Thermal time requirements for flowering of precocious Asiatic magnolias

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Abstract
Observations on flowering times of 55 different *Magnolia* species, hybrids and cultivars were made at Lincoln University over a period of five years. Results from June 1st until 50% full flowering showed thermal time was a better predictor of flowering time than number of days.

Key words
Base temperature, flowering, magnolia, precocious, thermal time.

Introduction

The magnolias used in this study are primarily precocious - those that flower on bare wood, before the leaves appear in spring. Bud dissections on a range of precocious magnolias at Lincoln showed that flowers have been initiated by early to mid summer. The hypothesis was that heat unit accumulation alone would be responsible for flowering times of precocious magnolias. The eight species involved in this study are *Magnolia liliiflora*, *M. denudata*, *M. campbelli*i, *M. kobus*, *M. stellata*, *M. sprengeri*, *M. sargentiana* and *M. acuminata*. All but the last species are Asiatic in origin, *M. acuminata* is North American. All magnolias included are in one of the three sections, Yulania, Tulipastrum and Buergeria within the subgenus Yulania. Hybrids and cultivars from crosses between species listed above are also included.

Thermal Time

A common approach for expressing the relationship between temperature and plant development is to calculate the thermal time (Tt) (also known as heat units or growing degree-days (°Cd)) required between two growing stages (Arnold & Monteith 1974). In its simplest form Tt is calculated as the mean temperature minus the (T_b) or threshold temperature below which no development takes place. Angus; Cunningham, Moncur and Mackenzie (1981) used this approach to define T_b and Tt required for field emergence of a range of tropical and temperate crops. For temperate species T_b was below 4°C compared with 10 to 14°C for tropical crops. Sangoi and Silva (1986) found 3 methods for calculating heat units were more reliable than calendar dates for the developmental stages of 2 cultivars of sunflower. They found no differences between the methods for calculating heat units. Jackson (1999) suggests, for fruit crops, 10°C is a suitable base, since little growth occurs below that temperature. Degree-days may be calculated using the following formula, Degree days = (M –10) x N where M = mean monthly temperature and N = the number of days in the month. Alternatively heat units can be calculated on a daily basis, i.e. the days when the temperature is above 10°C (M-10) are added to give an annual total which is higher than that calculated on a monthly basis. Besselat, Drouet and Palagos (1995) monitored temperature and phenological development of different grape cultivars at 5 different sites and concluded that; (1) it is better to take account of maximun rather than mean temperatures, (2) some models are better adapted to a fixed date rather than budburst and (3) variablity in thermal requirements can usually be explained as a climatic adaptation, although climatic conditions at the time of flowering can perturb this effect. Pitacco, Guerriero, Cipriani and Giovannini (1992) describe both chilling units as the number of hours below 7°C and the number of growing degree hours to determine the phenological stages of flower and leaf bud development for the peach ‘Springcrest’ at 3 different locations. Salinger, Kenny and Morley-Bunker (1993) investigated the climatic influences on growing kiwifruit in New Zealand showed the timing of the end of dormancy was determined by the amount of winter chilling. When sufficient chilling occurred, the time from dormancy end to bud-burst was positively correlated with temperature over this period but when insufficient chilling occurred, bud-burst dates were determined by the amount of exposure to low temperature. The transition from bud-burst to flowering required 415°C days above a base temperature of 7°C to be completed. Salinger and Kenny (1995) identified three important determinants for the distribution of kiwifruit cv. Hayward as winter chilling, growing season thermal time and annual rainfall to enable mapping of the most suitable areas in New Zealand for growing kiwifruit. These were May-July temperatures of 11°C as the optimal winter chilling requirement, a thermal time accumulation of 1100 degree-days above 10°C from October to April and an annual rainfall of 1250mm. Song-ChiaWei and Ou-ShyKuan. (1997) used a T_b of 10°C to show the time from full bloom of eleven cultivars of low chill peaches to harvest depended on both the length of the flowering period and the fruit development period. The eleven cultivars concerned were grouped by thermal time requirements into early, moderate and late ripening. Erez, Yablowitz, Korcinski, Bodson and Verhoyen (1998) showed vegetative buds of peaches normally need more heat units to break than floral buds and they respond differently to higher temperatures. Under natural cool climate conditions flower buds develop more quickly than vegetative buds adjacent on the same node, while under warmer conditions, leaf production may advance to the stage that flowering will occur concomitantly with vigorous vegetative growth.

