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Altitudinal variation in germination characteristics of yellow-poplar in the southern appalachians[1]

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Summary

Open-pollinated seed from parent trees located at high and low elevations in the southern Appalachians were germinated in factorial trials to develop germination procedures for genetically variable yellow-poplar. Test factors included light, temperature, stratification procedure, and collection time, all of which significantly influenced germination percentage. The main source of variation, however, was the elevation of parent trees, with high elevation families exhibiting substantially lower germination than did low elevation families. Significant variation was also noted among farnilies within elevational provenances. Stimulation of germination of the majority of seed from high elevation parents could be attained only through long stratification periods (18 months). Gibberellins were sporadically effective in stimulating gerrnination of unstratified seed from some families.

Key words: Stratification, light, temperature, collection date, and gibberellin.

Zusammenfassung

Saatgut von *Liriodendron* tulipifera L. aus einigen Provenienzen unterschiedlicher Seehöhe in den südlichen Appalachians wurde zu Keimversuchen mit verschiedenen Testfaktoren herangezogen. (Licht, Temperatur, Stratifikation und Zeitpunkt der Saatguternte). Als Hauptursache für die Variation der Herkünfte stellte sich die Höhe ü. NN der Ausgangsbäume heraus. Dabei zeigte das Saatgut aus höheren Lagen, über 1000 m, ein niedrigeres Keimprozent als solches aus tieferen Lagen, 270—470 m. Eine Stimulation der Keimung konnte nur durch Stratifikation erreicht werden. Die Anwendung von Gibberellin hatte bei nicht stratifiziertem Saatgut teilweise sporadischen Einfluß.

Introduction

Although seed handling recommendations for yellow-poplar (Liriodendron tulipifera L.) have been published for decades (TVA 1940; BONNER and RUSSELL 1974) and dormancy relations are known in a general way (ADAMS 1968; BOYCE and HOSNER 1963; CLARK and BOYCE 1964), recent nursery experience in connection with breeding programs has highlighted problems of predicting germination for individual open-pollinated and full-sibling progenies. For example, some stratified or fall-planted seed lots have failed to germinate adequately in the year of planting, but have produced seedlings abundantly the second year. Difficulty with progeny test establishment has been a result.

Yellow-poplar seed may remain in the litter (CLARK and BOYCE 1964) or stratified in soil pits (WILLIAMS and MONY 1962) for several years, with increasing germination capacity developing over time. Such a reproductive strategy has considerable fitness value for an intolerant species. Working with seed from a single tree in southern Illinois, BOYCE and HOSNER (1963) noted that several cycles of chilling followed by warm temperature resulted in complete germination over a six-month period. This suggested intra-family variation in chilling requirement, with a portion of the family requiring a single cycle and another portion two or more cycles. On the other hand, the work of ADAMS (1968) with a Virginia source indicated that complete germination could be obtained with a single 20-week exposure to a chilling temperature and that weekly alternatives from 36^0 to 54^0 F (2^0—12^0 C) resulted in reduced germination relative to constant chilling. Hence, it is still unclear whether yellow-poplar seed requires a single long period of chilling or several cycles of chilling followed by germination temperatures, or whether these two strategies are interchangeable. Patterns of natural variation in dormancy are not known, though such variation appears to be a dominant factor in germination. This investigation is aimed at clarification of these questions using open-pollinated seed from individual trees of altitudinally diverse provenances in the southern Appalachian mountains.

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Methods and Results

General

Seed from 20 open-pollinated trees were used in a series of tests which took place between 1971 and 1975. Ten of the trees were from low elevation (270—470 m) sources near Tellico Plains, Tennessee (latitude — 35° 32' N, longitude — 84° 30' W), and Clemson, South Carolina (latitude — 34° 36' N, longitude — 82° 42' W), on the northwest and southeast sides of the southern Appalachians, respectively. Ten high elevation (1,170—1,370 m) trees were selected in southeastern Tennessee and western North Carolina, roughly on a line between Tellico Plains and Clemson. Trees were selected for accessibility, and collections were made from the same 20 trees in 1971, 1972, and 1973. Cutting tests were made to determine filled samara percentages; three-year means and tree-to-tree ranges for high and low elevation trees were, respectively, 13 and 3—26 and 15 and 0.2—27. Year-to-year correlations of filled samara percentage for individual parent trees were high ($r = .73$ to .84) suggesting strong genetic control over this widely variable characteristic. Analysis of variation in cone and samara length and width using a hierarchical analysis of variance indicated that tree-to-tree variance accounted for 50 to 94 percent of size differences in the population; altitudinal effects were nonsignificant. Mean cone length for individual trees ranged from 5.9 to 8.5 cm and the equivalent range for samara air-dry weight was 17 to 45 mg.

