# Seed Propagation of Rare and Unusual *Acer* Species: A Review of Propagation at the Morris Arboretum

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## INTRODUCTION

For the past quarter-century one of the primary missions of the Morris Arboretum has been domestic and international plant exploration, evaluation, and introduction. Since the late 1970s, staff of the Arboretum has participated in 19 plant collecting expeditions, including trips to South Korea, China, the Caucasus Mountains, and the United States. The goals of the plant exploration program include broadening the genetic pool of known species, conserving rare and endangered species, and introducing appropriate new species. These plant collecting expeditions have resulted in a living collection that contains approximately 4,000 plants of wild-collected and documented origin, representing just over 900 taxa. The diversity of *Acer* (maples) in the Arboretum is one of the most significant collections developed through our plant exploration efforts.

This paper reports on two aspects of *Acer* seed germination at the Morris Arboretum. One aspect is a compilation of germination records from the past 25 years for approximately 80 taxa of maple. These germination results represent many years of trial and error when faced with taxa of *Acer* for which little if any information was available. The second aspect of *Acer* seed germination reported in this paper concerns germination trials with seed that was received at the Arboretum in the fall of 2005 from two collecting expeditions, one to Gansu Province, China, the other to central Japan. By sharing the results of our propagation trials (and tribulations) we hope to expand the knowledge of seed propagation of rare and unusual maples.

## MATERIALS AND METHODS

**Arboretum Propagation Records.** Beginning in the 1970s, the Arboretum's propagation records have been maintained on 5 inch × 8 inch index cards. For this project, propagation information from these cards on *Acer* taxa was reviewed and compiled, with a summary of successful and unsuccessful strategies (Table 1). For each taxon the data reported represent the highest germination percentage recorded in the Arboretum's propagation records.

***Acer* Seed Germination: Fall 2005.** In the fall of 2005, the Arboretum participated in the North America China Plant Exploration Consortium collecting expedition to Gansu Province, China (NACPEC05). We received six maple taxa from this expedition. Concurrently, additional maple seed was obtained from a plant-collecting trip to Japan (BBMJT) conducted by Quarryhill Botanical Garden, Royal Botanic Garden Edinburgh, Polly Hill Arboretum, and Howick Hall Arboretum. There were 25 taxa of *Acer* from the combined expeditions. Table 2 summarizes the propagation trials for 15 of these taxa, which were begun with an abundance of seed and the need to process the seed as quickly as possible.

Because of the difficulties of processing, storing, and transporting seed from China and Japan to the United States, the seed arrived at the Arboretum with varying levels of moisture content. Viability was determined by a cut test. Although there is not published information for many of these taxa, our germination protocols were guided by standard propagation references (Dirr and Heuser, 1987; U.S.D.A., 1974; Young and Young, 1992) as well as reference to the Arboretum's propagation records. An effort was made to perform as many treatments on each seed lot as practical while replicating the protocol on different species. Seeds were sown in a medium that was a mixture of perlite and peat (3 : 2, v/v) mix in seed trays to which RootShield® granules (*Trichoderma harzianum*) were added. After treatment the trays were placed in a fog and mist room with bottom heat of 70 °F (21 °C). Light was at 200 $Wm^2$ for 16 h duration. Seed treatments included:

- **Cold stratification** (c) was accomplished by placing seeds in polyethylene bags filled with moistened perlite and refrigerated at 41°F (5 °C).
- **Warm stratification** (w) was accomplished by placing seeds in polyethylene bags filled with moistened perlite and maintained at room temperature of 72 °F (22 °C).
- **Gibberellic acid** treatments (GA) were by immersion in a solution of 1000 ppm $GA_3$.
- **Acid scarification** is defined as immersion in undiluted sulfuric acid ($H_2SO_4$) for the referenced time period.
- **Embryo excision** (XP) is defined as removal of the pericarp. Testa remained intact unless inadvertently removed or ruptured.

Germination was defined as emergence of the cotyledon unless the radical was observed to have emerged during the stratification process.

## RESULTS AND DISCUSSION

**Arboretum Propagation Records.** In over 25 years of plant exploration, Morris Arboretum has received seed collections of approximately 80 taxa of *Acer* (van Gelderen et al., 1994); of those taxa, 83% have been successfully propagated (Table 1). For these taxa, the results show the treatment utilized and the germination percentage where available. In many cases we received very few seeds and germination was attempted on only one occasion. So, these results are preliminary and represent well-informed trials rather than controlled and replicated experiments.

