Storage as bare root vs containerised plants

The results this year clearly demonstrated that equally good results could be obtained by cold storing bare root plants and potting from store rather than holding ready containerised roses. This is an important result, partly because the storage of bare root plants has obvious advantages for efficient use of space. It was also useful to show that, for the cultivars used in this trial at least, establishment following late pottings was excellent. Other advantages of storing bare root plants are that during busy periods it provides a short term buffer to the workload as well as the smoother labour profile over the winter and spring period that a sequential potting programme offers.

There was little evidence that bare root plants deteriorated while in store for the cultivars and under the conditions used in this trial, except for cv. Sweet Dream which did exhibit some stem dieback. The susceptibility of Sweet Dream to this problem has been confirmed by other growers, and some other cultivars can also be affected. Project HNS 75 has started to address the problem of 'spring dieback' with a survey of grower's experience and some sample analyses, but it is likely that the stem blackening seen on some cultivars in cold storage is a different problem to bud or shoot death seen on some containerised roses in the spring.

With plants containerised before storage, there was very little, if any, new root development observed on the outside of the potball before they were removed and grown on outside. This is, perhaps, not surprising given the 0 - 1 °C temperature within the store, but the fact that containerised Sweet Dream did not develop a stem blackening problem indicates that they were responding to a more favourable environment, and may have been able to take up moisture from the growing medium. Clearly more work is needed to identify the causes of damage in store, but meanwhile containerising susceptible cultivars before storage, or leaving the final trimming of shoots until they are potted, should reduce problems.

The previous years trial in this project, and related MAFF funded work showed that temperatures of 3 °C were too warm for storage of bare root roses beyond late March or early April as buds began to develop etiolated shoots in store. A temperature of -3 °C did not appear to damage plants, but 0 - 1 °C is a more economical temperature at which to run stores and, from results reported here, appears satisfactory. Bundles of trimmed plants can be held in polythene sacks to help prevent them drying out. Good results have also been obtained by covering heaps of plants with polythene sheeting with occasional damping down with water. With this crude arrangement, inspections for desiccation or diseases were also easier than storage in sacks.

Provided shoot dieback in store is not a problem, Trial B indicated that there is no advantage from not trimming roots and shoots ready for potting before storage. More experience than this trial in a

single year with one cultivar is needed, however, before categorical recommendations can be made. It is certainly possible that L'Aimant may have been an easy-to-establish cultivar and that other cultivars may have responded differently to pruning.

A related project, HNS 85, 'Improving early establishment of bare root roses in containers using auxin dips' was started in September 1997. This will be looking at whether auxin applied to the roots of crops potted early, (ie in the dormant season and after cold storage) will give appreciable advantages in the speed of root development. If it works, this could be help overcome factors such as severe root pruning, 'difficult' cultivars, or midwinter potting, which might otherwise check establishment.

Plant development stages

In Trial A, the bud and shoot development times, and root development in spring, were very similar for both storage treatments from the March, April and May potting times. It appears, therefore, that an early autumn potting (eg September or early October) is required in order to get significant root development before winter dormancy if any useful advantage in spring growth is to be gained. Although not examined in this trial, this could be an important factor with container crops forced under heated glass for the very early market.

The three cultivars in Trial A showed different rates of development in the early stages, but varied less by the time they reached flower bud colour. For example, Freedom was late to reach first expanded leaf for the Ambient potting, was early to show flower buds, but bud colour stage was similar to the other cultivars. Sweet Dream tended to show bud late, but, perhaps because of the smaller size of individual flowers, had a short final development stage of flowering. While the final stage of bud colour is the key stage which determines when the crop is ready for marketing, knowledge about other easily identifiable stages in the crop's development has been useful for monitoring predicted crop schedules. From this project, and the related MAFF funded 'Manipulation of nursery stock scheduling' project (HH1513THN), the half way stage from potting to bud colour occurs shortly after the first expanded leaf stage.

In 1996, the 28 day spread in maturity from the Ambient treatment (14 June) to the May potted treatment (12 July) was more condensed than in the first years trial in 1995, and the season was also later. In 1995, Ambient treatment of Sweet Dream (a cultivar common to both years) reached maturity on 2 June. Experience from both this project, and the MAFF project, makes it clear that to obtain a regular sequence of maturity dates, potting dates need to be spaced out much more between early batches than later ones. This is to be expected as plants develop more quickly in the longer and warmer days later in the season.