Filled samaras were used in all germination tests. These were separated from "raw" seed lots by first dewinging samaras in a small grain thresher, then "upgrading" them by density fractionation in an aspirator after the method of Bonner and Switzer (1971). Upgraded samaras were placed on sheets of clear plastic covered with a sticky substance and radiographed using the Kodak Industrex process, which directly produces a positive print. Filled seed images were circled on this print and the plastic samara holder was superimposed on the print to allow quick and accurate identification and removal of filled samaras.

Test I — Effects of Stratification Time and Germination Environment

Samaras were collected in early October 1971 and 1972 from seven trees in each of the two altitudinal provenances. The 1971 seed was germinated in petri dishes on moist filter paper following 8, 16, or 24 weeks stratification at 3° C in polyethylene bags. Seed collected in 1972 was placed in square petri dishes containing a sand-peat (2 : 1) mixture for stratification treatments of 8 and 16 weeks as well as for germination tests. In both tests germination (radical 5 mm long) was recorded until no new germination occurred over a 10-day period. This germination period was four to six weeks. Ungerminated seed was then moved back to the chilling temperature for a second stratification period, after which germination was again observed in the same environments (*Table 1*). Two 10-seed replicates per tree-treatment combination were routinely used in both years. Appropriate factorial analyses of variance were performed with arc-sin transformations of germination percentages. This transformation produced approximately normal distributions of data in this and subsequent tests.

In the 1971 trial, general effects of stratification time were nonsignificant, and the higher germination temperature caused a significant ($P < .05$) reduction in germination percentage relative to 13—18° C after all stratification periods (*Table 1*). (Data for 16 weeks stratification are not included in *Table 1* because there was no significant difference between germination after 16 and 24 weeks stratification.) Light stimulated germination after eight weeks stratification but had no effect after longer chilling periods, as was evidenced by a significant light × stratification interaction for data from the first germination period. However, the most notable result was the major difference in germination between seed from high and low elevation trees, with seed from most high elevation trees exhibiting less than 30 percent germination. Wide variation was also noted in germination percent of seed from individual trees. If seed germinated at all, most did so after the first chilling period.

Table 1. — Germination Percentages of Yellow-poplar Seed as Influences by Seed' Source, Stratification, and Germination Environment. Treatment means based on 14 ten-seed replicates.

Stratification Period	Germination Environment		Percent Germination			
			High Elevation Trees		Low Elevation Trees	
Weeks	Temperature	Light	Cycle #1	Cycle #2	Cycle #1	Cycle #2
			1971 Seed			
8	13°–18° C[2]	Light[3]	25 (0–70)[1]	8	65 (45–90)	8
		Continuous Dark	8 (0–25)	21	47 (15–80)	10
	24°–29° C	Light	1 (0–10)	2	33 (10–70)	2
		Continuous Dark	0	1	29 (10–60)	11
24	13°–18° C	Light	24 (5–50)	5	67 (55–80)	2
		Continuous Dark	14 (0–40)	5	67 (40–85)	1
	24°–29° C	Light	1 (0–5)	6	41 (25–65)	3
		Continuous Dark	4 (0–15)	6	42 (15–70)	3
			1972 Seed			
8	13°–18° C	Light	36 (10–55)	4	52 (20–65)	2
		Continuous Dark	4 (0–10)	12	47 (25–60)	8
	18°–24° C	Light	24 (5–40)	12	66 (20–90)	1
		Continuous Dark	6 (0–20)	2	26 (5–50)	6
16	13°–18° C	Light	26 (10–35)	10	58 (40–75)	6
		Continuous Dark	8 (0–25)	12	50 (35–60)	6
	18°–24° C	Light	24 (5–35)	4	52 (5–80)	4
		Continuous Dark	4 (0–15)	2	28 (5–45)	1

1. Range of family means
2. Low temperature 10 hours (night); high temperature 14 hours (day)
3. Approximately 2,000 foot candles from inflorescent and incandescent sources during 14-hour day period

Provenance and individual tree effects were also noted in the test with 1972 seed from the same trees (*Table 1*). In this second test, about the same degree of germination occurred in both temperature regimes. While light stimulated germination, the effects of stratification time were nonsignificant.

