Project title:	**Roses: Predictive model development and testing for flowering in containerised crops**
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PRACTICAL SECTION FOR GROWERS

Background

It is estimated that half to three quarters of the UK bush rose crop is now containerised before retailing, and spring and summer sales of containerised roses in flower represent an important sector of the market. There is potential for extending the marketing season, and reducing waste from unsold stock, but this requires a continuity of supply of plants carrying attractive fresh new growth and flower buds showing colour. Cold stores are being increasingly adopted by nurserymen to hold dormant stock in good condition, and make more efficient use of potting, labour and growing-on areas. They are an essential facility if growers wish to produce sequential batches of roses in flower for marketing over an extended period.

An important MAFF project contribution to this subject was the formulation of a growth model to describe rose development from the potting stage to flowering, in terms of thermal time units, using the cultivar Warm Wishes. Warm Wishes took on average 772 day-degrees above a base temperature of 4 °C to start flowering (bud colour stage) from potting. Bud colour (BC) is the optimum time to market containerised roses for sale in flower. The overall aim of this project was to extend the flowering prediction model to a wider range of cultivars, and to test and develop its application to the industry for scheduling batches of containerised roses.

The previous HDC project HNS 65 had shown that cold stores could be used effectively to hold bare root roses lifted dormant for an extended period, and enable them to establish successfully in containers from potting dates as late as July. It was, therefore, possible to achieve a good sequence of crops in flower for marketing over an extended period. It was known that some cultivars flowered more quickly than others after potting, but it was necessary in this project to quantify the day-degree requirements for a range of roses, and see whether long-term average meteorological data from nearby meteorological stations could be used as a basis for scheduling potting dates to meet targeted flowering / marketing dates.

Summary of Results

In the first year of the project, dormant plants of 10 cultivars covering HT, floribunda, patio and climbing types, in addition to the control cultivar Warm Wishes, were potted ex-cold store on 12 March, 6 May and 15 June 1998. They were grown on both outdoor beds and those in unheated polythene tunnels to give a range of environments. Hourly temperatures were logged using TinyTalk II data loggers throughout the production period, and the dates when BC was reached recorded. The accumulated DD > 4 °C from potting to BC was calculated for each batch, and the mean differences for each cultivar from the 772 DD > 4 °C used for Warm Wishes, was used to reassign day-degree requirements for each of the additional cultivars. Warm Wishes in 1998 gave a good validation of the model, averaging only 22 DD > 4 °C earlier than the prediction (or an average of 1.7 days earlier), with relatively little variability between batches.

The following table gives a framework for growers to allocate additional cultivars to earliness groups with reference to those used in the 1998 trial, and their knowledge of relative flowering periods, until day-degree requirements can be established for a wider range of cultivars.

Earliness group	DD > 4 °C	Example cultivars	DD > 4 °C
Very Early	< 550	Firefly (patio)	515
		Indian Summer (HT)	527
Early	550 - 650	Alpine Sunset (HT)	580
		Iceberg (floribunda)	594
		Top Marks (patio)	602
		Sweet Dream (patio)	633
Mid	650 - 750	Trumpeter (floribunda)	674
		Courage (HT)	704
Late	>750	Warm Wishes (HT)	772
		Handel (climber)	772
		Swan Lake (climber)	845

To validate the model further in the second year, and test its application on the nursery, potting schedules were calculated by working backwards from three target BC dates at 4 week intervals of 5 July, 2 August and 30 August. This was done for Swan Lake, Warm Wishes, Courage, Trumpeter, Indian Summer and Firefly at HRI Efford plus Burston Nurseries Ltd., Herts, and Wharton's Nurseries Ltd., Norfolk. For each site, 30 year average daily maximum and minimum temperature data from a nearby meteorological station was used to derive a mean DD > 4 °C profile for the year, from which the appropriate potting date schedules were calculated. Potting dates of cold stored plants were thus staggered between the cultivars starting with the slowest (Swan Lake) and ending with the fastest (Firefly) for each batch. All batches were grown outdoors, hourly temperatures logged and key development stages, including BC dates, recorded.

When the 1999 temperatures were run through the model, for most treatments the observed dates for BC at Efford and Wharton's were well within 7 days of the predicted dates. Cultural problems with some of the trial plants at Burston's meant that growth data could not be used from this site, but temperature data continued to be collected. The slowest cultivar, Swan Lake, showed more variability between batches and sites than the other cultivars, but generally the model showed remarkably good results against predictions, especially as the assigned day-degree requirements for the 'new' cultivars was based on a single years data.

The spring and summer of 1999 was warmer than average for all three sites. This resulted in the first two batches reaching BC typically one to two weeks earlier than the target date, although the latest batch was less affected and flowered nearer to the target date.

Comparisons between meteorological station and nursery site logger data were examined further to identify sources of possible error which could contribute to scheduling inaccuracy. There was a small amount of error associated with using data from nearby meteorological stations, due to differences in actual temperatures between them and / or because of the method used to estimate day-degrees from daily maximum and minimum temperatures from meteorological station data. Effects of climate change also appeared to be influencing long-term average temperatures. For each of the meteorological sites at Everton, Morley St Botolph and Rothamsted, used to estimate long-term averages for Efford, Wharton's and Burston respectively, averages the over the latest 10 year period were about 0.4 DD > 4 °C / day warmer than the averages over the last 30 years, and would probably be the more accurate data to use for scheduling.

Action points

- This predictive model for flowering crops of containerised roses provides a framework for growers wishing to schedule batches of spring and summer potted plants, to extend the marketing season of a range of cultivars. While there are 'errors' associated with any model, especially when dealing with outdoor crops, and seasonal temperature fluctuations that cannot be controlled, the 'marketing window' associated with batches of roses should absorb sufficient error for it to be of practical benefit.

- The model requires that plants are as near dormant as possible at potting. This means that they will need to be held in cold stores running at 0 °C to prevent bud-burst, particularly for batches potted after late March.

- This model is also primarily applicable to crops scheduled for delayed flowering rather than early forcing. While light levels are not a significant factor affecting crop timing or quality within the spring and summer period, this is likely to be more important for very early batches produced under heated glass or those delayed to flower later than early or mid October.

- Local meteorological station data can be used to draw up an approximate 'starting point' potting schedule such as the generalised example below. Climate change may be causing an upward shift in long term average temperatures, therefore it is suggested that the latest 10 year mean data will give a more accurate estimate of day-degrees for scheduling, than using a longer period such as the 30 year mean.

- Affordable temperature loggers are available to enable data to be collected on the nursery and downloaded to a PC, so that predictions based on mean meteorological data can be updated at intervals using current year records. These are a necessary requirement for growers wishing to seriously develop crop scheduling on their nurseries. They also enable data to be collected for additional cultivars so that estimated day-degree requirements can be refined and updated.

Potting schedule based on 10 year mean data from Everton (Efford) meteorological station

Earliness Group:		Very Early	Early	Mid	Late
Day Degrees >4 °C:		500	600	700	800
Batch no.	**Target flowering**	**Scheduled pot date**	**Scheduled pot date**	**Scheduled pot date**	**Scheduled pot date**
1	**05 June**	17-Mar	12-Feb	06-Jan	Too early
2	**12 June**	01-Apr	08-Mar	28-Jan	Too early
3	**19 June**	19-Apr	27-Mar	27-Feb	19-Jan
4	**26 June**	03-May	14-Apr	21-Mar	19-Feb
5	**03 July**	14-May	30-Apr	10-Apr	17-Mar
6	**10 July**	24-May	12-May	27-Apr	06-Apr
7	**17 July**	03-Jun	23-May	10-May	25-Apr
8	**22 July**	10-Jun	30-May	19-May	05-May
9	**31 July**	21-Jun	12-Jun	01-Jun	21-May
10	**07 Aug**	30-Jun	21-Jun	12-Jun	01-Jun
11	**14 Aug**	08-Jul	30-Jun	21-Jun	11-Jun
12	**21 Aug**	15-Jul	07-Jul	29-Jun	20-Jun
13	**28 Aug**	22-Jul	15-Jul	07-Jul	28-Jun
14	**04 Sept**	29-Jul	21-Jul	13-Jul	05-Jul
15	**11 Sept**	04-Aug	27-Jul	20-Jul	12-Jul
16	**18 Sept**	09-Aug	02-Aug	25-Jul	18-Jul
17	**25 Sept**	14-Aug	07-Aug	31-Jul	23-Jul
18	**02 Oct**	20-Aug	12-Aug	05-Aug	28-Jul
19	**09 Oct**	24-Aug	17-Aug	09-Aug	02-Aug
20	**16 Oct**	29-Aug	21-Aug	14-Aug	06-Aug
21	**23 Oct**	02-Sep	25-Aug	18-Aug	10-Aug

Practical and financial benefits

Being able to schedule batches of roses effectively using cold storage facilities offers greater flexibility in handling and containerising plants, which will lead to more efficient use of both labour and production areas. Continuity of supplies to retailers should also help to reduce wastage from unsold stock, which rapidly deteriorates in quality.