Relationship of development stages to temperature

The critical relationship between temperature and plant development is being examined more closely in the MAFF trial. This will be a key component of a descriptive growth model which it is intended will ultimately be developed into a predictive model for use in scheduling crops of containerised roses. It has already been shown from the 1996 MAFF trial that rose growth (at least from potting bare root crops to flowering) is driven largely by temperature, and the model can be well described in terms of thermal units alone (or accumulated day degrees above a base temperature). Further work was carried out during 1997 with a wide range of potting dates from November (not cold stored), and February through to July with each batch being grown on after potting in both tunnel and outdoor environments. The MAFF project has used only one cultivar, the HT Warm Wishes, but the principles should be equally applicable to data collected for other cultivars.

With a knowledge of the accumulated temperature units required after potting before the flower bud colour (marketing) stage is reached (which may vary according to cultivar), it should be possible to schedule potting dates in advance for desired marketing dates to suit particular locations / environments. Further analysis of recent data is required before it is known how accurate predictions are likely to be, given seasonal temperature variations. However, if real time temperature records are logged on the nursery, deviations from the schedule can be predicted. Management actions can then be taken such as delaying or advancing subsequent potting dates, or possibly even moving the crop to a warmer / cooler environment accordingly. Maximum / minimum thermometers may suffice for temperature logging, or, if not, inexpensive electronic temperature loggers are now available which can be downloaded by PC software.

Quality of plants at marketing stage

As was found in the 1995 trial with cvs. Indian Summer (HT), Sweet Dream (patio), Trumpeter (floribunda) and Pretty Polly (patio), the size of plant at the marketing stage as measured by height and spread, did not vary significantly between batches. This indicates that although maturity times for the later potted plants was shorter, shoots simply grew as long but more quickly. Although not measured in this trial, the total number of leaves produced and internode length also appeared to be similar, that is plants developing more quickly, for example in warmer conditions, were neither more 'stretched' nor more compact than those developing more slowly.

The scores for root development also clearly showed that roots had developed as well from the late as from the earlier batches by the time plants were sold, although inevitably later batches had a higher proportion of new to old root.

What did emerge from this trial, though, was that the number of flowers present at marketing tended

to decrease with the later batches. There were between a half and two thirds the number of flowers present from the May batches compared with the Ambient batches when counted at the marketing stage. This may have been a reflection of denser growth or more branch development in the slower growing batches which lead to more terminal flowers, ie the slower growing plants 'filled out' with vegetative growth more fully before developing flowers. Although the data suggests that potentially this could be quite an important quality issue, the later batches of plants were not obviously 'lighter weight' in appearance and would still have been regarded as excellent commercial quality in this trial.

The plant spacing of 270 mm x 300 mm used in this trial proved adequate across the range of cultivars grown and meant that re-spacing of pots was not required during the growing season.

The use of Dormant eye and Started eye plants

Work with these types of plants formed only a minor part of this project, particularly in the 1996 trials, but the dormant eye and started eye technique has become a useful option for containerising patio cultivars in the industry. Inevitably, because a shoot framework needs to be developed first, before plants are large and bushy enough to be allowed to flower, it takes longer to achieve a marketable-size plant than growing on a two-year-old 'finished bush'. Fortunately the free branching form of patio cultivars makes them well suited to this technique, but nevertheless the successive pinching operations applied to a dormant eye plant will delay flowering. This delay varied from about 3 to 10 weeks in this project according to cultivar, prevailing temperatures, and the severity and frequency of pinching applied.

The use of dormant eye plants might appear to be a useful way of delaying cropping instead of cold storage, however the extra labour and management needed with the pinching operation is regarded as a serious disadvantage by most nurserymen. Also, in the 1995 trial, dormant eye plants cold stored until mid May and early June failed to achieve sufficient size and quality for sale before the end of the summer. For these reasons started eye plants have been used in preference to dormant eyes where available. Trial C, in 1996, demonstrated the improved quality obtained over a dormant eye crop where little pinching was used. It is possible that for some patio cultivars, as good quality can be obtained from containerising a strong started eye plant in a similar timescale to finished bushes, if no pinching or trimming operations are required. Provided, of course, the started eye plants are less expensive, they are an attractive option. Their younger root system should also reduce the amount of root pruning required for potting.