After the second cycle of germination was completed in these tests, ungerminated seed were examined and classified as sound or decayed. During the course of the tests an average of 60—70 percent of the ungerminated seed decayed. The percentage of ungerminated seed which decayed varied by individual tree and ranged significantly from 29 to 88 percent, but it was not influenced by elevational source. For these reasons a third cycle of chilling and germination was deemed unwarranted.

Test II — Effects of Collection Time and Warm Stratification

Seed collected in 1973 were used to investigate the possible influence of collection time and a period of warm stratification (18° C) prior to chilling. These were factors which might be related to elevational provenance effects. Seed were collected from the same eight low elevation and nine high elevation trees in mid-September and again in early November, immediately before disintegration of the cones. Cones from both collections were spread in a thin layer under warm (18—24° C), dry conditions until samaras were easily separated from the placenta. Seed were stored dry at 3° C until February 1974, when one-half of the seed from each parent-tree lot was subjected to two weeks moist storage in polyethylene bags at 18° C followed by 16 weeks at 3° C. The other half was given 16 weeks stratification at 3° C. After stratification, two 10-seed replicates from each tree-stratification-collection time combination were germinated under 14-hour photoperiods at 18—24° C on moist filter paper and in a sand-peat medium.

The analysis of variance of arc-sin transformations of germination percentages indicated that neither germination medium nor stratification procedure significantly influenced germination. However, seed collected in November had a significantly ($P < .05$) higher germination percent than seed from the September collection, and this difference was particularly striking for high elevation seed (*Table 2*). Bonner (1976) has reported a similar effect of collection time in some lots of seed collected in Mississippi. Due to wide family variance within provenances, general elevation effects were nonsignificant in this test. However, a significant collection time × source interaction indicated that high elevation seed were negatively affected more by early collection than were low elevation seed. As in Test I, a second stratification period resulted in only minor additional germination (< 10 percent).

Table 2. — Effects of Collection Time and Stratification Procedure on Germination Percent of High and Low Elevation Yellow-Poplar Seed. Treatment means based on 32 to 36 ten-seed replicates.

Source Elevation	Percent Germination: Early Collection Warm-Cold	Early Collection Cold	Late Collection Warm-Cold	Late Collection Cold
270–470 m	34 (0–65)[1]	36 (2–70)	43 (20–62)	53 (22–75)
1,160–1,370 m	11 (0–30)	15 (0–40)	40 (5–70)	35 (2–67)

1. Range of family means

Test III — Effects of Long Stratification Periods

Since the above conditions of collection, stratification, and/or germination all resulted in generally incomplete germination of high elevation seed, longer periods of continuous chilling were included in this test with the 1974 seed crop collected in middle to late October. Seed from seven trees from each of the two elevational provenances were used. Three 30-seed replicates (individual flats of sand : peat) from each tree were assigned to each of the following three treatments:

1. Stratified continuously at 3° C for 18 months, then germinated in the greenhouse at 18—24° C.
2. Stratified in an outdoor pit under sawdust for one winter, placed in the greenhouse until germination ceased, replaced in pit for second winter of stratification, then placed in the greenhouse for a second germination period. This treatment simulates the natural stratification-germination cycle.
3. Stratified at 3° C for six months, placed in the greenhouse until germination ceased, replaced at 3° C for a second six-month period, then placed in the greenhouse for a second germination period.

Germination was recorded when cotyledons had cleared the surface of the growth medium.

Continuous chilling for 18 months resulted in significantly ($P < .05$) higher total germination than either simulated natural chilling or six-month chilling cycles (*Table 3*). The 51 percent germination average in this treatment was the highest observed for high elevation seed in the series of tests and was not significantly lower than the 71 percent for low elevation families. Five of the seven high elevation trees exhibited germination over 50 percent. There was a major difference between the two cyclic treatments in that little germination took place after one winter's out-of-door chilling, while most of the germination in the seed stored at 3° C for six months occurred after the first chilling period. It must be noted, however, that when the test was dismantled after two seasons, practically all ungerminated seed were decayed.

