Research Reports:

Chilling and Bud Break in Silver Maple[1,2]

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Abstract

Silver maple (*Acer saccharinum* L.) goes dormant in the autumn and is greatly delayed in bud break unless the buds are exposed to prolonged low temperature. Approximately 1000 hours below 4°C (39°F) under natural conditions (early March in southern Illinois) will bring about bud break 2 to 3 weeks after juvenile plants are put under favorable growing conditions. Chilling in a dark cold room at 4°C (39°F) separated from natural changes required a greater number of hours, approximately 2000, for a similar response. Bud break for subterminal buds was earlier than for terminal buds on insufficiently chilled stem segments or larger plantlets. Terminal buds broke first with longer chilling periods. Rooted cuttings from adult trees had a greater chilling requirement than juvenile plant material, either micropropagated plantlets or stem segments from shoots. No geographic or provenance variation in response to chilling was observed within 11 provenances ranging from Mississippi to central Ontario to New Hampshire to West Virginia. Silver maple was similar to sugar maple and basswood in its chilling requirement. It was unlike red maple which has a chilling requirement in some but not all parts of its range.

Index words: *Acer saccharinum*, micropropagation, plantlets, cuttings, juvenile, adult, provenance

Significance to the Nursery Industry

Bud break governs early growth vigor, the period of foliage, and the length of the growing season. Apical dominance affects growth form. The demonstrated chilling requirement of silver maple calls for caution in movement southward very far beyond its natural range. Insufficiently chilled plants will have increased early lateral (subterminal) compared to terminal bud break. If plant material is kept in cold storage the chilling period needs to be considerably longer, up to 2000 hours, than under natural conditions. Rooted cuttings from adult trees may not grow in the second year even with chilling. Effective handling of silver maple for landscaping, reclamation, biomass or other needs should include provision for appropriate cold treatment of dormant planting stock.

Introduction

Plants that set buds, become leafless, and do not respond readily to favorable growing conditions are considered dor-

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mant. Those that can break bud only following prolonged exposure to low temperature are said to have a chilling requirement. This aspect of dormancy in woody plants has been widely reported and reviewed (3, 5, 11, 12). Although 5°C (41°F) is a generally accepted upper temperature limit for effective breaking of dormancy, there is less agreement as to the effects of subzero temperatures (4).

Chilling requirements for bud break have been reported for silver maple (*Acer saccharinum* L.) (9), sugar maple (*Acer saccharum* Marsh.) (4), and red maple (*Acer rubrum* L.) (6). Red maple from southernmost Florida did not, however, require chilling. With increasing use of forest trees for biomass, reclamation, urban forestry, and other needs, knowledge of chilling requirements for bud break assumes greater significance. The objective of this study was to determine specific chilling requirements for bud break of silver maple and whether these requirements varied with geographic origin (provenance).

Materials and Methods

Starting in mid-December 1988 the plant materials for bud break were brought to the greenhouse at monthly intervals until April. They were placed on a greenhouse bench with night interruption by fluorescent lights from 2200 to 0200 hours. The greenhouse was nominally at 20°C (68°F). Each week thereafter the plant materials were scored for bud break, using a minimum of one-cm shoot growth from any bud as a criterion. Plant materials having shoot growth were then removed from the study.

Four types of plant material from varied provenances (8) were used (Table 1). The conditions under which these plants became dormant was a variable. Potted rooted cuttings from adult trees became dormant in a greenhouse under natural autumnal daylength. Micropropagated plantlets in Rootmaster containers (2, 7) were split into those going dormant in the greenhouse and those dormant under natural conditions outside. In December plants of all three types were placed either in the greenhouse or stored at 4°C (39°F) without light. A fourth type was cuttings from stem sprouts (coppice) under natural conditions. Dormant shoots were cut into 3 segments, apical bud to 40 cm (16 in), 40 to 80 cm (16–32 in), and 80 to 120 cm (32–47 in) from the shoot apex. The segments were placed on a greenhouse bench in 2-liter jars with one liter of a 0.2 g/l 8-hydroxyquinoline citrate (bactericide, pH 4.5) aqueous solution.