Any pinching or pruning of new growth will clearly delay flowering for that shoot. This means that predictive scheduling models developed for containerised finished bushes would not be applicable to dormant eye crops for example. It is theoretically possible to add the effect of pinching into the model, but a lot work would be needed to collect the additional data necessary to cover an adequate range of the frequencies and timings of pinching operations that could be applied to this crop.

Advancing crops with glasshouses

This was not looked at in any detail in this project, but one of the first year treatments included starting some dormant eye plants under cold glass. These matured no earlier than the ambient treatment in that year, but appeared to be checked relatively severely following the first pinch under glass. Experience from some growers who use glass is that forcing too much soft growth too early can clearly make plants susceptible to damage from late frosts when moved out, particularly if they have not been adequately hardened off. There is scope, however, for using cold glass or perhaps some heat assistance to advance crops as part of a production schedule, if managed carefully. It is possible that the model being developed under the MAFF project could be extrapolated for early crops, but this would need further trialling and possibly modification to cope with the influence of lower light levels early in the year.

Late summer flowering crops

The peak sales periods for containerised roses are currently in spring and early summer for plants in flower, and in autumn for recently lifted and containerised 'dormant' plants. The most immediate benefits from this project will be from the use of cold storage to provide delays in flowering of up to about six weeks to extend the selling season from May into early July. However it has been shown from this project, and particularly from recent results in the related MAFF project, that flowering can be delayed successfully into August, September or even October from long term cold storage. Good quality flowering roses have not been widely available at this time in the past, but it may be possible to create demand for sales then. Well established flowering roses in containers could partially replace or complement sales of 'dormant' roses lifted early and offered for sale in September and October.

As demonstrated in the 1995 trial, late flowering can also be achieved very simply by pruning back plants after the first flush of flower to give a second flush ranging from 35 to 60 days later. However the old foliage on these plants is difficult to keep disease free and plants never look as attractive and 'fresh' as during the first flush of growth. The technique is therefore best reserved for stock left unsold after the first flowering.

CONCLUSIONS

- A sequence of good quality crops in flower during the spring and summer period of a range of HT, floribunda and patio rose cultivars containerised as finished bushes can be successfully achieved through the use of cold storage.

- Delays in maturity between plants receiving no cold storage, and those removed from store up to about mid April, while conditions are still cool, can be relatively small. Further cold storage has a progressively delaying effect as ambient temperatures increase through spring and early summer.

- Unless plants are potted up very early in the autumn, or unless they are given warm conditions, most root development in the container takes place in the spring at the same time as leaf and shoot growth.

- In general, roses appear capable of performing equally well if cold stored as bare root plants and subsequently potted on removal, as plants cold stored ready containerised. Initial indications are that most cultivars can have shoots and roots trimmed ready for potting prior to storage with no adverse affect on establishment. However some cultivars, eg Sweet Dream, have developed some stem dieback (blackening) while in store; it would therefore be better to delay the final trimming of shoots until potting for susceptible cultivars.

- Temperatures during cold storage need to be about 0 - 1 °C to hold plants in dormancy, particularly if being stored beyond February or March, and adequate measures need to be taken, such as keeping plants damped down and covered with polythene sheeting, to prevent desiccation.

- Dormant eye plants of patio cultivars are slower to develop than finished bushes, and are therefore marketable later. The shoot pinching operations needed for this crop can be labour intensive, and it also makes prediction of the flowering date more difficult. Patios from started eyes, while of a similar age to dormant eye plants, require less pinching and shaping, and reach a marketable size and quality more quickly.

- Clearly defined key stages of plant development have been identified for containerised roses that, together with temperature records, are enabling a predictive scheduling model to be developed for the crop. Some further work is needed to screen a wider range of cultivars and integrate the findings of HNS 65 with the MAFF funded project HH1513THN to complete development of the predictive model for grower's use.

