Chilling Affects Foliar Budbreak of Ornamental Trees©

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INTRODUCTION

A number of studies have been conducted seeking to determine the basis for differences in field production and landscape performance for specific cultivars of ornamental trees when grown in various regions of the country. When cultivars are introduced in the northern United States and then sold in the south, poor performance is often attributed to poor heat tolerance. Likewise, southern selections performing poorly in the north are frequently categorized as non-cold-hardy. Research suggests that performance of cultivars and selections of woody ornamentals can vary greatly depending upon their provenance or area of origin. This has been shown in studies of sugar maple (*Acer saccharum* Marshall) and red maple (*Acer rubrum* L.) as well as other species (Kriebel and Wang, 1962; Perry and Hellmers, 1973; Sibley et al., 1995, 1999; Townsend et al., 1982).

The influence of chilling temperatures on fruit-producing trees in the dormant season is widely known, while there is less understanding of the influence of chilling on ornamental trees. Chilling not only affects timing and amount of vegetative and floral budbreak of woody plants, but subsequent growth, development, and hardiness (Dokoozlian, 1999; Mahmood et al., 2000; Murray et al., 1989; Roberts and Zwiazek, 1999). A few years ago, I began to suspect that differences in performance of red maple cultivars might not be because of too much heat, but too little cold — or a lack of sufficient dormant chilling. After a period of time I began to evaluate linden and ginkgo in this same manner to see if these species might also have a differential response to chilling.

Red maple (*Acer rubrum*) is a popular ornamental tree found naturally in the forests of eastern North America, from southern Canada to south Florida (Sternberg and Wilson, 1995). The availability of over 58 red and Freeman maple (*A.* ×*freemanii*, a hybrid between red maple and silver maple, *A. saccharinum*) cultivars (Dirr, 1998) demonstrates the enormous genetic variation, adaptability to nursery culture and performance in the landscape for this group, and its resulting popularity. The genetic basis for this diversity (Townsend, 1977) makes red maple a good candidate for regional selection. Studies have shown that races of red maple from different provenances can vary in the chilling requirement necessary to complete rest (Perry and Hellmers, 1973; Perry and Wu, 1960; Townsend, 1977). In the studies by Perry and Hellmers (1973) and Perry and Wu (1960), red maples originating from within the northern part of the natural range required a longer duration of chilling temperatures to break endodormancy than trees from the southern part.

Ashby's (1962) work with American linden showed that increased chilling led to a significantly faster rate of budbreak. The least-chilled plants, which broke bud and began growth later, also stopped growth and began losing leaves at a later date. As a result, the growth periods did not vary greatly between chilling treatments. In other research, some lindens lifted from the field in the fall and stored at 38°F through spring showed partial budbreak while still in cold storage. Other trees receiving minimal chilling did not break bud at all.

Lindens are found in much of the northern hemisphere, with species native to North America, Europe, and Asia. There are around 10 cultivars of American linden (*Tilia americana*) (USDA Zones 3b-8), 23 cultivars of littleleaf linden (*T. cordata*) (U.S.D.A. Zones 3b-7), and 5 cultivars of silver linden (*T. tomentosa*) (U.S.D.A. Zones 4-7), (Dirr, 1998). Of the readily available cultivars, few have gained popularity in the southern United States, probably because of the prevailing belief that lindens are northern trees with poor performance in the South.

While previous studies have established the chilling requirement for many deciduous fruit tree cultivars, leading to models for regional planting recommendations (Westwood, 1993), no reports have documented the chilling requirements for *Ginkgo biloba* or individual red maple or linden cultivars. Dormancy release is of particular interest to the nursery industry, for early budbreak can not only lead to a longer growing season and accelerated production, but can result in cold and frost damage (Lechowicz, 1984; Townsend, 1977). Therefore, the objectives of these studies were to determine if *G. biloba* seedlings, red maple cultivars, and selected linden species and cultivars have differential responses to chilling and to estimate the chilling requirement for each selection. From this information, models for regional planting recommendations can eventually be constructed to assist in the selection of suitable ornamental trees for southern landscapes. Also, growers can use this information to modify lifting, storage, and transplanting schedules.

