Timing of *Pistacia chinensis* Bunge. Rooting Using Morphological Markers Associated with Calendar Date and Degree Days

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**Abstract.** The objective of this study was to determine the most advantageous time to collect cuttings of Chinese pistache, a commonly recommended ornamental shade tree that is difficult to propagate by cuttings. In 1993, calendar date and degree days (daily mean temperature –7.2°C) were used to estimate an appropriate cutting time. The greatest percentage of rooted cuttings occurred in male cuttings harvested on 13 May 1993 (397 degree days) and treated with 17,500 mg·liter⁻¹ IBA or in male cuttings harvested on 20 May 1993 (482 degree days) and treated with either 8750 or 17,500 mg·liter⁻¹ IBA. In 1994, cutting time was associated with calendar days, degree days, and morphology. The most rooted cuttings (44%) were from green softwood cuttings taken on 9 May 1994, which was 380 degree days from orange budbreak using a threshold temperature of 7.2°C. Orange budbreak was characterized by separation of the outer bud scales such that the orange, pubescent inner bud scales were visible. Cuttings taken on 9 May 1994 and treated with 8750 mg·liter⁻¹ IBA produced the most primary and secondary roots and the longest primary roots per cutting. Male Chinese pistache cuttings should be collected from green softwood or red semi-softwood stems when about 380 to 573 degree days have accumulated after orange budbreak. Chemical names used: indolebutyric acid (IBA).

Chinese pistache is hardy in USDA hardness zones 6 through 9 (Dirr, 1990), flourishes in full sun, and reaches a mature height of 9 to 12 m with a 4.2- to 9-m spread (Whitcomb, 1985). This tree is native to well-drained, alkaline soils and is tolerant of many soil conditions (Lee et al., 1976a). It is recommended for its drought hardiness, salt tolerance, and extreme heat and wind tolerance (Dewers, 1981; Behboudian et al., 1986). Furthermore, the tree endures winter temperatures to –26°C (Koller, 1978). As a street tree, it continues healthy growth even when planted on narrow spacings (Long, 1960). Most trees display shades of brilliant orange-red, although extreme diversity in coloration can exist even within the same tree (MacMillian Brows, 1988). Foliage is lush throughout the season and does not suffer any major insect or disease problems (Dirr, 1990; Whitcomb, 1985).

Currently, Chinese pistache trees are propagated from seed. Unfortunately, however, there is no dependable seed source for this species (MacDonald, 1986). Asexual reproduction of Chinese pistache would allow selection of cultivars having desirable characteristics such as reliable cold hardiness, vivid fall color, strong branching habit, and interesting bark texture. Male Chinese pistache cultivars could also be marketed for use in locations where fruitless trees are needed.

Adult cuttings of Chinese pistache are difficult to root. However, there has been some rooting success with cuttings from juvenile seedlings (Lee et al., 1976b; Pair and Khatamian, 1982). Attempts to root *Pistacia vera* L. cuttings from adult trees have been limited or unsuccessful with high concentrations of indolebutyric acid (IBA) (Al Barazi and Schwabe, 1982, 1984, 1985). Juvenility in Chinese pistache seems to be lost after two years (Lee et al., 1976b; Pair and Khatamian, 1982), making asexual propagation thereafter more difficult.

Proper timing is crucial to rooting success in many woody species. Methods for predicting optimum cutting time for various species include use of calendar date (Barnes and Lewandowski, 1991; Burd and Dirr, 1977), number of calendar days past budbreak (MacDonald, 1986; Whitcomb, 1982), degree day chilling-units (Major and Grossnickle, 1990), morphological condition of the cutting (Adams and Roberts, 1967), use of indicator plants (Congdon, 1965), and photoperiod (Butcher and Wood, 1984). Estimates of appropriate cutting time by degree day heat-units have not been documented, but they are commonly used to predict budbreak (Sparks, 1993; Spiers, 1976), leaf emergence (Eisensmith, et al., 1980), flowering (Anstey, 1966; Mainland, 1986), and harvest time (Addison, 1969; Fisher, 1962).

The objective of this study was to determine if a window of rootability exists for Chinese pistache which can be defined using calendar days, degree days, or morphological markers so that appropriate cutting dates could be determined regardless of geographic location.

