Arboriculture & Urban Forestry 2007. 33(3):193–201.

ARBORICULTURE & URBAN FORESTRY
Scientific Journal of the International Society of Arboriculture

Temperature Fluctuation in *Fraxinus pennsylvanica* var. *subintegerrima* and Its Surrounding Environment

A.M. Shirazi and S.H. Vogel

Abstract. Temperature fluctuation (TF) in an 18-year-old *Fraxinus pennsylvanica* var. *subintegerrima* and its surrounding environment was monitored using HOBO Pro temperature sensors recording every 15 min from December 2001 to February 2003 at The Morton Arboretum, Lisle, Illinois, U.S. There were significant differences ($P < 0.05$) between TF in 2001, mild cold temperatures, and 2003, severe record-breaking cold temperatures. In mid-December 2001, TF range in soil 30 cm (12 in) was 4°C (39.2°F) to 4.5°C (40.1°F), sod was 3°C (37.4°F) to 4°C (39.2°F), and soil surface was 2°C (35.6°F) to 2.5°C (36.5°F), whereas canopy and mulch ranged from −1°C (30.2°F) to 10°C (50°F). The south side of the trunk had the highest fluctuation of 1°C (33.8°F) to 14°C (57.2°F) followed primarily by the west side with occasional peaks in the east. However, the west side had the highest temperature peak in mid-June. The temperature difference between south and north sides during mid-December were approximately 7°C (44.6°F). In April, the TF inside the trunk ranged from 2°C (35.6°F) to 5.5°C (41.9°F) compared with the canopy, which varied between −0.5°C (31.1°F) and 8°C (46.4°F). The west side was 2°C (35.6°F) to 3°C (37.4°F) higher in mid-July than the south, east, and north sides. On 15 February 2003, which was the coldest day recorded, the soil 30 cm (12 in) temperature (under the mulch) reached ≈−1°C (≈30.2°F), whereas sod and soil surface were ≈−2°C (≈28.4°F). Mulch and base temperature ranged from −1°C (30.2°F) to −5°C (23°F) and −2.5°C (27.5°F) to −7.5°C (18.5°F), respectively. Root core temperature was ≈−1°C (≈30.2°F), the trunk temperature range was −2.5°C (27.5°F) to −3.5°C (25.7°F), whereas the canopy was −2.5°C (27.5°F) to −7.5°C (18.5°F). The south TF range was between −0.5°C (31.1°F) and −7.5°C (18.5°F) from midday to midnight. The TF difference between south and north sides was ≈2.5°C (≈36.5°F). This freeze and thaw of the south side during winter months has been attributed to sunscald in some trees. Based on temperature observations during the coldest and warmest week, a temperature fluctuation factor (TFF), a difference between weekly minimum and maximum temperature, was introduced. During the coldest week, the TFF for canopy to trunk was 2×, trunk to root or soil was 10×, and canopy to root or soil was 20×. During the warmest week, the TFF for canopy to trunk was 2×, trunk to root or soil was 7.5×, and canopy to root or soil was 15×. The stem water content was higher throughout the year; however, the bud water content was significantly higher when approaching budbreak in April to May. In a companion study, the effect of mulch depth on TF was reexamined showing that the temperature of mulch varies dependent on the time of year. In October, 15 cm (6 in) mulch was several degrees warmer than ground, 7.5 cm (3 in) mulch, and 30 cm (12 in) mulch ($P < 0.05$); however, in December and February, 30 cm (12 in) of mulch was significantly warmer ($P < 0.05$). There are many factors other than temperature that affect tree growth and development. The dynamics of TF give a greater understanding of the role temperature plays in tree physiology as well as improving horticultural and arboricultural understanding in urban environments, resulting in improved landscape management.

Key Words. Canopy; cold hardiness; HOBO Pro; mulch; root zone; sod; temperature sensor.

Higher plants are ectothermic and as such are unable to maintain a constant optimum temperature in their tissues (Fitter and Hay 1987); therefore, their growth, development, and performance are all affected by environmental factors of which none are as vital as temperature (Weiser 1970). Ability of temperate woody plants to withstand freezing temperatures is affected by temperature fluctuation (TF) within the tree and its surrounding environment before freezing temperatures (Levitt 1980; Sakai and Larcher 1987). Temperature fluctuation, a frequent freezing and thawing during winter in temperate woody plants, may contribute to reduced cold hardiness (Sakai and Larcher 1987) depending on the stage of dormancy (Shirazi and Fuchigami 1995) and poststress temperature (Shirazi and Fuchigami 1993). The extreme variability of air and soil temperatures forces plants to adapt, tolerate, or avoid temperature extremes (Levitt 1980). In temperate climates, roots begin to grow after soil is thawed compared with milder climates in which roots grow all year round. The ability of roots to grow is dependent on species and genotype but is also affected by soil temperature, soil moisture, and oxygen availability (Kozlowski and Pallardy 1997).

Huttunen and Soveri (1993) reported that soil freezes to a mean annual depth of 15 (6 in) to 150 cm (60 in) depending on the location, soil moisture, soil texture, air temperature, and snow depth (Sakai 1970; Solantie 2000). The same factors also determine the time of soil thaw (Solantie 2003). Root zone temperature is dependent on soil depth and properties such as color, bulk density, moisture, texture, and type of vegetative cover. Extensive study on TF in wintering trees was first reported by Sakai in 1966. He found that the bark temperature on the south side of a tree increased sharply at noon to ≈21°C (≈69.8°F), whereas the temperature on the north side stayed nearly constant ≈−1°C (≈30.2°F) to −2°C (28.4°F) in *Kalopanaz septemlobus* koidz in Sapporo, Japan. He also reported that TF in the center of a stem is dependent on stem diameter. In the center of a tree (*Ulmus davidiana* planch var. *japonica nakai*) with a diameter of 86 cm (34.4 in), the temperature remained nearly constant throughout the day, from −0.5°C (31.1°F) to −2°C (28.4°F) in the winter. With advanced computerized sensors, we monitored TF at 14 locations in an 18-year-old *Fraxinus pennsylvanica* var. *subintegerrima* located at The Morton Arboretum, Lisle, Illinois, U.S. The objective of this study was to understand more about how trees sense their surrounding environment and how temperatures fluctuate within a tree. This information gives a greater understanding of the role temperature plays in tree physiology as well as improving horticultural and arboriculture practices in urban environments.

