EFFECTS OF CHILLING AND HEAT ON GROWTH OF *GINKGO BILOBA* L.

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Abstract. The effects of chilling on growth and development of ginkgo biloba (*Ginkgo biloba* L.) seedlings were evaluated in a study initiated on February 1, 1999, and terminated on September 10, 2002. Thirteen levels of chilling were applied to trees in increments of 100 hours, with 12 replications per treatment. Increased chilling led to a decreased heat unit requirement, resulting in greater overall growth and development. Within the group of trees receiving the same treatment for three consecutive years, trees receiving 1,100 chill hours had greater caliper, terminal shoot extension, and total plant height. In this same group, greater limb structure was obtained from trees receiving 600 chill hours. Chilling was a determinate factor in growth and development.

Key Words. Chilling requirement; cold storage; dormancy; heat; endodormancy; ornamental; provenance.

Ginkgo biloba L., often referred to as a living fossil, is a valuable and interesting landscape tree. A monotypic genus, *G. biloba* is native to China. In North America, *Ginkgo* is grown from southern Canada to central Florida, and from the East Coast to the West Coast (USDA Hardiness Zones 3–9) (Kwant 2002). *Ginkgo biloba* can reach a mature height of 24.4 m (80 ft) and a width of 12.2 m (40 ft), with a naturally slow to medium growth rate. Trees are often pyramidal when young and become wide spreading when older. Although a common urban tree, resistant to many insects and diseases, *G. biloba* grows best in full to partial sun and moist, well-drained soils. More than 40 cultivars, with forms ranging from dwarf to majestic or broad to fastigate, are available for landscape plantings (Dirr 1998).

Dormancy in plants has been described as a state in which visible growth is temporarily suspended (Samish 1954), a phase in a plant's development allowing it to survive winter conditions (Saure 1985), and a state in which deciduous plants are not in leaf or are lacking visible growth (Westwood 1995). Endodormancy release from within plant parts, as controlled by chilling temperatures, is a major factor in determining a plant's performance in a given climate or hardiness zone (Westwood 1995). Temperate-zone plants must be exposed to a certain period of chilling temperatures above freezing (Westwood 1995) or a minimum number of hours below 7°C (45°F) (Saure 1985) for dormancy release to occur, with this exposure period referred to as the chilling requirement. Dormancy requirements of landscape trees are of particular interest to the arborist and urban forester. Trees noted to perform well in northern climates, such as flowering cherries, spruce, or beech, may perform poorly or not at all in southern climates. In other cases, trees noted to perform well in the south may leaf out too early in the north, resulting in cold and frost damage (Lechowicz 1984).

Much work has been reported on fruit species with respect to dormancy and chilling requirements. In a study with peaches (*Prunus persica* (L.) Batsch), once rest was satisfied, prolonged chilling was shown to enhance leafing over blooming (Citadin et al. 2001). There are also cultivar differences in heat requirement for bloom. In a study with several fruit tree species, once rest was satisfied, prolonged chilling led to a decreased need for heat to reach budbreak (Couvillon and Erez 1985).

Some work on the dormancy and chilling requirements of ornamental species has also been done. Increased chill hours in dogwood (*Cornus florida* L.) leads to fewer days to budbreak, indicating that early lifting and transplanting increases survival rates (Ruter et al. 1994). Ashby et al. (1991) report that terminal buds require more chilling than lateral buds in silver maple (*Acer saccharinum* L.). The optimal chilling requirements of two red maple (*Acer rubrum* L.) cultivars and one Freeman red maple (*Acer × freemanii* E. Murray) cultivar have been determined (Sibley et al. 2001; Wilson et al. 2002a). Also, increasing the duration of chilling accelerates the rate of foliar budbreak and reduces the number of heat units required to initiate foliar budbreak in linden (*Tilia* spp.) cultivars (Sibley et al. 2001; Wilson et al. 2002b).

Most research on *G. biloba* has been focused on medicinal purposes (Follett et al. 2001; Juretzek 1997), with little attention given to cultural and environmental requirements. No reports have addressed the dormancy requirements of *G. biloba*. The objective of this work was to evaluate the overall growth and development responses of *G. biloba* to incremental chilling.