**Materials and Methods**

**Calendar timing.** Cuttings were collected from two 34-year-old male and two 34-year-old female trees at 2-week intervals from 13 May 1993 through 24 Aug. 1993. Cuttings were immediately placed in 10°C tap water, taken to a greenhouse and recut to 10 cm long. The basal 1 cm of the cuttings was dipped for 5 sec in 17,500 mg·liter⁻¹ IBA. The auxin solution was prepared by dissolving the appropriate amount of IBA in 50 ml of 70% isopropyl alcohol then using tap water to bring the solution to 100 ml. After auxin treatment, cuttings were placed in 12 cm wide × 36 cm long × 6 cm deep plastic rooting flats containing 1 peat: 4 perlite (by volume) and then kept in a polyethylene greenhouse under natural photoperiod with a maximum photosynthetic photon flux (PPF) of 845 µmol·m⁻²·s⁻¹ and maximum/minimum air temperatures of 36/13°C.
Flats were placed on benches equipped with Flora Mist nozzles (A.H. Hummert, St. Louis) with an output of 32 liters/h placed 50 cm above the flats at 121-cm intervals. Mist cycles were adjusted as necessary to allow foliage to dry before misting, and averaged 2-sec duration every 8 min between 0800 and 1800 HR daily.

Degree days were calculated from 15 Mar. 1993 to the cutting date using the following formula: \( \frac{\text{daily maximum temperature} + \text{minimum temperature}}{2} - \text{threshold temperature} \). A threshold temperature of 7.2°C was used (Baker and Brooks, 1994; Brown, 1952). Degree day calculations began 15 Mar. 1993 because this was the earliest date in which daily temperatures were consistently warm enough to accumulate degree day heat units using a 7.2°C threshold. The 15 Mar. 1993 date was before budbreak.

A split-block design was used with 3 replications of 10 sub-samples per treatment combination. Gender was the main plot and cutting date the subplot. Cuttings were evaluated 12 weeks after planting using the following rating scale: 0 = dead, 1 = no callus or roots, 2 = callus present, 3 = roots present. Statistical analysis was performed using analysis of variance (ANOVA) with mean separation by the protected least significant difference (LSD) procedure.

A second study was conducted using cuttings harvested on 13 or 20 May from the same male and female trees. Cuttings were treated with either 8750 or 17,500 mg-liter\(^{-1}\) IBA. Treatment combinations were replicated three times with 10 sub-samples per replication. The experimental design was a split plot with gender and IBA concentration as the main plots and cutting date as the subplot. Other conditions were identical to those described earlier.

### Table 1. Observation, bud diameter, number of calendar days from budbreak, and degree days using a threshold temperature of 7.2°C from budbreak of various morphological characteristics of Chinese pistache in 1994.

| Date     | Morphological marker                                                                 | RHS color chart description of stem color\(^a\) | Bud diam (mm)\(^b\) | Calendar days from budbreak\(^c\) | Degree days from budbreak\(^c\) |
|----------|--------------------------------------------------------------------------------------|-----------------------------------------------|---------------------|-------------------------------|-------------------------------|
| 18 Mar.  | Dormant terminal bud                                                                 | Greyed-Green 197D                             | 4.6                 | ---                           | ---                           |
| 24 Mar.  | Orange budbreak                                                                      | Greyed-Green 197D                             | 4.8                 | ---                           | ---                           |
| 04 Apr.  | Green budbreak                                                                      | Greyed-Green 197D                             | ---                 | 11                            | 31                            |
| 11 Apr.  | Closed cone                                                                         | Greyed-Green 197D                             | ---                 | 18                            | 73                            |
| 16 Apr.  | Open cone                                                                           | Greyed-Green 197D                             | ---                 | 23                            | 123                           |
| 20 Apr.  | Bud completely open                                                                 | Greyed-Green 197D                             | ---                 | 27                            | 177                           |
| 24 Apr.  | Early shoot expansion                                                               | Yellow-Green 144B                             | 1.7                 | 31                            | 249                           |
| 09 May   | Green softwood stem                                                                 | Yellow-Green 144B                             | 2.8                 | 46                            | 380                           |
| 25 May   | Red semi-soft stem                                                                  | Greyed-Red 181B                               | 3.6                 | 62                            | 573                           |
| 07 June  | Red semi-hard stem                                                                  | Greyed-Orange 174B                             | 4.0                 | 75                            | 799                           |
| 06 July  | Brown semi-hard stem                                                                | Greyed-Orange 164B                             | 4.2                 | 104                           | 1371                          |
| 05 Aug.  | Brown hardwood stem                                                                 | Greyed-Orange 164B                             | 4.1                 | 134                           | 1937                          |
| 16 Nov.  | Dormant terminal bud                                                                 | Greyed-Green 197A                             | 4.3                 | 237                           | ---                           |

\(^a\)Royal Horticultural Society color charts.

\(^b\)Mean of 10 replications. Buds measured were the third bud basipetal to the terminus.

\(^c\)Budbreak is considered to be when the outer bud scales open and the orange inner bud scales are showing.

Fig. 1. Morphological changes in Chinese pistache cuttings from 18 Mar. through 4 Apr. (A) 18 Mar., dormant terminal bud; (B) 24 Mar., orange budbreak with outer bud scales open and pubescent orange inner buds closed; (C) 4 Apr., green budbreak, with pubescent orange inner bud scales open and green leaf tissue exposed.
Society (RHS) color charts and recorded for five random cuttings per observation time (Table 1), with photographs illustrating the morphological condition from 18 Mar. through 4 Apr. (Fig. 1). Calendar days and degree days were calculated from orange budbreak (Table 1) to the date the morphological change was observed or cutting date. Degree days were calculated as described above.

