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Effects of Chilling Duration on Time to Shoot Emergence and Subsequent Growth of *Hosta*[1]

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Abstract

Eight hosta species or cultivars, *Hosta plantaginea*, *H. ventricosa* 'Aureo Marginata', *H.* 'Tokudama', *H.* 'Francee', *H.* 'Sum and Substance', *H.* 'Fragrant Bouquet', *H.* 'Frances Williams', and *H. sieboldiana* 'Elegans', were chilled in a walk-in cooler in two-week increments from 2 to 10 weeks at 4C (39F), prior to forcing in a heated greenhouse. More than 80% of all cultivars in all treatments emerged, except for *H.* 'Tokudama'. For all cultivars tested, days to shoot emergence and days to first leaf unfurled decreased quadratically as chilling duration increased. Most rapid decreases occurred between 0 and 6 weeks of chilling. In the absence of chilling, *H. plantaginea* was the first cultivar to emerge, between 34 and 79 days before other cultivars. *H. plantaginea* was followed by *H. ventricosa* 'Aureo Marginata', *H.* 'Sum and Substance', and *H.* 'Fragrant Bouquet', all of which emerged before *H.* 'Frances Williams'. Leaf area index, an indicator of plant vigor, increased linearly as chilling duration increased. Shoot dry weight increased in *H.* 'Fragrant Bouquet', *H.* 'Frances Williams' and *H.* 'Francee', decreased slightly in *H. plantaginea,* and did not change in *H. ventricosa* 'Aureo Marginata', *H.* 'Tokudama', *H.* 'Sum and Substance', or *H. sieboldiana* 'Elegans' as chilling duration increased. This study indicates that there is no absolute chilling requirement for shoot emergence or subsequent growth of hosta tested. All cultivars benefited from chilling with quicker shoot emergence and fewer days to first leaf unfurled, with the greatest benefits occurring between 0 and 6 weeks. However, the benefits of chilling, as exemplified by growth and vigor, varied widely among species and cultivars.

Index words: chilling requirements, leaf emergence, greenhouse production.

Species used in this study: Fragrant plantain lily (*Hosta plantaginea* Asch.); 'Aureo Marginata' hosta (*H. ventricosa* Stearn 'Aureo Marginata'); 'Tokudama' hosta (*H.* 'Tokudama'); 'Francee' hosta (*H.* 'Francee'); 'Sum and Substance' hosta (*H.* 'Sum and Substance'); 'Fragrant Bouquet' hosta (*H.* 'Fragrant Bouquet'); 'Frances Williams' hosta (*H.* 'Frances Williams'); 'Elegans' hosta (*H. sieboldiana* Hooker 'Elegans').

Significance to the Nursery Industry

Lack of sufficient chilling in hosta can increase time to shoot emergence and decrease shoot emergence uniformity, plant vigor and product quality. Each hosta species or cultivar has a specific chilling duration required for maximum plant health and vigor. Knowledge of these specific minimum chilling requirements can help growers and landscapers choose appropriate selections for use in their specific climate.

Introduction

Hosta, one of the most striking and diverse groups of shade-loving perennials, is the number one selling herbaceous perennial in the United States (3). There are over 100 species, in addition to several thousand registered and unregistered cultivars. Hosta foliage color ranges from green, blue-green, chartreuse, white variegated, and yellow variegated with many other color combinations. Cultivars are available in many different sizes, shapes, and textures, and usually have a creamy white flower on a spike that can be very fragrant. Native to temperate Japan, China and Korea, hostas grow in most temperate climate regions of the world (8). Armitage (1) cites USDA Hardiness Zone 8 as the southernmost area for most hostas, except for *H. plantaginea* and *H. ventricosa* 'Aureo Marginata', which are rated for Zone 9. In the southeastern United States, hosta performance varies widely among cultivars, possibly due to seasonal temperatures, yearly rainfall, humidity and proximity to large bodies of water (9).