We have included both successful and unsuccessful germination as a means of stimulating interest in the germination requirements of little known maple species. In many cases propagation percentages were very low (< 1%) but for the purpose of adding maple taxa to our living collections, growing a few plants is generally adequate. Clearly for commercial propagation, even for specialty nurseries, further work is required to increase these percentages. These results are intended as a basis for furthering the understanding of the propagation of unusual maples and a way to stimulate additional research on germinating these taxa.

***Acer* Seed Germination: Fall 2005.** Several observations can be made based on the 2005 propagation trials (Table 2). Treatments with cold stratification in excess of 3 months showed increased germination percentages. *Acer palmatum* ssp. *matsumurae* (2005 × 156) had no germination with 3 months cold stratification, but

**Table 1.** Results of *Acer* taxa propagated at the Morris Arboretum (MOAR) from 1979 through 2005.

| Acer taxon | Times propagated (no.) | MOAR propagation no. of most successful treatment | Treatment[1] | Highest germination (%)[2] |
|---|---|---|---|---|
| *acuminatum* | 1 | 94 × 139 | 3c | 2% |
| *argutum* | 2 | 2005 × 138 | 1 w/4c XP | 5% |
| *barbinerve* | 10 | 2003 × 010 | 1w/3c/MH | 4% |
| *buergerianum* | 12 | 88 × 173 | 3c | 68% |
| *caesium* | 1 | 94 × 135 | 3c | < 1% |
| *caesium* subsp. *giraldi* | 1 | --- | 3c | 0 |
| *campbellii* | 1 | 93 × 635 | 1w/3c | 20% |
| *campbellii* subsp. *sinense* | 1 | 95 × 076 | 4c | > 10% |
| *campbellii* subsp. *wilsonii* | 1 | 96 × 420 | 3c | < 1% |
| *campestre* | 7 | 92 × 005 | 4w/4c | > 1% |
| *capillipes* | 2 | 89 × 272 | 1c | 100% |
| *cappadocicum* | 1 | 94 × 143 | 3c | 14% |
| *cappadocicum* var. *sinicum* | 1 | 81 × 248 | 3c | < 1% |
| *carpinifolium* | 6 | 94 × 160 | 3c | < 1% |
| *caudatifolium* (*morrisonense*) | 2 | 79 × 278 | 3c | > 1% |
| *caudatum* subsp. *multiserratum* | 4 | 2005 × 116 | 1w/3c | 1% |
| *caudatum* subsp. *ukurunduense* | 9 | 97 × 164 | 4c | 10% |
| *caudatum* (var. *prattii*) | 2 | --- | 3c | 0 |
| *circinatum* | 2 | 92 × 182 | 2w/3c/MH | 10% |
| *cissifolium* | 3 | 2005 × 146 | XP/1c/1w/3c | 6% |
| *crataegifolium* | 8 | 96 × 246 | 3c/MH | 5% |
| *davidii* | 6 | 2002 × 273 | 3c | < 1% |
| *davidii* subsp. *davidii* | 2 | 96 × 481 | 3c | > 5% |
| *davidii* subsp. *grosseri* | 2 | 94 × 461 | 3c | 13% |
| *diabolicum* | 1 | 2005 × 149 | 1w/3c | 0 |
| *distylum* | 2 | 93 × 571 | 3c | 100% |
| *erianthum* | 2 | --- | 3c | 0 |
| *fabri* | 1 | 86 × 014 | 2c | > 1% |
| *forresti* | 1 | --- | 3c | 0 |
| *glabrum* | 2 | 93 × 667 | 1w/6c/MH | 2% |
| *glabrum* subsp. *douglasii* | 3 | 97 × 103 | 6w/6c | 16% |
| *glabrum* var. *torreyi* | 2 | 2000 × 327 | 6w/6c | 21% |
| *grandidentatum* | 2 | 90 × 257 | 1.5c | > 1% |
| *griseum* | 22 | 84 × 58 | Knick/1.5c | > 20% |
| *heldreichii* | 1 | --- | 3c | 0 |
| *heldreichii* subsp. *trautvetteri* | 2 | 2002 × 250 | MH | 39% |
| *henryi* | 2 | 93 × 581 | 3c | > 1% |
| *japonicum* | 4 | 98 × 217 | 5c | > 1% |
| *kawakamii* | 1 | --- | 3c | 0 |