MATERIALS AND METHODS

For *G. biloba*, about 200 seedlings, 30 to 40 cm (12 to 18 inch) tall, were obtained from Musser Forests (Indiana, Pennsylvania) in June 1998. For linden, tissue-cultured plants of *Tilia cordata* 'Greenspire' and Fairview™ littleleaf linden, *T. tomentosa* 'Sterling Silver', and *T. americana* 'Redmond' were obtained as bare-root whips 1.2 to 1.5 m (4 to 5 ft) tall from A. McGill & Son Nursery (Canby, Oregon), in February, 1999. About 20 red and Freeman maple cultivars from both tissue culture and rooted cutting origins have been obtained for evaluation so far. All trees were container grown in a pine bark and sand (6 : 1, v/v) substrate amended with 2.8 $kg \cdot m^{-3}$ (5 lb per yd^3) dolomitic limestone, 0.8 $kg \cdot m^{-3}$ (1.5 lb per yd^3) Micromax, and 6 $kg \cdot m^{-3}$ (11.1 lb per yd^3) 18N-6P-12K Osmocote. Trees were grown in full sun with overhead irrigation in Auburn, AL (32° 36 N x 85° 29 W, USDA Hardiness Zone 8a).

For the lindens and maples, each study included 6 levels of chilling applied in increments of 200 h (200-1200), with each treatment consisting of 3 single-tree replications per cultivar. Chilling hours were calculated using the Old 45 Chilling Model (Powell et al., 1999). In this model, beginning 1 Oct., 1 h at temperatures below 7°C (45°F) equals 1 chilling h. Upon accumulation of 200 h of natural, ambient chilling in December each year, the first treatment was placed in a standard glass greenhouse maintained at a minimum temperature of 22°C (72°F) under natural photoperiods. Trees were placed in a completely randomized design (CRD). Subsequent treatments were placed in the greenhouse after intervals of 200 chilling h were accumulated. Ginkgos were placed in the greenhouse in chilling increments of 100 h from 0 to 1200 h.

After placement in the greenhouse, trees were monitored twice weekly for foliar budbreak. From the total number of buds counted, percentage budbreak was determined throughout the study. Budbreak was considered to be the point where overlapping bud scales began to separate, revealing leaf tips. The highest budbreak count recorded for each cultivar by the end of a study was assumed to be the highest possible number attainable for the study. Predicted heat unit values required to reach budbreak for different chilling treatments were determined by PROC REG multiple regression model, where one heat unit was equal to 1 h in the greenhouse at 22°C (72°F).

Table 1. Predicted number of heat units required to reach a given budbreak percentage on selected linden (*Tilia* spp.) cultivars.

Cultivar	Hours chilled	Initial budbreak	10% bubreak	25% budbreak	50% budbreak
		Predicted number of heat units[z]			
T. cordata 'Greenspire'	200	1935[y]	2370	2843	—[x]
	400	1389	1824	2297	2604
	600	922	1357	1830	2137
	800	535	970	1442	1750
	1000	227	662	1134	1442
	1200	—[x]	433	906	1213
		r2=0.58			
T. cordata 'Fairview'	200	1925	2320	2760	—[x]
	400	1368	1763	2203	2532
	600	883	1278	1718	2047
	800	470	865	1306	1634
	1000	130	524	965	1293
	1200	—[x]	256	696	1024
		r2=0.65			
T. tomentosa 'Sterling'	200	1941	2051	2217	2494
	400	1312	1423	1589	1866
	600	788	898	1064	1341
	800	367	478	644	920
	1000	50	161	327	604
	1200	—[x]	—[x]	114	391
		r2=0.65			
T. americana 'Redmond'	200	1900	2293	2723	—[x]
	400	1268	1661	2091	2382

Cultivar	Hours chilled	Initial budbreak	10% bubreak	25% budbreak	50% budbreak
		Predicted number of heat units[z]			
T. americana 'Redmond'	600	747	1141	1571	1861
	800	337	730	1160	1451
	1000	38	431	861	1152
	1200	—[x]	243	672	963
		r2=0.71			

[z]Calculated with PROC REG, using the SAS stepwise procedure to determine the best model.
[y]One heat unit equals 1 h in greenhouse at a temperature of at least 22°C (72°F).
[x]Predicted heat unit level was less than or greater than that which was applied.

RESULTS AND DISCUSSION

In all selections evaluated, the rate of foliar budbreak was accelerated by increasing the level of chilling and increased chilling reduced the number of heat units required to initiate budbreak (Table 1). Studies for *G. biloba* continue, therefore data will be presented in later reports.

For lindens, all cultivars required over 1900 heat units to initiate budbreak after 200 h of chilling, but only 747 to 922 heat units after 600 h and between 38 to 227 following 1000 h of chilling for initiation of budbreak.

Heat units required for initial budbreak were similar for 'Sterling' and 'Redmond'. Although the model predicted heat units required for budbreak to occur for 'Greenspire' and 'Fairview', actual budbreak was never observed for these cultivars in trees receiving only 200 h of chilling. 'Greenspire' and 'Fairview' trees receiving 200 h of chilling eventually declined to a point of death. Silver linden 'Sterling' performed well in this study and was the only cultivar receiving 200 h of chilling that reached 50% budbreak by the time the trees were moved from the greenhouse and transplanted to larger containers (Table 1).