Methods and materials

During a five-year period between 1998 and 2002 estimates of the percentage of flowering were made for temperate magnolias in flower in a collection at Lincoln University. Observations were made for individual species, hybrids and cultivars. The *Magnolia* collection at Lincoln University has been developed since 1990 and plants included in this study are typically from the earlier plantings that now flower regularly. Visual estimates of the percentage flowering were recorded every 7 days. Estimated flowering percentage data and flowering dates were entered into a database. Climate data was obtained from Broadfields Meteorological Station nearby and these data were compared with flowering. June 1st each year was used as a start point for accumulation of thermal time. Observations made for each species, hybrid or cultivar was based on a sample of the one plant in the collection. Results were analysed by looking at each plant separately and by aggregating records for species, hybrids and cultivars with common parents as well as combining the results for all and comparing heat unit accumulation for each of the five years. Many of the references reviewed dealt with annual crops, few deal with woody perennials and those that do have concentrated on thermal time requirements from flowering to fruit harvest. The T_b of 10°C chosen is the period from spring and is therefore too high for the period being looked at with the magnolias in this study. Base temperatures between 0°C and 5°C were compared with flowering data 0°C was selected as appearing to be most appropriate. June 1st was chosen as a starting date each year, coinciding with the completion of leaf fall for the magnolias involved in this study at Lincoln. Because the magnolias involved in this study are precocious, leaves were not present until flowering is well underway for the period and therefore light levels were not considered.

Statistical analysis

Calculations of means for 1998 and 1999 as observed against flowering in 2000 as the predicted were made. Comparisons between groups of hybrids and cultivars of different numbers were standardised using coefficient of variation (CV). Root mean square deviations (RMSD) were used to compare days to flowering with accumulation of thermal time (TT).

RMSD formula: $\{\sum (\text{observed} - \text{predicted})^2/n\}^{1/2}$. Observed values come from the mean of years 1998 and 1999 minus 2000 as the predicted.

Results and discussion

Magnolias were analysed individually and collectively based on their reputed parentage (Table 1). The main parents involved in the 53 magnolias involved are *M. liliiflora*, *M. stellata*, *M. campbellii* and *M. denudata*. *M. liliiflora* tends to have two flowering periods, the main one in early to mid spring, followed by a lesser flowering in mid or late summer. This characteristic is clearly evident in a number of cultivars with this parent. *M. campbellii* tends to be amongst the earliest flowering and cultivars with this as a parent are variable, but usually early. 'Star Wars' however will flower over a large range of times, presumably based on *M. liliiflora* being the other parent, whilst 'Early Rose' has shown it can flower in early August, although at Lincoln is usually early to mid September (Table 1). The RMSD calculations showed that TT as a predictor of flowering for the sum of all the magnolias was less than half of that for number of days. (Table 3). All groups except 17 had larger RMSD's for number of days compared with those for thermal time. The largest RMSD's for number of days were also generally with the earlier flowering magnolia groups. This difference was not apparent with the RMSD's for TT. It is likely that the earlier flowering magnolias exhibiting the larger RMSD's is due to the variable nature of winter temperatures compared with the later flowering magnolia RMSD's where fluctuations in accumulated temperature have evened out by this stage. All groups except 5, 8 and 14 had larger CV's for number of days compared with those for thermal time. The largest CV's for number of days were generally with the earlier flowering magnolia groups. This difference was not seen with the CV's for TT.

