Effect of Chilling Duration on Growth of *Hosta plantaginea* and 11 Related Cultivars[1]

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Abstract

Hosta *plantaginea* and 11 selections with H. *plantaginea* parentage were chilled at 4C (39F) for 0, 1, 2, 3, or 4 weeks to determine the effect of chilling duration on subsequent plant growth. At 6 and 12 weeks after chilling treatment (WAT), response to chilling duration was selection dependent with three trends evident. At 6 WAT, eight of the 12 selections showed a decrease in new leaf formation with one or two weeks of chilling, but an increase in new leaf formation with additional chilling. In three of the 12 selections, new leaf formation increased linearly with increased chilling. New leaf formation of *H. plantaginea* 'Grandiflora' was not affected by chilling duration at 6 or 12 WAT. At 12 WAT, growth response of four of the 12 selections changed quadratically with increased chilling, similar to the response at 6 WAT, while leaf formation in seven of the 12 selections increased linearly with increasing chilling duration. At 18 WAT, leaf counts increased linearly in all *H. plantaginea* selections with increasing chilling duration, demonstrating increased vigor. All selections showed increases in new leaf formation over the 18-week period following chilling, demonstrating that chilling, though beneficial, was not required, and in the short-term, the response to chilling was selection dependent.

Index words: chilling requirements, herbaceous perennial, plantain lily.

Species used in this study: fragrant plantain lily (*Hosta plantaginea* Asch.); 'Grandiflora' hosta (*H plantaginea* Asch. 'Grandiflora'), hosta (*H*. 'Honeybells', 'Royal Standard', 'Fragrant Bouquet', 'Sweet Winifred', 'Iron Gate Bouquet', 'Buckwheat Honey', 'Sweet Susan', 'Sweet Marjorie', Summer Fragrance', and 'So Sweet').

Significance to the Nursery Industry

In the short-term, the growth of *Hosta plantaginea* and closely related selections differed in response to chilling duration, but at no time was chilling required for continued growth. Short-term benefits of chilling on new leaf formation were not apparent in some *H. plantaginea* selections, and actually decreased growth in some selections, while all selections benefitted from chilling in the long term. Knowledge of how chilling duration affects plant vigor over time for individual hosta selections will enable growers to schedule chilling events to maximize plant growth. Additionally, vigorous growth in the absence of chilling will allow the use of *H. plantaginea* and its selections in regions where little or no natural chilling occurs.

Introduction

H. plantaginea, with chartreuse-green foliage and fragrant, night blooming flowers has long been a favorite in southern U.S. gardens because of its ability to withstand warm, humid climates (14). The ability of *H. plantaginea* to thrive under these conditions may be due to the environmental similarities between the southeastern United States and the native habitat of the species in the southerly Zhejiang Province, China. In other genera such as *Lilium*, environmental conditions necessary for dormancy have been found to correlate with the natural winter conditions of their native habitat (12). In the southern United States, vigor of many hosta cultivars may be less than when grown in the North due to heat stress resulting in high respiration rates (15) or to plants receiving fewer chilling hours below 5C (41F) (10). Armitage (2) cites USDA Hardiness Zone 9 as the southern extreme for *H. plantaginea*, although performance may vary widely among selections with *H. plantaginea* parentage.

Plant attributes such as cold hardiness, heat tolerance and chilling requirements are controlled by genetic factors and environmental conditions such as prior exposure to low or high temperatures. A plant may or may not exhibit characteristics of its parents due to the nature and complexity of genotypic expression (1). Because selections with *H. plantaginea* parentage are made following both asexual and sexual reproduction, their growth response to chilling is largely unknown. Several hosta cultivars with varied parentage have been found to benefit from but not require, chilling. Keever et al. (11) found that for *H*. 'Francee' and *H*. 'Frances Williams', there was a selection dependent optimum chilling duration for growth and vigor. Fausey et al. (7) examined 11 hosta species and stated that most required no more than 6 weeks of chilling at 5C (41F) for 100% emergence and growth. Warr et al. (16) found that, with no chilling, *H. plantaginea* emerged between 34 and 79 days before other selections tested.

While it is known that *H. plantaginea* performs well in the mid to lower South (15), and exhibits vigor with little or no chilling (16), the performance of selections with *H. plantaginea* parentage is unknown. Similar performance among these selections to *H. plantaginea* would provide growers and homeowners with additional selections for production and use in the landscape in these regions. Therefore, our objective was to determine how chilling duration affects growth and vigor of *H. plantaginea* and 11 related selections.