| | | | | |
|---|---|---|---|---|
| *laxiflorum* | 2 | --- | 3c | 0 |
| *macrophyllum* | 4 | 92 × 547 | 2c | 27% |
| *mandshuricum* | 15 | 97 × 225 | XP/3c | 15% |
| *maximowiczianum* | 1 | --- | direct sow | 0 |
| *micranthum* | 3 | 2005 × 152 | GA/1w/1.5c | 4% |
| *miyabei* | 2 | 98 × 231 | 3c | > 1% |
| *miyabei* subsp. *miaotaiense* | 3 | 98 × 268 | GA/MH | > 1% |
| *mono* | 22 | 96 × 061 | 3c | > 10% |
| *mono* subsp. *okamotoanum* | 4 | 90 ×416 | No strat | < 1% |
| *monspessulanum* | 2 | 87 × 166 | 3c | > 1% |
| *nigrum* | 1 | 93 × 408 | 3c | 3% |
| *nipponicum* | 2 | 2004 × 136 | 3c | 71% |
| *oblongum* | 1 | --- | 3c | 0 |
| *oliverianum* subsp. *oliverianum* | 1 | 96 × 428 | 3c/MH | > 1% |
| *palmatum* | 3 | 91 × 222 | 5c | < 1% |
| *palmatum* subsp. *amoenum* | 2 | 88 × 035 | 5c | 10% |
| *palmatum* subsp. *matsumurae* | 3 | 2005 × 156 | 1w/4c | 21% |
| *pectinatum* subsp. *maximowiczii* | 6 | 2005 × 105 | 3c/3w/3c | 4% |
| *pensylvanicum* | 1 | 93 × 016 | 3c | > 10% |
| *pseudoplatanus* | 1 | --- | 3c | 0 |
| *pseudosieboldianum* | 14 | 91 × 587 | 3c | < 1% |
| *pseudosieboldianum* subsp. *takesimense* | 2 | 91 × 539 | 3c | > 1% |
| *rufinerve* | 9 | 2001 × 093 | 3c | 14% |
| *schneiderianum* | 1 | --- | 3c | 0 |
| *serrulatum* | 2 | 79 × 277 | ? | > 1% |
| *shirasawanum* | 5 | 2005 × 158 | 1w/5c | 32% |
| *sieboldianum* | 4 | --- | 3c | 0 |
| *spicatum* | 5 | 2003 × 018 | 3c | 33% |
| *stachyophyllum* | 3 | --- | 1w/3c | 0 |
| *stachyophyllum* var. *pentaneurum* | 1 | 93 × 168 | 1w/3c | 44% |
| *sterculiaceum* subsp. *franchetii* | 6 | 93 × 167 | 1w/3c | 50% |
| *tataricum* | 2 | 92 × 555 | 3c | < 1% |
| *tataricum* subsp. *ginnala* | 5 | 80 × 6 | 3c | > 50% |
| *tataricum* subsp. *semenovii* | 1 | 93 × 401 | 1w/4c | 35% |
| *tegmentosum* | 7 | 97 × 195 | 1w/4c | 4% |
| *tetramerum* subsp. *betulifolium* | 3 | --- | 6.5c/XP | 5% |
| *triflorum* | 19 | 97 × 205 | 9w/3c/MH | 3% |
| *truncatum* | 5 | 85 × 025 | 2c | > 1% |
| *tschonoskii* | 4 | 2001 × 232 | 1wkw/3c | > 10% |
| *tschonoskii* var. *rubripes* | 2 | 90 × 418 | None | > 1% |
| *yui* | 1 | 2005 × 126 | 3c/3w/3c | 4% |

[1] 1w = 1 month warm, 1c = 1 month cold, GA = gibberellic acid, MH = Medicinal House [seed flats overwintered in glass house heated to 35 °F (2 °C)], XP = pericarp removed.

[2] Percentages indicated by < or > are used when seeds were not counted and accurate germination percentages could not be calculated.

**Table 2.** *Acer* germinated beginning in the fall of 2005. Seed collected on the NACPEC05 expedition to China and BBMJT 2005 expedition to Japan.