Table 1. Types, numbers, and origins of dormant plant materials used in the silver maple chilling study.

I. Potted rooted cuttings (10 cm [4 in] tall, 87 plants) from large adult trees
 Origin Southern Illinois
 Greenhouse-grown and dormant by mid-December

II. Containerized plantlets from juvenile trees (10 or more cm [4 in] tall, 261 plants)
 Origin Central Ontario, Vermont, New Hampshire, Southern Ontario
 Greenhouse-grown and dormant by mid-December

III. Containerized plantlets (10 or more cm [4 in] tall, 645 plants)
 Origin Central Ontario, Vermont, Southern Ontario, Wisconsin, Northeast Pennsylvania, Southern Illinois, Southern West Virginia, Mississippi
 Greenhouse-grown and dormant after moved outdoors in full leaf from October to mid-December

IV. Stem segments (40 cm [16 in] long, 336 segments) from first-year shoots
 Origin Central Illinois, Tennessee
 Stem sprout (coppice) trees up to 3 meters (10 ft) tall outdoors

The chilling hours experienced each month prior to placing plant materials in the greenhouse were calculated from elapsed time recorded in the cold room or from charts of a hygrothermograph operated near one of the outdoor plantings. The amount of chilling received by these plant materials varied from 0 to nearly 3000 hours below 4°C (39°F) (Fig. 1). By April the plants in the cold room received twice as many hours at or below 4°C (39°F) as those outdoors. The outdoor temperatures fluctuated, and the number of chilling hours was greater in the 30 days before mid-December than in either of the two following months.

The experimental design varied within the four types of plant material (Table 1). No subdivisions were present among the rooted adult cuttings and the number used per month varied from 18 to 31. Statistical analysis on these data was not feasible. The other three types of plant materials were subdivided into provenance groupings of nominally 14 plants each. Within these subdivided types the number of weeks until earliest or last bud break for each provenance was the data base for statistical analyses. These included t-test, 95% confidence interval, and correlation coefficients.

Results and Discussion

Most of the rooted cuttings from mature trees did not break bud with or without chilling during the experimental period (Fig. 1). A majority of the containerized plantlets that had gone dormant in the greenhouse and received no subsequent chilling (December trial) also did not break bud within the 21 weeks of the study period. All of the other plants in this study broke bud.

The number of hours of chilling had a marked effect on bud break, both for the plants from the cold room and for the stem segments from the tree sprouts outside (Fig. 1). In all instances, after being removed from cold storage or outdoor chilling, the plant material broke bud more quickly with increased number of chilling hours. The duration of the period of bud break also shortened appreciably with additional chilling. The number of weeks until both earliest and last bud break became progressively shorter from month to month, with a correlation coefficient of $r = 0.83$.

Terminal bud break of plants brought to the greenhouse in December and January was delayed compared to bud break of sub-terminal buds. For example, the December Tennessee terminal stem segments after 8 to 15 weeks broke bud mainly from lower buds. In contrast, the upper buds of the lower part of that same stem broke in only 5 to 9 weeks. By March these differences had disappeared and the terminal buds were the first to grow on all stem segments. There were no shoots with unbroken buds to use in April.

These same relationships were found for the plantlets. The lower buds on less chilled plantlets of the December and January trials, especially those unusually tall, were more likely to flush first. By March and strongly in April the terminal buds typically broke first.

