Chilling Effects on Shoot Emergence and Subsequent Growth in Hosta[1]

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Abstract

Two hosta cultivars, 'Francee' and 'Frances Williams', were chilled for 0 to 16 weeks at 4C (39F) prior to forcing in a heated greenhouse. As chilling duration increased, times to shoot emergence and first unfurled leaf and days gained in shoot emergence time per day of chilling decreased at a decreasing rate, leaf area index (length × width) of the first unfurled leaf increased at a decreasing rate and shoot dry weight increased linearly. Shoots of non-chilled plants of 'Francee' emerged an average of 32 days before those of 'Frances Williams'. In 'Francee' chilled for 0 and 2 weeks, 30% and 10% of plants, respectively, failed to emerge shoots and 60% and 10% failed to unfurl a leaf. In 'Frances Williams' chilled for 0, 2 and 4 weeks, 60%, 30% and 50% of plants, respectively, failed to emerge shoots and 80%, 30% and 50% failed to unfurl a leaf. All plants of both cultivars chilled for longer durations emerged shoots and unfurled at least one leaf.

Index words: low temperature exposure, chilling, dormancy.

Species used in this study: 'Francee' hosta (*Hosta* 'Fortunei Francee') and 'Frances Williams' hosta (*H. sieboldiana* (Lodd.) Engl. 'Frances Williams').

Significance to the Nursery Industry

Chilling of hosta is beneficial in promoting quicker shoot emergence and more vigorous growth. Lack of sufficient chilling may explain the poor performance of hostas overwintered the last two years in USDA Hardiness Zone 8b. Minimal requirements for shoot emergence and subsequent growth appear cultivar dependent, with 'Frances Williams' requiring 6 weeks for 100% emergence and 90% and 100% of 'Francee' emerging with 2 and 4 weeks of chilling, respectively. Knowledge of chilling effects in hosta provides growers guidelines for rapid forcing. Also, there may be opportunities for holding hostas in a dormant state for subsequent forcing later in the season when the quality of many hostas has declined.

Introduction

Hosta, a member of the lily family, is the most popular herbaceous perennial in the U.S. for use in shaded landscapes, and was the best-selling perennial in 1993 (4). Indigenous to temperate regions of Japan, China and Korea, the genus *Hosta* is comprised of over 100 species (6), 1,420 registered cultivars and 600 valid but non-registered cultivars (personal communication, David H. Stevenson, International Registrar for the Genus *Hosta*, Chanhassen, MN). No other herbaceous perennial offers the tremendous diversity in plant size and habit, leaf shape and surface effects, variegation patterns and scape characteristics as hostas (6). Aesthetic qualities coupled with minimal cultural and maintenance requirements account for the widespread use of hostas in the landscape.

Dormancy in perennial plants of the temperate zone is an evolved mechanism which aids winter survival, and is probably the single most important factor preventing adaptation of most temperate zone plants to tropical areas (5). Dormancy has been widely studied in woody plants, especially fruit trees, and has led to regional cultivar selections based on low temperature exposure or chilling necessary to release vegetative and floral buds from dormancy (8). Much less is known about dormancy requirements in herbaceous perennials.

Schmid (6) stated in general terms that the southern extreme of optimal growing conditions for hosta was a line between the south-central parts of the southeastern states of Georgia and Alabama. Other authors cite USDA Hardiness Zone 8 as the southern extreme for growing hosta (1, 7). Following the winter of 1997, a commercial nursery in USDA Zone 8b experienced delayed emergence and weak growth in a stock block of 'Royal Standard' hosta, while plants obtained from northern sources rapidly emerged and grew vigorously. Similarly, following the winter of 1998, we observed delayed emergence and weak growth in 'Frances Williams' and 'Francee' hostas at the Ornamental Horticulture Substation in Mobile, AL, also in USDA Zone 8b. These symptoms were similar to those associated with insufficient winter chilling to completely break dormancy in deciduous fruit and nut trees (3). Both winters were relatively mild, with chilling hours at the three closest weather stations, Semmes, Grand Bay, and Fairhope, AL, averaging 740 and 870 in 1996/1997 and 1997/1998, respectively (Agricultural Weather Information Services, Auburn, AL). Chilling hours included time ≤ 7C (45F) and was measured at a 1.5 m (5 ft) height.