In the South, vigor of many hosta cultivars may be less than that of the same cultivars grown in the North because of the fewer number of chilling hours below 4C (39F) received (5). One notable exception Fausey et al. (3) found was that cultivars with *H. plantaginea* parentage required no chilling for vigorous growth. *H. plantaginea*, noted for its beautiful,

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fragrant flower, is also reported to be the most heat and sun tolerant hosta. Native to China, this species originated from further south than any other species in this genus (8). Origin may contribute to *H. plantaginea* and its cultivars' ability to withstand, and indeed thrive, in warmer climates. *H.* 'Francee' and *H.* 'Tokudama' required a minimum of six weeks at 4C (39F) for 100% emergence (3). Finical et al. (4) noted that *H.* 'Francee', with no chilling, had a low percent emergence, with many of the plants that did emerge lacking vigor and eventually dying. All plants that received a 15-week cold treatment at 5C (41F) emerged and were, in general, more vigorous than those with no chilling. The catalyst for this study was previous experimentation conducted by Keever et al. (6), in which chilling requirements in two hosta cultivars, 'Francee' and 'Frances Williams', were studied. They reported that as chilling duration at 4C (39F) increased, time to emergence and first leaf unfurling decreased at decreasing rates. They also noted that leaf area index (LAI = length of leaf × width at widest point of first leaf unfurled) increased at decreasing rates and shoot dry weight increased linearly as chilling duration increased. Non-chilled *H*. 'Francee' emerged an average of 32 days earlier than non-chilled *H.* 'Frances Williams'. *H.* 'Francee' required four weeks of chilling (WOC) for 100% emergence, while *H.* 'Frances Williams' required six weeks. These results suggested clear differences between these hosta cultivars in response to chilling duration. As yet, hosta has not been shown to have an absolute chilling requirement, although chilling for six to eight weeks was a requirement for vigorous growth in *H*. 'Francee' and *H.* 'Frances Williams' (6). The objective of this study was to determine how chilling duration affects emergence and growth of hosta with diverse parentage.

Materials and Methods

Between June and July 1998, stock plants of eight hosta species or cultivars were divided into single-eye sections and potted into 3.8 liter (#1) pots using a 7:1 (v:v) bark:sand mix amended per cu m (cu yd) with 5.3 kg (9 lb) of 22N–1.7P–11.6K (Polyon 22–4–14, Pursell Industries, Sylacauga, AL), 3.0 kg (5 lb) dolomitic limestone, and 0.9 kg (1.5 lb) Micromax (Scott's Chemical Co., Marysville, OH). After potting, plants were placed outdoors under 47% shadecloth and irrigated by overhead sprinklers twice daily for a total of 3.8 cm (1.5 in) per day.

On October 1, 1998, prior to exposure to temperatures below 10C (50F), 48 or 60 plants per cultivar were transferred into a double-poly heated greenhouse with a heat setpoint of 18C (65F) and ventilation setpoint of 26C (78F) under natural photoperiod. On December 2, 1998, all plants, except controls, were randomized in a dark walk-in cooler set at 4C (39F) and watered as needed throughout the entire experiment. Control plants remained in the greenhouse. Every two weeks, for a ten-week period, ten plants of *H*. 'Francee', *H.* 'Frances Williams', *H.* 'Fragrant Bouquet' and *H. plantaginea*, and eight plants of *H. ventricosa* 'Aureo Marginata', *H.* 'Sum and Substance', *H.* 'Tokudama' and *H. sieboldiana* 'Elegans' were transferred from the cooler to the greenhouse where they were completely randomized. Observations on days to emergence (DTE) [buds elongated at least 1 cm (0.4 in)] and days to first leaf unfurled began upon removal from the cooler and continued until the study was terminated on July 22, 1999, 232 days after the initiation of treatments and 134 days after the last plants were removed from the cooler. Days to first leaf unfurled was the number of days between removal of plants from the cooler and the day the first leaf unfurled completely. LAI (length of leaf × width at widest point of first leaf unfurled) was calculated and used as an indicator of plant vigor (2). On July 22, 1999, offsets were counted and foliage cut at the substrate surface for dry weight determination. Plants were placed in a drying oven for a minimum of 72 hours at 75C (167F) and weighed. Data were subjected to analysis of variance using SAS statistical software to determine the significance of main effects and interactions (7). Regression analysis was used to determine response of cultivars to chilling duration. Duncan's multiple range test was used to compare cultivars ($P = 0.05$).