MATERIALS AND METHODS

HOBO Pro (Onset Corp., Bourne, MA) temperature sensors were placed at 14 different locations: east, west, north, south (1.37 m [4.5 ft] above the soil), trunk (10 cm [4 in] inside the trunk of the tree, 1.41 m [4.7 ft] above the soil layer), root (1.25 cm [0.5 in] inside the root, 30 cm [12 in] under the soil, 20 cm [8 in] from the tree), canopy (7.5 m [24.8 ft] inside the tree canopy), soil surface (under the mulch, approximately 15 cm [6 in]), mulch (7.5 cm [3 in] inside the mulch layer), base (approximately 15 cm [6 in] above mulch layer on the west side), soil 30 cm (12 in) (30 cm [12 in] into the soil under mulch), ground (placed 45 cm [18 in] aboveground, 1.8 m [5.9 ft] from the trunk), sod (placed just under the sod 1.8 m [5.9 ft] from the trunk), and snow (2.5 cm [1 in] above the mulch at trunk flair on the south side). All locations were positioned by using a handheld GPS receiver (eTrex Summit; Garmin, Olathe, KS) (Figure 1; Table 1). The temperature was recorded every 15 min from December 2001 through February 2003. Data were downloaded with an Onset HOBO Shuttle at the site and transferred to a computer in the laboratory (The Morton Arboretum, Lisle, Illinois, U.S.).

The water content of the stem and buds was measured by weighing the fresh tissues (FW) and placing them in a conventional oven at 75°C (167°F) for 48 hr. Samples were then weighed again for dry weight (DW). Percent water content was calculated by subtracting the DW from FW, dividing by FW, and multiplying by 100 (percent water content = ((FW-DW)/FW) × 100). Three samples were taken weekly from October 2002 through May 2003.

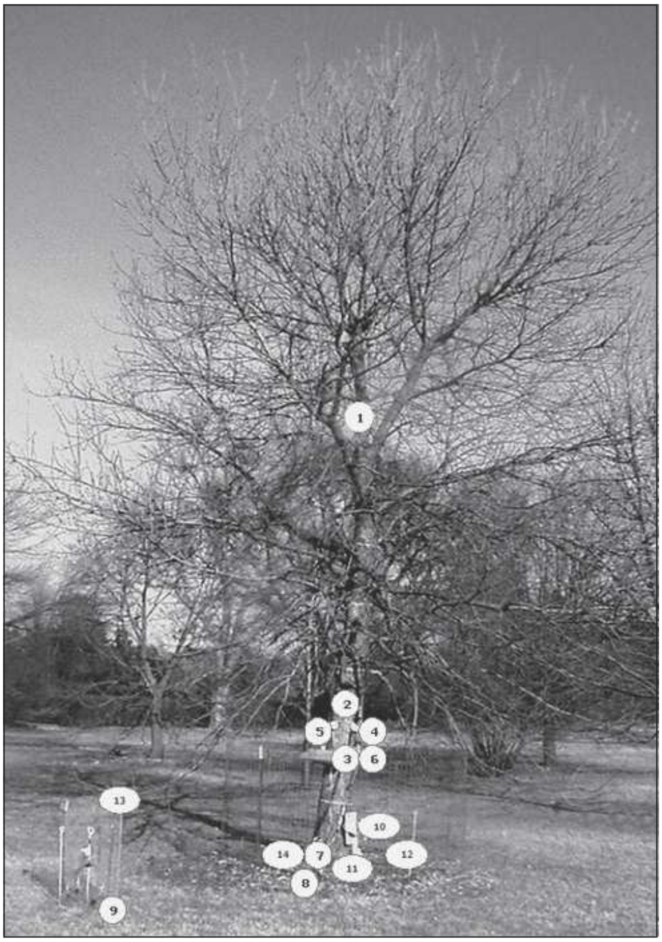

Figure 1. Location of the HOBO Pro temperature sensors on the *Fraxinus pennsylvanica* var. *subintegerrima* (red ash) tree and its surrounding environment.

For the mulch study, mixed wood mulch was placed around four *Acer saccharum* (sugar maple) 60 cm (24 in) from the trunk and HOBO Pro temperature sensors were placed approximately 20 cm (8 in) from the trunk and 10 cm (4 in) below the surface of the mulch layer. Mulch depths were 7.5, 15, and 30 cm (3, 6, and 12 in) and a bare ground area served as the control. A stake secured the HOBO Pro temperature sensors for all locations. Statistical analysis was performed using SAS software 2003 (SAS Institute Inc, Cary, NC). Analysis of variance for data were performed using time interval as the replication.

RESULTS AND DISCUSSION

There was a significant difference ($P < 0.05$) in TF among locations and years. Total mean temperature observation for

Table 1. Weekly mean of maximum and minimum temperatures observations from the 14 HOBO Pro temperature sensors[z].

Sensor number	Sensor name	Sensor position	Date	Maximum	Date	Minimum
1	Canopy	7.5 m (24.8 ft) above mulch on west side of trunk	7/16–7/23/02	26.16	1/21–1/28/03	−11.74
2	North	1.37 m (4.5 ft) above soil facing north	7/16–7/23/02	25.25	1/21–1/28/03	−11.87
3	South	1.37 m (4.5 ft) above soil facing south	7/30–1/28/03	25.54	1/21–1/28/03	−10.28
4	East	1.37 m (4.5 ft) above soil facing east	7/30–8/06/02	25.31	1/21–1/28/03	−11.15
5	West	1.37 m (4.5 ft) above soil facing west	7/16–7/23/02	25.52	1/21–1/28/03	−11.84
6	Trunk	10 cm (4 in) inside the trunk core 1.41 m (4.7 ft) above soil facing east	7/30–8/06/02	22.78	1/21–1/28/03	−10.02
7	Root	Placed into root, 30 cm (12 in) under the soil, 20 cm (8 in) from trunk, into root tissue core, 1.25 cm (0.5 in); root spreads from southwest side of trunk	7/30–8/06/02	21.95	2/11–2/18/03	−0.87
8	Soil 30 cm (12 in)	30 cm (12 in) below the soil near the root sensor	7/30–8/06/02	12.06	2/11–2/18/03	−1.14
9	Sod	5 cm (2 in) under grass	7/30–8/06/02	24.48	1/21–1/28/03	−3.14
10	Soil surface	Soil surface 15 cm (6 in) under the mulch	7/30–8/06/02	23.87	1/21–1/28/03	−3.67
11	Snow	Placed on south side of trunk, at trunk flair; ≈2.5 cm (≈1 in) above mulch	7/16–7/23/02	[y]	12/10–12/17/03	−17.39
12	Mulch	7.5 cm (3 in) into the mulch	7/30–8/06/02	25.45	1/21–1/28/03	−7.02
13	Ground	Approximately 180 cm (72 in) from trunk, to the west, 45 cm (18 in) above the sod on stake in grass area outside of canopy (grass kept trimmed)	7/16–7/23/02	25.76	1/21–1/28/03	−12.34
14	Base	15 cm (6 in) above the mulch on west side of tree	7/30–8/06/02	25.62	1/21–1/28/03	−12.06