There are also new market opportunities that may be exploited through scheduling and season extension. These could include extending the selling season for 'special occasion' named cultivars such as Wedding Day or Congratulations which would be needed throughout the year. Also, there may be opportunities for substituting 'freshly potted' early autumn lifted maiden roses with batches of established containerised plants in flower in September and early October.

SCIENCE SECTION

INTRODUCTION

Background

It is estimated that half to three quarters of the UK bush rose crop is now containerised before retailing, and spring and summer sales of containerised roses in flower represent an important sector of the market. There is potential for extending the marketing season, and reducing waste from unsold stock, but this requires a continuity of supply of plants carrying attractive fresh new growth and flower buds showing colour. Cold stores are being increasingly adopted by nurserymen to hold dormant stock in good condition, and make more efficient use of potting labour and growing-on areas. They are an essential facility if growers wish to produce sequential batches of roses in flower for marketing over an extended period.

The HDC project HNS 65 (Development of scheduling techniques for containerised bush roses for successional spring and summer sales) and MAFF project HH1513THN (Manipulation of nursery stock scheduling by investigating factors involved in flower initiation and development - part 3; Roses) made a significant contribution to our understanding of the containerised rose crop. We were able to show how cold stores could be used most effectively to hold bare root roses dormant for an extended period, and enable them to establish successfully in containers from potting dates as late as July. Following a series of potting dates a good sequence of crops in flower for marketing over an extended spring and summer period was achieved. Management aspects, such as cold store temperatures and humidity, pruning of bare root plants before storage, and disease control, were also addressed.

The important MAFF project contribution to this subject, was to formulate a model to describe rose development from the potting stage to flowering, using the cultivar Warm Wishes (Burgess, Wurr & Fellows, 2000). A series of lifting and potting dates, and temperature treatments both during cold storage and after, were imposed on plants. Key development stages of shoots were monitored up to the 'marketing' stage of flower bud colour (BC). Intermediate stages recorded were budburst (BB), first expanded leaf (EL) and first appearance of the flower bud (FB). Flowering stage was reached in progressively shorter times as batches were potted later and grown on under warmer conditions. However, when these production periods were evaluated in terms of 'thermal time' units (ie day-degrees above a given base temperature), batches were remarkably consistent (Appendix Fig 1). The data set from two years work formulated a good descriptive model, based on acquired thermal units, for this cultivar. On average, Warm Wishes required 772 day-degrees (DD) above a base temperature of 4 °C from potting dormant plants to bud showing colour, and 543 DD >4 °C from the first expanded leaf to the same stage. Incorporating light levels into the model did not give any significant improvement in its precision. This meant that only temperature data was required to run the model, which could be readily collected on nurseries using affordable temperature monitoring and logging equipment.

From previous experience in HNS 65, and within the industry, it was known that there were significant differences between cultivars in the development times from potting to flowering. However this had not been quantified in thermal unit terms. The next stage was to screen a selected range of 'early' and 'late' flowering range of cultivars against the control cultivar Warm Wishes, to test the robustness of the model and improve its applicability for the industry, which was covered in this project HNS 65a.

This project had the following objectives:

1 To extend the applicability of the model from Warm Wishes, to a broader range of cultivars covering some different rose types and rates of maturity. Thus obtain an indication of the range of thermal time response that could be expected in containerised rose cultivars.

2 Validate the model by comparing predictions of flowering dates based on thermal time requirements from 1 above with observed dates and thermal time data in a further experiment at Efford and on two commercial nurseries.

3 Obtain an estimate of the accuracy of using long-term mean meteorological data from nearby meteorological stations as a basis for scheduling potting dates to meet targeted flowering dates, for batches of roses grown on outdoors.

4 Gain experience testing the model and handling data from grower's nurseries. In particular, how real-time temperature data, which can be used to provide ongoing predictions of flowering times in a particular season, might best be applied as a management tool for growers.

MATERIALS AND METHODS

YEAR 1 - 1998 - Cultivar screening trial (HRI Efford)

Treatments

3 Potting dates	-	12 March 1998		
	-	6 May 1998		
	-	15 June 1998		
2 Growing environments		Outdoor beds		
		Unheated polythene tunnel beds		
11 Cultivars		Warm Wishes	HT	(Control)
		Alpine Sunset	HT	
		Courage	HT	
		Indian Summer	HT	
		Iceberg	floribunda	
		Trumpeter	floribunda	
		Handel	climber	
		Swan Lake	climber	
		Sweet Dream	patio	
		Top Marks	patio	
		Firefly	patio	

This covered a range of early and late flowering cultivars (as guided by growers' experience and recommendations) and four different types of garden roses.

The above treatments were factorially combined to effectively provide 6 'observations' for each cultivar. Each 'observation' consisted of a plot of 6 - 10 plants for each of the new cultivars, and 10 - 16 plants of the control cultivar Warm Wishes.

Culture

Dormant bare root plants of cvs Firefly, Iceberg, Alpine Sunset, Courage, Swan Lake and Handel were bought from commercial nurseries in mid-late February 1998. Warm Wishes, Indian Summer, Trumpeter, Sweet Dream and Top Marks were grown at Efford from 1997 budded stocks. All plants were held in a cold store at Efford running at approximately 0 °C until required for potting. Bundles of plants were stacked on duckboards in the store, and kept covered under polythene sheeting. They were inspected at least weekly, and damped down as necessary to prevent desiccation.

Each of the three batches were potted into deep 4.0 litre pots in the following growing medium:

100%	Premium grade Shamrock peat
4.0 kg/m^3	Ficote 140 day TE 14.8.8 + trace elements CRF
2.4 kg/m^3	Magnesian limestone
150 ml/m^3	Aquagro 2000 wetting agent.

Plant roots were trimmed to about 200 mm from the bud union, and shoots to about 130 mm, at potting. After well watering in, plants were stood within 24 hrs of potting under their tunnel or outdoor growing environment on woven polypropylene covered growing-on beds. They were spaced at 300 mm centres and irrigated with a pot drip system. Although cultivar plots were not replicated, the trial was sufficiently compact to avoid problems with temperature variation across the plots. For example, the plants under protection were all located within the middle portion of the tunnel away from the end doors. Side and end ventilation was given to the tunnel grown crop to avoid excessively high temperatures, while still maintaining a higher mean temperature regime to the outside plots. Effectively this meant tunnels were permanently fully ventilated from late April onwards.

A pest and disease spray programme was applied as necessary. No pruning of new shoots was carried out or was necessary. This would also have interrupted the timing of shoot development. Occasionally some dieback of original framework shoots occurred in cold store on some cultivars (e.g. Sweet Dream) which was pruned back to healthy tissue at potting or shortly after.

Records and analyses

Crop development and environment

1. Dates were recorded when each plant reached first expanded leaf (EL) and bud colour (BC). Plots were examined up to three times per week when growth was rapid during the summer. Plants showing atypical growth or development due to disease or shoot dieback, which may have affected rate of establishment and development, were noted and eliminated from the analyses.

Dates when EL and BC stages were reached were averaged for each plot, and these plot means used for subsequent analyses.

2. Hourly temperatures were logged using TinyTalk II data loggers (IP68 housing and probe -10 to +40 °C range). Two replicate loggers were placed in each of the outdoor and tunnel environments towards each end (north and south) of the block of plants. Temperature records between replicate loggers in each environment agreed well. The thermistor probes were screened from solar radiation, and set at about 0.5 m height from the ground.

3. Day-degrees > 4 °C for each day were calculated as:

$$DD > 4\,°C = \sum \frac{t_1^{24} - 4}{24}$$

where t_1^{24} was the hourly temperature in °C for all temperatures >4 °C. Readings < 4 °C contributed zero.

4. Predictions of flowering date using the existing model derived for Warm Wishes, where crops require 772 DD > 4°C from potting to BC, were run for each of the 1998 treatments. The deviations in the model predictions were calculated as observation - prediction, so that earlier flowering appeared as a negative value, and later as a positive value. Prediction errors and mean deviations were calculated for each cultivar using the 6 (potting date x environment) observations for both deviation in days and in DD. The prediction error (Spre) was calculated as:

$$\text{Spre} = \sqrt{\frac{\sum d^2}{n}}$$

where d were the deviations of the observations from the model prediction, and n = 6 observations (Mikkelsen, 1981). The prediction error is a more meaningful statistic for estimating the variability of the data from the prediction than the simple mean deviation, in that it allows for variations being both earlier or later than the observation.

5. Mean deviations in DD requirement for each cultivar from the Warm Wishes model were then used as adjustments to arrive at a set of suggested new DD requirements for the other cultivars from potting to BC. Calculations were also made of the mean days and DD > 4 for the intermediate growth stages potting to EL, and EL to BC.