Discussion

While collection time, stratification procedure and germination environment were all shown to influence the degree of yellow-poplar germination significantly, variation among open-pollinated families and between altitudinal provenances was the most notable feature of the study. Average germination (based on data from Tests I, II, and

Table 3. — Germination Percents of Yellow-Poplar Seed Treated with Three Stratification Procedures. Treatment means are based on 21 30-Seed replicates.

Source Elevation	Cumulative Germination Percent following: Stratification at 3° C, 18 Months	One 6-Month Stratification Period at 3° C	Two 6-Month Stratification Periods at 3° C	One Winter of Outdoor Stratification	Two Winters of Outdoor Stratification
270–470 m	71 (50–82)[1]	48 (8–90)	50 (12–90)	12 (1–35)	46 (23–90)
1,160–1,370 m	51 (9–80)	30 (3–83)	38 (5–83)	1 (0–3)	21 (0–42)

1. Range of family means

III) of filled seed from six low elevation trees, following various short stratification periods (six months or less) and germination conditions, was 55 percent with family means ranging from 45 to 61 percent. Equivalent means based on data from high elevation trees were 29 percent and 13 to 42 percent. Only continuous cold stratification for as long as 18 months substantially promoted germination of these high elevation seed. Of the several other observed relationships, the positive effects of light and late fall collection warrant consideration in seed testing and handling.

Seed from many high elevation trees apparently have a complex and/or long chilling requirement which has not been fully elucidated in this study. Part of the observed variation may be due to environmental preconditioning effects associated with parent tree locations. Furthermore, the clarification of this chilling requirement is complicated by the fact that many seed which were subjected to long stratification-germination cycles decayed during these treatments. Results of CLARK and BOYCE (1964) also suggest some loss to decay in such cycles though this was not directly observed. Familial variation in susceptibility to such decay is probable.

It is clear, however, that populations of yellow-poplar have seed germination strategies which contribute to fitness mainly by extending the germination period over the course of several years, as has been noted by previous investigators. Data from this study further suggest that both intra- and interfamily variation in dormancy relations contribute to this attribute. This variation should be recognized in breeding and planting programs where the possibility exists of eliminating large portions of a population through unintentional selection of early germinators. While this selection may not always be undesirable, it should be done consciously and based upon a knowledge of the material's germination characteristics. Until further information is available on the genetics of germination characteristics, a long stratification period which, will result in a more complete germination is recommended, particularly for progenies from high elevation provenances in the southern Appalachians.

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A comparison of seedlings and clonal cuttings of sitka spruce (Picea sitchensis (Bong.) Carr.)

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Abstract

Eight clones of Sitka spruce *(Picea sitchensis* (BONG.) CARR.) and a comparable set of seedlings were investigated in a period of six years concerning the traits: height, stem form, and time of flushing.

At the end of this period the cuttings were 44% higher than the seedlings. The variation in height is smaller within clones than between seedlings. In stem form the variation is smaller during the first years and equal at the last assessment. The variation in flushing is considerably smaller within clones than among seedlings.

This may indicate that this character is highly heritable.

Key words: Cuttings, *Picea sitchensis* (BONG.) CARR.

Zusammenfassung

Acht Stecklings-Klone von *Picea sitchensis* (BONG.) CARR. sowie vergleichbare aus Samen hervorgegangene Sitkafichten wurden sechs Jahre lang auf die Merkmale Höhe, Stammform und Triebentwicklung hin untersucht. Nach sechs Jahren waren die Stecklingspflanzen 44% höher als die Sämlingspflanzen, wobei die Variation innerhalb der Stecklings-Klone geringer war als zwischen den Stecklingspflanzen. Die Stammform variierte in den ersten Jahren weniger und war bei der letzten Schätzung gleich. Die Variation der Triebentwicklung war innerhalb der Klone erheblich geringer als bei den Sämlingen. Das könnte bedeuten, daß die Pflanzen in diesem Merkmal einen hohen Heritabilitätsgrad aufweisen.

Introduction

Sitka spruce *(Picea sitchensis* (BONG.) CARR.) is an important tree species in Denmark, and has been cultivated in the last hundred years. Compared to Norway spruce *(Picea abies* L. KARST) the preferences are tolerance against salt, which makes cultivation possible in coastal areas, especially in the dunes, and rapid growth which is evident on poorer soils.

In 1970 a breeding programme was set up (BRANDT, 1970). This programme included a traditional seed orchard system with backwards selection i.e. selection among the clones according to their breeding value based on progeny testing,