A split-block design was used with 10 replications of 5 subsamples for each cutting date. IBA concentration was the main plot and cutting time was the subplot. Cuttings were evaluated 12 weeks after planting for primary root number, length of three longest primary roots, and number of secondary roots on three longest primary roots. Cuttings were rated using the previously described rating scale. Analysis of variance procedures (GLM) were performed on visual ratings using SAS statistical software (SAS Institute, Cary, N.C.). Protected LSD values were determined for visual ratings and means and standard errors were calculated for primary root number and length and secondary root number on cuttings that rooted.

### Results

#### Calendar timing

There was a significant interaction between cutting date in 1993 and tree gender for visual root rating (Table 2) with cuttings harvested from male trees on 13 or 20 May 1993 (397 or 482 degree days (DD), respectively) having higher root ratings and rooting percentages than cuttings harvested from either male or female trees on 27 July and 24 Aug. 1994 (1725 and 2006 DD). Regardless of gender, no rooting occurred on cuttings harvested on or after 2 July (1196 DD).

There was a significant interaction between cutting date, tree gender and IBA concentration for visual root rating (Table 3). Cuttings that were harvested 13 May (397 DD) from male trees and treated with 8750 mg·liter⁻¹ had a significantly lower visual root rating than those harvested from the same date from male trees and treated with 17,500 mg·liter⁻¹.
Morphology and degree days. The interaction of IBA with cutting date was significant at $P \leq 0.01$ (Table 4). Green softwood cuttings taken on 9 May 1994, (380 DD after orange budbreak) and receiving 8750 mg·liter$^{-1}$ IBA had the highest root rating with the most rooted cuttings (44%) compared to cuttings harvested on all other dates, except 25 May (Table 5). The largest number of primary and secondary roots and longest primary roots occurred on cuttings harvested on 9 May and treated with 8750 mg·liter$^{-1}$ IBA. With the exception of one cutting on 6 July, rooting only occurred when cuttings were taken between orange budbreak and red semi-hardwood stems (0 to 799 DD). No rooting occurred when the parent plants had been exposed to more than 799 DD.

Discussion

Many cuttings, including *Acer palmatum* Thunb., *Betula nigra* L., *Betula pendula* Roth, *Fraxinus* spp. and cultivars, *Ulmus*...
was from green softwood stems matched to yellow-green 144B on year. Morphologically, the highest percentage of rooted cuttings potential essentially ended after accumulation of 573 DD each using a threshold temperature of 7.2°C. While the criteria for rootability. The greatest potential for root formation occurred 20 visual root rating, and in 1994, 8750 mg·liter–1 IBA produced the highest for rooting outweighs the effect of chemical treatments. In 1993 Lewandowski (1991) stated that the status of the shoot harvested DD) regardless of IBA treatment. Schmidt (1989) and Barnes and cuttings with green soft stems or red semisoft stems (380 to 573 mid-August as stem hardening progressed (Barnes, 1989). In our window of opportunity for rooting.

The degree day (heat-unit) system has been used in horticulture to predict phenological events such as budbreak (Sparks, 1993) and leaf emergence (Eisensmith et al., 1980). Use of degree days from budbreak to predict the most advantageous rooting time has not been previously reported. Major and Grossnickle (1990) used a method of accumulation of chilling units to determine collection time. Using Juniperus, they found that the chilling-unit method can be used to determine rooting ability for plants with a narrow window of opportunity for rooting. Prunus serrulata ‘Kwanzan’ Lindl. rooting declined more than 30 percent from mid-July to mid-August as stem hardening progressed (Barnes, 1989). In our studies, with the exception of one cutting, rooting was limited to cuttings with green soft stems or red semisoft stems (380 to 573 DD) regardless of IBA treatment. Schmidt (1989) and Barnes and Lewandowski (1991) stated that the status of the shoot harvested for rooting outweighs the effect of chemical treatments. In 1993 cuttings receiving 17,500 mg·liter–1 IBA produced the highest visual root rating, and in 1994, 8750 mg·liter–1 IBA produced the most roots per cutting and the most rooted cuttings.

In conclusion, Chinese pistache has a narrow window of rootability. The greatest potential for root formation occurred 20 May in 1993 and 9 May in 1994. The 20 May 1993 date corresponded to 482 DD while the 9 May date corresponded to 380 DD, using a threshold temperature of 7.2°C. While the criteria for starting DD calculations differed somewhat by year, rooting potential essentially ended after accumulation of 573 DD each year. Morphologically, the highest percentage of rooted cuttings was from green softwood stems matched to yellow-green 144B on the RHS color chart, with buds about 2.8 mm in diameter.

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