Table 1. Magnolias grouped by similarity of reputed parents

Species, hybrids and cultivars	**Groups**	**a *liliiflora* a1 'Nigra' a2 'O'Neill' a3 'Reflorescens'**	**b *stellata* b1 'Rosea' b2 'Waterlily' seedling b3 'Waterlily'**	**c *kobus* d *denudata* e *acuminata* 'Klassen'**	**f *campbellii* f1 ssp. *mollicomata* 'Lanarth' f2 ssp. *mollicomata* f3 var. *alba***	**g *sprengeri* g1 *sprengeri* 'Diva' h *sargentiana* var. *robusta***
'Ann'	1	a1	b			
'Betty', 'Susan'	1	a1	b1			
'Pinkie'	1	a3	b1			
'Leonard Messel'	2		b1	c		
'Merrill'	2		b	c		
M. stellata	3		b			
'King Rose', 'Waterlily'	3		b			
'Royal Star'	3		b2			
'Pristine'	4		b3	d		
M. denudata	5			d		
'Forrests Pink'	5			d		
M. kobus	6			c		
M. liliiflora, M. liliiflora *'Nigra'*	7	a				
M.x brooklynensis 'Woodsman'	8	a2		e		
'Early Rose', 'Star Wars'	9	a			f	
'Apollo', 'Vulcan'	9	a1			f1	
M. campbellii	10				f	
M. campbellii 'Charles Raffill'	10				ff2	
M. campbellii 'Strybing White'	10				ff3	
'Heaven Scent', 'Peppermint Stick'	11	a		d	f	
'Royal Crown', 'Sayonara'	11	a		d	f	
'Galaxy'	12	a1				g1
M. sargentiana var. *robusta*	13					h
M. sprengeri 'Burncoose Purple'	14					g
'Athene', 'Iolanthe'	15	a		d	f1	h
'Lotus', 'Milky Way'	15	a		d	f1	h
'Manchu Fan', 'Tina Durio', 'Todd Gresham'	16	a		d	f	
M.x soulangeana	17	a		d		
'Alba', 'Alexandrina', 'Amabilis', 'Burgundy'	17	a		d		
'Lennei', 'Lennei Alba', 'Norbetii', 'Picture'	17	a		d		
'Ruby', 'Rustica Rubra', 'San Jose'	17	a		d		
'Sweet Simplicity', 'Unknown', 'Verbanica'	17	a		d		

Table 2. Magnolias first observed at 50% or more of full flowering from June 1st for each of 5 consecutive years at Lincoln University

Species, hybids & cultivars		Observation Date				
	Group	1998	1999	2000	2001	2002
'Betty'	1	17/09	13/09	10/09	19/9	13/9
'Ann'	1	26/09	24/09	21/09	20/9	17/9
'Susan'	1	19/09	22/09	09/09	20/9	12/9
'Pinkie'	1	03/09	17/09	19/09	16/9	11/9
'Leonard Messel'	2	28/08	09/09	06/09	6/9	3/9
'Merrill'	2	21/09	13/09	14/08	3/9	29/8
M. stellata	3	21/09	24/09	04/09	10/9	4/9
'King Rose'	3	07/09	13/09	31/08	12/9	9/9
'Royal Star'	3	04/09	09/09	30/08	6/9	4/9
'Waterlily'	3	10/09	10/09	21/08	5/9	5/9
'Pristine'	4	14/09	13/09	31/08	13/9	5/9
M. denudata	5	11/09	10/09	19/08	5/9	31/8
'Forrests Pink'	5	03/09	03/09	21/08	4/9	29/8
M. kobus	6	12/09	27/09	14/09	7/9	5/9
M. liliiflora	7	21/09	23/09	21/09	26/9	18/9
M. liliiflora 'Nigra'	7	24/09	27/09	18/09	26/9	18/9
M. x *brooklynensis*''Woodsman'	8	08/10	02/10	06/10	30/9	26/9
'Early Rose'	9	09/09	28/08	11/08	31/8	29/8
'Star Wars'	9	07/09	04/09	31/08	12/9	5/9
'Apollo'	9	17/09	11/09	30/08	8/9	4/9
'Vulcan'	9	07/09	28/08	24/08	3/9	29/8
M. campbellii	10	14/09	28/08	28/07	27/8	31/8
M. campbellii''Charles Raffill'	10	27/08	03/09	17/08	27/8	29/8
M. campbellii 'Strybing White'	10	18/09	17/09	08/09	12/9	7/9
'Heaven Scent'	11	13/09	13/09	31/08	14/9	8/9
'Peppermint Stick'	11	17/09	17/09	07/09	14/9	7/9
'Royal Crown'	11	12/08	26/08	07/08	1/9	30/8
'Sayonara'	11	24/09	24/09	16/09	15/9	13/9
'Galaxy'	12	10/09	06/09	27/08	14/9	5/9
M. sargentiana *var.* robusta	13	14/09	10/09	07/09	6/9	2/9
M. sprengeri 'Burncoose Purple'	14	04/09	13/09	18/08	30/8	29/8
'Iolanthe'	15	13/09	10/09	11/09	31/8	30/8
'Athene'	15	17/09	11/09	07/09	13/9	5/9
'Lotus'	15	21/09	13/09	07/09	12/9	5/9
'Milky Way'	15	04/09	09/09	03/09	7/9	5/9
'Manchu Fan'	16	17/09	10/09	01/09	12/9	5/9