MATERIALS AND METHODS

Two hundred, 46 cm (18 in.) tall liners of *Ginkgo biloba* L. seedlings were purchased from Musser Forests, Inc. (Indiana, PA) from a Mississippi seed source, in winter 1999.

Trees were initially potted into 3.8 L (#1) containers using a 6:1 pinebark:sand substrate amended with 2 kg m^{-3} (3.3 lb/yd^3) dolomitic limestone, 0.6 kg m^{-3} (1 lb/yd^3) Micromax (The Scotts Co., Marysville, OH), and 4.2 kg m^{-3} (7.3 lb/yd^3) 18N-6P-12K Osmocote (The Scotts Co.). Trees were transplanted to 7.9 L (#2), 13.5 L (#3), and 22 L (#5) containers in 2000, 2001, and 2002, respectively, of the study. Trees were grown outdoors with overhead irrigation at the Paterson Greenhouse Complex, Auburn, Alabama (32° 36' N × 85° 20' W, USDA Hardiness Zone 8a).

The 4-year study included 13 treatment levels of chilling applied in increments of 100 hours (0–1,200). Each treatment was applied to four single tree replications at the end of year 1 (1999–2000) for a total of 52 trees. Trees not selected for treatment at the end of year 1 received ambient chilling (998 hours for the season), while remaining on the container pad area. In year 2 (2000–2001), four single-tree replications were added to each treatment for a total of 104 trees. Trees not selected for treatment at the end of year 2 received ambient chilling (1,487 hours for the season), while remaining on the container pad area. In year 3 (2001–2002), four single-tree replications were added to each treatment for a total of 156 trees. Treatment levels were applied to the same replicates each year. Therefore, four replications received the same treatment for 3 years (group one); four replications received the same treatment for 2 years (group two); and four replications received the same treatment for 1 year (group three). Chilling hours were calculated using the Old 45 Chilling Model (Powell et al. 1999), which counts hours below 7°C (45°F) as chilling hours beginning October 1 for each year.

Each September before receiving any chill hours, four trees were randomly selected to receive 0 chill hours and placed in a heated greenhouse maintained at a minimum of 22°C (72°F). In late fall 1999, with an accumulation of 100 and 200 natural, ambient chill hours, four trees were randomly selected to receive 100 and 200 chill hours, respectively, and placed into the greenhouse. After receiving 200 ambient chill hours, the 40 trees to receive 300 to 1,200 chill hours were placed into a thermostatically controlled cooling unit (Funchess Hall, Auburn University, AL) maintained at 3°C (38°F) until the desired chill-hour increments were accumulated. Trees were removed in 100-hour increments and placed into the greenhouse. Trees were arranged in a completely randomized design (CRD), hand-weeded, and watered as needed. The same pattern of treatment management was used in fall 2000 and fall 2001 on the first four replicates (year 1 trees) and followed by the same pattern for year 2 trees and year 3 trees.

After placement in greenhouse each year, trees were evaluated at the end of the annual growth cycle for overall growth and development. Terminal new shoot extension, number of limbs, and average length of each limb were measured. At the end of the summer growing period, trees were measured for total plant height and caliper. Data were analyzed with regression analysis, performed using orthogonal contrast statements in order to prevent masking of significant effects due to multicollinearity (Neter et al. 1996). All analyses were performed with SAS Software (SAS 1999).

RESULTS AND DISCUSSION

This report presents data following four growing seasons. Chilling is a determinate factor in growth and development of ginkgo biloba (*Ginkgo biloba* L.). As chilling levels were increased, different aspects of growth increased, such as terminal shoot extension, caliper, total plant height, and total limb length.

Caliper

A linear treatment effect in caliper was observed in trees that received 3 consecutive years of forced chilling (group one) ($y = 18.0 + 0.0053x$, $r = 0.39$, $p = 0.007$). Mean caliper ranged from 17 mm (0.7 in.) (300 hours) to 26.7 mm (1.1 in.) (1,100 hours). Trees receiving 1,100 hours had greater caliper than trees receiving 200 to 600 and 1,000 hours. Trees receiving 700, 900, and 1,200 hours had greater caliper than trees receiving 300 and 500 hours (Table 1).