YEAR 2 - 1999 - Model validation trial (HRI Efford + two commercial nurseries)

Treatments

6 Cultivars:	Firefly	patio	early	
	Indian Summer	HT	early	
	Trumpeter	floribunda	mid	
	Courage	HT	mid	
	Warm Wishes	HT	late	(Control)
	Swan Lake	climber	late	

3 Sites:	HRI Efford, Lymington, Hampshire SO41 OLZ Wharton's Nurseries Ltd, Harleston, Norfolk IP20 9AX Burston Nurseries Ltd, St Albans, Hertfordshire AL2 2DS
3 Target flower (BC) dates: (4 week intervals)	5 July 2 August 30 August

All the plants were grown outdoors for this trial. As in Year 1, the above treatments were factorially combined to give 9 'observations' for each cultivar. In this instance a nominal 10 plants per plot were used.

Derivation of potting dates to meet target flowering dates

To validate and apply the model in practice, it was necessary to work backwards from a target date for BC stage, in order to arrive at a schedule of potting dates appropriate to each cultivar's day-degree requirements. Historical data over a 30 year period from 1968 - 1997, from the following meteorological stations near to the trial sites was used to obtain a long-term mean DD > 4°C profile over the year (Appendix Fig 2). Integration of a sine curve approximation from daily maximum and minimum temperatures was used to give a good estimate of day degrees compared with the hourly temperature record method.

Trial site	*Meteorological site*
HRI Efford	Everton (at HRI Efford)
Burston Nurseries	RES (Rothamsted)
Wharton's Nurseries	Morley St Botolph

Using this long-term mean day-degree data calculated for each day of the year, the scheduled potting date for a cultivar occurred when the cumulative total of day-degrees working backwards from the target BC date just equalled or exceeded that cultivar's requirement. This gave the potting schedule in Table 1 below. For Batch 1, there was up to 4 months difference in the potting schedule for the earliest and latest cultivars, whereas by Batch 3, only 1 month difference was required.

Table 1 Potting schedule based on 30 year mean temp. data from nearby meteorological sites

			Scheduled potting date		
Batch	**Target BC date**	**Cultivar**	**Efford**	**Wharton's**	**Burston's**
1	5 July	Swan Lake	2 Mar	13 Jan	6 Jan
1	5 July	Warm Wishes	26 Mar	7 Mar	2 Mar
1	5 July	Courage	13 Apr	1 Apr	29 Mar
1	5 July	Trumpeter	19 Apr	10 Apr	8 Apr
1	5 July	Indian Summer	14 May	10 May	9 May
1	5 July	Firefly	15 May	12 May	11 May
2	2 Aug	Swan Lake	19 May	14 May	14 May
2	2 Aug	Warm Wishes	28 May	24 May	24 May
2	2 Aug	Courage	4 Jun	1 Jun	2 Jun
2	2 Aug	Trumpeter	7 Jun	5 Jun	5 Jun
2	2 Aug	Indian Summer	22 Jun	20 Jun	20 Jun
2	2 Aug	Firefly	23 Jun	21 Jun	21 Jun
3	30 Aug	Swan Lake	25 Jun	23 Jun	23 Jun
3	30 Aug	Warm Wishes	1 Jul	30 Jun	30 Jun
3	30 Aug	Courage	7 Jul	6 Jul	6 Jul
3	30 Aug	Trumpeter	9 Jul	8 Jul	8 Jul
3	30 Aug	Indian Summer	21 Jul	20 Jul	20 Jul
3	30 Aug	Firefly	22 Jul	21 Jul	21 Jul

Culture

As in Year 1, some of the cultivars were commercially grown and others produced at Efford, but the same source of dormant plants within each cultivar was divided up between the three sites and held in their own cold stores. Cultural details were similar to Year 1, except that a slightly lower rate of 3.0 kg/m^3 of Ficote 140 day TE CRF was adopted, as commonly used by some nurserymen. Plants were all grown on after potting on outdoor beds, with overhead irrigation used on the two commercial nurseries and pot drip irrigation at Efford.

Records and analyses

Crop development and environment

1. Dates were recorded when plants reached first expanded leaf (EL), bud visible (FB), and bud colour (BC).

2. Hourly temperatures logged using a single TinyTalk II logger per site at about 0.5 m height. These were exchanged with a second set of loggers, by post weekly where possible, for the commercial sites, for data to be downloaded for collation at Efford, along with updates of growth stage data.

As in Year 1, plants showing atypical growth or development were eliminated from the analyses, and dates for EL, FB and BC averaged for each plot, with plot means used in subsequent analysis.

3. An Excel spreadsheet was developed to handle the temperature data and to enable the scheduled potting dates and updated predictions from current years temperature data to be calculated easily. Day-degrees from long term mean meteorological station temperatures were used to calculate the potting schedules. Elsewhere on the spreadsheet, the actual potting date was entered, and starting point predictions using a set of long term mean day-degree data were overwritten with day-degrees calculated from 1999 TinyTalk temperature data as they became available. In this way, the predictions could be updated.

At the end of the trial, the plot means for dates of BC were used to calculate the actual DD > 4 °C accumulated from potting for each batch, which were compared with the day-degree requirements for each cultivar derived from the Year 1 trial. Deviations in days and DD > 4 °C were calculated for both observed minus predicted BC dates and observed minus target BC dates. In addition, the prediction errors were calculated as described previously.

5. Day degrees calculated from nearest meteorological stations to the trial sites for 1999 were also compared to the TinyTalk derived day-degrees for that year, and used to make flowering date predictions. This helped quantify deviations that might occur from using meteorological site data rather than nursery based loggers. It also gave some measure of their suitability for estimating long-term mean temperatures relevant to the nursery.

6. The long-term meteorological data was also examined more closely for trends over the 30 year period, and whether any trends might be important when using long-term mean temperatures as a basis for drawing up potting schedules.

RESULTS

YEAR 1 - 1998 - Cultivar screening trial

Table 2 shows the mean dates at which bud colour was reached for each treatment, and days from potting to BC. Cultivars are listed in approximate order of rate of development with Firefly, the fastest to flower and Swan Lake the slowest. In most plots establishment and growth was good with no plant losses, but in a few plots some plants were excluded, due to severe shoot dieback or plant death, particularly with Swan Lake, and to a lesser extent Sweet Dream, and Top Marks. However, apart from the 15 June / Outside treatment with Sweet Dream, there were sufficient good quality plants to make a reliable record of growth development stages.

Table 2. Mean bud colour (BC) dates and days from potting to BC

	Batch 1		Batch 2		Batch 3	
Potting date:	12 Mar		6 May		15 Jun	
Cultivar	Outside	Tunnel	Outside	Tunnel	Outside	Tunnel
Firefly	27 May	16 May	22 Jun	16 Jun	29 Jul	25 Jul
Indian Summer	26 May	22 May	22 Jun	19 Jun	29 Jul	22 Jul
Alpine Sunset	1 Jun	26 May	28 Jun	19 Jun	1 Aug	30 Jul
Iceberg	3 Jun	28 May	29 Jun	24 Jun	2 Aug	26 Jul
Top Marks	28 May	23 May	28 Jun	22 Jun	7 Aug	5 Aug
Sweet Dream	3 Jun	27 May	2 Jul	26 Jun	N/A	5 Aug
Trumpeter	8 Jun	31 May	2 Jul	3 Jul	12 Aug	2 Aug
Courage	9 Jun	7 Jun	6 Jul	3 Jul	13 Aug	4 Aug
Warm Wishes	26 Jun	8 Jun	5 Jul	29 Jun	15 Aug	11 Aug
Handel	11 Jun	7 Jun	22 Jul	8 Jul	19 Aug	13 Aug
Swan Lake	12 Jun	11 Jun	23 Jul	21 Jul	22 Aug	15 Aug
			Days from potting to bud colour			
Firefly	76	65	47	41	44	40
Indian Summer	75	71	47	44	44	37
Alpine Sunset	81	75	53	44	47	45
Iceberg	83	77	54	49	48	41
Top Marks	77	72	53	47	53	51
Sweet Dream	83	76	57	51	N/A	51
Trumpeter	88	80	57	58	58	48
Courage	89	87	61	58	59	50
Warm Wishes	106	88	60	54	61	57
Handel	91	87	77	63	65	59
Swan Lake	92	91	78	76	68	61

As expected, development times from potting to BC became shorter with successive batches as they were grown in warmer periods of the year. Also, the batches grown under the tunnel flowered earlier than those grown outside in all cases except for the May potted Trumpeter.

The 1998 temperature and development dates for each treatment were used to calculate observed day degrees. Appendix Fig 2 shows the deviations of the day-degrees as observed minus predicted for each batch when using the Warm Wishes model of 772 DD > 4°C from potting to BC. Table 3 gives the mean deviations from the Warm Wishes model for each cultivar expressed as both days and as DD > 4°C with their prediction errors, and, based on these means gives the suggested 'new' day degree totals for the other cultivars.

Table 3.
Mean deviations in days and day-degrees using Warm Wishes model of 772 DD > 4 °C from potting to BC with suggested new DD requirements.