Except for December, any differences in the number of weeks for bud break of the two micropropagated plantlet

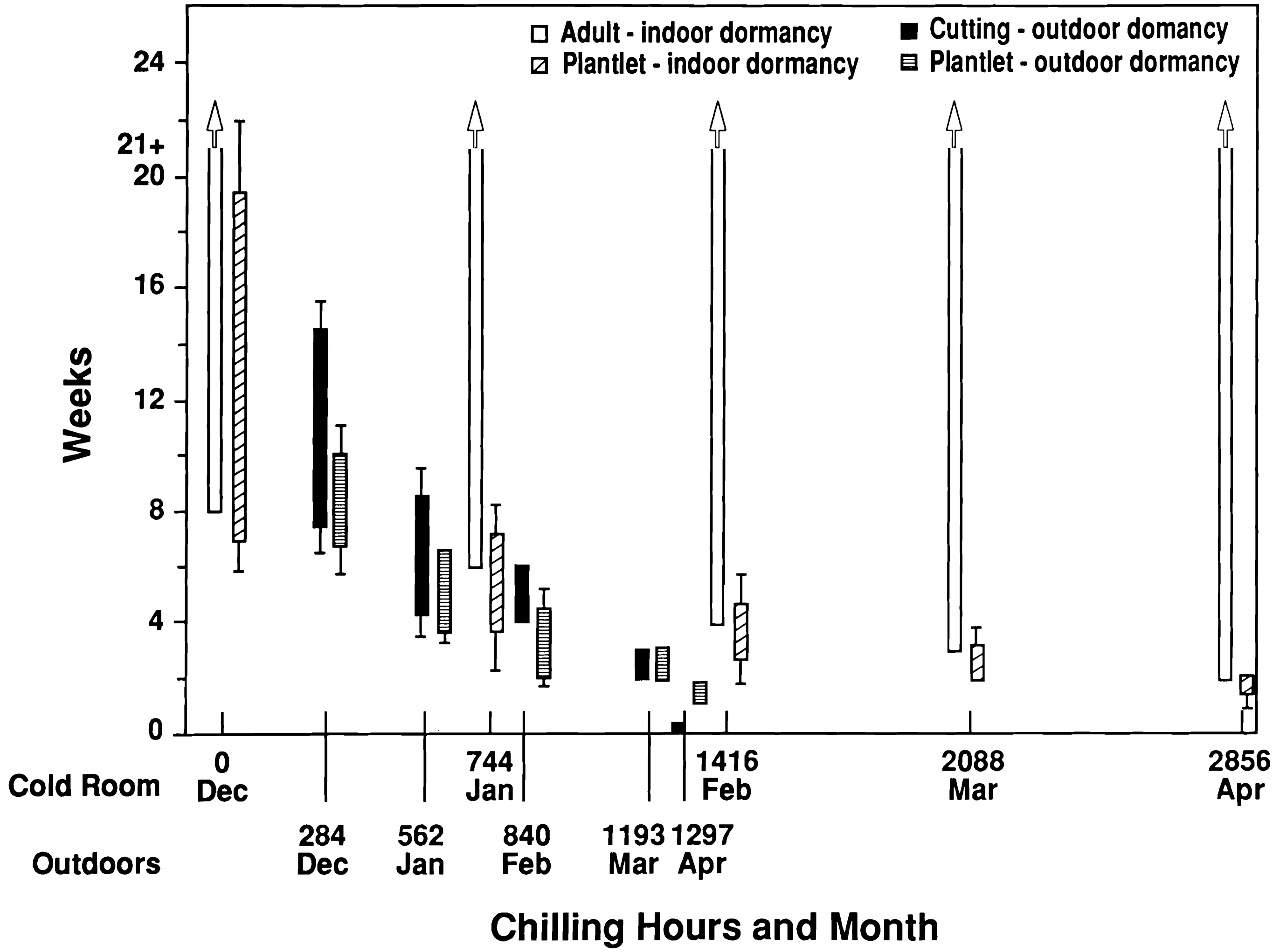

Fig. 1. **Response of silver maple to previous chilling outdoors or in a cold room. A bar represents the number of weeks between bud break by the average first and last plant in a treatment. A vertical line represents the 95% confidence interval (c.i.). No c.i. is shown if all provenances in a treatment broke bud in the same week.**

monthly groups with differing pre-treatments were found not be significant in bud-break responses by month. All monthly values were significantly different with the exception of earliest bud break, February versus March. In no instance were differences in chilling requirement between provenances within a treatment found.