Materials and Methods

Stock plants of *H. plantaginea* and 11 selections with *H. plantaginea* parentage (*H*. 'Honeybells', *H*. 'Royal Standard', *H* 'Fragrant Bouquet', *H*. 'Sweet Winifred', *H*. 'Iron Gate Bouquet', *H*. 'Buckwheat Honey', *H*. 'Sweet Susan', *H*.

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'Sweet Marjorie, *H.* 'Summer Fragrance', *H. plantaginea* 'Grandiflora', *H.* 'So Sweet') were grown outdoors under 47% shadecloth and irrigated for 30 minutes twice daily using overhead rotary nozzles for a total of 3.8 cm (1.5 in) of water. On September 22, 2000, before ambient temperatures dropped below 10C (50F), plants were moved into a double polyethylene greenhouse with a heat setpoint of 18C (65F) and a ventilation setpoint of 26C (78F). Fifty plants of each selection, except *H.* 'Royal Standard', were divided into single-eye divisions and potted into 3.8 liter (#1) pots using a bark:sand mix (7:1 by vol) amended 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 (The Scotts Co., Marysville, OH) per m^3 (yd^3) on November 2, 2000. *H.* 'Royal Standard' had been divided into single-eye divisions in mid-summer and had no new offsets at the time other selections were divided. On December 6, 2000, at which time all plants were foliated, 40 plants of each selection were placed randomly in a dark cooler set at 4C (39F) and watered as needed. Ten plants of each selection were removed weekly during a four-week period and returned to the greenhouse where they were completely randomized. Control plants were left in the greenhouse for the entire treatment period. Because post-chilling foliage was in a state of decline, all remaining foliage from the previous season's growth of plants in all treatments, both in and out of the cooler, was removed by pruning to the base of the petiole on December 28, 2000. Removal of this older foliage allowed us to discern new growth and lessened disease potential. New leaves were counted on all plants at 6, 12 and 18 weeks after removal from the cooler (WAT). New leaves on control plants were counted on the same dates as those plants chilled for one week. In this 5 × 12 (chilling duration × selection) factorial experiment, treatments were completely randomized in both the cooler and greenhouse and replicated using 10 single plants. Data were subjected to analysis of variance using SAS statistical software package to determine the significance of main effects and interactions (13). Response to chilling duration was determined using orthogonal polynomials and regression analysis, and selections were compared using Fisher's Protected Least Significant Difference Test (P = 0.05).

Results and Discussion

Short-term growth response (6 WAT). At 6 WAT, non-chilled plants of all selections, which were not dormant at the beginning of the study and whose older leaves did not senesce prior to hand removal, had formed new leaves indicating chilling was not required for continued growth. New leaf formation in response to chilling duration was selection dependent, with three trends evident. In eight of 12 selections, new leaf formation decreased as chilling duration increased from zero to one or two weeks, before increasing with additional chilling (Fig. 1a). However, the magnitude of change varied among selections. In selections that responded quadratically to chilling duration, the decrease in new leaf formation ranged from 19 to 100% with 1 week of chilling (WOC) compared to no chilling. With 4 WOC, compared to none, changes in new leaf formation ranged from a decrease of 11% to an increase in new leaf formation of 372%. New leaf formation in three of the 12 hosta selections increased linearly with chilling duration (Fig. 1b). With 4 WOC, compared to none, new leaf formation increased up to 220%. Leaf counts of one selection, *H. plantaginea* 'Grandiflora', were not affected by chilling duration (Fig. 1b).

Reduced vigor, as defined by a decrease in the rate of new leaf formation, in selections responding quadratically indicates a slower metabolism due to plant exposure to low temperature. At temperatures between 0C (32F) and 10C (50F), all plants have lower respiration rates, slowed metabolism and an inactivation of enzymatic processes responsible for plant growth (9). Although it is likely metabolism in all selections slowed in response to chilling, the linear increase in