To our knowledge, there are no published scientific studies which have determined the chilling requirements necessary to satisfy dormancy in hosta, although Schmid (6) stated that winter chilling to around 0C (32F) or below for several weeks is required for all taxa in the genus. Knowledge of chilling requirements in hosta would be beneficial in forcing plants into leaf for spring sales, as well as identifying southern extremes for hosta production from stock plants and for landscape use. The objective of this study was to determine chilling effects on shoot emergence and subsequent growth of two hosta cultivars.

Materials and Methods

Stock plants of two hosta cultivars were divided on September 15 ('Frances Williams') and October 9 ('Francee'), 1997, into uniform, single-eye divisions and potted into 3.8

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liter (#1) containers of a pine bark:sand substrate (7:1 by vol). The growth medium was amended per m[3] (yd[3]) with 3.0 kg (5 lb) dolomitic limestone, 0.9 kg (1.5 lb) Micromax (Scott's Chemical Co. Marysville, OH), and 5.3 kg (9 lb) of 22N_1.7P–11.6K (PolyOn 22–4–14, Pursell Industries, Sylacauga, AL). Plants were placed outdoors under 47% shadecloth in Auburn, AL, and irrigated daily by overhead sprinklers.

On October 25, 1997, prior to exposure to temperatures below 7C (45F), plants were transferred to a double-polyethylene greenhouse with a heat setpoint of 18C (65F) and a ventilation setpoint of 26C (78F). At this time, leaves were in a state of decline, especially those of the cultivar 'Frances Williams'. Poor appearance in fall, prior to exposure to low temperatures, is typical for many cultivars of hostas grown in USDA Hardiness Zone 8. On November 26, plants were arbitrarily assigned to 9 treatments. Those in 8 treatments were randomly placed in a dark cooler at a constant 4C (39F). Ten plants of each cultivar remained in the greenhouse. At two-week intervals, 10 plants of each cultivar were transferred to the greenhouse. Treatments consisted of chilling two cultivars for 0, 2, 4, 6, 8, 10, 12, 14 or 16 weeks. Plants in this 2 × 9 factorial experiment were completely randomized among treatments and cultivars, and were replicated 10 times.

Dates of first shoot emergence (terminal bud elongated 1 cm (0.4 in)) and first unfurled leaf were recorded; length and width of the first leaf were measured at first unfurling. For statistical analysis, leaf length was multiplied by width to calculate a leaf area index (LAI) which was used as an indicator of plant vigor. Emergence in non-chilled plants, which did not defoliate in the greenhouse, was based on visible shoot elongation. Collection of shoot emergence and leaf unfurling data was terminated on April 3, 1998, 169 days after the initiation of treatments and 57 days after the last group of plants was removed from the cooler. Emergence after this period was considered beyond the economic threshold. Days gained in emergence time per day of chilling was calculated using the equation $(\hat{y}_o - \hat{y}_n) / (7 * n \text{ weeks})$, where $\hat{y}_o$ = predicted days to emergence for non-chilled plants; $\hat{y}_n$ = predicted days to emergence during forcing for chilled plants; and n = the number of weeks plants were chilled. Days gained in emergence time also was calculated using the same equation where $\hat{y}_n$ = predicted days to emergence from the beginning of treatment initiation (chilling + forcing times) for chilled plants. This is a deterministic model (no error) and represents a re-expression of predicted days to shoot emergence in terms of gain; hence, no coefficient of multiple determination (R^2) was reported.