The optimal chilling range for 'Greenspire' began at 800 to 1000 hours, with 25% to 50% budbreak occurring after accumulation of 1134 to 1750 heat units. 'Fairview' produced minimal budbreak after 400 h, with an optimal range of 800 to 1000 h and 25% to 50% budbreak with 965 to 1634 heat units. An optimal chilling range for 'Sterling' was 600 to 800 h with 25% to 50% budbreak occurring after accumulation of 644 to 1341 heat units. 'Redmond', an American linden, exhibited sparse budbreak after only 200 h chilling, with a wide optimal chilling range of 600 to 1000 h producing 25% to 50% budbreak after accumulation of 861 to 1861 heat units.

The work presented here indicates that littleleaf lindens 'Greenspire' and Fairview™ littleleaf linden have the highest chilling requirement of the selections evaluated. 'Sterling Silver' silver linden demonstrated the lowest chilling requirement and the highest budbreak percentage of all selections across all treatments evaluated. American linden 'Redmond' and silver linden 'Sterling Silver' required the fewest hours of chilling to produce measurable foliar budbreak.

Following termination of the greenhouse portion of this study, all trees were moved back to the growing area outdoors to allow observation of subsequent growth. By the end of the growing season in Fall 2000, differences observed in initial budbreak were magnified. Trees within each cultivar that had received greater amounts of chilling were larger than trees receiving less chilling. Furthermore, overall growth was greater on 'Sterling Silver' than other cultivars, with the least overall growth occurring for 'Redmond'. This study indicates the need to carefully select lindens suitable for the region in which they will be grown, whether in field or container production or in the landscape.

For red maple cultivars, the level of chilling exposure required for foliar budbreak was inversely related to heat unit accumulation. By extending the chilling duration, fewer heat units were required to produce budbreak. The higher chilling treatments also generally exhibited the highest mean percent budbreak over the course of the experiment. For example, October Glory® PP2116 red maple required a minimum of 600 chilling h to reach budbreak. Subsequent treatments produced greater budbreak percentages but with fewer heat units. Both 'Autumn Fantasy'(see *A.* ×*freemanii* 'Autumn Fantasy') and 'Franksred' (Red Sunset® red maple) exhibited minimal budbreak after 200 h of chilling. As with October Glory®, higher budbreak percentages from fewer heat units were achieved by increasing the chilling levels. In one red maple study, seven cultivars, including Northwood® PP5053 red maple, a cultivar from Minnesota; October Glory® from New Jersey; and 'Florida Flame' from central Florida were placed in the greenhouse prior to any chilling accumulation. In the late spring trees of October Glory® eventually broke bud and 'Florida Flame' never seemed to go completely dormant and started growing again before any other cultivars. However, no 'Northwood' trees broke bud, and all trees became dried with dead stems.

These observations were similar to those recorded by Ashby et al. (1991). It may be concluded that growers who modify lifting and transplanting schedules based upon chilling accumulation could accelerate production of these cultivars. Tissue-cultured plantlets and rooted cuttings could be produced at a faster rate by alternating cold storage with greenhouse growing conditions (Sorenson et al., 1994; Wood and Hanover, 1981). The interaction of chilling and subsequent heat necessary to release a plant from dormancy is a complex problem to understand. At first glance, an earlier study by Townsend (1977) appears to indicate that some southern red maple progenies have longer chilling requirements than more northern progenies. However, careful study indicates that the chilling levels received by all progenies prior to budbreak would have been the same. What varied was the subsequent heat units necessary to release the different progenies from dormancy.

More research will be needed to develop regional planting models for various ornamental trees. The processes that lead to dormancy and budbreak within a plant consist of many interacting factors (temperature, light, physiological and chronological age of plant, apical dominance, provenance, hormonal balances, environmental conditions, drought, fertility, etc.). These factors as related to chilling and heat must be studied further to present a more accurate picture of specific chilling requirements in individual cultivars. Finally, one of the most critical concerns yet to be addressed is a determination of the optimal temperatures to break dormancy. The study presented here assumed ambient temperatures below 7°C (45°F) and a constant 3°C (38°F) when applied in a cooler as adequate to accomplish chilling, and that maintaining the greenhouse environment above 22°C (72°F) was ideal for flushing. Perhaps lower or higher temperatures could be considered more effective for breaking dormancy. Also, differences between constant versus fluctuating temperatures in a natural or simulated environment merit additional study.

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