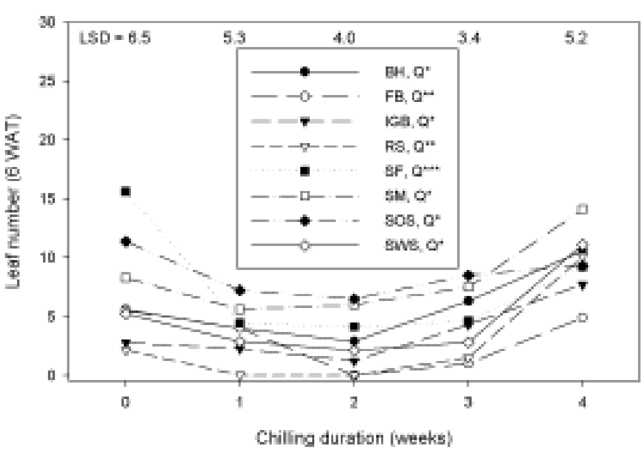

Fig. 1a. Leaf counts 6 weeks after chilling treatment (WAT) for 8 related taxa of *H. plantaginea*. Trend response quadratic (Q) at P = 0.05 (*), 0.01 (**), or 0.001 (***), n = 10. BH = *Hosta* 'Buckwheat Honey', FB = *H.* 'Fragrant Bouquet', IGB = *H.* 'Iron Gate Bouquet', RS = *H.* 'Royal Standard', SF = *H.* 'Summer Fragrance', SM = *H.* 'Sweet Marjorie', SOS = *H.* 'So Sweet', SWS = *H.* 'Sweet Susan'. LSD value noted above each chilling treatment for comparing cultivars within a chilling treatment.

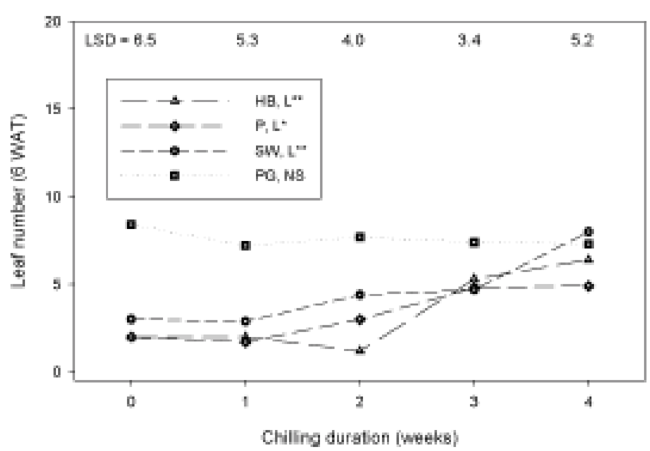

Fig. 1b. Leaf counts 6 weeks after chilling treatment (WAT) for *H. plantaginea* and 3 related taxa. Trend response Linear (L) at P = 0.05 (*) or 0.01 (**), or non-significant (NS), n = 10. HB = *Hosta* 'Honeybells', P = *H. plantaginea*, SW = *H.* 'Sweet Winifred', PG = *H. plantaginea* 'Grandiflora'. LSD value noted above each chilling treatment for comparing cultivars within a chilling treatment.

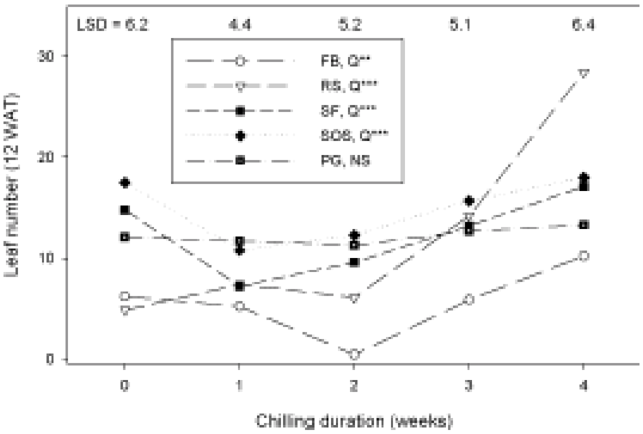

Fig. 2a. Leaf counts 12 weeks after chilling treatment (WAT) for 5 related taxa of *H. plantaginea*. Trend response quadratic (Q) at *P* = 0.01 (**) or 0.001 (***) or non-significant (NS), n = 10. FB = *Hosta* 'Fragrant Bouquet', RS = *H.* 'Royal Standard', SF = *H.* 'Summer Fragrance', SOS = *H.* 'So Sweet', PG = *H. plantaginea* 'Grandiflora'. LSD value noted above each chilling treatment for comparing cultivars within a chilling treatment.