Table 1. Final caliper of *Ginkgo biloba* L. following 3 years of forced chilling (group one); 1 year of ambient chilling (998 hours) and 2 years of forced chilling (group two); and 2 years of ambient chilling (998 and 1,487 hours) and 1 year of forced chilling (group three).[z]

Chill hours[y]	Group one[x]	Group two[x]	Group three[x]
100	22.5 ab	16.3 d	21.0 cd
200	19.8 bc	22.1 abcd	20.6 cd
300	17.0 c	16.7 cd	22.9 bcd
400	19.2 bc	21.1 abcd	19.5 cd
500	17.1 c	18.2 bcd	21.8 bcd
600	18.0 bc	22.9 abcd	29.1 a
700	24.2 ab	26.1 a	17.5 d
800	23.7 abc	23.0 abcd	20.8 cd
900	24.9 ab	20.6 abcd	22.9 bcd
1,000	19.5 bc	19.1 abcd	23.6 abc
1,100	26.7 a	25.0 ab	27.3 ab
1,200	24.2 ab	23.4 abc	25.0 abc
Regression equation	$y = 18.0 + 0.0053x$	$y = 18.0 + 0.0049x$	$y = 20.1 + 0.0039x$
r	0.39	0.35	0.30
p-value	0.007	0.016	0.036

[z]Caliper measured in mm at 51 mm above soil line at the end of 3 years, 1999–2002.
[y]Chilling was applied to each treatment at 4°C (38°F) in a cooler in 100-hour increments following 200 hours of ambient chilling to ensure dormancy prior to treatments.
[x]Means within a column with the same letter are similar according to Duncan's multiple range test ($\alpha = 0.05$).

A linear treatment effect in caliper was observed in trees that received 1 year of ambient chilling and 2 years of forced chilling (group two) (y = 18.0 + 0.0049x, r = 0.35, p = 0.016). Mean caliper ranged from 16.3 mm (0.65 in.) (100 hours) to 26.1 mm (0.1 in.) (700 hours). Trees receiving 700 hours had greater caliper than trees receiving 100, 300, and 500 hours. Trees receiving 1,100 hours had greater caliper than trees receiving 100 and 300 hours. Trees receiving 1,200 hours had greater caliper than trees receiving 100 hours (Table 1).

A linear treatment effect in caliper was observed in trees that received 2 years of ambient chilling and 1 year of forced chilling (group three) (y = 20.1 + 0.0039x, r = 0.30, p = 0.036). Mean caliper ranged from 17.5 mm (0.7 in.) (700 hours) to 29.1 mm (1.2 in.) (600 hours). Trees receiving 600 hours had greater caliper than trees receiving 100 to 500 and 700 to 900 hours. Trees receiving 1,100 hours had greater caliper than trees receiving 100, 200, 400, 700, and 800 hours. Trees receiving 1,000 and 1,200 hours had greater caliper than trees receiving 700 hours (Table 1).

A linear treatment effect in caliper was observed when all three groups were combined. While year started was not significant, chill hours were. There was also an interaction between the two. Mean caliper results were similar to those from group one.

Table 2. Final total plant height of *Ginkgo biloba* L. following 3 years of forced chilling (group one); 1 year of ambient chilling (998 hours) and 2 years of forced chilling (group two); and 2 years of ambient chilling (998 and 1,487 hours) and 1 year of forced chilling (group three).[z]

Chill hours[y]	Group one[x]	Group two[x]	Group three[x]
100	210 abc	157 b	204 b
200	188 abc	203 ab	187 b
300	160 c	149 b	214 ab
400	166 bc	200 ab	200 b
500	166 bc	185 ab	214 ab
600	165 bc	212 ab	221 ab
700	218 abc	232 a	189 b
800	223 abc	208 ab	203 b
900	232 ab	197 ab	217 ab
1,000	193 abc	184 ab	212 ab
1,100	244 a	248 a	254 a
1,200	231 ab	225 a	225 ab
Regression equation	y = 166.0 + 0.053x	y = 166.3 + 0.052x	y = 192.5 + 0.029x
r	0.40	0.41	0.34
p-value	0.005	0.004	0.017

[z]Total plant height measured in cm from base of the plant to highest possible point, at the end of 3 years, 1999–2002.
[y]Chilling was applied to each treatment at 4°C (38°F) in a cooler in 100-hour increments following 200 hours of ambient chilling to ensure dormancy prior to treatments.
[x]Means within a column with the same letter are similar according to Duncan's multiple range test (α = 0.05).