Results and Discussion

All non-chilled controls of *H.* 'Fragrant Bouquet', *H. plantaginea* and *H. ventricosa* 'Aureo Marginata' emerged, while 90% of *H.* 'Francee' and *H. plantaginea* controls emerged, and 80% of *H.* 'Sum and Substance' and *H.* 'Frances Williams' emerged with no chilling. These results clearly demonstrate that hosta has no absolute chilling requirement and support results of a previous study using two hosta cultivars, *H.* 'Francee' and *H.* 'Frances Williams' (6). Emergence in *H.* 'Tokudama' ranged from 50% with 2 weeks of chilling (WOC) to 88% with 6 WOC. Ten WOC were required for 100% emergence. One to four plants of *H.* 'Tokudama' failed to emerge in all treatments except with 10 WOC, and plants that did emerge lacked vigor. Plants of *H.* 'Tokudama' used in this study were grown in the previous season under nursery conditions in Auburn, AL, during which time growth was weak relative to all other cultivars. This relative lack of vigor in *H.* 'Tokudama', compared to other hosta cultivars, has also been reported by Zilis (10). Since this study was completed, *H.* 'Tokudama' received from a northern source, likewise performed poorly in subsequent tests, affirming reports that *H.* 'Tokudama' lacks vigor in warm climates (9).

There was a significant cultivar by chilling duration interaction for DTE (Fig. 1) and days to first leaf unfurled (Fig. 2). As chilling duration increased, DTE and days to first leaf unfurled decreased quadratically for all cultivars tested. The most rapid decrease in DTE in all cultivars except *H sieboldiana* 'Elegans', which emerged 52% quicker with 8 WOC as compared to 6 WOC, occurred with between 0 and 6 WOC, with minimal further decreases in DTE with additional chilling. The magnitude of the decrease in DTE with each incremental increase in chilling is indicative of the relative benefit that each cultivar experienced. With 2 WOC, *H.* 'Sum and Substance' emerged 28 days earlier than controls, and *H. ventricosa* 'Aureo Marginata' emerged 66 days earlier than controls, demonstrating a clear benefit of minimal chilling. With an additional 2 WOC (a total of four weeks) there was a further pronounced mean decrease in DTE: 72 days for *H.* 'Fragrant Bouquet' and *H. plantaginea* to 100 days for *H.* 'Sum and Substance', as compared to no chilling. With 6 WOC, the mean decrease in DTE ranged from 90 (*H. plantaginea*) to 141 (*H.* 'Frances Williams') days earlier than without chilling.

In the absence of chilling, *H. plantaginea* was the first cultivar to emerge, between 34 and 79 days before other cultivars. *H. plantaginea* was followed by *H. ventricosa* 'Aureo Marginata', *H.* 'Sum and Substance', and *H.* 'Fragrant Bouquet', all of which emerged before *H.* 'Frances Williams'. *H. ventricosa* 'Aureo Marginata', *H.* 'Sum and Substance',

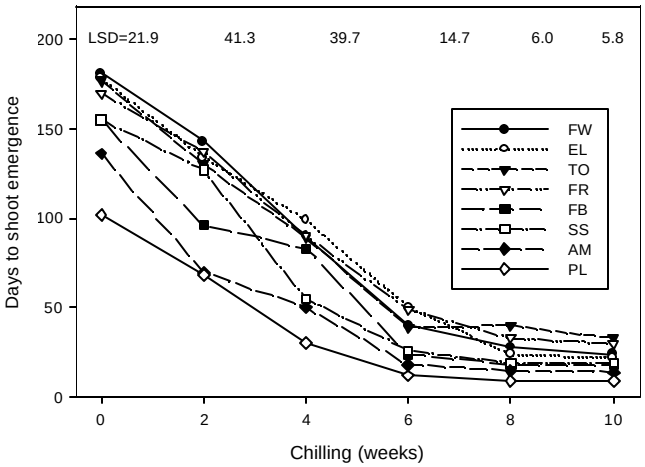

Fig. 1. Days to shoot emergence of eight hosta species and cultivars chilled for 0 to 10 weeks. FW = *Hosta* 'Frances Williams', EL = *H. sieboldiana* 'Elegans', TO = *H.* 'Tokudama', FR = *H.* 'Francee', FB = *H.* 'Fragrant Bouquet', SS = *H.* 'Sum and Substance', AM = *H. ventricosa* 'Aureo Marginata', PL = *H. plantaginea.* All regression responses were quadratic at *P* = 0.01 or 0.001, n = 10. Shoot emergence date recorded when shoot length was 1 cm. LSD value noted above each chilling treatment for comparing cultivars within a chilling treatment.