APPENDICES

Appendix I Layout and plan of container growing-on area - Trial A

Layout Plan - HNS65 - Successional Marketing of Bush Roses 1996
Trial A - Cold Storage of Containers vs Bare Root
for HT, FL and Patio cultivars

GLP 2031

N

Bed 1

1	APR	BR De	Rep I
2	APR	Co Fr	
3	APR	Co SD	
4	APR	BR SD	
5	APR	BR Fr	
6	APR	Co De	
7	MAY	BR De	
8	MAY	Co De	
9	MAY	BR SD	
10	MAY	Co SD	
11	MAY	BR Fr	
12	MAY	Co Fr	
13	AMB	Co Fr	
14	AMB	Co SD	
15	AMB	Co De	
16	MAR	Co Fr	
17	MAR	BR SD	
18	MAR	Co De	
19	MAR	Co SD	
20	MAR	BR De	
21	MAR	BR Fr	
22	AMB	Co SD	Rep II
23	AMB	Co De	
24	AMB	Co Fr	
25	MAY	Co SD	
26	MAY	Co Fr	
27	MAY	BR De	
28	MAY	BR SD	
29	MAY	BR Fr	
30	MAY	Co De	
31	MAR	Co SD	
32	MAR	BR De	
33	MAR	Co Fr	
34	MAR	BR SD	
35	MAR	Co De	
36	MAR	BR Fr	
37	APR	BR Fr	
38	APR	BR De	
39	APR	Co SD	
40	APR	BR SD	
41	APR	Co Fr	
42	APR	Co De	

Bed 2

43	APR	Co Fr	Rep III
44	APR	Co De	
45	APR	BR De	
46	APR	BR Fr	
47	APR	Co SD	
48	APR	BR SD	
49	AMB	Co De	
50	AMB	Co SD	
51	AMB	Co Fr	
52	MAY	Co De	
53	MAY	Co Fr	
54	MAY	BR De	
55	MAY	BR Fr	
56	MAY	Co SD	
57	MAY	BR SD	
58	MAR	BR Fr	
59	MAR	Co Fr	
60	MAR	BR De	
61	MAR	Co De	
62	MAR	Co SD	
63	MAR	BR SD	
64	MAR	BR De	Rep IV
65	MAR	Co De	
66	MAR	Co Fr	
67	MAR	Co SD	
68	MAR	BR SD	
69	MAR	BR Fr	
70	MAY	BR De	
71	MAY	BR SD	
72	MAY	Co SD	
73	MAY	Co Fr	
74	MAY	BR Fr	
75	MAY	Co De	
76	APR	BR Fr	
77	APR	Co De	
78	APR	BR SD	
79	APR	Co SD	
80	APR	BR De	
81	APR	Co Fr	
82	AMB	Co Fr	
83	AMB	Co De	
84	AMB	Co SD	

Main plot treatments - Times from Cold Store:

		Label colour:
AMB	Ambient (no cold storage)	Red
MAR	March (wk 11)	Yellow
APR	April (wk 15)	Green
MAY	May (wk 19)	Pink

Subplot treatments - Storage as Containers vs Bare root x Cultivar:

Co Fr	Container / Freedom	White
Co De	Container / Dearest	White
Co SD	Container / Sweet Dream	White
BR Fr	Bare root / Freedom	Orange
BR De	Bare root / Dearest	Orange
BR SD	Bare root / Sweet Dream	Orange

Plot Size:
5 plants across bed

Spacing down bed:
300 mm

Spacing between rows across bed:
270 mm

▨ = single row gap to minimise shading between contrasting potting times

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Appendix II Layout and plan of container growing-on area - Trial B

Layout Plan - HNS65 - Successional Marketing of Bush Roses 1996 GLP 2031
Trial B Severity of Pruning for Cold Storage of Containerised and Bare Root Plants

	Bed 4	
1	AMB HP Co	Rep I
2	APR HP Co	
3	APR HP BR	
4	APR LP Co	
5	AMB LP Co	
6	APR LP BR	
7	APR LP Co	Rep II
8	AMB HP Co	
9	AMB LP Co	
10	APR HP Co	
11	APR LP BR	
12	APR HP BR	
13	AMB LP Co	Rep III
14	AMB HP Co	
15	APR LP BR	
16	APR HP Co	
17	APR HP BR	
18	APR LP Co	
19	AMB HP Co	Rep IV
20	APR LP Co	
21	AMB LP Co	
22	APR HP Co	
23	APR HP BR	
24	APR LP BR	