[z] The sensor for 15 cm (6 in) mulch failed in February.
[y] No snow was present.

all 14 HOBO Pro temperature sensor locations from December 2001 through April 2002, which was considered a mild year in Northern Illinois, are shown in Figure 2. Root total TF was slightly higher than soil 30 cm (12 in). Sod and soil surface were the same as well as east and south. Canopy and base were also the same as well as the west and north sides. Total mean temperature observation from October 2002 through March 2003, which was considered a severe, record breaking cold year in Northern Illinois, are shown in Figure 2B. Root and soil 30 cm (12 in) total TF was the same as well as sod and soil surface followed by mulch, trunk, east, and canopy TF. West, north, and base were all similar with a total mean of −0.5°C (31.1°F) to 0°C (32°F). The ground location above the sod (45 cm [18 in] above sod, outside the canopy) had the lowest total mean temperature (≈−1°C [≈30.2°F]). The minimum and the maximum weekly temperature observation for all the sensor locations are shown in Table 1. The lowest minimum temperature occurred in the root −0.87°C (30.4°F) and the highest occurred in the ground −12.34°C (9.8°F), which was observed in January 2003. The root also had the lowest maximum temperature of 21.95°C (71.5°F) occurring in the first week of August 2002. The highest maximum temperature of 26.16°C (79.1°F) occurred in the canopy. The comparison of the coldest and warmest week in root, trunk, soil 30 cm (12 in), and canopy are shown in Figure 3. During the coldest week, the canopy had a TF of

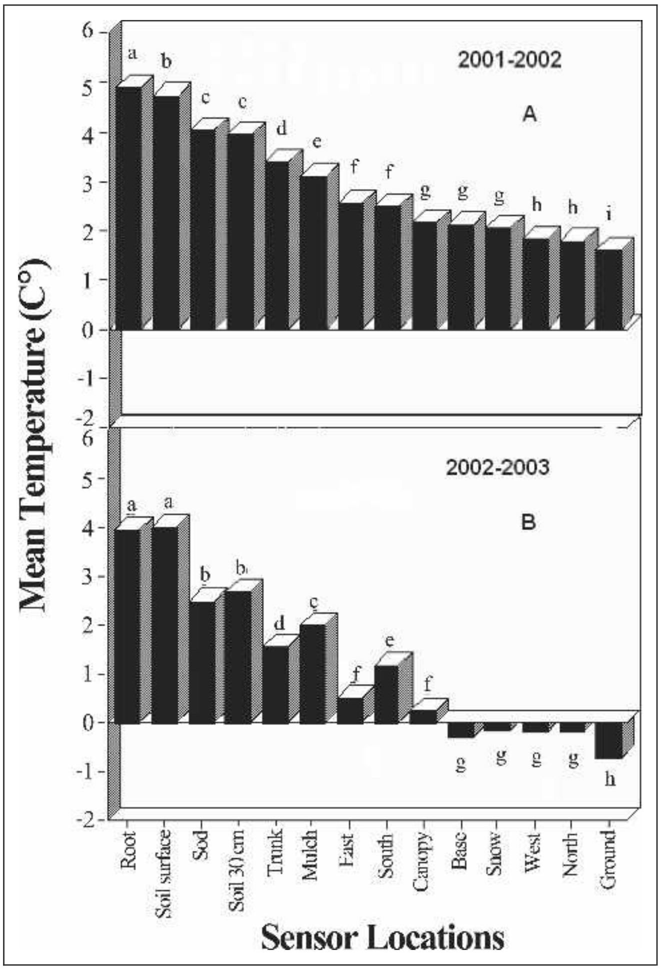

Figure 2A–B. Mean weekly temperature at 14 locations in *Fraxinus pennsylvanica* var. *subintegerrima* (red ash) during 2001 through 2003. Mean separation by Duncan's multiple range test ($P < 0.05$). Data are means of ≈16,000 observations.

20°C (68°F) (2°C [35.6°F] to −18°C [−0.4°F]) followed by the trunk with a TF of 10°C (50°F) (0°C [32°F] to −10°C [14°F]). Soil and root core had a TF of 1°C (33.8°F) (−0.5°C [31.1°F] to 0.5°C [32.9°F]). During the warmest week, the canopy experienced TF of 15°C (59°F) (17°C [62.6°F] to 32°C [89.6°F]) followed by the trunk with a TF of 7.5°C (45.5°F) (17.5°C [63.5°F] to 25°C [77°F]). Soil and root core had a TF of 1°C (33.8°F) (22.5°C [72.5°F] to 25.5°C [77.9°F]). The same pattern of TF was observed for both the coldest and the warmest weeks. The canopy showed twice the TF when compared with the trunk. The soil and root experienced only 1°C (33.8°F) TF both in the coldest and the warmest week (Figure 3). Based on this information, a temperature fluctuation factor (TFF) was developed, reflecting the difference between weekly minimum and maximum temperature. The following TFF ratios are the outcome of TF for the coldest and warmest week, in which C = canopy, T = trunk core, R = root core, and S = soil.