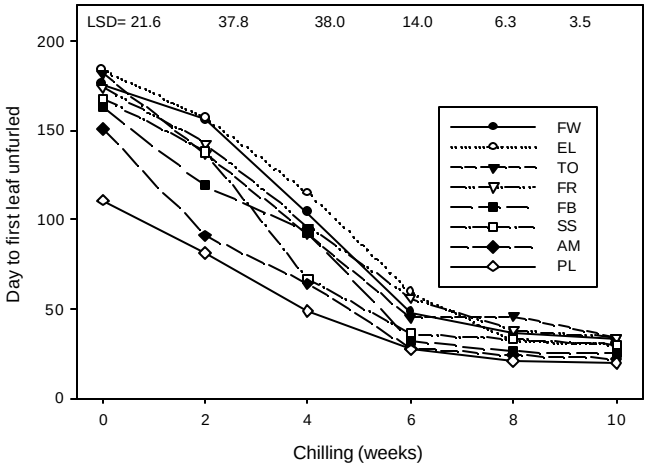

Fig. 2. Days to first leaf unfurled of eight hosta species and cultivars chilled for 0 to 10 weeks. FW = *Hosta* 'Frances Williams', EL = *H. sieboldiana* 'Elegans', TO = *H.* 'Tokudama', FR = *H.* 'Francee', FB = *H.* 'Fragrant Bouquet', SS = *H.* 'Sum and Substance', AM = *H. ventricosa* 'Aureo Marginata', PL = *H. plantaginea.* All regression responses were quadratic at *P* = 0.01 or 0.001, n = 10. Shoot emergence date recorded when shoot length was 1 cm. LSD value noted above each chilling treatment for comparing cultivars within a chilling treatment.

and *H.* 'Fragrant Bouquet' emerged an average of 26 days before *H. sieboldiana* 'Elegans', *H.* 'Tokudama' and *H.* 'Francee'. These data are in agreement with previously reported findings that *H. plantaginea* emerged quickly without chilling, while *H.* 'Francee' and *H.* 'Tokudama' were slower to emerge (3). In general, *H. plantaginea*, *H. ventricosa* 'Aureo Marginata', *H.* 'Sum and Substance', and *H.* 'Fragrant Bouquet' tended to emerge quicker with chilling than *H.* 'Frances Williams', *H. sieboldiana* 'Elegans', *H.* 'Tokudama' and *H.* 'Francee'.

Hosta species and cultivars exhibited a similar trend in days to first leaf unfurled (Fig. 2). The most rapid decrease in days to first leaf unfurled occurred between 0 and 6 WOC and minimal further decrease in days to first leaf unfurled with additional chilling in all cultivars. As with DTE, a reduction in the number of days to first leaf unfurled with each incremental increase of chilling is indicative of the relative benefit of low temperature for each cultivar. With 2 WOC, days to first leaf unfurled ranged from 20 (*H.* 'Frances Williams') to 60 (*H. ventricosa* 'Aureo Marginata') days sooner than the controls, demonstrating a clear benefit of minimal chilling. With an additional 2 WOC (a total of four weeks), there was a further pronounced decrease in days to first leaf unfurled from 62 (*H. plantaginea*) to 101 (*H.* 'Sum and Substance') days sooner than the controls. With 6 WOC, the decrease in days to first leaf unfurled was reduced by 83 (*H.*

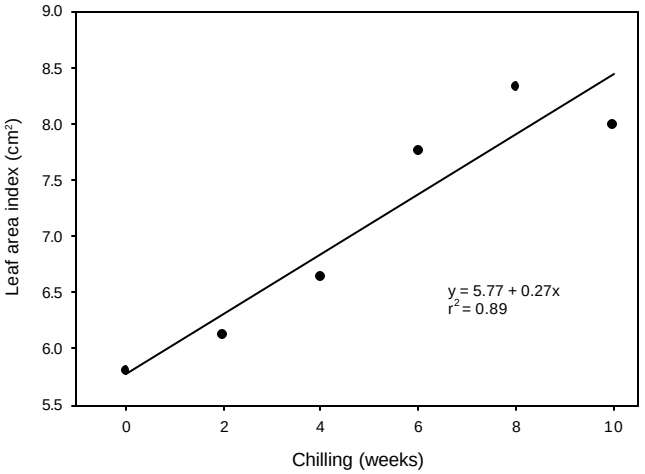

Fig. 3. Average leaf area index (LAI, leaf length × widest width of the first unfurled leaf) of eight hosta species or cultivars chilled for different durations. Cultivar × chilling duration was non-significant and regression response was linear at *P* = 0.05.