Cultivar	Mean deviation in days	Prediction error Spre in days	Mean deviation in DD>4	Prediction error Spre in DD>4	Suggested 'new' total DD>4 °C	Earliness group
Firefly	-20.5	20.8	-257	259	***515***	Very early
Indian Summer	-19.7	19.9	-245	246	***527***	Very early
Alpine Sunset	-15.2	15.4	-192	194	***580***	Early
Iceberg	-14.0	14.1	-178	179	***594***	Early
Top Marks	-13.8	15.2	-170	170	***602***	Early
Sweet Dream	-11.4	12.3	-139	144	***633***	Early
Trumpeter	-7.8	8.7	-98	106	***674***	Mid
Courage	-5.3	6.1	-68	74	***704***	Mid
Warm Wishes	-1.7	5.2	-22	68	***772***	Late
Handel	1.0	6.0	20	73	***772***	Late
Swan Lake	5.0	8.9	73	118	***845***	Late

Warm Wishes in 1998 deviated very little from the predictions made using the model developed previously in the MAFF project. Its mean deviation was only 1.7 days earlier on average than would have been predicted, or 22 DD > 4 °C less than 772. This was well within the 95% confidence interval of the model, and because this trial was based on relatively few observations, and was also being used partly to validate the model for Warm Wishes, there was no justification for adjusting the 772 day-degree total. Likewise, because Handel was similarly close to the model (albeit on average slightly later rather than earlier), the suggested DD requirement was set the same. For the other cultivars, their suggested 'new' DD requirements were set by simply adding the mean deviation to 772 DD > 4 °C.

Mean numbers of days and DD > 4 °C up to, and after, the intermediate growth stage of EL is shown in Table 4.

Table 4.
Mean days and DD > 4 °C between potting and first expanded leaf (EL) and EL to bud colour (BC) in 1998.

	Potting to EL		EL to BC	
Cultivar	**Days**	**DD > 4 °C**	**Days**	**DD > 4 °C**
Firefly	20.5	173	31.7	342
Indian Summer	22.3	192	30.7	335
Alpine Sunset	25.8	217	31.7	363
Iceberg	25.0	204	33.7	390
Top Marks	12.7	117	46.2	484
Sweet Dream	9.0	86	54.6	547
Trumpeter	14.7	141	50.2	533
Courage	21.0	176	46.3	528
Warm Wishes	24.7	204	46.3	546
Handel	25.3	222	48.3	570
Swan Lake	22.8	222	54.8	622

Sweet Dream required fewest DD from potting to EL, but apart from Top Marks and Trumpeter, which were intermediate, the differences in mean DD > 4 °C were relatively small between the other cultivars. Differences in the DD requirement for the post leafing out phase until BC were greater, however, and broadly followed the trend for overall rate of development for the cultivar.

YEAR 2 - 1999 - Model validation trial

Plant growth and flowering dates

In general, plants from all batches established and grew well at the Efford and Wharton's site. There were some crop management problems with the second and third batches at the Burston site, however, which meant that the growth data from this site was unavailable. Temperature data continued to be collected.

As in 1998, Swan Lake proved susceptible to shoot die-back on all the sites, and Indian Summer showed some die-back of shoots at Efford, but there were sufficient healthy plants on the Efford and Wharton's sites from each batch to get satisfactory records of these cultivars.

Table 5. Observed and predicted flowering dates in relation to potting dates, 1999.

Batch	Cultivar	Target date to BC	Actual potting date	Predicted date to BC	Predicted days potting to BC	Observed date of BC	Days deviation from Predicted	Days deviation from target
				Efford				
1	Swan Lake	5 Jul	2 Mar	21 Jun	111	23 Jun	2	-12
1	W. Wishes	5 Jul	26 Mar	22 Jun	88	27 Jun	5	-8
1	Courage	5 Jul	13 Apr	26 Jun	74	23 Jun	-3	-12
1	Trumpeter	5 Jul	19 Apr	25 Jun	67	28 Jun	3	-7
1	I. Summer	5 Jul	14 May	1 Jul	48	28 Jun	-3	-7
1	Firefly	5 Jul	14 May	30 Jun	47	26 Jun	-4	-9
2	Swan Lake	2 Aug	19 May	25 Jul	67	25 Jul	0	-8
2	W. Wishes	2 Aug	28 May	27 Jul	60	25 Jul	-2	-8
2	Courage	2 Aug	4 Jun	28 Jul	54	30 Jul	2	-3
2	Trumpeter	2 Aug	8 Jun	28 Jul	50	26 Jul	-2	-7
2	I. Summer	2 Aug	22 Jun	29 Jul	37	31 Jul	2	-2
2	Firefly	2 Aug	23 Jun	29 Jul	36	23 Jul	-6	-10
3	Swan Lake	30 Aug	25 Jun	23 Aug	59	2 Sep	10	3
3	W. Wishes	30 Aug	1 Jul	23 Aug	53	21 Aug	-2	-9
3	Courage	30 Aug	7 Jul	25 Aug	49	31 Aug	6	1
3	Trumpeter	30 Aug	9 Jul	25 Aug	47	30 Aug	5	0
3	I. Summer	30 Aug	21 Jul	27 Aug	37	31 Aug	4	1
3	Firefly	30 Aug	22 Jul	27 Aug	36	28 Aug	1	-2
				Wharton's				
1	Swan Lake	5 Jul	1 Feb	21 Jun	140	3 Jun	-18	-32
1	W. Wishes	5 Jul	8 Mar	21 Jun	105	18 Jun	-3	-17
1	Courage	5 Jul	1 Apr	23 Jun	83	20 Jun	-3	-15
1	Trumpeter	5 Jul	9 Apr	26 Jun	78	19 Jun	-7	-16
1	I. Summer	5 Jul	10 May	30 Jun	51	26 Jun	-4	-9
1	Firefly	5 Jul	12 May	1 Jul	50	26 Jun	-5	-9
2	Swan Lake	2 Aug	14 May	25 Jul	72	17 Jul	-8	-16
2	W. Wishes	2 Aug	24 May	26 Jul	63	23 Jul	-3	-10
2	Courage	2 Aug	1 Jun	28 Jul	57	23 Jul	-5	-10
2	Trumpeter	2 Aug	4 Jun	28 Jul	54	21 Jul	-7	-12
2	I. Summer	2 Aug	21 Jun	29 Jul	38	26 Jul	-3	-7
2	Firefly	2 Aug	21 Jun	29 Jul	38	24 Jul	-5	-9
3	Swan Lake	30 Aug	23 Jun	24 Aug	62	16 Aug	-8	-14
3	W. Wishes	30 Aug	30 Jun	24 Aug	55	21 Aug	-3	-9
3	Courage	30 Aug	6 Jul	26 Aug	51	31 Aug	5	1
3	Trumpeter	30 Aug	8 Jul	26 Aug	49	15 Aug	-11	-15
3	I. Summer	30 Aug	20 Jul	28 Aug	39	30 Aug	2	0
3	Firefly	30 Aug	21 Jul	28 Aug	38	25 Aug	-3	-5

The actual potting dates and scheduled potting dates for each treatment (Table 5 vs. Table 1) were the same, or within 1 day except for the Batch 1 Swan Lake at Wharton's (and Burston), where the scheduled potting date occurred prior to commencement of the experiment.

The spring and summer of 1999 was warmer than average for all sites. Hence, using the actual potting dates and temperatures for that year, the model predictions for date of BC was earlier than the target date. The observed dates for BC at both Efford and Wharton's were generally very close to the predictions. For the majority of treatments, deviation in flowering date was within 4 days of the prediction. Flowering at Wharton's erred to being earlier than predicted across the range of cultivars. As in 1998, the model predicted Warm Wishes flowering accurately, to within 3 - 5 days. Although not presented in Table 5, the results for Batch 1 from Burston also gave BC dates within 5 days of that predicted, except for Swan Lake which was 10 days earlier than predicted.

For both Efford and Wharton's, the warmer than 30 year average spring and summer caused the first two batches to reach BC appreciably earlier than the target date, but the final batch was less affected and flowered nearer to the target.

Table 6 details the deviations of the observed flowering dates from the model predictions and target dates, grouped by cultivar. The mean difference expressed in days from predicted was less than 4 days for all cultivars when averaged across batches x sites, but this doesn't take into account the cancelling out effect on the mean of positive vs. negative deviation. The prediction error Spre, in days, was greatest for Swan Lake at 9.6 days and least for Warm Wishes at 3.2 days. The prediction errors in day-degrees were 109 DD > 4 °C for Swan Lake down to 41 DD > 4 °C for Warm Wishes.