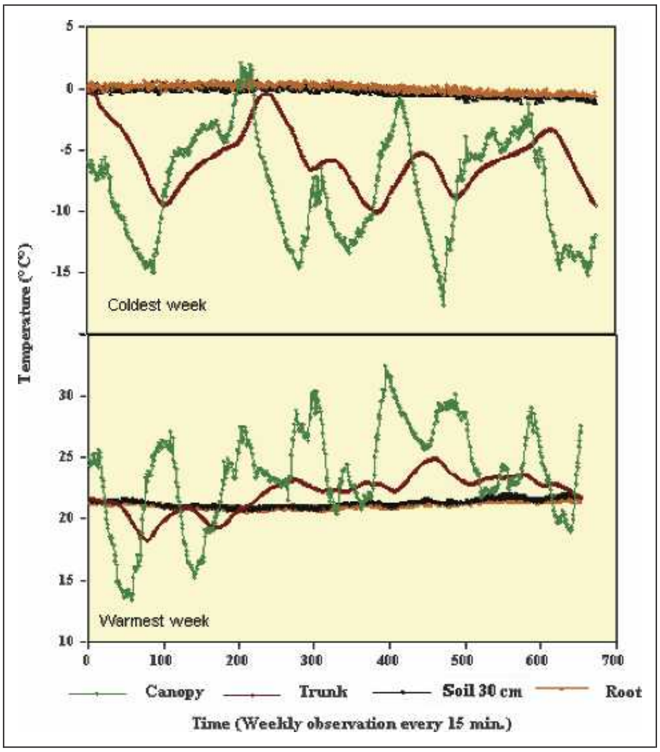

Figure 3. Comparison of coldest and warmest week temperature fluctuations in root, trunk, and canopy of *Fraxinus pennsylvanica* var. *subintegerrima* (red ash).

TFF (Coldest week)	TFF (Warmest week)
C to T = 2×	C to T = 2×
T to R or S = 10×	T to R or S = 7.5×
C to R or S = 20×	C to R or S = 15×

Considering other variables such as trunk and root diameter, soil moisture, soil textures as well as altitude and latitude may contribute to prediction of the TFF for tree management practices.

Dynamics of TF in 14 locations are shown in Figure 4 for the 15th day of each month (January 13, February 18, May 16) from January through December 2002. The first graph for each month (Figure 4) shows TF in the soil surface, sod, mulch, base, and soil 30 cm (12 in). The second graph for each month (Figure 4) shows TF in the root, trunk, and canopy. The third graph for each month (Figure 4) shows TF in the north, south, east, and west. The color codes represent each HOBO Pro temperature sensor. We observed dynamic changes in temperature every 15 min in one day of each month. April 15 shows the most classic graph regarding the TF in this study, which indicates the TF in the soil surface, soil 30 cm (12 in), sod, mulch, and base. Budbreak at this time of the year as well as the greening of grasses is often an

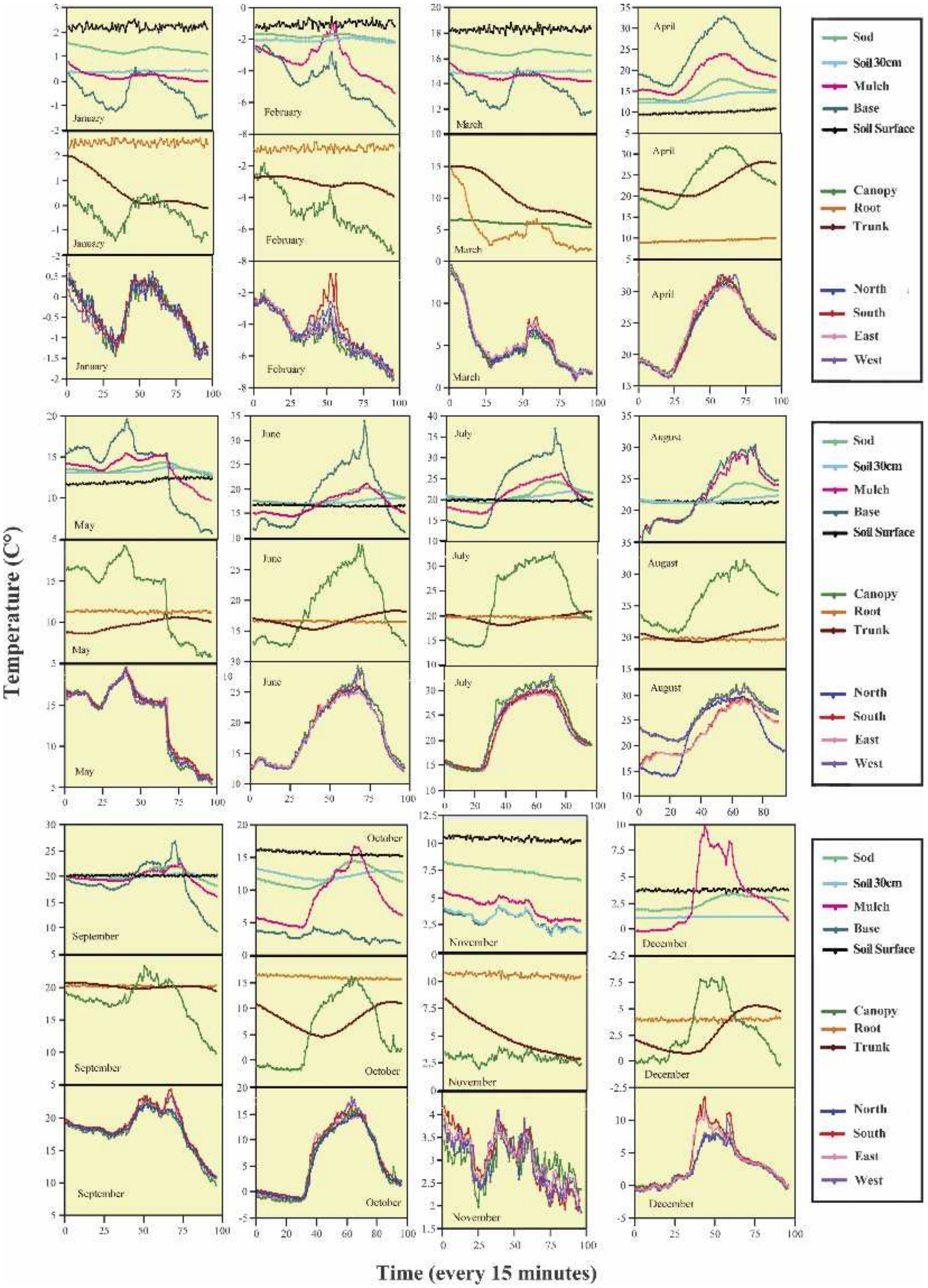

Figure 4. Daily temperature fluctuation (TF) in *Fraxinus pennsylvanica* var. *subintegerrima* (red ash) tree and its surrounding environment for the 15th day of each month from January through December 2002. The first graph for each month shows TF in soil surface, sod, mulch, base, and soil 30 cm (12 in). The second graph for each month shows TF in root, trunk, and canopy. The third graph for each month shows TF in north, south, east, west, and canopy.

