Observations on the Relationship Between Degree-day Summations and Timing of Easter Lilies

E.N. O'Rourke, Jr. and Patricia C. Branch

Department of Horticulture, Louisiana Agriculture Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803

The timing of the crop is probably the most important thing that Easter lily (*Lilium longiforum* thunb) forcers must accomplish, and the variable date of Easter complicates scheduling (6, 12). The influence of bulb maturity and treatments prior to being placed in the greenhouse, often not under the grower's control, makes forcing a challenge (2, 11, 17). Several methods are used to monitor progress of the crop, but adjusting temperatures is the actual means of controlling the rate of growth and development. Measurements of time and temperature, expressed as heat units or degree-days, are used to monitor the growth and development of many crops (1, 13, 21) and to predict with a high level of precision certain stages of their development. Degree-days or heat units offer little advantage over time alone as indicators of crop progress under conditions where temperature can be controlled to eliminate or minimize variations. Variations in greenhouse temperatures, greater during daytime hours than at night, especially in southern U.S. locations, are largely responsible for timing problems with Easter lilies. Heat unit summations may be reliable indicators where such variations occur. There are apparently no reports of attempts to use heat units or degree-days to monitor Easter lily shoot development.

Performance of Easter lilies under various forcing temperature regimes has been reported, and the study by Smith and Langhans (16) is cited frequently. Five different night and day temperatures were used in that study, with plants moved at 1630 and 0800 HR to the appropriate temperature. Days required for precooled 'Croft' lilies to flower from the date of potting at the various temperature regimes are presented in Table 1. Mean days shown in the 25 forcing periods was 106, with a CV of about 20%.

We converted data in Table 1 to degree-day summations corresponding to various forcing periods and a base temperature of 0°C (Table 2). The proper base temperature is dependent on the sensitivity of the response being studied (1). There is little information concerning the proper base temperature for use with Easter lily cultivars. Estes (4) found evidence supporting 3.7° as the proper base temperature for 'Ace' and 'Harson' and 0° for 'Nellie White'.

Received for publication 5 Dec. 1986. Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript no. 86-28-0273. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Using Smith and Langhans' (16) data, degree-day summations were calculated for night and day portions as well as the total forcing periods, and correlations of degree-day summations with lengths of the periods were examined (Table 3). Correlations between lengths of forcing periods in days and day degree-day summations or total degree-day summations were not significant ($r = 0.346$ for day summations and -0.399 for total summations). There was, however, a strong negative correlation between night degree-day summations and forcing time in days ($r = -0.758$). Smith and Langhans (16) had considered that night temperatures appeared to be more closely related to the lengths of the forcing periods than day temperatures, but attributed much of this to the longer nights employed.

Table 1. The number of days to flower from potting of 'Croft' Easter lilies exposed to various night and day temperatures[z].

Night temp (°C)	Days to flower: Day temp (°C) 10	15.6	18.3	21.1	26.7
10	155[y]	141	138	135	131
15.6	125	110	109	102	107
18.3	116	106	106	106	105
21.1	102	95	93	86	87
26.7	84	82	80	81	76
Mean (all temperatures)					106
CV (%)					20

[z]Adapted from Smith and Langhans (16).
[y]HSD at 5% level = 2.3 days; at 1% level = 2.6 days.

Table 2. Degree-days above a base temperature of 0°C required from potting to flowering for 'Croft' Easter lilies[z].

Night temp (°C)	Degree-days: Day temp (°C) 10	15.6	18.3	21.1	26.7
10	2786	3033	3214	3385	3784
15.6	3053	3076	3203	3214	3751
18.3	3207	3307	3494	3682	4019
21.1	3149	3270	3057	3267	3561
26.7	3432	3352	3412	3597	3644
Mean (all temperatures)					3493
CV (%)					9

[z]Adapted from Smith and Langhans (16).

Table 3. Correlation coefficients for total degree-days (TDD), day degree-days[z] (DDD), and night degree-days (NDD) and the length of the forcing period[x] (FP) for flowering 'Croft' Easter lily shoots[w].

Parameter	Correlation coefficients: FP	TDD	DDD	NDD
FP	---	−0.399	0.346	−0.758
TDD	−0.399	---	---	---
DDD	0.346	---	---	---
NDD	−0.758	---	---	---

[z]Days were 8.5 hr long.
[y]Nights were 15.5 hr long.
[x]Days.
[w]Adapted from Smith and Langhans (16).