Table 6. Analyses of observed BC deviations from predicted and target dates

Site	Batch	Pred. days potting to BC	Deviations from predicted date: Obs. - pred. in days	Deviations from predicted date: Obs. - pred. in DD > 4 °C	Deviations from target date: Obs. - target in days	Deviations from target date: Obs. - target in DD > 4 °C
			Swan Lake			
Efford	1	111	2	22	-12	-155
Efford	2	67	0	0	-8	-128
Efford	3	59	10	136	3	41
Wharton's	1	140	-18	-177	-32	-352
Wharton's	2	72	-8	-119	-16	-242
Wharton's	3	62	-8	-82	-14	-166
Mean		***85.2***	***-3.7***	***-36.5***	***-13.2***	***-167***
Spre			***9.6***	***108.9***	***16.8***	***205***
			Warm Wishes			
Efford	1	88	5	65	-8	-103
Efford	2	60	-2	-30	-8	-128
Efford	3	53	-2	-27	-9	-122
Wharton's	1	105	-3	-33	-17	-208
Wharton's	2	63	-3	-45	-10	-157
Wharton's	3	55	-3	-32	-9	-116
Mean		***70.7***	***-1.3***	***-17.0***	***-10.2***	***-139.0***
Spre			***3.2***	***40.6***	***10.6***	***143.3***
			Courage			
Efford	1	74	-3	-41	-12	-155
Efford	2	54	2	33	-3	-50
Efford	3	49	6	82	1	13
Wharton's	1	83	-3	-29	-15	-183
Wharton's	2	57	-5	-69	-10	-157
Wharton's	3	51	5	67	1	13
Mean		***61.3***	***0.3***	***7.0***	***-6.3***	***-86.5***
Spre			***4.2***	***57.0***	***8.9***	***119.0***
			Trumpeter			
Efford	1	67	3	35	-7	-92
Efford	2	50	-2	-30	-7	-113
Efford	3	47	5	69	0	0
Wharton's	1	78	-7	-75	-16	-194
Wharton's	2	54	-7	-92	-12	-180
Wharton's	3	49	-11	-123	-15	-177
Mean		***57.5***	***-3.2***	***-36***	***-9.5***	***-125.9***
Spre			***6.5***	***77.5***	***11.0***	***142.9***

continued ....

Table 6. (cont.)

Site	Batch	Pred. days potting to BC	Deviations from predicted date Obs. - pred. in days	Obs. - pred. in DD > 4 °C	Deviations from target date Obs. - target in days	Obs. - target in DD > 4 °C
			Indian Summer			
Efford	1	48	-3	-37	-7	-92
Efford	2	37	2	33	-2	-34
Efford	3	37	4	53	1	13
Wharton's	1	51	-5	-59	-9	-119
Wharton's	2	38	-3	-40	-7	-112
Wharton's	3	39	2	28	0	0
Mean		*41.7*	*-0.5*	*-3.6*	*-4.0*	*-57.3*
Spre			*3.3*	*43.1*	*5.5*	*78.0*
			Firefly			
Efford	1	47	-4	-46	-9	-114
Efford	2	36	-6	-95	-10	-162
Efford	3	36	1	13	-2	-27
Wharton's	1	50	-5	-59	-9	-119
Wharton's	2	38	-5	-67	-9	-139
Wharton's	3	38	-5	-41	-5	-69
Mean		*40.8*	*-3.7*	*-49.1*	*-7.3*	*-105.0*
Spre			*4.3*	*59.1*	*7.9*	*114.1*

Meteorological station data compared to on site temperature loggers

DD > 4 °C were calculated from daily maximum and minumum temperatures for 1999 for each of the nearest meteorological stations to the trial sites for comparison with the TinyTalk data for those sites. Meteorological data from the Morley St Botolph site nearest to Wharton's nursery was only available 18 months in arrears, so the next nearest site at Honington was used for 1999 data. The mean differences in the day-degree values between both sources, calculated for a period day 50 - day 200 (mid February - mid July) when TinyTalk data was available from all three trial sites were:

Trial site	Meteorological site	Trial site minus Met. site difference mean DD > 4 °C / day
Efford	Everton	0.63 (S.E. 0.074)
Wharton's	Honington	0.06 (S.E. 0.070)
Burston	Rothamsted	0.41 (S.E. 0.058)

When the day-degrees derived from the meteorological sites were run through the prediction model, the following differences in predicted date to BC, from those in Table 5 using the on-site Tiny Talk data, were obtained.

Table 7.
Difference (days) in predicted dates to BC using 1999 day-degrees derived from meteorological station temperatures instead of on-site Tiny Talk data loggers.

		Meteorological site (Trial site)		
Batch	**Cultivar**	**Everton (Efford)**	**Honington (Wharton's)**	**Rothamsted (Burston)**
1	Swan Lake	+5	0	+5
1	W. Wishes	+5	0	+4
1	Courage	+4	+1	+4
1	Trumpeter	+4	+1	+3
1	I. Summer	+3	+2	+2
1	Firefly	+3	+1	+1
2	Swan Lake	+5	+1	+3
2	W. Wishes	+4	+2	+2
2	Courage	+4	+1	+2
2	Trumpeter	+4	+1	+3
2	I. Summer	+3	+1	+1
2	Firefly	+2	+1	+1
3	Swan Lake	+4	+1	+2
3	W. Wishes	+4	+1	+1
3	Courage	+2	0	+1
3	Trumpeter	+2	0	+1
3	I. Summer	+2	0	0
3	Firefly	+2	+1	0

This indicated that using the Honington meteorological station data near to Wharton's nursery was likely to give a very close approximation to the on-site Tiny Talk values, and that for Burston and Efford, the nearest meteorological stations were likely to slightly underestimate temperatures, which could account for up to 5 days delay in predicted BC dates.

Long term average temperatures from meteorological sites

Appendix Fig 3 illustrates the 30 year long term average day-degree profile for the Efford meteorological site, and the DD > 4 °C values for 1999. The 1999 data clearly illustrates the warmer than average temperatures experienced that year. A very similar pattern was found for the Morley St Botolph meteorological site used for Wharton's, and the Rothamsted meteorological site used for Burston. Long term mean temperatures were slightly lower there than at Efford (hence the earlier scheduled potting dates), but 1999 temperatures were still clearly warmer.

Appendix Fig 4 shows the difference in 30 year long term mean temperatures when split into three 10 year periods, for the Everton (Efford) and Morley St Botolph (nr. Wharton's) meteorological sites. It clearly shows that on both sites, the temperatures in the latest 10 year period were significantly warmer than the previous 20 years.

When averaged over the whole year the latest 10 year period was between 0.35 and 0.41 DD > 4 °C warmer than the 30 year average for the three meteorological sites used in the trial.

Table 8.

Mean DD > 4 °C / day averaged over the whole year for successive 10 year periods and the 30 year mean.

		Meteorological station	
Period	**Everton**	**Morley St Botolph**	**Rothamsted**
10yr mean 1968 - 1977	6.67	5.91	5.90
10 yr mean 1978 - 1987	6.49	5.79	5.79
10 yr mean 1988 - 1997	7.17	6.48	6.37
30 yr mean 1968 - 1997	6.78	6.07	6.02
Difference latest 10 yrs from 30 yr mean	*+ 0.39*	*+0.41*	*+0.35*

DISCUSSION

Assigning DD requirements to cultivars

The trial in 1998 validated the prediction model well for the cultivar Warm Wishes. The assumption was made that the same basic relationship between thermal time and time to BC would apply to the additional cultivars screened, but that they would probably have different accumulated DD requirements to Warm Wishes depending on their rate of development. It is possible that different cultivars would have different base temperatures than 4 °C from which day-degrees were calculated. This was looked at informally, and with the limited data available there was some indication that a slightly better fit of the model might be found if other base temperatures between 0 and 3 °C were used for some of the cultivars. However, there were insufficient data sets to re-model these cultivars reliably, and maintaining a single model using a 4 °C base temperature appeared sufficiently accurate for practical purposes.

The range of cultivars screened demonstrated large differences in rates of development, with DD > 4 °C requirements ranging from 515 to 845, and should provide a good reference framework within which to place other unknown cultivars. A grower wishing to start scheduling a range of cultivars will inevitably have to make some estimates as to where on the DD requirement scale particular cultivars will fall, until further information is available. This will be based on grower's previous experience of the cultivar, and its rate of development, preferably relative to one of the cultivars listed below. Provided basic records of date of potting, date of BC and temperatures are maintained for sufficient replicate plants and batches, it will be possible to update initial estimates empirically to give reasonably accurate estimates of DD requirements for new cultivars for practical purposes.

Table 9. Suggested framework for allocating cultivars to earliness groups

Earliness group	DD > 4 °C	Example cultivars	DD > 4 °C
Very Early	< 550	Firefly	515
		Indian Summer	527
Early	550 - 650	Alpine Sunset	580
		Iceberg	594
		Top Marks	602
		Sweet Dream	633
Mid	650 - 750	Trumpeter	674
		Courage	704
Late	>750	Warm Wishes	772
		Handel	772
		Swan Lake	845

Model validation

The model's validity is determined by how far the observed flowering dates deviate from the predicted dates using the actual temperatures for that season, not deviations from the target flowering date which is based on long term average temperatures. The 1999 results gave remarkably good validation of the model across the range of cultivars tested, especially considering the DD requirements for the 'new' cultivars was based on a relatively small data set from 1998. The control cultivar Warm Wishes, as might be expected, had a small prediction error, and predictions were on average only about 1 day out. Swan Lake was the most variable of the cultivars with a mean BC date about 4 days earlier than predicted and with the largest prediction error, so this varied from +10 to –18 days from the prediction. The cultivars with the slowest development rates are likely to be the most difficult to model accurately, because proportional errors in estimating day degree requirements will represent a longer period of time than a fast developing cultivar. In addition, the problems with shoot die-back in Swan Lake may have added to the variability of the results despite removing badly affected plants from the analyses.