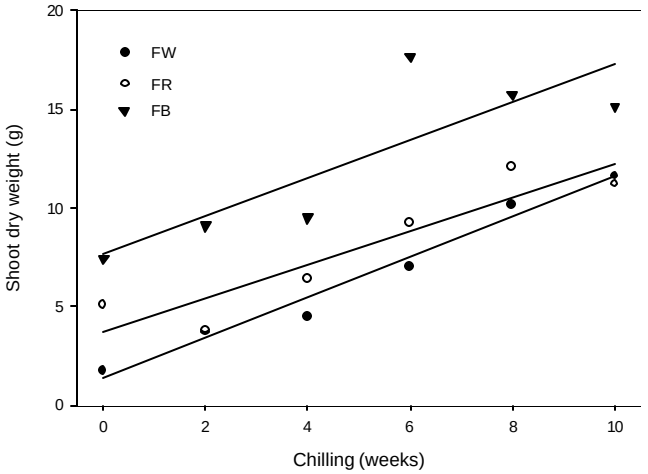

Fig. 4. Shoot dry weight for three hosta cultivars chilled for different durations. FW = *Hosta* 'Frances Williams', FR = *H.* 'Francee', and FB = *H.* 'Fragrant Bouquet'. Regression responses were linear at *P* = 0.001, n = 10. Regression equation for FB = 7.68 + 0.96x, r^2 = 0.26; FR = 3.66 + 0.85x, r^2 = 0.37; FW = 1.34 + 1.02x, r^2 = 0.36.

plantaginea) to 137 (*H.* 'Tokudama') days as compared to controls. Some plants that did emerge failed to unfurl a leaf during experimentation. Therefore, some averages of days to first leaf unfurled were less than DTE.

LAI was determined as an indicator of how chilling duration can affect plant vigor. Because there was no significant interaction between chilling duration and cultivar, main effects only are reported. LAI increased linearly (Fig. 3) as chilling duration increased, demonstrating that there was a continuous increase in vigor as chilling duration increased from zero to ten weeks, regardless of cultivar. LAI (cm) was highest in *H.* 'Sum and Substance' (13.3a), followed by *H. plantaginea* (8.1b), which was statistically similar to *H.* 'Frances Williams' (7.9bc) and *H.* 'Fragrant Bouquet' (7.8bc), and lowest in *H.* 'Tokudama' (3.0f). These differences are inherent and not considered related to a response to chilling duration.

Chilling duration had no effect on leaf number or offset number in most cultivars. Only in *H.* 'Fragrant Bouquet' and *H. ventricosa* 'Aureo Marginata' did leaf number increase with increased chilling from zero to ten weeks by 31% and 44%, respectively. Offset counts in *H.* 'Francee' and *H. ventricosa* 'Aureo Marginata' increased from 1.7 to 2.1 (Q*), and from 0.1 to 1.6 (L*Q*), respectively, as chilling increased from zero to ten weeks (data not shown). Comparisons among cultivars were not considered relevant.

Shoot dry weight varied tremendously among cultivars in response to chilling duration. Increased chilling duration from zero to ten weeks resulted in shoot dry weight increases of 582% in *H.* 'Frances Williams', followed by increases of 120% and 104% in *H.* 'Francee' and *H.* 'Fragrant Bouquet', respectively (Fig. 4.). In contrast, shoot dry weight in *H. plantaginea* decreased by 23% with 10 WOC. Shoot dry weight of *H.* 'Tokudama', which grew minimally in all treatments, was not affected by chilling duration (P = 0.05, data not shown). Due to high variability within treatments, changes in shoot dry weight in *H. sieboldiana* 'Elegans' and *H. ventricosa* 'Aureo Marginata' were non-significant (P = 0.05, data not shown).

Results of this study clearly demonstrate that there is no absolute chilling requirement for shoot emergence or subsequent growth of hosta. However, chilling greatly shortens time to emergence and subsequent leaf growth. All cultivars benefited from chilling with quicker shoot emergence and fewer days to leaf unfurled, with the greatest benefits occurring between zero and six weeks. Each hosta species or cultivar has a specific minimum duration of chilling required for maximum leaf emergence and vigor. *H. plantaginea* responded to increased chilling with more rapid emergence and first leaf unfurled; however, total leaf counts over the study were not affected by chilling duration, and shoot dry weight actually decreased. This suggests that increased chilling duration may shorten the time to marketability for *H. plantaginea* with no season-long benefit to chilling. Differences in response to chilling among hosta species and cultivars may relate to native habitat and genotype.

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