Converting the days in Table 1 to degree-days in Table 2 reduced the degree of variation in the table. Summations increased with increasing temperature, however, indicating that the base temperature (0°C) was too high, or that factors other than temperature influenced the development of flowering shoots, or that the development was not linear according to Arnold (1). Base temperatures for use in degree-day summations may be evaluated in several ways (1, 4, 13). Examining the results of applying degree-day summations to the data of Smith and Langhans (16) led to studies of the relationship of degree-day summations to the development of Easter lily shoots in 1982, 1983, and 1984 using the cultivars Ace, Nellie White, and Harson, the latter being a selection of 'Georgia' (4). One objective of the studies was the determination of base temperatures indicated for degree-day summations with the cultivars grown.

A review of the literature provided information about forcing times under a range of conditions for the cultivar Ace (3, 5, 7–10, 14–16, 18). Some of the sources are forcing recommendations prepared by floriculturists in several states (3, 5, 9, 15, 18), while some are studies involving controlled forcing conditions (7, 8, 10, 14, 16). There are some differences in programing treatments and in forcing temperatures reported or recommended. In some reports there were no actual records of the time between the visible bud and open flower stages, but it was possible to estimate the interval using details of treatment reported. Using the forcing times reported or implied and the temperatures provided, it was possible to estimate degree-day summations associated with the development of the various crops. Where day and night temperatures differ during forcing, the separate influences of night and day temperature exposures were examined. In only a few of the reports, however, were the actual durations of the night and day temperatures reported.

The night and day lengths used in calculations in Tables 4 and 5 were 15.5 and 8.5 hr, respectively—those used by Smith and Langhans (16). In their discussion, they noted that this forcing regime is common to the greenhouse industry.

Table 4 presents information about 14 crops of 'Ace' Easter lilies grown from 1957 to 1986 with pre-forcing handling, forcing regimes, and time required between the visible bud stage and the first open flower. Values for night and day degree-day summations and total degree-day summations for this developmental period also are shown, using a base temperature of 3.7°C. Table 5 presents similar information about the period between the start of forcing and the first open flower for 11 crops of 'Ace' Easter lilies. Some were the same crops as those reported in Table 4.

Even with all the constraints noted in the comments about the crops examined, there were good trends toward consistency in degree-day requirements for the two crop periods over the various crops and seasons. The mean forcing time in the period from visible bud to first open flower for the 14 crops shown in Table 4 was 37 days. This period is in agreement with the report of Roh and Wilkins (14). The mean degree-day summation above a base temperature of 3.7°C corresponding to this period was 515. Of this total, 292 degree-days were accumulated during night exposures and 223 were accumulated during day exposures. Coefficients of variation were calculated for the array of period lengths in days and the degree-day summations for nights, days, and the total development period. These were 13% for days, 14% for night summations, 15% for day summations, and 6% for total degree-day summations (Table 4).

The mean forcing time from the start of forcing to first open flower is shown in Table 5, with the degree-day summations corresponding to the crop time and the night and day exposures during that crop period. The mean length of the period in days for the 11 crops was 106. The degree-day summation above a base temperature of 3.7°C associated with that period was 1487, with 799 degree-days accumulated during night exposures and 688 degree-days accumulated during day exposures in the forcing period. The CV for the array of period lengths in days was 8%, that for night degree-day summations was 7%, for day degree-day summations it was 6%, and for degree-day summations it was 9% (Table 5).

Table 5. Days and degree-days above a base temperature of 3.7°C associated with development of 'Ace' Easter lily shoots from start of forcing to first open flower.

Pre-forcing handling (°C)	Forcing temp, N/D[z] (°C)	Forcing period (days)	Night degree-days[y]	Day degree-days[y]	Total degree-days	Year	Ref.
10 wk, 11.1–25.6	15.5/15.5	109	831	456	1287	1957	8
6 wk, 1.7	15.5/21.1	108	823	666	1489	1960	10
6 wk, 0.6	15.5/21.1	104	793	641	1434	1961	10
6 wk, 1.7–4.4	15.5/21.1	101	770	622	1392	1982	15
6 wk, 4.4	14.4/27.2	117	808	974	1782	1983	4
6 wk, 4.4	14.1/27.2	101	698	841	1539	1984	4
6 wk, 1.7–4.4	15.5/21.1	112	770	691	1461	1984	5
6 wk, 1.7–4.4	15.5/21.1	118	899	727	1626	1984	9
6 wk, 4.4	15.5/21.1	112	770	691	1461	1985	18
6 wk, 4.4	16.7/23.4	91	764	635	1399	1986[x]	
6 wk, 4.4	18.3/22.8	92	862	622	1484	1986	7
Mean		106	799	688	1487		
Mean degree-days/ day			7.5	6.5	14.0		
CV (%)		8	6.8	19.2	8.8		

[z]N/D = night/day.
[y]Based on 15.5 hr nights, 8.5 hr days.
[x]E.N.O. and P.C.B., unpublished data.