The stage of buds showing colour appears to have been recorded slightly earlier at Wharton's where this was interpreted as the very first shoot on a plant that had a bud showing colour, compared to Efford where typically 2 or more buds had reached BC before this stage was recorded. This would account for Wharton's differences from the predicted dates typically being earlier than Efford's. Although the definition of BC stage is open to some interpretation, it is likely to be precise enough for practical purposes and has the advantage of being easily observed and coinciding with the optimal stage for marketing.

The mean deviations in DD > 4 °C from the predictions can be used to adjust the assigned day-degree requirements for cultivars if necessary. This will usually be necessary to refine estimated DD requirements with new cultivars, but once these have been established with some reliably recorded batches of plants, they should only be revised with care. The prediction model has 'error' associated with it, and small adjustments in DD assignments need to be justified by a reasonably consistent trend from a large number of batches.

Meteorological station vs. nursery temperature logger data

The Everton meteorological station on the Efford site, which was only about 300 m from the rose container trial site, gave the largest discrepancy between day-degree values of the three trial sites. Thermometers in the meteorological sites were located at about 1.5 m above the ground instead of at 0.5 m with the Tiny Talk sensors. Together with other differences in microclimate, it is not surprising that there are inaccuracies when comparing meteorological station and Tiny Talk logger data even from nearby positions. The method needed to estimate day-degrees from daily maximum and minumum temperatures from meteorological stations is also less accurate than hourly logged readings and could lead to some error, although this method has proved generally reliable for estimates incorporating several weeks data.

Currently, the use of historical data from meteorological sites is probably the best way of determining average temperature profiles for use in scheduling outdoor crops where temperatures cannot be readily manipulated. Where local meteorological station data corresponds well with on-site measurements, then it may be a useful backup when using an on-site data logger. In most cases, however, up to date local meteorological station data is not readily available, and with the relatively low price of a simple logger, probes and downloading software (<£160), it is well worth nurserymen investing in this equipment for serious application of crop scheduling.

Scheduling potting dates from long-term average DD profiles

A good predictive model is of most value when it can be used to schedule key operations (in this case potting dates), so that crops will meet targeted maturity dates (ie BC), or so that pottings can be planned to give a succession of batches for market. For containerised roses grown outdoors (or under protection with limited environmental control), temperature profiles will vary from year to year. Simulations with Warm Wishes for the MAFF project, using temperature profiles of 'warm' and 'cool' years with spring / summer periods + or – about 1 °C from average, resulted in predicted flowering dates about 7 days earlier or later than average. Experience from the 1999 trial showed a range of deviations from the target dates across the cultivars, batches and sites, but that often BC date was between 7 and 14 days earlier than targeted. Much of this deviation was because 1999 was actually warmer than average. For Efford, obtaining long term averages from the 'cooler' meteorological station cf. trial site could also account for some of the deviation, by scheduling potting dates a little too early. This cannot be tested yet for Wharton's site until the Morley St Botolph meteorological data for 1999 is available. Finally, the use of a 30 year mean tended to underestimate temperatures. If the fact that the last 10 years mean was about 0.4 DD > 4 °C / day higher than the 30 year mean is a true indication of a climate change trend, then using the last 10 year temperature means should be a better basis for scheduling.

Application on the nursery

While it is important to understand the various sources of 'errors' inherent in the process of crop prediction and scheduling, and sensible to minimise these as far as is practical, great precision is not necessary for most applications in containerised rose production. The containerised roses will be in good marketing condition over a range of time and development stages before they are 'past their best'. This represents a 'marketing window' which can accommodate some error in the scheduling process. Also, unless a spot crop is aimed at a specifically timed market, and the main goal is to spread potting to achieve a better continuity of supply, there is more flexibility for plants to be sold from earlier or later batches and to absorb seasonal fluctuations in growth rates.

Day-degree requirements can be chosen of 500, 600, 700 or 800 DD > 4 °C according to the four earliness groups if insufficient is known about a new cultivar to estimate more accurately relative to one of the example cultivars.

It is recommended that to obtain any more reliable estimate of day-degree requirements for a new cultivar, at least six separate potting batches should be monitored with a spread of potting dates. Each batch should include 10 plants which are individually recorded for date of BC stage, and these averaged to obtain a date for the batch to use in the model. Should any individual plants show obvious signs of poor health or establishment after potting which appeared to delay development, then these should be excluded from the plot means. It is also important to ensure that plants are as near dormant as possible at potting, with buds that have not broken. It has been found that cold stores need to maintain temperatures of 0 °C to maintain roses sufficiently dormant for potting beyond the end of March. Roses have been successfully cold stored and potted as late as mid August at Efford for late flowering.

Intermediate growth stages

The monitoring of dates of definable intermediate growth stages, i.e. first expanded leaf, and flower bud first visible, was included to see whether these might enable the progress of batches to be tracked more accurately, and give advance warning of how far batches might be ahead or behind schedule to meet a targeted bud colour date. The 1998 trial showed relatively little difference in the DD requirement for most of the cultivars to reach EL, but mean DD > 4 °C for the longer stage from EL to BC tended to follow the trend for overall development rate of the cultivars. Analyses of DD requirements between intermediate growth stages have shown more variability, however, than for the overall production period, which makes them less reliable for practical application. There is also the problem that by the time EL or FB is reached, options are limited for delaying or advancing batches (such as moving them out of or under protection), or retarding or advancing potting dates of subsequent batches to maintain continuity of production.

If there was a specific cultivar or group of roses that was particularly suited to being scheduled for a niche market, or where it was important to time spot production accurately, it could be worthwhile collecting more data, including intermediate growth stages and re-modelling the cultivar. However, collecting just the potting and BC date records for a range of cultivars and batches will be sufficient to enable basic scheduling to be applied to a nursery, and is more likely to be an acceptable undertaking for the grower.

Unless reliable temperature data over a 10 year period is already available from the nursery, it will be necessary to use nearby meteorological station data as a starting point for scheduling. As a rough guide, simple look-up tables listing target flowering dates at weekly intervals (see Table 10), could be drawn up covering a typical site in the south, midlands and north. This might be sufficient for growers just wanting some guidance on how best to start spreading potting dates to avoid a surplus of containers in flower at once, but it would be subject to the errors discussed. To progress to anything more precise, on-site logging of temperatures, and commencement of simple recording of date of potting, and date of bud colour will be necessary. Once the potting date and DD requirement of the cultivar is known, current year temperature data can be used as described previously to update predictions from the average, and give advance warning of whether batches are likely to be ahead or later than scheduled.

Developing a dedicated rose modelling software package for grower use was beyond the scope of this project, but a Microsoft Excel spreadsheet (Office 97 version) can be made available to growers who are familiar with working with spreadsheets, and who may wish to handle their own temperature data and scheduling in liaison with HRI Efford. HDC should be contacted in the first instance.

This project has concentrated on developing the model for use with containers grown on outdoors after potting, with the main aim of extending the marketing season later rather than earlier, and using the model with batches of plants potted from January onwards.

Within limits, the model will be applicable to crops given some early protection, provided temperatures are monitored while under this environment. However, drawing up a 'starting point' potting schedule for these crops is more difficult as there is not usually a database of protected environment temperatures available to refer to. Another difficulty is that autumn pottings can often make some shoot growth prior to the onset of dormancy, particularly if protection is used. Whether or not this growth gets damaged by frost over winter, and plants have to develop new shoots to run up to flower, this check to growth can cause errors in the prediction of flowering from the time of potting.

Within the range of spring and summer growing conditions used in the MAFF and HDC trials on scheduling to date, light level has not been a significant factor affecting timing of flowering. However, it is likely to become important if flowering is forced very early or very late when this model will cease to be applicable. Light levels have been found to affect development rates of cut roses grown under glass and supplementary lighting is often used in the winter period.

Market opportunities

In addition to the benefits of extending the traditional summer period for marketing containerised roses, there is the potential for developing a new market for very late flowering batches (e.g. Sept - early Oct). These offer a substitute to the early autumn lifted and containerised 'dormant' season plants that are frequently retailed as 'freshly potted' plants before new roots have established in the container. Some surplus plants of a range of cultivars that had been held in cold store at HRI Efford were potted in early - mid August 1999, and reached BC in mid to late September. For Warm Wishes and Indian Summer, for which we had day-degree requirement data, BC dates of these batches were just two and five days earlier than the predicted dates. These plants were of good marketable quality, although the density of top growth was slightly less than a plant produced in spring and summer. Poor light levels will limit how late batches can be delayed for autumn flowering before quality is adversely affected, but market opportunities may make this worth investigating further.

There may be opportunities also for promoting sales of 'special occasion' cultivars (e.g. Many Happy Returns, Wedding Day, Happy Anniversary, Congratulations) if offered as gifts in flower over a longer period of the year supported by a planned programme of successional supplies. Display material may need to make it clear that flowering time in subsequent years would occur in its natural season.