Total Plant Height

A linear treatment effect in height was observed in trees that received 3 consecutive years of forced chilling (group one) (y = 166.0 + 0.053x, r = 0.40, p = 0.005). Mean total plant height ranged from 160 cm (63 in.) (300 hours) to 243 cm (95.7 in.) (1,100 hours). Trees receiving 1,100 hours had greater height than trees receiving 300 to 600 hours. Trees receiving 900 and 1,200 hours had greater height than trees receiving 300 hours (Table 2).

A linear treatment effect in height was observed in trees that received 1 year of ambient chilling and 2 years of forced chilling (group two) (y = 166.3 + 0.052x, r = 0.41, p = 0.004). Mean total plant height ranged from 149 cm (58.7 in.) (300 hours) to 248 cm (97.6 in.) (1,100 hours). Trees receiving 700, 1,100 and 1,200 hours had greater height than trees receiving 100 and 300 hours (Table 2).

A linear treatment effect in height was observed in trees that received 2 years of ambient chilling and 1 year of forced chilling (group three) (y = 192.5 + 0.029x, r = 0.34, p = 0.017). Mean total plant height ranged from 186 cm (73.2 in.) (200 hours.) to 253 cm (99.6 in.) (1,100 hours). Trees receiving 1,100 hours had greater height than trees receiving 100, 200, 400, 700, and 800 hours (Table 2).

With all three groups combined, a linear treatment effect in height was observed. While year started was not significant, chill hours were. Mean caliper results were similar to those from groups one through three.

Terminal Shoot Extension (TSE)

There was no statistical significance with terminal shoot extension between the treatments that received 3 consecutive years of forced chilling (group one). Mean terminal shoot extension ranged from 39.3 cm (15.5 in.) (400 hours) to 64.8 cm (25.5 in.) (1,100 hours) (Table 3). A linear treatment effect in TSE was observed in trees that received 1 year of ambient chilling and 2 years of forced chilling (group two) (y = 42.0 + 0.017x, r = 0.30, p = 0.040). Mean terminal shoot extension ranged from 31 cm (12.2 in.) (500 hours) to 71.8 cm (28.3 in.) (1,100 hours). Trees receiving 700 and 1,100 hours had greater TSE than trees receiving 100 and 500 hours. Trees receiving 200 hours had greater TSE than trees receiving 500 hours (Table 3).

There was little difference between the treatments that received 2 years of ambient chilling and 1 year of forced chilling (group three) (y = 55.5 + 0.012x, r = 0.24, p = 0.096). Mean terminal shoot extension ranged from 52.3 cm (20.6 in.) (1,000 hours) to 80.5 cm (31.7 in.) (800 hours). Trees receiving 800 hours had greater TSE than trees receiving 1,000 hours (Table 3). With all three groups combined, a linear treatment effect in TSE was observed. Chill hours and year started were significant, but there was no interaction. Trees started in year 3 had greater TSE than trees started in years 1 and 2. This result could be due to receiving more ambient chilling and or other factors.

Limb Length and Average

A linear treatment effect was observed for total limb length and number of limbs, and a quadratic effect for average limb length, for trees receiving forced chilling for 3 consecutive years (group one). Mean total length ranged from 168 cm (66.1 in.) (200 hours) to 446 cm (175.6 in.) (600 hours). Trees receiving 600, 900, and 1,100 hours had greater total limb length than trees receiving 200 hours (Table 4) ($y = 224.3 + 0.122x$, $r = 0.27$, $p = 0.062$). Mean limb number ranged from 4.5 (200 hours) to 13.3 (600 hours). Trees receiving 600 hours had greater limb numbers than trees receiving 200 and 300 hours. Trees receiving 900 hours had greater limb numbers than trees receiving 200 hours (Table 5) ($y = 5.5 + 0.0044x$, $r = 0.33$, $p = 0.022$). Mean limb length ranged from 29.4 cm (11.6 in.) (600 hours) to 45.3 cm (17.8 in.) (100 hours). Trees receiving 100 hours had greater mean limb length than trees receiving 500 and 600 hours (Table 6).