indication that soil is warming up with a steady increase in soil temperature ≈10°C (≈50°F) to 15°C (59°F) during the spring. Peak of the soil temperatures are reached at ≈22°C (≈71.6°F) in mid-August and gradually decreases monthly to 20°C (68°F) in September, 17°C (62.6°F) in October, 12°C (53.6°F) in November, and 4°C (39.2°F) by December. The optimum temperature for root growth depends on species, genotype, stage of development, and availability of oxygen and water. The minimum temperature for root growth for temperate zone woody plants is between 0°C (32°F) and 5°C (41°F), whereas the optimum temperature is between 20°C (68°F) and 25°C (77°F). Lyr and Garbe (1995) reported the occurrence of lower root temperature optima in species of northern origin compared with species of southern origin. The impact of soil temperature on root growth is affected by soil moisture. Teskey and Hinckley (1981) demonstrated in white oak in Missouri that root elongation is affected by soil temperature below 17°C (62.6°F); however, above 17°C (62.6°F), it is soil moisture that is the dominant factor. Based on our results, September to November are the most appropriate times for planting trees in northern latitudes because the temperature of the root zone makes an ideal situation for root growth. TF for January and mid-February are shown in Figure 5. On 15 February 2003, which was the coldest day recorded, the soil 30 cm (12 in) temperature reached approximately −1°C (30.2°F), whereas sod and soil surface were ≈−2°C (≈28.4°F). Mulch and base temperature range was −1°C (30.2°F) to −5°C (23°F) and −2.5°C (27.5°F) to −7.5°C (18.5°F), respectively. Root core temperature was ≈−1°C (≈30.2°F), the trunk temperature was −2.5°C (27.5°F) to −3.5°C (25.7°F), whereas the canopy TF was −2.5°C (27.5°F) to −7.5°C (18.5°F). The south HOBO Pro temperature sensor TF range was between −0.5°C (31.1°F) and −7.5°C (18.5°F) from midday to midnight. The fact that soil temperature does not fluctuate and that there is a lack of cold freezing temperatures in the root zone when compared with aboveground and canopy temperatures explains the lack of cold hardiness induction in roots. Overall, the underground organs are more sensitive to frost than the shoot organs. Root tip low temperature tolerance is between −1°C (30.2°F) and −3°C (26.6°F) (Sakai and Larcher 1987). Depending on the stage of development and species, the permanent roots freeze at −5°C (23°F) to −20°C (−4°F) (Sakai and Larcher 1987). In this study, the minimum root core temperature recorded was nearly −1°C (30.2°F). The location of the sensor in the root core was under mulch, making it less likely that the fine roots in the root zone would be affected by frost. Exposure of the roots to cold temperatures resulted in double the cold hardiness in both roots and shoots in *Lonicera tatarica, Cotoneaster horizontalis,* and *Euonymus europaeus* (Pellet 1971). However, this effect was not achieved in *Ligustrum obtusifolium*. Root cold hardiness is species-specific as a result of different seasons of growth in root and shoot (Sakai and Larcher 1987). Repo et al. (2005), using simulated winter to summer conditions, reported that 2 weeks of delayed soil thawing caused death in the saplings of *Pinus sylvestris* L., whereas no delay or a short delay caused only minor damage and reversible recovery.

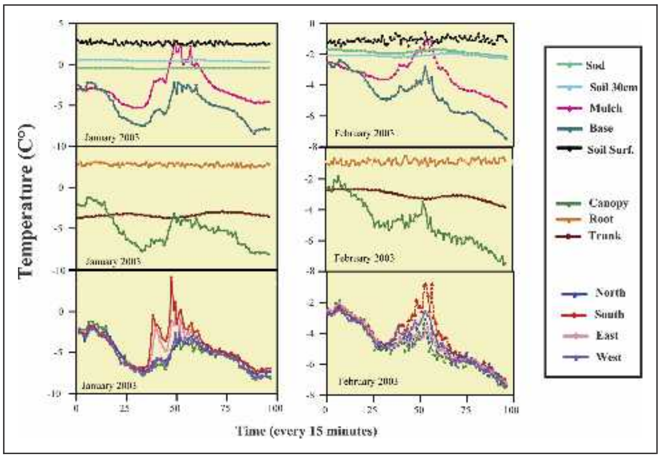

Figure 5. Daily temperature fluctuation (TF) in *Fraxinus pennsylvanica* var. *subintegerrima* (red ash) tree and its surrounding environment for the 15th day of each month from January through mid-February 2003. The first graph for each month shows TF in soil surface, sod, mulch, base, and soil 30 cm. The second graph for each month shows TF in root, trunk, and canopy. The third graph for each month shows TF in north, south, east, west, and canopy.

There were significant temperature differences depending on time of day between the south and west sides compared with the north and east sides. These higher temperatures, during the winter months, have been associated with sun-

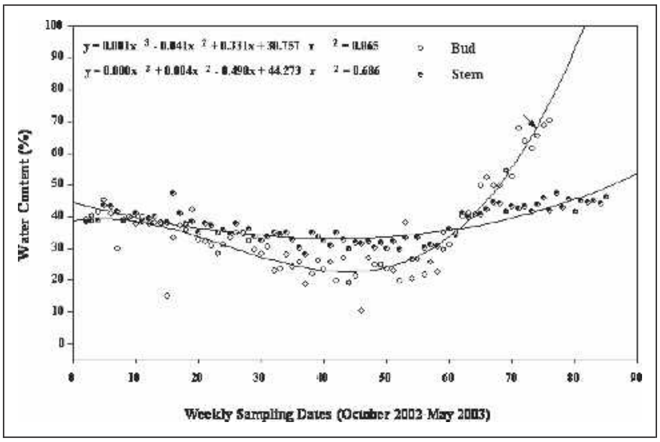

Figure 6. Percent water content in stems and buds of *Fraxinus pennsylvanica* var. *subintegerrima* (red ash) tree. Arrow indicates date of budbreak. Curves were fitted (polynomial third order) through weekly observation from October 2002 to May 2003.