Plot Size:
5 plants across bed

Spacing down bed:
300 mm

Spacing between rows across bed:
270 mm

= single row gap to minimise shading between contrasting potting times

Cultivar L'Aimant througout

Treatments - Pruning x Store as Containerise vs Bare Root

					Label colour
AMB HP Co	Hard prune top + root	Container	Ambient		Red + white
AMB LP Co	Light prune top (hp root)	Container	Ambient	(Reprune top in spring)	Red + white
APR HP Co	Hard prune top + root	Container	April		Green + white
APR LP Co	Light prune top (hp root)	Container	April	(Reprune top in spring)	Green + white
APR HP BR	Hard prune top + root	Bare root	April		Green + orange
APR LP BR	Light prune top + root	Bare root	April	(Prune top & roots at potting)	Green + orange

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Appendix III Layout and plan of container growing-on area - Trial C

Layout Plan - HNS65 - Successional Marketing of Bush Roses 1996
Trial C Sequential Flowering of Patio cultivars
Dormant Eye vs. Started Eye plants

GLP 2031

Main plot treatments - Times from Cold Store:

		Label colour:
AMB	Ambient (no cold storage)	Red
MAR	March (wk 11)	Yellow
APR	April (wk 15)	Green
MAY	May (wk 19)	Pink

Subplot treatments - Dormant eye vs. Started eye x Cultivar:

DE SD	Dormant eye / Sweet Dream	Blue
DE CC	Dormant eye / Cider Cup	Blue
SE SD	Started eye / Sweet Dream	White
SE CC	Started eye / Cider Cup	White

Plot Size:
5 plants across bed

Spacing down bed:
300 mm

Spacing between rows across bed:
270 mm

▨ = single row gap to minimise shading between contrasting potting times

N

(Trial A) ↑

Bed 1

1	AMB	DE SD	Rep I
2	AMB	DE CC	
3	AMB	SE SD	
4	AMB	SE CC	
5	APR	DE SD	
6	APR	DE CC	
7	APR	SE CC	
8	APR	SE SD	

(Trial A) ↑

Bed 2

9	MAY	SE CC
10	MAY	SE SD
11	MAY	DE CC
12	MAY	DE SD
13	MAR	SE CC
14	MAR	DE CC
15	MAR	SE SD
16	MAR	DE SD

Bed 3

17	AMB	SE CC	Rep II
18	AMB	SE SD	
19	AMB	DE CC	
20	AMB	DE SD	
21	APR	SE SD	
22	APR	DE SD	
23	APR	SE CC	
24	APR	DE CC	
25	MAR	SE SD	
26	MAR	SE CC	
27	MAR	DE SD	
28	MAR	DE CC	
29	MAY	DE SD	
30	MAY	SE CC	
31	MAY	DE CC	
32	MAY	SE SD	
33	APR	SE CC	Rep III
34	APR	DE SD	
35	APR	DE CC	
36	APR	SE SD	
37	MAY	SE SD	
38	MAY	DE CC	
39	MAY	SE CC	
40	MAY	DE SD	
41	AMB	DE SD	
42	AMB	SE CC	
43	AMB	SE SD	
44	AMB	DE CC	
45	MAR	SE CC	
46	MAR	SE SD	
47	MAR	DE CC	
48	MAR	DE SD	
49	MAY	DE SD	Rep IV
50	MAY	DE CC	
51	MAY	SE SD	
52	MAY	SE CC	
53	AMB	DE SD	
54	AMB	SE SD	
55	AMB	SE CC	
56	AMB	DE CC	
57	APR	DE SD	
58	APR	SE SD	
59	APR	DE CC	
60	APR	SE CC	
61	MAR	SE CC	
62	MAR	SE SD	
63	MAR	DE SD	
64	MAR	DE CC	

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Appendix IV

Trial A: The main effect of cold storage times on the time of appearance of key development stages of three rose cultivars. Mean of bare root / containerised storage for March - May treatments.