While there was no statistical significance, a trend indicated that trees receiving 1 year of ambient chilling and 2 years of forced chilling had noticeable effects (group two). Mean total limb length ranged from 132 cm (52 in.) (300 hours) to 338 cm (133.1 in.) (800 hours) (Table 4). Mean limb number ranged from 3.5 (300 hours) to 9 (400 hours) (Table 5). Mean limb length ranged from 35.1 cm (13.8 in.) (1,000 hours) to 45 cm (17.7 in.) (600 hours) (Table 6).

A linear treatment effect was observed for total limb length and number of limbs for trees receiving 2 years of ambient chilling and 1 year of forced chilling (group three). Mean total limb length ranged from 147 cm (57.9 in.) (400 hours) to 483 cm (190.2 in.) (1,100 hours). Trees receiving 1,100 and 1,200 hours had greater total limb length than trees receiving 100, 300, 400, 700, and 800 hours (Table 4) ($y = 102.0 + 0.279x$, $r = 0.51$, $p = 0.001$). Mean limb number ranged from 4.3 (400 hours) to 12.3 (1,200 hours). Trees receiving 1,200 hours had greater total limb length than trees receiving 100 to 400 and 700 hours. Trees receiving 1,100 hours had greater total limb length than trees

Table 3.Terminal shoot extension of *Ginkgo biloba* L. following 3 years of forced chilling (group one); 1 year of ambient chilling (998 hours) and 2 years of forced chilling (group two); and 2 years of ambient chilling (998 and 1,487 hours) and 1 year of forced chilling (group three).[z]

Chill hours[y]	Group one[x]	Group two[x]	Group three[x]
100	48.5 a	36.5 bc	53.3 ab
200	51.0 a	62.3 ab	55.8 ab
300	46.5 a	43.0 abc	60.8 ab
400	39.3 a	53.5 abc	63.5 ab
500	50.8 a	31.0 c	63.0 ab
600	43.7 a	59.8 abc	61.0 ab
700	58.0 a	70.8 a	57.8 ab
800	45.3 a	50.8 abc	80.5 a
900	51.3 a	56.5 abc	65.5 ab
1,000	50.0 a	54.0 abc	52.3 b
1,100	64.8 a	71.8 a	77.5 ab
1,200	60.8 a	58.0 abc	65.8 ab
Regression equation	NS	$y = 42.0 + 0.017x$	$y = 55.5 + 0.012x$
r	—	0.30	0.24
p-value	—	0.040	0.096

[z]Terminal shoot extension measured in cm from tip of previous season's growth to tip of current season's terminal bud, at the end of 3 years, 1999–2002.
[y]Chilling was applied to each treatment at 4°C (38°F) in a cooler in 100-hour increments following 200 hours of ambient chilling to ensure dormancy prior to treatments.
[x]Means within a column with the same letter are similar according to Duncan's multiple range test ($\alpha = 0.05$).

Table 4.Total limb length of *Ginkgo biloba* L. following 3 years of forced chilling (group one); 1 year of ambient chilling (998 hours) and 2 years of forced chilling (group two); and 2 years of ambient chilling (998 and 1,487 hours) and 1 year of forced chilling (group three).[z]

Chill hours[y]	Group one[x]	Group two[x]	Group three[x]
100	312 ab	180 a	159 b
200	168 b	327 a	234 ab
300	225 ab	132 a	186 b
400	269 ab	321 a	147 b
500	217 ab	158 a	227 ab
600	446 a	290 a	371 ab
700	249 ab	251 a	147 b
800	397 ab	338 a	187 b
900	424 a	179 a	414 ab
1,000	252 ab	236 a	377 ab
1,100	445 a	283 a	483 a
1,200	281 a	255 a	468 a
Regression equation	$y = 224.3 + 0.122x$	NS	$y = 102.0 + 0.279x$
r	0.27	—	0.51
p-value	0.062	—	0.001