| *Acer* species or subspecies (collector no.) | Greenhouse Propagation (no.) | TRT[2] | Seed (no.) | Pretreatment | Stratification Warm | Stratification Cold | Stratification Warm | Stratification Cold | Additional TRTS[2] | Germination Date | Germination (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *argutum* | 2005 × 138 | 1 | 100 | acid 5 min. | 1 mo | 4 mo | | | | | N/A 0 |
| (BBMJT-223) | | 2A | 22 | | 1 mo | 4 mo | | | | N/A | 0 |
| | | 2B | 20 | | 1 mo | 4 mo | | | XP 5/16 | 05/22/06 | 5% |
| *caudatum* subsp. | 2005 × 116 | 1 | 100 | | 1 mo | | | | MH | | 1% |
| *multiserratum* | | 2 | 100 | | 1 mo | 3 mo | | | | 06/26/06 | 1% |
| (NACPEC05-057) | | 3 | 131 | | 1 mo | 3 mo | | | | 05/15/06 | < 1% |
| | | 4 | 100 | | 2 mo | 6 wk | | | GA 24 h 2/9 | 02/16/06 | 1% |
| *caudatum* subsp. ukurunduense (BBMJT-252) | 2005 × 144 | 1 | | | | | | | | | < 1% |
| *cissifolium* | 2005 × 146 | 1 | 89 | | | 1 mo | 1 mo | 2 mo | XP 2/11 | N/A | 0 |
| (BBMJT-278) | | 2 | 100 | XP | | 1 mo | 1 mo | 3 mo | stratify in pot | | 6% |
| *davidii* subsp. *grosseri* | 2005 × 110 | 1 | 100 | | | 1 mo | | | | MH | 05/20/06 |
| 1% | (NACPEC05-043) | | 2 | 100 | | 1 mo | 2 mo | | | | N/A 0% |
| | | | 3 | 100 | | 1 mo | 3 mo | | | | N/A 0% |
| | | | 4 | 100 | | 2 mo | 6 wk | | | GA 24 h | 02/26/06 |
| 1% | | | | 5b | 33 | | 2 mo | 3 mo | | | GA 26 h |
| 04/10/06 | 1% | | | | 5c | 33 | | 2 mo | 5 mo | | XP af- |
| ter strat | 06/08/06 | 7% | | | | | | | | | |
| *diabolicum* | 2005 × 149 | 1 | 45 | acid 8 min. | 1 mo | 3 mo | | | | N/A | 0 |
| (BBMJT-190) | | 2 | 44 | nick | 1 mo | 3 mo | | | | | N/A 0 |
| *distylum* | 2005 × 150 | 1 | 13 | | | 3 mo | | | XP 5/5 | N/A | 0 |
| (BBMJT-062) | | | | | | | | | | | |
| *micranthum* | 2005 × 152 | 1 | 28 | GA 21 h | 1 mo | 6 wk | | | | 05/06/06 | 4% |
| (BBMJT-240) | | 2 | 23 | knick | 1 mo | 1 mo | | | | N/A | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *miyabei* | 2005 × 153 | 1 | 14 | | 1 mo | 4 mo | | | XP | N/A | 0 |
| (BBMJT-267) | | 2 | 12 | XP | 1 mo | 3 mo | | | | N/A | 0 |
| *palmatum* subsp. | 2005 × 155 | 1 | 60 | | 1 mo | 5 mo | | | | 06/13/06 | 17% |
| *matsumurae* | | 2 | 60 | GA 2/14 | 1 mo | 1 + 3 | | | | 05/21/06 | 3% |
| (BBMJT-077) | | | | | | | | | | | |
| *palmatum* subsp. | 2005 × 156 | 1 | 67 | acid 7 min. | 1 mo | 3 mo | | | | N/A | 0 |
| *matsumurae* | | 2 | 67 | | 1 mo | 4 mo | | | | 05/19/06 | 21% |
| (BBMJT-135) | | | | | | | | | | | |
| *pectinatum* subsp. | 2005 × 105 | 1 | 200 | direct sow | | | | | MH | 06/07/06 | 4% |
| *maximowiczii* | | 2 | 200 | | 1 wk | 3 mo | | | | 03/23/06 | < 1% |
| (NACPEC05-034) | | 3 | 200 | | 1 wk | 3 mo | 3 mo | 3 mo | | 08/04/06 | 4% |
| | | 4 | 200 | | 2 mo | 6 wk | | | GA 24 h | 04/12/06 | < 1% |
| *argutum* | 2005 × 138 | 1 | 100 | acid 5 min. | 1 mo | 4 mo | | | | | N/A0 |
| *shirasawanum* | 2005 × 158 | 1 | 29 | | 1 mo | 4 mo | | | | 05/10/06 | 7% |
| (BBMJT-191) | | 2 | 29 | | 1 mo | 5 mo | | | | strat | 32% |
| *tetramerum* subsp. | 2005 × 093 | 2 | 100 | | 1 wk | 3 mo | | | | | 0% |
| *betulifolium* | | 3 | 100 | | | | | | | | |
| (NACPEC05-020) | | 4 | 100 | | 2 mo | 6 wk | | | GA 24 h | | 0% |
| | | 5 | 80 | | 1 wk | indef. | | | | 05/18/06 | 1% |
| | | 6 | 20 | | 1 wk | indef. | | | XP | 05/19/06 | 5% |
| *tschonoskii* | 2005 × 161 | 1 | 28 | | 1 mo | 3 mo | | | | N/A | 0 |
| (BBMJT-005) | | 2a | 12 | | 1 mo | 4 mo | | | | N/A | 0 |
| | | 2b | 10 | | 1 mo | 4 mo | | | XP | 05/21/06 | 10% |
| *yui* | 2005 × 126 | 1 | 143 | | 1 mo | 3 mo | | | | 03/12/06 | 1.40% |
| (NACPEC05-071) | | 2 | 141 | | 1 mo | 3 mo | 3 mo | 3 mo | | strat | 4% |