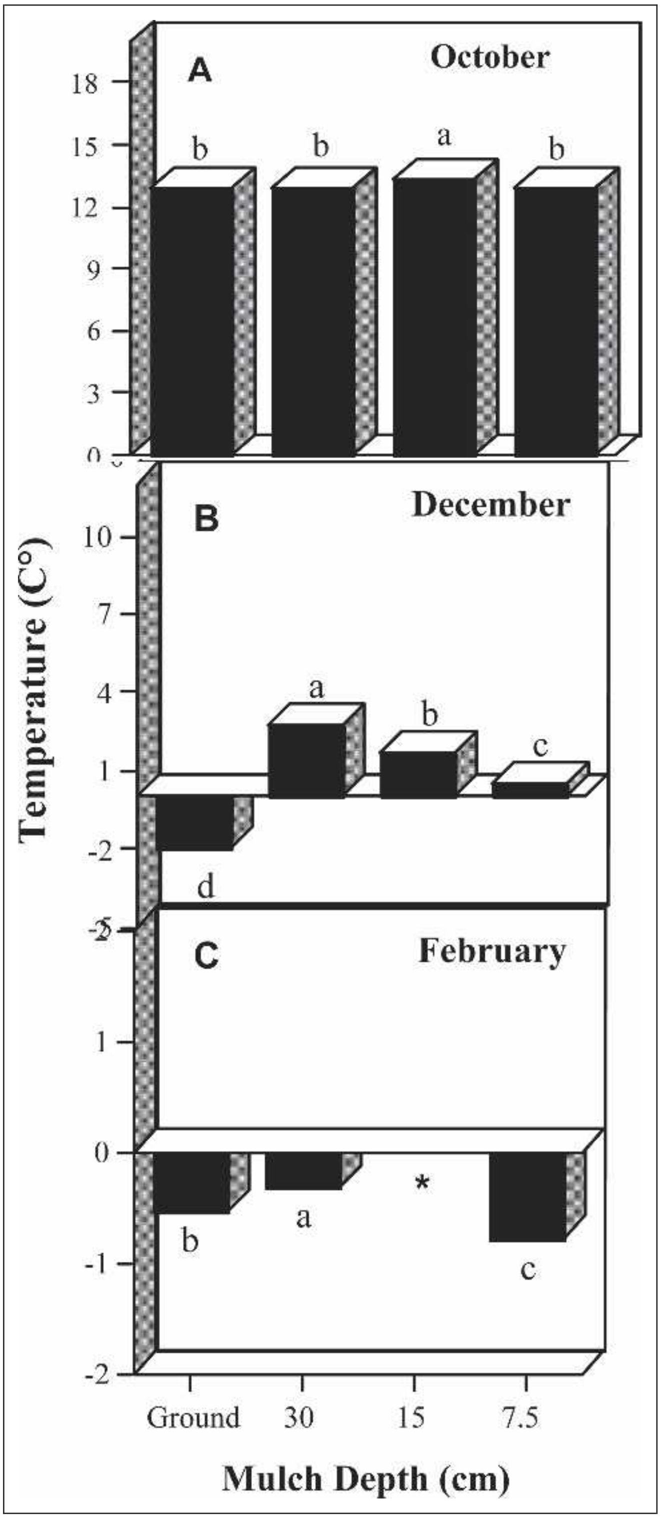

Figure 7. Temperature fluctuation in different mulch depths in four *Acer saccharum* (sugar maple) during October and December 2004 and February 2005. Mean separation by Duncan's multiple range test ($P < 0.05$). Data are means of ≈3,000 observations.

scald, which often results in low temperature-induced cracks on the southwest side of the trunk (Sakai 1966). A higher south side temperature was observed in December and February, but not in January, because we had a very mild January in 2002. This higher peak on the south side also was observed in September and October as well as in December.

When approaching budbreak, bud water content was significantly higher than stem water content (Figure 6). The stem water content and budbreak have a direct relationship; however, root zone temperature and soil moisture also contribute to earlier budbreak, with the exception of genetically controlled species. These TF observations and TFF determinations may be useful for a better understanding of how a tree can sense its surrounding environment and how temperatures fluctuate in and around a tree. This data are also useful for freeze protection as well as horticultural and arboricultural practices in urban environments. More research is needed for understanding the interaction of temperature and other environmental factors such as soil moisture, soil structure, and availability of oxygen in the root zone. Regarding mulch depth, more research is warranted for better landscape management and healthier trees in urban environments.

Having higher TF than expected in mulch prompted the reinvestigation of TF with regard to mulch depth. The TF of mulch at different depths is shown in Figure 7. TF varies depending on time of year. In October, 15 cm (6 in) mulch was several degrees warmer ($P < 0.05$) than ground, 7.5 cm (3 in) mulch, and 30 cm (12 in) mulch. However, in December and February, 30 cm (12 in) mulch was significantly warmer ($P < 0.05$) (Figure 7). The microbial activity in the mulch may contribute to the higher temperature. Borges and Chaney (1989) indicated that the development and efficiency of mycorrhizal fungi is higher when soil temperature is between 8°C (46.4°F) and 27°C (80.6°F). Our results indicated that the higher the mulch depth, the warmer the temperature. However, overmulching may cause problems in urban landscapes such as adventitious root formation at the base of the trees, which may result in root girdling.

LITERATURE CITED

Borges, R.G., and W.R. Chaney. 1989. Root temperature affects mycorrhizal efficacy in *Fraxinus pennsylvanica* Marsh. The New Phytologist 112:411–417.

Fitter, A.H., and R.K.M. Hay. 1987. The temperature fluctuations of plants, p. 187. In Environmental Physiology of Plants. 2nd Edition. Academic Press, New York, NY.

Huttunen, L., and J. Soveri. 1993. The regional and temporal variation of frost in natural conditions in Finland. Public. Nat. Board of Watersand the Env. Series A 139:1–74. In Finnish with English summary.

Kozlowski, T.T., and S.G. Pallardy. 1997. Environmental regulation of vegetative growth, pp. 195–322. In Growth Contol in Woody Plants. Academic Press, San Diego, CA.

Levitt, J. 1980. Responses of Plants to Environmental Stresses. Vol. 1, 2nd Edition. Kozlowski, T.T., Ed. Academic Press, New York, NY.

Lyr, H., and V. Garbe. 1995. The influence of root temperature on growth of *Pinus sylvestris*, *Fagus sylvatica*, *Tilia cordata*, and *Quercus robur*. Trees (Berlin) 9:220–223.

Pellet, H. 1971. Comparison of cold hardiness levels of root and stem tissue. Canadian Journal of Plant Science 51: 193–195.

Repo, T., T. Kalliokoski, T. Domisch, T. Lehto, H. Mannerkoski, S. Sutinen, and L. Finer. 2005. Effects of timing of soil frost thawing on Scots pine. Tree Physiology 25: 1053–1062.

Sakai, A. 1966. Temperature fluctuation in wintering trees. Physiologia Plantarum 19:105–114.

———. 1970. Mechanism of desiccation damage of conifers wintering in soil frozen areas. Ecology 51:657–664.