Time of removal from cold store	Day number of development stage*		
	Sweet Dream	Freedom	Dearest
		Bud burst	
Ambient (no storage)	47	47	47
March (13/3/96)	105	106	104
April (11/4/96)	120	120	115
May (9/5/96)	143	145	143
SED (45 df)	*0.71 except when comparing means within same timing:*		*0.74*
LSD (5%)	*1.4*	*1.5*	
		First expanded leaf	
Ambient	71	86	69
March	114	120	115
April	130	134	130
May	152	156	152
SED (45 df)	*0.78 except when comparing means within same timing:*		*0.87*
LSD (5%)	*1.6*		*1.8*
		Appearance of flower bud	
Ambient	147	132	135
March	152	145	137
April	162	154	151
May	174	173	169
SED (45 df)	*1.80 except when comparing means within same timing:*		*1.62*
LSD (5%)	*3.6*		*3.3*
		Flower bud showing colour	
Ambient	164	166	167
March	172	175	172
April	178	178	178
May	193	196	194
SED (45 df)	*0.90 except when comparing means within same timing:*		*0.78*
LSD (5%)	*1.8*		*1.6*

* See Appendix V for conversion table for day numbers to calendar dates

Appendix V Conversion table of day numbers to calendar dates for a leap year (1996)

Month Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Month Date
1	1	32	61	92	122	153	183	214	245	275	306	336	**1**
2	2	33	62	93	123	154	184	215	246	276	307	337	**2**
3	3	34	63	94	124	155	185	216	247	277	308	338	**3**
4	4	35	64	95	125	156	186	217	248	278	309	339	**4**
5	5	36	65	96	126	157	187	218	249	279	310	340	**5**
6	6	37	66	97	127	158	188	219	250	280	311	341	**6**
7	7	38	67	98	128	159	189	220	251	281	312	342	**7**
8	8	39	68	99	129	160	190	221	252	282	313	343	**8**
9	9	40	69	100	130	161	191	222	253	283	314	344	**9**
10	10	41	70	101	131	162	192	223	254	284	315	345	**10**
11	11	42	71	102	132	163	193	224	255	285	316	346	**11**
12	12	43	72	103	133	164	194	225	256	286	317	347	**12**
13	13	44	73	104	134	165	195	226	257	287	318	348	**13**
14	14	45	74	105	135	166	196	227	258	288	319	349	**14**
15	15	46	75	106	136	167	197	228	259	289	320	350	**15**
16	16	47	76	107	137	168	198	229	260	290	321	351	**16**
17	17	48	77	108	138	169	199	230	261	291	322	352	**17**
18	18	49	78	109	139	170	200	231	262	292	323	353	**18**
19	19	50	79	110	140	171	201	232	263	293	324	354	**19**
20	20	51	80	111	141	172	202	233	264	294	325	355	**20**
21	21	52	81	112	142	173	203	234	265	295	326	356	**21**
22	22	53	82	113	143	174	204	235	266	296	327	357	**22**
23	23	54	83	114	144	175	205	236	267	297	328	358	**23**
24	24	55	84	115	145	176	206	237	268	298	329	359	**24**
25	25	56	85	116	146	177	207	238	269	299	330	360	**25**
26	26	57	86	117	147	178	208	239	270	300	331	361	**26**
27	27	58	87	118	148	179	209	240	271	301	332	362	**27**
28	28	59	88	119	149	180	210	241	272	302	333	363	**28**
29	29	60	89	120	150	181	211	242	273	303	334	364	**29**
30	30		90	121	151	182	212	243	274	304	335	365	**30**
31	31		91		152		213	244		305		366	**31**