Note: Acid = sulfuric acid scarification; GA = gibberellic acid; MH = medicinal house [seed flats overwintered in glass house heated to 35 °F (2 °C)]; XP = pericarp removed; strat = stratification; TRT, TRTS = treatment and treatments; mo = month; wk = week; min = minute; strat = stratification.

21% germination after 4 months. *Acer shirasawanum* (2005 × 158) had 7% germination after 4-months cold stratification, but 32% germination after 5 months. Of six treatments of *Acer davidii* ssp. *grosseri*, its highest germination percentage (7%) occurred with 2 months warm and 5 months cold stratification.

Removal of the pericarp was not universally successful. This indicates either that the testa is impeding germination or that the embryo has a physiological dormancy that was not overcome by the stratification period (Wiegrefe, 1998). In two cases, removal of the pericarp after stratification resulted in higher germination rates (Table 2: *A. tetramerum* ssp. *betulifolium* and *A. tschonoskii*). *Acer cissifolium* germinated when the pericarp was removed prior to stratification rather than after stratification, although the two treatments differed in the length of the cold stratification (Table 2).

Alternating periods of warm and cold stratification show potential for increasing germination percentages (Table 2). One treatment of *A. pectinatum* (2005 × 105 Trt. 1) was direct sown and placed in a greenhouse heated in the winter to 35 °F (2 °C). A second treatment had alternating periods of warm and cold stratification (2005 × 105 Trt. 3). Both treatments resulted in 7% germination, higher than those treatments that received only one period of warm and one period of cold stratification. *Acer yui,* a rare species for which propagation protocol is virtually nonexistent, germinated after 1 month warm and 3 months cold stratification, but more than doubled germination when given a second period of cold stratification (Table 2). These results raise the question of whether the periods of cold stratification are cumulative; thereby reinforcing the finding that increasing cold stratification often increases germination, or whether the critical factor is the alternating periods of warm and cold stratification (Coggeshall, 1999; Krautmann, 1999).

## SUMMARY

The results presented in this paper represent more than 25 years of seed propagation of a large number of *Acer* taxa. In many cases, germination rates were low but the resulting plants added important and unusual maples to the collection of the Morris Arboretum. Because the genus *Acer* is a large and variable group, it is difficult to make generalizations about germination protocols. A sensible approach is to base germination on the type of seed coat (Krautmann, 1999) which may or may not correspond to the taxonomic sections of the genus.

Our results, as expected, show a wide range of responses to various treatments. These propagation trials will be used by the Arboretum, and hopefully by others, to expand and refine our procedures for germination of maples. As mentioned previously, these trials are preliminary in nature and represent our efforts to germinate maple taxa for which there is little if any published information on germination requirements. When reviewing the number of maple taxa added to the collection of the Morris Arboretum, we have successfully achieved our plant exploration goals of broadening the genetic pool of known species and introducing appropriate new species.

## LITERATURE CITED

**Coggeshall, M.V.** 1999. Seed propagation of *Acer diabolicum*. Comb. Proc. Intl. Plant Prop. Soc. 49: 255-258.

**Dirr, M.A.,** and **C.W. Heuser, Jr.** 1987. The reference manual of woody plant propagation: from seed to tissue culture. Varsity Press, Athens, Georgia.

**Krautmann, M.E.** 1999. Germination and growth of *Acer* species. Comb. Proc. Intl. Plant Prop. Soc. 49: 595-598.

**U.S. Department of Agriculture, Forest Service.** 1974. Seeds of woody plants in the United States. Agriculture Handbook 450. Washington, D.C.

**van Gelderen, D.M., P.C. De Jong,** and **H.J. Otterdoom.** 1994. Maples of the world. Timber Press, Portland, Oregon.

**Wiegrefe, S.J.** 1998. Embryo excision for accelerated and uniform germination of hard-to-germinate maple species: Comb. Proc. Intl. Plant Prop. Soc. 48: 347-353.

**Young, J.A.,** and **C.G. Young.** 1992. Seeds of woody plants in North America. Timber Press, Portland, Oregon.