Sakai, A., and W. Larcher. 1987. Frost survival of plants. Responses and adaptation to freezing stress. Billings, W.D., Golley, F., Lange, O.L., Olson, J.S., and Remmert, H., Eds. Ecological Studies 62. Springer Verlag, Berlin, Germany.

Shirazi, A.M., and L.H. Fuchigami. 1993. Recovery of plants from 'near-lethal' stress. Oecologia 93:429–434.

———. 1995. Effect of 'near-lethal' heat stress on bud dormancy and stem cold hardiness in red-osier dogwood. Tree Physiology 15:275–279.

Solantie, R. 2000. Snow depth on January 15th and March 15th in Finland 1919–1998, and its implications for soil frost and forest ecology. Meteor. Public. Finn. Meteorol. Inst. 42:1–176.

———. 2003. On definition of ecoclimatic zones in Finland. Finn. Meteorol. Inst. Report No. 2, p. 44.

Teskey, R.O., and T.M. Hinckley. 1981. Influence of temperature and water potential on root growth of white oak. Physiologia Plantarum 52:363–369.

Tumanov, I.I., G.V. Kuzina, and L.D. Karankova. 1973. Dormancy period and ability of trees for hardening with low temperatures. Soviet Plant Physiology 20:1–9.

Weiser, C.J. 1970. Cold resistance and injury in woody plants. Science 169:1269–1277.

A.M. Shirazi (corresponding author)
Research Horticulturist
(formerly) The Morton Arboretum
4100 IL Route 53
Lisle, IL 60532, U.S.
drshirazi@UrbanHort.com
(currently) Urban Horticulture Academy
799 Roosevelt Road, Suite 3-104C
Glen Ellyn, IL 60137, U.S.

S.H. Vogel
Volunteer
The Morton Arboretum
4100 IL Route 53
Lisle, IL 60532, U.S.

Résumé. La fluctuation des températures d'un *Fraxinus pennsylvanica* var. *subintegerrima* de 18 ans ainsi qu'au sein de son environnement immédiat a été suivie au moyen de senseurs de température de type HOBO Pro qui enregistraient des données toutes les 15 minutes de décembre 2001 à février 2003 au sein de l'Arboretum Morton à Lisle en Illinois aux États-Unis. Il y avait des différences significatives ($P < 0,05$) entre les fluctuations de température de 2001 – températures moyennement froides – et celles de 2003 – températures très froides ayant brisées des records. À la mi-décembre 2001, les fluctuations de température se situaient entre 4 à 4,5°C à 30 cm de profondeur dans le sol, entre 3 à 4°C dans le gazon et entre 2 à 2,5°C à la surface du sol, tandis que dans la cime et le paillis elles se situaient entre −1 à 10°C. La face sud du tronc présentait la plus grande fluctuation, soit de 1 à 14°C, suivie généralement par la face ouest et occasionnellement par des sommets sur la face est. Cependant, la face ouest avait le sommet le plus élevé de température à la mi-juin. La différence de température entre les faces sud et nord était approximativement de 7°C à la mi-décembre. En avril, la fluctuation de température à l'intérieur du tronc variait de 2 à 2,5°C comparativement à celle de la cime qui variait de −0,5 à 8°C. La face ouest était de 2 à 3°C plus élevée à la mi-juillet que les faces sud, est et nord. Le 15 février 2003 qui a été la journée la plus froide enregistrée, la température du sol à 30 cm sous la surface a atteint −1°C tandis que celles du gazon et de la surface du sol étaient approximativement de −2°C. La température du paillis et celle de l'air variaient respectivement de −1 à −5°C et de −2,5 à −7,5°C. La température de la couche racinaire était d'environ −1°C, celle du tronc était entre −2,5 et −3,5°C et celle de la cime était entre −2,5 et −7,5°C. Sur le côté sud, la fluctuation de température était entre −0,5 et −7,5°C de midi à minuit. La différence de fluctuation de température entre les côtés sud et nord était d'environ 2,5°C. Ce gel-dégel sur le côté sud durant les mois d'hiver a été attribué à des insolations sur certains arbres. En se basant sur les observations de températures durant la semaine la plus froide et celle la plus chaude, un facteur de fluctuation de température, soit la différence entre la température hebdomadaire minimale et celle maximale, a été introduit. Durant la semaine la plus froide, le facteur de fluctuation de température de la cime par rapport au tronc était de 2X, de 10X du tronc par rapport aux racines ou au sol, et de 20X de la cime par rapport aux racines ou au sol. Durant la semaine la plus chaude, ce même facteur de la cime par rapport au tronc était de 2X, de 7,5X du tronc par rapport aux racines ou au sol, et de 15X de la cime par rapport aux racines ou au sol. Le contenu en eau des tiges était plus élevé durant l'année; cependant, le contenu en eau des bourgeons était significativement plus élevé lorsque le bourgeon approchait de sa période d'éclosion en avril-mai. Dans une étude parallèle, l'effet de l'épaisseur du paillis a été réexaminé en fonction de la fluctuation de température, ce qui a permis de déterminer que la température du paillis varie selon la période l'année. En octobre, le paillis de 15 cm d'épaisseur était de plusieurs degrés plus chaud que le sol, la couche de paillis de 7,5 cm d'épaisseur et la couche de paillis de 30 cm d'épaisseur ($P < 0{,}05$); cependant, en décembre et en février, la couche de paillis de 30 cm d'épaisseur était significativement plus chaude ($P < 0{,}05$). Il y a plusieurs facteurs autres que la température qui affectent la croissance et le développement d'un arbre. Les dynamiques des fluctuations de température donnent une meilleure compréhension du rôle que la température joue dans la physiologie de l'arbre tout comme cela permet d'améliorer la compréhension de l'arboriculture et de l'horticulture dans les environnements urbains, ce qui résulte en une amélioration de la gestion des espaces verts.