On June 25, 1998, leaves and offsets were counted and foliage cut at the substrate surface for dry weight determination. Data were subjected to an analysis of variance and regression analysis. Polynomials were used to describe significant trends using regression analysis.

Results and Discussion

A significant cultivar × chilling interaction occurred for days to emergence. Non-chilled plants of 'Francee' emerged an average of 32 days earlier than those of non-chilled 'Frances Williams' (Fig. 1a). With both cultivars, there was a rapid decrease in days to emergence, after up to about 8 weeks of chilling, followed by a more gradual decrease. However, with increased chilling, differences in emergence times lessened for the two cultivars and predicted curves eventually converged. 'Frances Williams' chilled for 8 and 16 weeks emerged 79% and 93%, respectively, quicker than non-chilled plants. 'Francee' plants chilled for 8 and 16 weeks emerged 84% and 89%, respectively, quicker than plants not chilled. When days to emergence included both chilling and forcing times cubic responses were observed for the two cultivars (Fig. 1b). Days to emergence decreased with up to 6–7 weeks of chilling before increasing. The increase in days to emergence represents the influence of longer chilling periods and a diminishing decrease in forcing time by additional chilling. Predicted minimum days to emergence were achieved with chilling periods of 6.2 weeks for 'Francee' and 7.0 weeks for 'Frances Williams'. Including chilling time in the model allows growers to more fully weigh the benefits of shorter forcing times considering the longer chilling periods required.

Based on days-to-emergence curves, there was not a clear breakpoint below which emergence did not occur and above which all plants emerged, although slopes indicated a clear benefit of at least 6–8 weeks of chilling. When results were expressed as days gained in emergence time per day of chill-

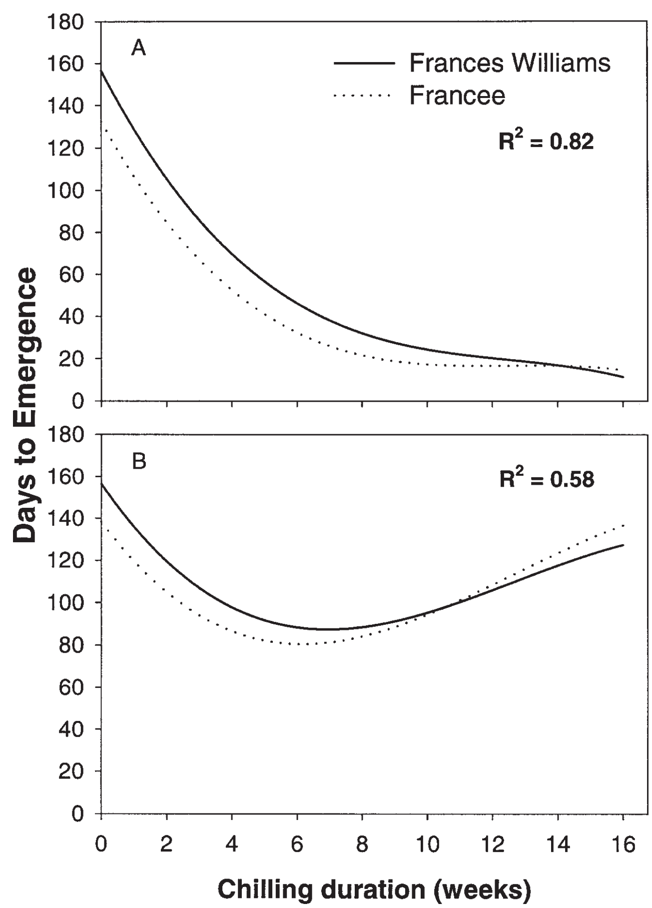

Fig. 1. Predicted days to shoot emergence of 'Frances Williams' (FW) and 'Francee' (FR) hostas following 0 to 16 weeks of chilling; a) days to shoot emergence includes forcing time only. Cultivar significant at $P \leq 0.0001$ and cultivar × chilling interaction significant at $P \leq 0.01$. FW: $y = 156.40 - 29.70x + 2.25x^2 - 0.06x^3$; FR: $y = 132.40 - 28.00x + 2.25x^2 - 0.06x^3$; b) days to shoot emergence includes chilling and forcing times. Cultivar significant at $P \leq 0.0001$ and cultivar × chilling interaction significant at $P \leq 0.01$. FW: $y = 156.40 - 22.70x + 2.25x^2 - 0.06x^3$; FR: $y = 138.38 - 21.00x + 2.25x^2 - 0.06x^3$.