Table 10. Example of a look-up table as a guide for scheduling potting dates

Meteorological Station: Everton (Efford) 10-Year Mean Data

Earliness Group: Example Cultivar: Day Degrees >4°C		Very Early Firefly 515	Very Early Indian Summer 527	Early Alpine Sunset 580	Early Iceberg 594	Early Top Marks 602	Early Sweet Dream 633	Mid Trumpeter 674	Mid Courage 704	Late Warm Wishes 772	Late Swan Lake 845
Batch No.	**Target flower**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**	**Scheduled Pot date**
1	**5 Jun**	14 Mar	10 Mar	20 Feb	14 Feb	11 Feb	29 Jan	14 Jan	5 Jan	Too early	Too early
2	**12 Jun**	29 Mar	26 Mar	14 Mar	10 Mar	8 Mar	24 Feb	9 Feb	27 Jan	4 Jan	Too early
3	**19 Jun**	16 Apr	13 Apr	31 Mar	28 Mar	26 Mar	19 Mar	9 Mar	26 Feb	30 Jan	5 Jan
4	**26 Jun**	30 Apr	28 Apr	18 Apr	15 Apr	14 Apr	6 Apr	27 Mar	20 Mar	1 Mar	1 Feb
5	**3 Jul**	12 May	10 May	3 May	1 May	30 Apr	24 Apr	15 Apr	9 Apr	23 Mar	4 Mar
6	**10 Jul**	23 May	21 May	14 May	13 May	11 May	7 May	2 May	27 Apr	13 Apr	26 Mar
7	**17 Jul**	1 Jun	31 May	25 May	24 May	23 May	19 May	14 May	9 May	30 Apr	16 Apr
8	**22 Jul**	8 Jun	7 Jun	1 Jun	30 May	30 May	26 May	22 May	18 May	9 May	29 Apr
9	**31 Jul**	20 Jun	19 Jun	14 Jun	13 Jun	12 Jun	9 Jun	4 Jun	1 Jun	25 May	16 May
10	**7 Aug**	29 Jun	28 Jun	23 Jun	22 Jun	21 Jun	18 Jun	14 Jun	11 Jun	4 Jun	27 May
11	**14 Aug**	7 Jul	6 Jul	1 Jul	30 Jun	29 Jun	27 Jun	23 Jun	20 Jun	14 Jun	6 Jun
12	**21 Aug**	14 Jul	13 Jul	9 Jul	8 Jul	7 Jul	4 Jul	1 Jul	29 Jun	22 Jun	16 Jun
13	**28 Aug**	21 Jul	20 Jul	16 Jul	15 Jul	15 Jul	12 Jul	9 Jul	6 Jul	1 Jul	24 Jun
14	**4 Sep**	27 Jul	27 Jul	23 Jul	22 Jul	21 Jul	19 Jul	16 Jul	13 Jul	8 Jul	2 Jul
15	**11 Sep**	2 Aug	2 Aug	29 Jul	27 Jul	27 Jul	25 Jul	22 Jul	19 Jul	14 Jul	8 Jul
16	**18 Sep**	8 Aug	7 Aug	3 Aug	2 Aug	2 Aug	30 Jul	27 Jul	25 Jul	20 Jul	14 Jul
17	**25 Sep**	13 Aug	12 Aug	8 Aug	7 Aug	7 Aug	5 Aug	2 Aug	30 Jul	25 Jul	20 Jul
18	**2 Oct**	18 Aug	17 Aug	13 Aug	12 Aug	12 Aug	10 Aug	7 Aug	5 Aug	30 Jul	25 Jul
19	**9 Oct**	23 Aug	22 Aug	18 Aug	17 Aug	17 Aug	14 Aug	11 Aug	9 Aug	4 Aug	30 Jul
20	**16 Oct**	28 Aug	27 Aug	23 Aug	22 Aug	21 Aug	19 Aug	16 Aug	13 Aug	9 Aug	3 Aug
21	**23 Oct**	1 Sep	31 Aug	27 Aug	26 Aug	25 Aug	23 Aug	20 Aug	18 Aug	12 Aug	7 Aug

CONCLUSIONS

The overall aim of the project was to extend the prediction model developed under a MAFF funded project with cv. Warm Wishes to a wider range of cultivars, and to test and develop its application to the industry for scheduling containerised roses.

- The prediction model developed for Warm Wishes appears to work well for a range of other cultivars given appropriate adjustments in their day-degree requirements. Day-degree allocations ranged from 515 - 845 DD > 4 °C and Warm Wishes fell amongst the 'late' cultivars.

- The allocated day-degree values were generally well validated across the range of cultivars tested, although the latest cultivar, Swan Lake was more variable than the others and showed the largest prediction errors. For the other cultivars, most of the batches reached bud colour (BC) stage within a week of the date predicted by the model.

- Use of long-term average temperature data from local meteorological stations data can be used to estimate temperature profiles for the season and draw up potting schedules for outdoor grown container crops to meet targeted BC dates. Seasonal variations of temperature from the average, however, may contribute up to about 14 days error from slow to develop cultivars potted early in the year, but errors should be less for later potted batches which develop more quickly. Because of possible influences of climate change, it is suggested that the latest 10 year mean data will give a more accurate estimate of day-degrees for scheduling, than using a longer period such as the 30 year mean.

- On-site temperature loggers which can be periodically downloaded to a PC proved a simple and convenient way of collecting temperature data for use on the nursery. There can be some error associated with using data from even nearby meteorological stations, and usually this data is not available quickly enough for current year updating of the model.

- While it is sensible to minimise the errors associated with crop prediction and scheduling, absolute precision will not be necessary. The 'marketing window' that exists for batches of containerised roses should absorb sufficient of the error for it to be of practical use on the nursery. This will apply particularly where the aim is to maintain better continuity of supply where plants can be drawn from a range of batches at any one time.

- There are new market opportunities that may be exploited through scheduling and season extension. These could include extending the selling season for 'special occasion' named cultivars such as Wedding Day or Congratulations which would be needed throughout the year. Also, there may be opportunities for substituting 'freshly potted' early autumn lifted maiden roses with batches of established containerised plants in flower in September and early October.

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APPENDIX

Figure 1. The time from potting to bud colour stage expressed in days and DD > 4 °C for cv. Warm Wishes used in MAFF project HH1513THN

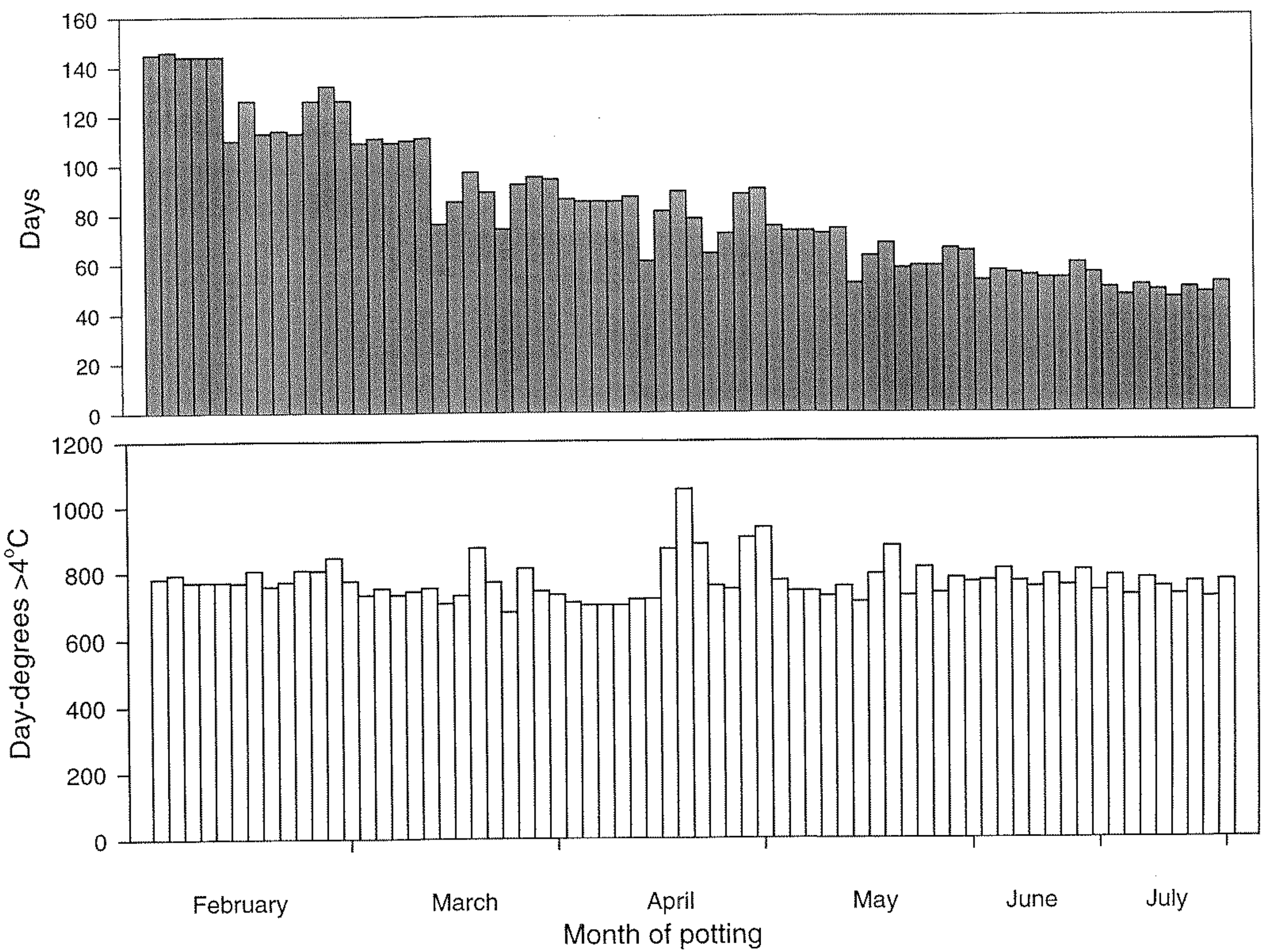

Figure 2 **Cultivar screening trial 1998. Predictions made using Warm Wishes model from potting to bud shows colour (DD > 4 °C).**