Length of time until bud break of the stem segments was very similar to that of the containerized plantlets. No statistically significant differences were found between the time for bud break of stem segments from the central Illinois and the Tennessee material.

In evaluating these results the effects of ecological and physiological factors were chiefly evident. Unlike red maple, no geographic differences in response of silver maple to chilling were evident based on these 11 well-distributed provenances. The equally rapid bud break by plants from the cold room with approximately 2000 hours of chilling and by those continuously outdoors with half that number of chilling hours was also noteworthy. Absolute number of hours is not an adequate criterion.

Ritchie (10) pointed out that plant materials in cold storage rooms are separated from the sources of environmental energy and information they need to develop in synchrony with the changing seasons. Conifer tree seedlings showed negative effects such as carbohydrate depletion and slowing of dormancy release in cold storage compared to natural chilling. The number of hours of cold storage or chilling needed depends on the desired results for a given set of plants. Assuming that bud break of silver maple in 2 to 3 weeks represents full release of dormancy, 2000 hours of cold storage at or below 4°C (39°F) was fully adequate in our studies. This compares with 1400 hours of chilling for reasonably rapid bud break of the stem segments brought to the greenhouse from outdoors in mid-February.

The chilling requirements of the adult and the juvenile silver maple plant materials in this study differed greatly. Both went dormant in the greenhouse under natural daylength without cold as an environmental stress. Juvenile plant materials, either micropropagated plantlets or unrooted stem segments, were indistinguishable in response to chilling. The plants of adult origin were, in contrast, markedly more refractory in responding to chilling. Nurserymen have recognized that if Japanese maple stem cuttings do not put on a flush of growth during the summer in which they are rooted, they will not survive the winter, leaf out, or grow well the next year. Our adult cuttings in the chilling study had made little or no growth after rooting in the previous year.

We found the number of hours of chilling required by silver maple to be similar to that reported in other studies of eastern U.S. hardwoods. Richardson (9), working in The Netherlands, regarded physiological bud dormancy of silver maple as completed in February when the number of hours below 5°C (41°F) totalled about 1500. Seedlings kept continuously at 20°C (68°F) required a period of 5 months before the buds opened.

Sugar maple seedlings from southern Wisconsin broke bud in 7 weeks after approximately 1200 hours of outdoor chilling in Chicago (4). This is equivalent to the silver maple average of 7 weeks for our mid-January silver maple group. Some plants of sugar maple grew without chilling and others remained dormant for 15–18 months and then grew after chilling. Basswood (*Tilia americana* L.) also from southern Wisconsin remained dormant for 20 months or more without chilling and then grew after chilling (1). Increasing length of winter exposure up to 4 months hastened basswood bud break, and with 1200 hours of outdoor chilling in Chicago the seedlings broke bud in 7 weeks.

Based on this study and the reports by Olmsted (4) and Richardson (9), some trees of a population of silver or sugar maple may not have an obligate chilling requirement. The number of hours of chilling for increasingly rapid and more uniform opening of buds was approximately equal in the two species.

Position effects in bud growth have been reported and are considered to be a balance of growth promoters and inhibitors (11). This study showed that terminal buds of silver maple had greater chilling requirements than subterminal buds. Earliest bud break in our seedling provenance nursery was also commonly from lower buds. Apical dominance, typically associated with auxin effects, increased with release of the terminal bud from dormancy. A practical consequence is that insufficiently chilled trees would have a greater tendency to branch and be bushy. Sugar maple is a valuable timber tree with excellent form in more northern areas and yet has poor form and low value for timber in the southern parts of its range. Form has been relatively little studied in silver maple. The distribution of silver maple in the southern part of its range is much more localized than further north. Inadequate chilling may be an important factor affecting its southern range limit.

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