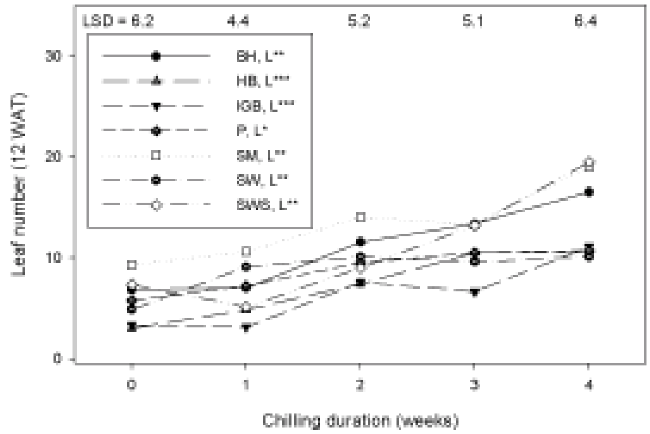

Fig. 2b. Leaf counts 12 weeks after chilling treatment (WAT) for *H. plantaginea* and 6 related taxa. Trend response Linear (L) at *P* = 0.05 (*), 0.01 (**), or 0.001 (***), n = 10. BH = *Hosta* 'Buckwheat Honey', HB = *H.* 'Honeybells', IGB = *H.* 'Iron Gate Bouquet', P = *H. plantaginea*, SM = *H.* 'Sweet Marjorie', SW = *H.* 'Sweet Winifred', SWS = *H.* 'Sweet Susan'. LSD value noted above each chilling treatment for comparing cultivars within a chilling treatment.

leaf count with additional chilling in some selections at 6 WAT indicates an early benefit of chilling. In addition to more rapid leaf formation, benefits from chilling hostas have included decreased time to shoot emergence, decreased time to first leaf unfurled (11, 16), increased percent flowering if chilling is accompanied by night interrupted lighting (8), and increased leaf area index (7). However, the benefits of chilling are selection specific. *H. plantaginea* 'Grandiflora', for example, was not adversely affected by minimal chilling, nor did it benefit from additional chilling at 6 WAT, as all other selections did.

Differences in new leaf formation varied among selections depending upon chilling duration. Without chilling, *H.* 'Summer Fragrance' formed the most new leaves but a similar number to *H.* 'So Sweet'. Two of the three selections that showed linear increases in new leaf formation, *H.* 'Honeybells' and *H. plantaginea*, produced fewer leaves than most other selections without chilling (Fig. 1b). Leaf formation relationships among selections that responded quadratically generally remained constant with increased chilling except in *H.* 'Summer Fragrance' and *H.* 'Fragrant Bouquet'. All selections had formed two to 15 new leaves at 6 WAT without chilling, demonstrating that chilling is not required for growth of *H. plantaginea* and its selections. These results are in agreement with previous findings (7, 8, 11, 16), although they disagree with Schmid (14) who stated all taxa in the genus *Hosta* required several weeks of chilling. However, trends in leaf formation in response to increasing chilling duration show clear differences among *H. plantaginea* selections.

Mid-term growth response (12 WAT). At 12 WAT, new leaf formation in response to chilling duration again was selection dependent. New leaf formation changed quadratically in four of the 12 selections in response to increased chilling (Fig. 2a) as compared to eight of 12 selections at 6 WAT. New leaf formation decreased up to 92% with 1 WOC when compared to no chilling, before increasing with 2, 3 and 4 WOC in three of the four selections that responded quadratically to chilling. However, the number of new leaves of *H.* 'Royal Standard' increased 53% with 1 WOC, 26% with 2 WOC, and 484% with 4 WOC. Compared to plants not chilled, all selections increased leaf counts from 3 to 484%, with 4 WOC (Fig. 2a).

At 12 WAT, new leaf numbers in seven of the 12 selections increased linearly as chilling duration increased (Fig. 2b). With 2 WOC, the number of leaves increased up to 147% (*H.* 'Honeybells') and with 4 WOC up to 234% (*H.* 'Iron Gate Bouquet'), compared to plants not chilled.

Most temperature zone species, including many fruit trees, require chilling before growth resumes in spring (4). In grape (*Vitis vinifera* 'Perlette'), inadequate chilling resulted in non-uniform budbreak and fruit development and decreased fruit production (6). In pistachio (*Pistacia vera* 'Kerman'), insuf-

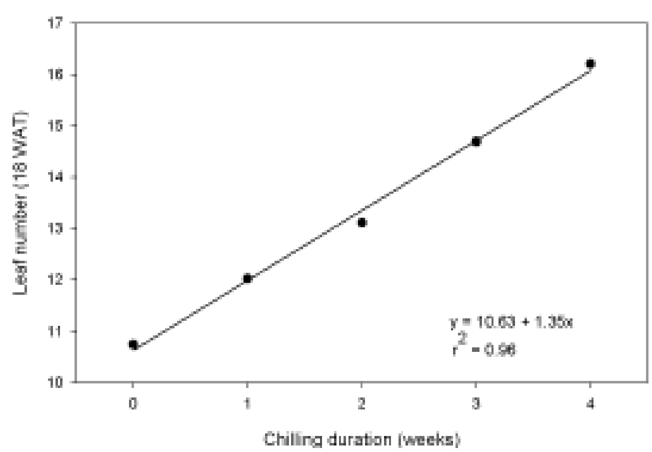

Fig. 3. Average leaf counts for *H. plantaginea* and 11 related taxa at 18 weeks after chilling treatment (WAT). Regression response linear at *P* = 0.001, n = 120.