Daily temperature regimes may be evaluated as degree-days or heat units per day accumulated above a given base temperature. Constant monitoring and adjustment of temperatures are possible where degree-day per day requirements are known. The mean degree-day per day requirement above a base temperature of 3.7°C was 13.9 for the period from visible bud to first open flower, and 14.0 for the entire period from the start of forcing to the first open flower for the crops studied over both periods. The mean forcing temperature required to provide this environment is 17.6° for the period from visible bud to first open flower and 17.7° for the period from start of forcing to first open flower. These regimes are consistent with most forcing recommendations.

The shortest crop time shown, 91 days (Table 5), was associated with a degree-day per day requirement of 15.4, whereas the longest crop time, 118 days, was associated with a degree-day per day requirement of 13.8 above a base temperature of 3.7°C.

Leaf number in a cultivar varies from year to year with bulb size and with programing treatments. Wilkins (20) reported leaf numbers for 'Ace' over the period 1970–1977 ranging from 66.5 to 96.3, with a mean of 86.6. Estes (4) determined leaf numbers for 'Ace' in 1983 and 1984 of 81.7 and 63.1, respectively. Heins (7) reported a mean leaf number of 97 for six crops of 'Ace' studied in the period 1981–1986. He attributed the long time needed between emergence and visible bud observed in 'Ace' compared with 'Harbor' and 'Chetco' to its large leaf complement, since the leaf unfolding rates varied little between these cultivars. There does not appear to be a close relationship between leaf number and degree-day per day requirements. Estes' (4) 1983 crop of 'Ace' with higher leaf numbers required 15.3 degree-days per day, the same as the 1984 crop. We estimated degree-days per day requirements for the crops of 'Ace', 'Harbor', and 'Chetco' reported on by Heins (7) and found them close, with values of 17.8, 17.9, and 17.9, respectively, corresponding to average crop times and leaf number of 93 days and 97 leaves for 'Ace', 97 days and 69 leaves for 'Chetco', and 97 days (no leaf numbers reported) for 'Harbor'.

Wang and Roberts (19) concluded from their studies of the influence of air and soil temperatures on the growth and development of Easter lilies that the rate of leaf unfolding, stem elongation, and flower bud development in the primary axis have the same air and soil temperature optima during the prebloom period, and that these factors can be used interchangeably in monitoring crop growth rate and predicting subsequent growth

Table 4. Days and degree-days above a base temperature of 3.7°C associated with development of 'Ace' Easter lily shoots from visible bud stage to first open flower.

Pre-forcing handling (°C)	Forcing temp, N/D[z] (°C)	Forcing period (days)	Night degree-days[y]	Day degree-days[y]	Total degree-days	Year	Ref.
10 wk, 11.1–25.6	15.5/15.5	45	343	188	531	1957	8
6 wk, 1.7	15.5/21.1	41	212	253	565	1960	10
6 wk, 0.6	15.5/21.1	34	259	210	469	1961	10
5 wk, 1.7–4.4	15.5/15.5	45	343	188	531	1971	14
6 wk, 1.7–4.4	21.1/21.1	30	337	185	522	1978	20
6 wk, 1.7–4.4	15.5/21.1	42	320	259	579	1982	15
6 wk, 4.4	14.4/27.2	33	228	275	503	1983	4
6 wk, 4.4	14.4/27.2	33	228	275	503	1984	4
6 wk, 1.7–4.4	15.5/21.1	35	267	216	483	1984	5
6 wk, 1.7–4.4	15.5/21.1	35	267	216	483	1984	9
6 wk, 1.7–4.4	15.5/21.1	35	267	216	483	1985	18
6 wk, 4.4	17.2/17.2	37	323	177	500	1985	3
6 wk, 4.4	16.7/23.4	34	286	236	522	1986[x]	
6 wk, 4.4	18.3/22.8	33	311	223	534	1986	7
Mean		37	292	223	515		
Mean degree-days/ day			7.9	6.0	13.9		
CV (%)		13	14	15	6		

[z]N/D = night/day.
[y]Based on 15.5 hr nights, 8.5 hr days.
[x]E.N.O. and P.C.B., unpublished data.

phases.