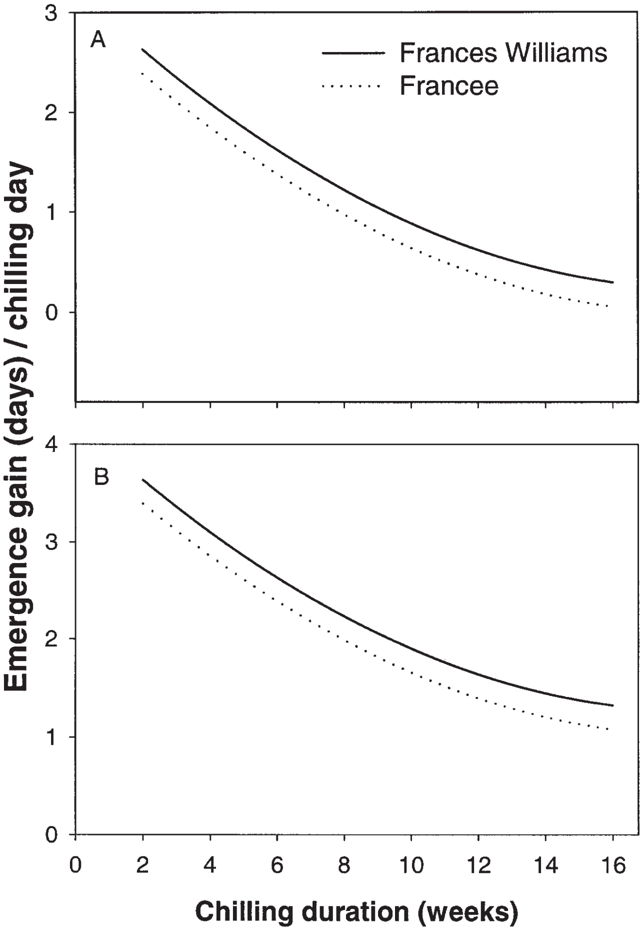

Fig. 2. **Predicted days gained in emergence time per day of chilling for 'Frances Williams' (FW) and 'Francee' (FR); a) emergence time includes forcing time only. Cultivar significant at $P \leq 0.01$ but cultivar × chilling interaction nonsignificant. FW: $y = 4.243 - 0.320x + 0.0086x^2$; FR: $y = 4.000 - 0.320x + 0.0086x^2$; b) emergence time includes chilling and forcing times. Cultivar significant at $P \leq 0.01$ but cultivar × chilling interaction nonsignificant. FW: $y = 3.243 - 0.320x + 0.0086x^2$; FR: $y = 3.000 - 320x + 0.0086x^2$.**

ing, decreasing quadratic curves with increased chilling were observed for both cultivars (Fig. 2a). For example, with 2 weeks of chilling 'Frances Williams' and 'Francee' gained 3.6 and 3.4 days, respectively, in emergence time per day of chilling relative to non-chilled plants. The 0.2 day difference in gain for the two cultivars represents a slightly greater benefit of chilling in 'Frances Williams'. Interestingly, even with 16 weeks of chilling, there was more than a day's gain for each day of chilling, 1.3 days for 'Frances Williams' and 1.1 days for 'Francee'. However, this model does not include chilling time in the predicted time to emergence values. When chilling and forcing times are included in the equation, curves similar to those excluding chilling time result but with lower emergence gains (Fig. 2b). With 7.9 and 9.3 weeks of chilling, there was one day's gain for each day of chilling for 'Francee' and 'Frances Williams', respectively. With longer chilling periods emergence gains were less than a day for each day of chilling.