Appendix VI a **HRI Efford Meteorological Data**

Mean Daily Maximum Temperature (°C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1997	4.9	9.1	11.8	13.7	16.3	18.0	20.6	22.0	19.1	15.6		
1996	**7.2**	**6.6**	**8.0**	**12.2**	**13.5**	**18.9**	**20.5**	**21.0**	**17.8**	**15.5**	**10.4**	**6.3**
1995	**9.2**	**10.6**	**10.7**	**13.6**	**16.7**	**20.2**	**22.8**	**25.5**	**18.5**	**17.2**	**12.4**	**6.8**
1994	9.5	8.2	11.5	12.2	14.8	18.7	22.2	21.2	17.5	15.6	13.8	11.3
1993	9.8	7.8	10.4	13.2	16.5	19.5	19.1	19.6	17.1	13.0	9.4	9.7
1992	7.2	9.0	10.9	12.7	18.7	20.6	20.1	19.5	17.6	12.9	12.3	8.2
1991	7.3	5.1	11.0	12.2	15.5	15.5	20.5	21.0	20.0	14.0	10.9	8.5
1990	10.4	11.2	11.8	13.6	18.4	16.9	21.9	22.7	19.1	16.1	10.8	7.9
1989	9.9	10.0	11.5	10.8	19.3	20.2	23.9	21.6	19.5	16.5	11.5	9.5
1988	9.1	8.9	10.2	12.7	16.7	18.8	17.5	19.1	17.7	15.1	10.6	10.7
1987	3.9	7.4	8.1	13.4	15.2	16.6	20.5	20.4	18.1	14.7	10.5	8.3
1986	7.8	2.2	8.3	9.9	13.7	20.0	19.4	17.9	15.9	15.4	12.3	10.0
1985	4.2	5.8	8.4	12.7	15.8	17.2	20.5	18.1	18.4	14.9	8.3	9.8
1984	8.5	7.7	8.6	13.7	14.4	19.5	22.0	22.0	18.0	15.0	12.1	9.8
3/4 yr mean	7.7	8.6	10.5	12.9	15.3	19.0	21.5	22.4	18.2	16.0	12.2	8.1
43/44 yr mean	*7.4*	*7.4*	*9.8*	*12.0*	*15.6*	*18.5*	*20.5*	*20.4*	*18.2*	*15.0*	*10.9*	*8.6*

N.B. **Bold** figures in the body of the table relate to the two years of the project

Appendix VI b

HRI Efford Meteorological Data

Mean Daily Minimum Temperature (°C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1997	0.2	3.8	4.7	3.9	7.2	11.0	11.9	14.6	10.8	8.0		
1996	**3.5**	**-0.1**	**2.1**	**4.7**	**5.4**	**9.3**	**11.9**	**11.2**	**10.0**	**9.3**	**3.1**	**1.4**
1995	**3.2**	**5.8**	**2.6**	**5.7**	**7.8**	**10.2**	**13.7**	**13.8**	**10.5**	**11.0**	**5.1**	**1.2**
1994	4.1	2.1	5.6	4.4	8.6	10.4	13.8	13.7	10.9	7.7	9.6	5.3
1993	5.1	3.3	3.8	6.5	8.8	11.4	12.4	11.3	10.0	7.0	2.8	4.1
1992	1.7	2.8	5.3	5.6	9.2	10.8	13.5	13.4	12.0	5.4	6.2	2.7
1991	3.1	0.5	5.4	4.8	7.0	9.4	12.9	12.8	11.5	8.1	4.8	4.0
1990	5.5	6.3	5.6	4.3	8.6	10.8	12.6	13.5	9.7	10.3	5.8	3.3
1989	4.3	3.3	5.1	3.9	9.4	10.9	14.3	13.0	12.0	10.0	5.6	4.3
1988	4.0	2.5	4.5	4.8	8.8	10.7	12.4	11.9	10.3	7.6	3.0	5.3
1987	0.6	1.7	1.9	6.1	7.0	9.7	12.4	11.9	11.9	8.4	4.8	4.5
1986	1.8	2.2	2.2	2.9	7.8	10.5	12.4	11.5	7.6	8.8	5.9	4.2
1985	1.3	0.2	1.5	4.5	7.3	9.2	11.9	12.5	11.1	8.7	2.2	5.5
1984	2.7	2.1	2.3	3.7	6.7	10.3	11.6	13.3	11.2	9.3	6.6	3.2
3/4 yr mean	2.8	2.9	3.8	4.7	7.3	10.2	12.8	13.3	10.6	9.0	3.3	2.6
43/44 yr mean	*2.3*	*1.9*	*3.3*	*4.4*	*7.4*	*10.3*	*12.4*	*12.4*	*10.6*	*8.3*	*4.8*	*3.3*

N.B. **Bold** figures in the body of the table relate to the two years of the project