The high level of consistency in the degree-day values calculated or recorded for these various Easter lily crops over the wide range of time and conditions reported suggests that degree-day summations offer a means of monitoring the progress of Easter lily crops and of calculating temperature regimes needed to finish crops on time. Daily mean temperature records are sufficient to allow such calculations, or electronic degree-day accumulators may be used to indicate the current status of a crop.

Literature Cited

1. Arnold, C.Y. 1959. The determination and significance of the base temperature in a linear heat unit system. Proc. Amer. Soc. Hort. Sci. 74:430–445.
2. Blaney, L.T. and A.N. Roberts. 1966. Influence of harvest date and precooling on leaf and stem elongation in the 'Croft' Easter lily (*Lilium longiflorum* Thunb.). Proc. Amer. Soc. Hort. Sci. 89:651–656.
3. De Hertogh, A. 1985. Holland bulb forcer's guide. 3rd ed. Intl. Flower-Bulb Centre, Hillegom, Netherlands.
4. Estes, L. 1986. Qualitative and quantitative effects of temperature on the growth and development of three cultivars of *Lilium longiflorum*, Thunb. PhD Diss., Louisiana State Univ., Baton Rouge.
5. Hammer, P.A. 1984. Timing potted Easter lilies, 1984. Focus on floriculture, Purdue Univ. 12(3):1.
6. Healy, W.E. and H.F. Wilkins. 1984. Temperature effects on 'Nellie White' flower bud development. HortScience 19:843–844.
7. Heins, R.D. 1986. Forcing performance of old and new lily cultivars. Grower Talks 50(5):90–96.
8. Kohl, H.C., Jr. 1958. Effects of temperature variation on forced *Lilium longiflorum*, Thunb. var. Ace. Proc. Amer. Soc. Hort. Sci. 72:477–480.
9. Koths, J.S., J.J. Maisano, C. Salsedo, and A. Botacchi. 1983. 1984 Easter lily schedule. Connecticut Greenhouse Nwsl. 117. (Suppl.)
10. Langhans, R.W. and D.R. Smith. 1965. Storage temperature and time for Easter lilies. Florists' Rev. 137(3550):19–20, 41–46.
11. Lin, W.C. and H.F. Wilkins. 1975. Influence of bulb harvest date and temperature on growth and flowering of *Lilium longiflorum*. J. Amer. Soc. Hort. Sci. 100:6–9.
12. Mastalerz, J.W. 1977. The greenhouse environment; the effect of environmental factors on the growth and development of flower crops. Wiley, New York.
13. Perry, K.B., T.C. Wehner, and G.L. Johnson. 1986. Comparison of 14 methods to determine heat unit requirements for cucumber harvest. HortScience 21:419–423.
14. Roh, S.M. and H.F. Wilkins. 1973. Influence of temperature on the development of flower buds from the visible stage to anthesis of *Lilium longiflorum*, Thunb. cv. Ace. HortScience 8:129–130.
15. Seeley, J.G. 1982. Growing with Seeley. Grower Talks 46(7):12–14.
16. Smith, D.R. and R.W. Langhans. 1962. The influence of day and night temperatures on the growth and flowering of the Easter lily, *Lilium longiflorum*, Thunb. var. 'Croft'. Proc. Amer. Soc. Hort. Sci. 80:593–598.
17. Stuart, N.W. 1954. Moisture content of packing medium, temperature and duration of storage as factors in forcing lily bulbs. Proc. Amer. Soc. Hort. Sci. 63:488–494.
18. Tayama, H.K., R.K. Lindquist, and C.C. Powell. 1985. Essentials of potted lily culture Easter. Ohio Florists' Assn. Bul. 672:5–7.
19. Wang, Y.T. and A.N. Roberts. 1983. Influence of air and soil temperatures on the growth and development of *Lilium longiflorum*, Thunb. during different growth phases. J. Amer. Soc. Hort. Sci. 108:810–815.
20. Wilkins, H.F. 1977. Late Easter lily leaf counting technique and time schedule. Minnesota State Florists Bul. Dec. p. 1–2.
21. Wilson, L.T. and W.W. Barnett. 1983. Degree-days; an aid in crop and pest management. California Agr. 37(1–2):4–7.