Days to the first unfurled leaf followed a similar trend as days to emergence, although the cultivar × chilling interaction was nonsignificant; therefore, data were pooled (Fig. 3). Relative to non-chilled plants, days to the first unfurled leaf decreased 74% and 82% after 8 and 16 weeks of chilling, respectively. Predicted days to emergence and first unfurled leaf analyses did not include plants that failed to emerge or unfurl during the 57 days after the last group of plants was removed from the cooler or 169 days after treatments were initiated. In 'Frances Williams' chilled for 0, 2 and 4 weeks, six, three and five plants, respectively, failed to emerge and eight, three and five plants failed to unfurl a leaf. In 'Francee' chilled for 0 and 2 weeks, three and one plants, respectively, failed to emerge and six and one plant failed to unfurl a leaf. All plants of both cultivars chilled for longer durations emerged and unfurled at least one leaf. Plants that did not emerge or unfurl a leaf represent significant percentages of plants receiving those treatments and may be a good indicator of minimum chilling requirements. Based on these data, 'Frances Williams' requires a minimum chilling period of 6

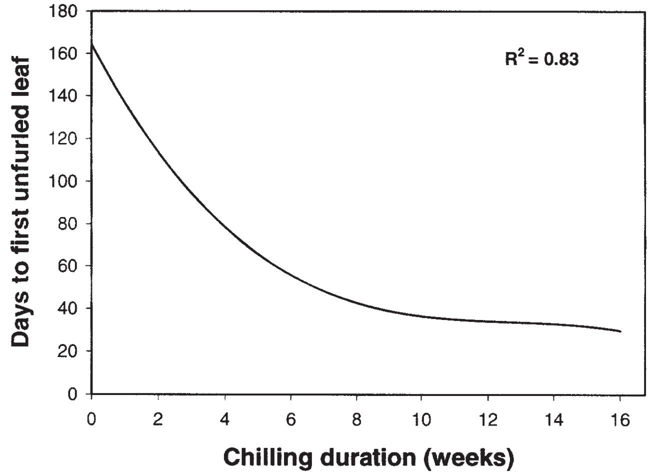

Fig. 3. **Predicted days to first unfurled leaf for 'Frances Williams' (FW) and 'Francee' (FR) hostas following 0 to 16 weeks of chilling. Cultivar and cultivar × chilling interaction nonsignificant. FW and FR: $y = 164.5 - 29.7x + 2.29x^2 - 0.06x^3$.**

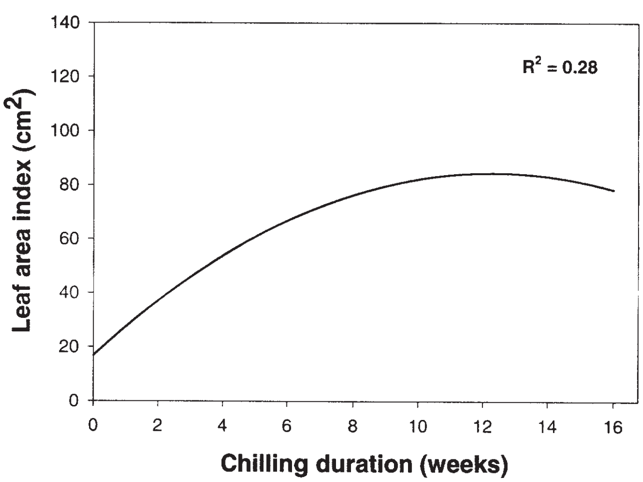

Fig. 4. **Predicted leaf area index (length × width) for 'Frances Williams' (FW) and 'Francee' (FR) hostas following 0 to 16 weeks of chilling. Cultivar and cultivar × chilling interaction nonsignificant. FW and FR: $y = 16.865 + 11.020x - 0.448x^2$.**