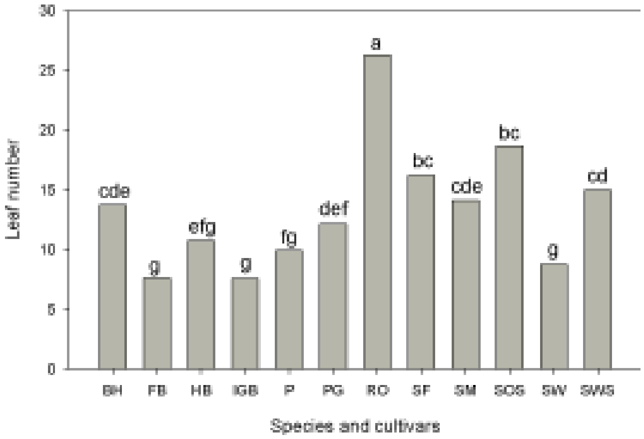

Fig. 4. Leaf counts for *Hosta plantaginea* and 11 related taxa at 18 weeks after chilling treatment (WAT) averaged over 0, 1, 2, 3 and 4 weeks. BH = *Hosta* 'Buckwheat Honey', FB = *H.* 'Fragrant Bouquet', HB = *H.* 'Honeybells', IGB = *H.* 'Iron Gate Bouquet', P = *H. plantaginea*, PG = *H. plantaginea* 'Grandiflora', RS = *H.* 'Royal Standard', SF = *H.* 'Summer Fragrance', SM = *H.* 'Sweet Marjorie', SOS = *H.* 'So Sweet', SW = *H.* 'Sweet Winifred', SWS = *H.* 'Sweet Susan'. Mean separation by Fisher's Protected Least Significant Difference, *P* = 0.05.

ficient chilling precluded a reduced number of leaflets per leaf and reduced pollen production and overall vigor (5). Chilling is beneficial but not required for herbaceous perennials such as forget-me-not (*Myosotis scorpiodes*) and creeping baby's breath (*Gypsophila repens*) (3). The benefits of chilling on subsequent growth, including enhanced vigor and decreased time to flower (3), are plant specific. Chilling affects plant metabolism by temporarily slowing plants processes before plants resume growth in response to increasing temperature. This response was evident in half of the selections that showed a decrease in new formation at 6 WAT with minimal chilling followed by enhanced vigor at 12 WAT. This is consistent with previous reports in which responses to chilling were plant specific, and benefits of chilling resulted in decreased time to flower (3) and shoot emergence, increased vigor and more uniform emergence (11). In the mid-term, at 12 WAT, new leaf formation in hosta selections decreased, increased, or was not affected by chilling, however in response to increasing chilling duration, all selections except *H. plantaginea* 'Grandiflora' resumed growth in response to higher temperatures following chilling.

Long-term growth response (18 WAT). By 18 WAT, all selections benefitted from increasing chilling duration. New leaf formation for all selections increased linearly as chilling duration increased, from 11 leaves without chilling to 16 leaves with 4 WOC (Fig. 3). *H.* 'Royal Standard' produced the most new leaves of all selections, perhaps due, in part, to earlier division, which allowed for longer establishment of these plants and quicker new leaf formation (Fig. 4). New leaf formation at 18 WAT differed greatly from that at 6 or 12 WAT in response to chilling. AT 6 and 12 WAT, new leaf formation in response to chilling was selection dependant and decreased in some selections in response to minimal chilling (1 to 2 WOC), before increasing with additional chilling, in contrast to 18 WAT, where all selections increased linearly with increasing chilling.

Plant vigor, as characterized by the rate of new leaf formation, varied among *H. plantaginea* and its selections, dependent upon chilling duration and time after treatment when leaf counts were made. In the short and mid-term, some selections were adversely affected by minimal chilling of one or two weeks, while others benefitted or were not affected. However, in the long-term (18 WAT), new leaf formation increased regardless of selection or chilling duration indicating a dissipation of the adverse effect on new leaf formation and a stimulation of plant vigor by chilling. While vigor was clearly enhanced with a longer duration of chilling, all plant survived and grew well, even without chilling, suggesting that *H. plantaginea* and its selections are viable options for growers and consumers in areas where natural chilling is minimal.

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