‘Tina Durio’	16	05/09	11/09	06/09	15/9	4/9
‘Todd Gresham’	16	21/08	27/08	16/08	5/9	2/9
*M.*x *soulangeana*	17	18/09	13/09	07/09	14/9	9/9
‘Alba’	17	11/09	13/09	07/09	11/9	6/9
‘Alexandrina’	17	07/09	10/09	07/09	12/9	6/9
‘Amabilis’	17	17/09	17/09	01/09	8/9	4/9
‘Burgundy’	17	14/09	13/09	31/08	14/9	5/9
‘Lennei’	17	21/09	24/09	21/09	7/9	5/9
‘Lennei Alba’	17	18/09	18/09	14/09	21/9	17/9
‘Norbertii’	17	11/09	13/09	01/09	14/9	10/9
‘Picture’	17	03/09	10/09	24/08	11/9	4/9
‘Ruby’	17	14/09	18/09	07/09	8/9	3/9
‘Rustica Rubra’	17	11/09	17/09	07/09	13/9	5/9
‘San Jose’	17	07/09	03/09	25/08	14/9	7/9
‘Sweet Simplicity’	17	28/09	07/10	21/09	6/9	2/9
‘Unknown’	17	07/09	30/08	24/08	24/9	21/9
‘Verbanica’	17	18/09	17/09	07/09	1/9	30/8

Table 3. Mean durations to 50% full flowering for a five year period for temperate (mainly precocious) *Magnolia* species, hybrids and cultivars grouped by parentage and recorded from June 1st each year. Durations are expressed in calendar time (days) and thermal time (TT), with respective coefficients of variation (CV) and root mean square deviation (RMSD).

Groups	Days from June 1st.	CV Days	RMSD Days % Predicted	TT	CV TT	RMSD TT % Predicted
1	112	7.3	10.15	819.6	8.95	11.41
2	100.2	15.4	26.42	713.5	12.98	18.09
3	102.9	11.2	21.87	731.6	7.75	7.06
4	104.3	11.5	20.11	738.6	2.2	2.94
5	96.2	13.6	28.69	674.2	5.65	9.1
6	*113*	*5.8*	9.91	807.4	8.0	1.39
7	117.7	5.2	8.79	869.4	4.2	7.69
8	130.7	6.4	3.13	1021.5	8.6	10.97
9	97.1	13.8	22.71	678	9.83	7.59
10	95.9	20.1	36.94	675.3	16.9	18.3
11	102.3	16.6	17.29	730	16.7	2.18
12	99.3	12.1	19.32	698.1	3.4	2.29
13	*105.7*	*8.6*	10.10	752.4	5.5	7.4
14	96.7	15.8	33.54	679.4	7.9	12.17
15	105.8	8.2	10.97	757.3	6.9	8.11
16	97.7	12.4	14.80	686.5	12.14	7.28
17	106.6	10.3	14.92	764.2	9.97	5.67
All			17.98			8.97

Conclusion

TT is a better predictor of flowering than number of days. Early flowering magnolias are likely to show greater variation in number of days to flowering depending on the vagaries of the winter weather, more so than the later in spring flowering magnolias, when accumulated thermal time equates more closely to number of days. This was observed with many of the magnolias with *M. campbellii* as a parent during the warmer winter of 2000. In a practical sense the information about flowering times could be used to plan flowering displays for an event with more certainty later in the season rather than with early flowering magnolias….

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