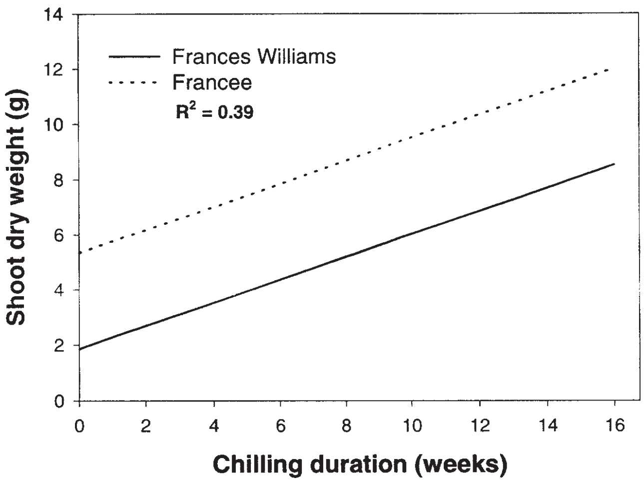

Fig. 5. Predicted shoot dry weights of 'Frances Williams' (FW) and 'Francee' (FR) hostas following 0 to 16 weeks of chilling. Data were collected 8 weeks after completion of the 16-week chilling period. Cultivar significant at $P \leq 0.0001$ but cultivar × chilling interaction nonsignificant. FW: $y = 1.86 + 0.42x$; FR: $y = 5.34 + 0.42x$.

weeks. 'Francee' appears to require less chilling, 2 and 4 weeks for 90% and 100% emergence and leaf unfurling, respectively. However, emergence and unfurling were much more rapid with additional chilling (Figs. 1 and 3).

Leaf area index responded quadratically to chilling duration; however, neither cultivar nor the cultivar × chilling interaction was significant (Fig. 4). Leaf area index increased as chilling duration increased up to about 12 weeks; the LAI was 400% higher after 12 weeks than with no chilling. Chilling duration had no effect on leaf count or offset number (data not shown); the nonsignificance of leaf count may in part relate to the persistence of leaves on non-chilled plants which were counted. Cultivars differed in both leaf counts and offset numbers, averaging 20 and 2.2, respectively, in 'Francee' and 11 and 0.4, respectively, in 'Frances Williams'. These differences were expected due to inherent differences between the two cultivars and previous research (2).

Shoot dry weight increased linearly in both cultivars as chilling duration increased (Fig. 5). 'Francee' plants chilled for 8 and 16 weeks had shoot dry weights 63% and 126%, respectively, higher than that of controls. Corresponding increases in 'Frances Williams' at 8 and 16 weeks were 181% and 361%, respectively. Cultivars differed in shoot dry weights although the interaction was not significant. 'Francee' averaged 3.5 g (0.12 oz) more shoot dry weight than 'Frances Williams'.

Results of this study are inconclusive concerning an absolute chilling requirement of hosta for shoot emergence due to emergence of some non-chilled plants. However, based on times to emergence and leaf unfurling, shoot dry weight, and plant vigor, there is a clear benefit to chilling. In general, with a longer chilling period, plants emerged quicker and shoot biomass increased. Cultivars responded differently to chilling with 'Frances Williams' requiring 6 weeks for 100% emergence and 'Francee' emerging 90% and 100% with 2 and 4 weeks of chilling, respectively. Information from this study will provide growers guidelines for forcing hosta for early markets. Additionally, there may be opportunities for holding hostas longer in coolers to force a flush of new growth at times of the year when hostas are growing slowly or foliage quality is typically poor, such as July–September in the southeastern United States. These results also help to explain the poor performance of hostas overwintered the last two years in USDA Hardiness Zone 8b.

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