[z]Total limb length measured in cm from trunk to tip of lateral bud, at the end of 3 years, 1999–2002.
[y]Chilling was applied to each treatment at 4°C (38°F) in a cooler in 100-hour increments following 200 hours of ambient chilling to ensure dormancy prior to treatments.
[x]Means within a column with the same letter are similar according to Duncan's multiple range test ($\alpha = 0.05$).

receiving 100, 300, 400, and 700 hours. Trees receiving 900 hours had greater total limb length than trees receiving 100, 400, and 700 hours (Table 5) ($y = 2.9 + 0.007x$, $r = 0.53$, $p = 0.001$). Mean limb length ranged from 22.3 cm (8.8 in.) (800 hours) to 41.8 cm (16.4 in.) (1,100 hours). Trees receiving 200, 1,000, and 1,100 hours had greater mean limb length than trees receiving 800 hours (Table 6).

CONCLUSIONS

Tree growers often must make decisions about which species best fit into their production cycle. Many aspects influence the product-mix decision, most notably whether a species can be produced in a given region in a timely manner. For *G. biloba*, satisfying dormancy requirements is of great importance for the production process. This study reveals chilling to be a determinate factor in growth and development of *G. biloba*. Optimal chilling for overall growth and development appears to begin in the 600 to 700 chill hour range. Increasing chill hours results in greater overall growth and development with a decreased need for heat. For growers using greenhouse production methods, adjusting environmental conditions to allow chilling can accelerate and lead to more efficient production. For growers using field production methods, modifying lifting and transplanting schedules based on chilling accumulation can lead to improved growth in the first year for the customer, providing more rapid foliar emergence. It is reasonable to predict that tissue-cultured plantlets and rooted cuttings may be produced at a faster rate by alternating cold storage with greenhouse growing conditions (Sorenson et al. 1984; Wood and Hanover 1981). Although *G. biloba* is a suitable landscape choice based on the amount of chilling received for much of the United States, this study shows that field production may be better suited to areas receiving 700 or more hours of chilling. This study may also provide a basis for future evaluation of chilling response for *G. biloba* cultivars.

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Table 5. Total limb number of *Ginkgo biloba* L. following 3 years of forced chilling (group one); 1 year of ambient chilling (998 hours) and 2 years of forced chilling (group two); and 2 years of ambient chilling (998 and 1,487 hours) and 1 year of forced chilling (group three).[z]

Chill hours[y]	Group one[x]	Group two[x]	Group three[x]
100	7.0 abc	4.8 a	4.3 d
200	4.5 c	8.8 a	5.5 bcd
300	5.5 bc	3.5 a	4.8 cd
400	6.5 abc	9.0 a	4.3 d
500	7.3 a	4.3 a	7.0 abcd
600	13.3 a	6.5 a	9.0 abcd
700	7.8 abc	5.8 a	4.3 d
800	10.8 abc	8.0 a	6.3 abcd
900	12.3 ab	5.0 a	11.3 acd
1,000	7.3 abc	7.0 a	8.5 abcd
1,100	11.8 abc	6.5 a	11.8 ab
1,200	8.3 abc	5.8 a	12.3 a
Regression equation	$y = 5.5 + 0.0044x$	NS	$y = 2.9 + 0.007x$
r	0.33	—	0.53
p-value	0.022	—	0.001

[z]Total limb number measured at the end of 3 years, 1999–2002.
[y]Chilling was applied to each treatment at 4°C (38°F) in a cooler in 100-hour increments following 200 hours of ambient chilling to ensure dormancy prior to treatments.
[x]Means within a column with the same letter are similar according to Duncan's multiple range test ($\alpha = 0.05$).