Zusammenfassung. Die Fluktuation von Temperatur (TF) in einer 18jährigen *Frax. Penn. Var. Subintegerrima* und ihrer Umgebung wurde mit einem HOBO Pro Temperatur Sensor alle 15 Minuten von Dezember 2001 bis Februar 2003 im Morton Arboretum, Lisle, Illinois, USA überwacht. Es gab deutliche Unterschiede ($P < 0{,}05$) zwischen TF in 2001, milde Wintertemperaturen, und 2003 mit Rekordbrechenden kalten Temperaturen. Mitte Dezember 2001 war die TF im Boden bei 30 cm Tiefe 4–4,5 °C, der Oderboden hatte 3–4 cm °C und an der Bodenoberfläche 2–2,5 °C, wobei Laub und Mulch −1–10°C hatten. Die Südseite des Stammes hatte die höchste Fluktuation von 1–14°C, gefolgt von der Westseite mit gelegentlichen Höhepunkten auf der Ostseite. Dennoch zeigte die Westseite die höchste Temperatur Mitte Juni. Die Temperaturunterschiede zwischen der Nord- und Südseite Mitte Dezember betrugen schätzungsweise 7 Grad. Im April rangierte die TF innerhalb des Stammes von 2–5,5°C im Vergleich zur Krone, die zwischen −0,5–8°C variierte. Die Westseite war Mitte Juni 2–3°C höher als auf der Süd- Ost- oder Nordseite. Am 15. Februar 2003 war der kälteste Tag und die Bodentemperatur bei 30 cm Tiefe betrug −1°C und darüber etwa −2°C. Mulch- und Stammbasistemperatur rangierte von −1–5°C und −2,5 bis −7,5°C entsprechend. Die Wurzelkerntemperatur betrug −1°C, die Stammtemperatur betrug −2,5 bis −3,5°C und in der Krone −2,5 bis −7,5°C. Die Süd TF rangierte zwischen −0,5 bis −7,5°C von Mittag bis Mitternacht. Die TF Differenz zwischen der Süd- und Nordseite betrug 2,5°C. Dieses Frieren und Tauen auf der Südseite während der Wintermonate hat bei einigen Bäumen zu Sonnenbrand geführt. Basierend auf den Temperaturbeobachtungen während der kältesten und der wärmsten Woche wurde ein Temperaturfluktuationsfaktor (TFF), eine Differenz zwischen der wöchentlich höchsten und niedrigsten Temperatur, eingeführt. Während der kältesten Woche betrug der TFF von Krone bis zum Stamm 2X, Stamm zu Boden oder Wurzel 10X und Laub zu Wurzel/Boden 20X. Während der wärmsten Woche betrug der TFF von der Krone zum Stamm 2X, vom Stamm zum Boden 7,5X und Krone zum Boden 15X. Der Wassergehalt des Stammes war über das Jahr höher, der Wassergehalt der Knospen war deutlich höher zur Zeit des Aufbrechens im April/Mai. In einer begleitenden Studie wurde der Effekt von Mulchtiefe auf die TF untersucht, Dabei zeigte sich, dass die Temperatur von Mulch über die Jahre variierte. Im Oktober waren 15 cm Mulch um einige Grade wärmer als der Boden, 7,5 cm Mulch und 30 cm Mulch, doch im Dezember und Februar waren 30 cm Mulch wärmer. Es gibt noch viele andere Faktoren als die Temperatur, die das Wachstum und die Baumentwicklung beeinflussen. Die Dynamik des TF gibt ein besseres Verständnis für die Rolle der Temperatur in der Baumphysiologie, ebenso wie eine Verbesserung der Lebensbedingungen am Standort, die zu einem besseren Landschaftsmanagement führen.

Resumen. Se monitorearon las fluctuaciones de temperatura (FT) en *Fraxinus pennsylvanica* var. *subintegerrima* de 18 años y su ambiente circundante usando sensores de temperatura HOBO, registrando cada 15 minutos de Diciembre de 2001 a Febrero de 2003 en el Morton Arboretum, Lisle, Illinois, USA. Hubo diferencias significativas ($P < 0.05$) entre FT en 2001, temperaturas templado frías, y 2003, temperaturas severas. En Diciembre de 2001, FT varió de los 30 cm. de suelo donde fue 4 a 4.5ºC, menos profundo 3 a 4ºC, y en la superficie del suelo fue de 2 a 2.5ºC; mientras en la copa y el mulch variaron de −1 a 10°C. El lado Sur del tronco tuvo la más alta fluctuación de 1 a 14°C seguido por el lado Oeste, con picos ocasionales en el Este. Sin embargo, el lado Oeste tuvo el pico más alto en temperatura en la mitad de junio. La diferencia en temperatura entre los lados Sur y Norte durante la mitad de diciembre fue aproximadamente 7°C. En Abril, la FT dentro del tronco varió de 2 a 5.5°C comparado con la copa, la cual varió entre −0.5 a 8°C. El lado Oeste fue 2 a 3°C más alto en la mitad de Julio que los lados Sur, Este y Norte. En Febrero 15 del 2003, el cual fue el más frío registrado, la temperatura del suelo a 30 cm. alcanzó alrededor de −1°C, mientras que la superficie fue aproximadamente −2°C. El mulch y la temperatura base variaron de −1°C a −2.5°C, respectivamente. La temperatura de la raíz fue alrededor de −1°C, la temperatura del tronco varió entre −2.5°C a −3.5°C, mientras que la copa fue −2.5° a −7.5°C. La FT Sur varió entre −0.5°C a −7.5°C de mediodía a medianoche. La diferencia en FT entre los lados Sur y Norte fue alrededor de 2.5°C. Este congelamiento y descongelamiento del lado Sur durante los meses de invierno ha sido responsable de quemaduras en algunos árboles. Se introdujeron las observaciones de temperatura durante las semanas más frías y más calientes, factor de fluctuación (FFT), una diferencia entre mínimo semanal y la temperatura máxima. Durante la semana más fría, la FFT para la copa al tronco fue 2X, tronco a raíz o suelo fue 10X, y copa a raíz o suelo fue 20X. Durante la semana más caliente, el FFT para la copa al tronco fue 2X, tronco a raíz o suelo fue 7.5X y copa a raíz o suelo fue 15X. El contenido de agua del tallo fue más alto a través del año, sin embargo, el contenido de agua de la yema fue significativamente mayor cuando se alcanzó el rompimiento de las yemas en Abril-Mayo. En un estudio parecido fue revisado el efecto de la profundidad del mulch en FT, mostrando que la temperatura del mulch varía dependiendo de la época del año. En Octubre, una capa de 15 cm. de mulch fue varios grados más caliente que el terreno, 7.5 cm. de mulch, y 30 cm. de mulch ($P < 0.05$). Sin embargo, en Diciembre y Febrero, 30 cm. de mulch fue significativamente más caliente ($P < 0.05$). Hay muchos factores diferentes a la temperatura que juegan un papel en la fisiología del árbol, así como también el manejo horticultural y arboricultural en un ambiente urbano, resultando en un mejoramiento del paisaje.