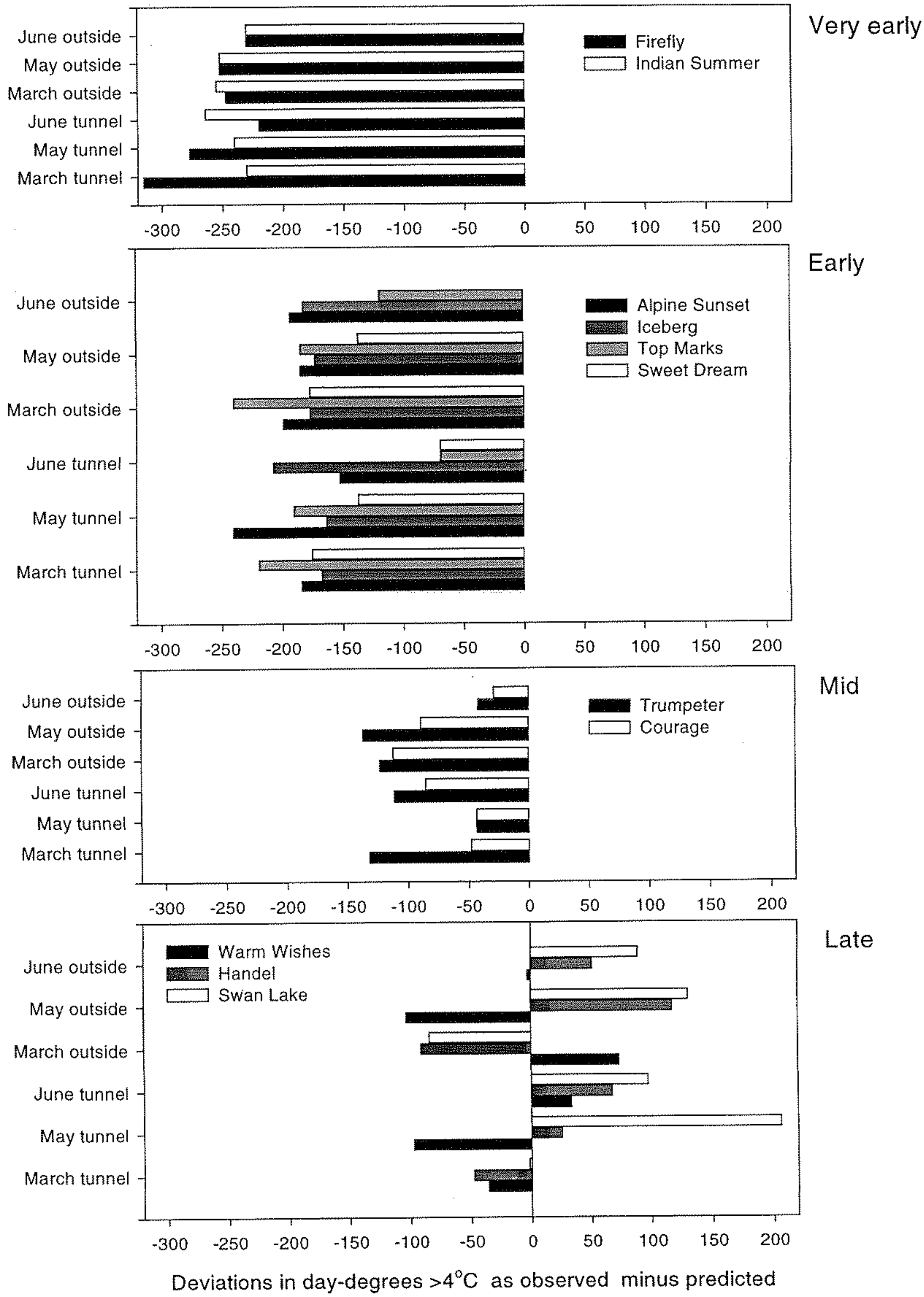

Figure 3. Day-degrees > 4 °C - 30 year mean met. data and 1999 data at HRI Efford from 28/1/99 - 26/10/99

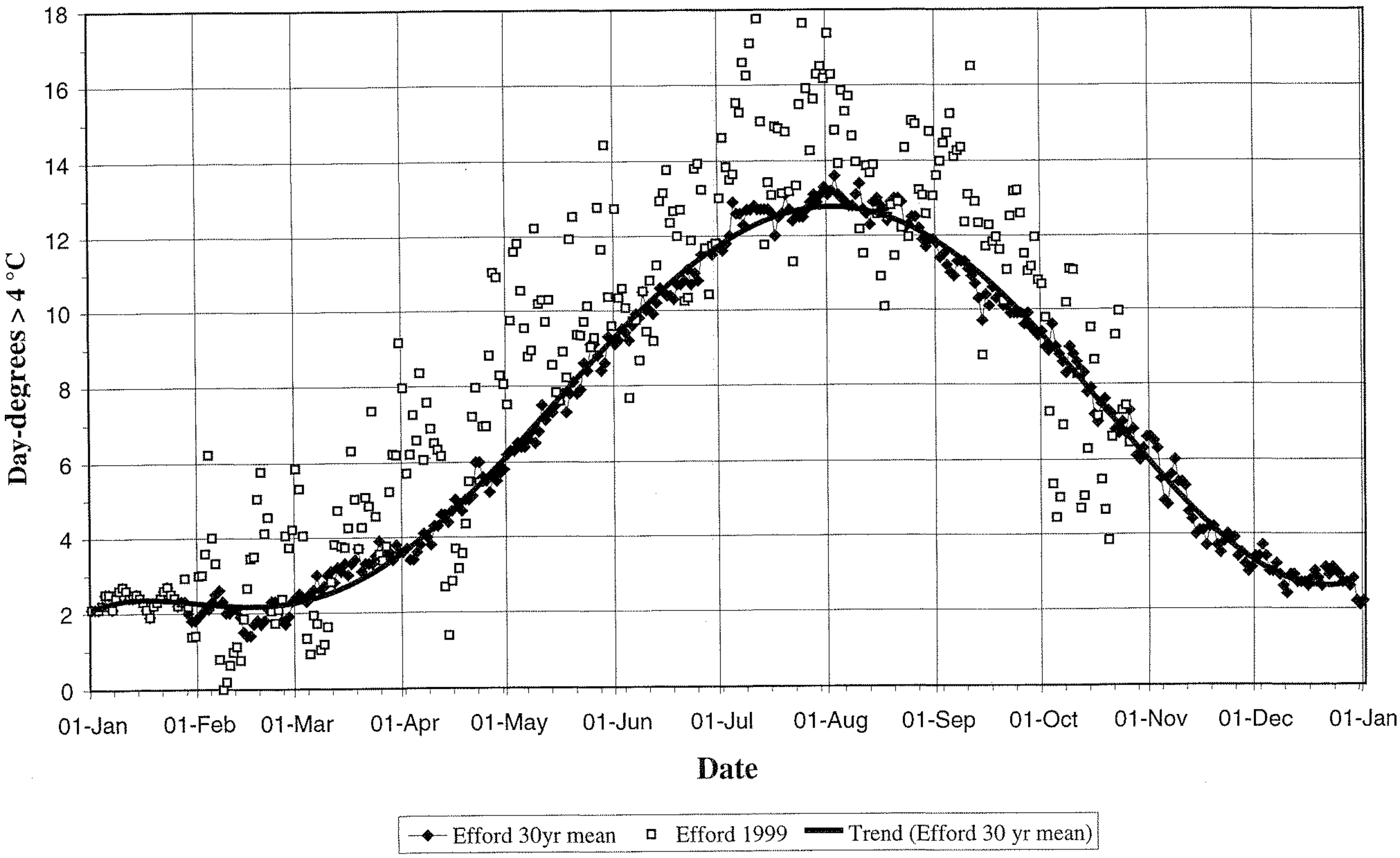

Figure 4. Differences in average day degrees > 4°C from met. sites. 10-year averages minus 30-year averages for Everton (Efford) and Morley St Botolph (nr Wharton's).