Table 6. Final limb length average of *Ginkgo biloba* L. following 3 years of forced chilling (group one); 1 year of ambient chilling (998 hours) and 2 years of forced chilling (group two); and 2 years of ambient chilling (998 and 1,487 hours) and 1 year of forced chilling (group three).[z]

Chill hours[y]	Group one[x]	Group two[x]	Group three[x]
100	45.3 a	37.3 a	28.6 ab
200	37.2 ab	39.2 a	41.3 a
300	41.3 ab	36.1 a	36.2 ab
400	40.4 ab	40.4 a	34.3 ab
500	30.4 b	36.5 a	28.6 ab
600	29.4 b	45.0 a	38.9 ab
700	32.7 ab	44.5 a	25.8 ab
800	37.7 ab	43.0 a	22.3 b
900	37.1 ab	37.1 a	36.0 ab
1,000	35.5 ab	35.1 a	41.6 a
1,100	41.0 ab	43.1 a	41.8 a
1,200	36.1 ab	44.8 a	38.7 ab
Regression equation	NS	NS	NS
r	—	—	—
p-value	—	—	—

[z]Final limb length average measured in cm from trunk to tip of lateral bud, at the end of 3 years, 1999–2002.
[y]Chilling was applied to each treatment at 4°C (38°F) in a cooler in 100-hour increments following 200 hours of ambient chilling to ensure dormancy prior to treatments.
[x]Means within a column with the same letter are similar according to Duncan's multiple range test ($\alpha = 0.05$).

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Résumé. Les effets du froid sur la croissance et le développement de semis d'arbres aux quarante écus (*Ginkgo biloba* L.) a été évalué dans une recherche initiée le 1er février 1999 et terminée le 10 septembre 2002. Treize degrés de froid ont été appliqués sur les arbres par gradients de 100 heures, et ce à 12 reprises par traitement. Le froid accrû produisait une diminution du besoin en unités de chaleur, ce qui résultait en une croissance globale et un développement accrus. À l'intérieur du groupe d'arbres ayant reçu le même traitement durant trois années consécutives, les arbres ayant reçu 1100 heure de froid avaient un calibre de tronc, une croissance apicale et une hauteur totale plus élevés. Dans ce même groupe, une structuration supérieure des branches était obtenue des arbres ayant reçu 600 heures de froid. Le froid a été un facteur déterminant dans la croissance et le développement.

Zusammenfassung. Die Einflüsse von Frost auf das Wachstum und die Entwicklung von *Ginkgo biloba*-Sämlingen wurde in einer Studie, die am 1. Februar 1999 begann und am 10. September 2002 endete, bewertet. 13 Grade von Frost wurden an den Bäumen getestet über einen Zeitraum von 100 Stunden mit 12 Wiederholungen pro Behandlung. Stärkere Frosteinwirkung führte zu abnehmender Wärmeanforderung, was zu größerem Wachstum und Entwicklung führte. Innerhalb der Gruppe von Bäumen, die dieselbe Behandlung über drei aufeinander folgende Jahre erhielten, hatten die Bäume mit 1100 Froststunden einen größeren Umfang, Ausdehnung der Terminalknospe und absolute Pflanzenhöhe. In der selben Gruppe entwickelte sich eine größere Verzweigung für Bäume mit 600 Froststunden. Der Frost war eine entscheidende Größe für Wachstum und Entwicklung.

Resumen. Fueron evaluados los efectos de la exposición a horas frío sobre el crecimiento y desarrollo de brinzales de Ginkgo biloba (*Ginkgo biloba* L.) en un estudio iniciado en Febrero de 1999 y terminado en Septiembre 10 de 2002. Se aplicaron trece niveles de enfriamiento a los árboles en incrementos de 100 horas, con doce repeticiones por tratamiento. El incremento en horas frío permitió un requerimiento de menos unidades de calor, resultando en mayor crecimiento y desarrollo. Dentro del grupo de los árboles que recibieron el mismo tratamiento por tres años consecutivos, los árboles que recibieron 1100 horas frío tuvieron mayores diámetro del tronco, extensión de brotes terminales y altura total de la planta. En este mismo grupo, se obtuvo mayor estructura del tronco de los árboles que recibieron 600 horas frío. Las horas frío es un factor determinante en el crecimiento y desarrollo.