GERMINATION OF NORTHERN RED OAK: EFFECTS OF PROVENANCE, CHILLING, GIBBERELLIC ACID

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Early studies of northern red oak *(Quercus rubra* L.) seed dormancy pointed to existence of embryo dormancy (Korstain, 1927; Cox, 1942; McDermott, 1941), and recent observations of gibberellic acid effects (Vogt, 1970) support this hypothesis. Jones and Brown (1966), on the other hand, noted that excised embryos and seed with the apical end of the pericarp removed or split exhibited no dormancy. They concluded that pericarp structure causes dormancy, and cell expansion during stratification exerts enough pressure to burst the pericarp. While cold stratification for various periods has been recommended for breaking dormancy, observations in some southern red oaks *(Q. nigra* L., *Q. phellos* L., *Q. shumardzi* Buckl., *Q. falcata* var. pagodaefolia Ell.) indicate that these species do not have absolute stratification requirements (Usanis, 1968; Bonner, 1970). Russell (1971) has noted that successful storage conditions for red oaks (i.e., low temperature, high moisture content) are equivalent to stratification and will overcome dormancy. Suszka [1] has recently suggested that a period of cold storage at collection moisture content may be sufficient to break northern red oak dormancy and that stratification may be unnecessary. In this study, Suszka's hypothesis has been tested. The chilling requirements of seed from several provenances, as well as their response to gibberellic acid (GA3), have also been determined.

METHODS

Acorns were collected from isolated trees shortly after seedfall. Seed from four trees were collected in Cheboygan County, Michigan (latitude 45°N) on September 29. Six trees from high elevations (4000 - 8000 feet) in western North Carolina and six trees from low elevations (1000 feet) in eastern Tennessee were sampled October 13 and 18 respectively. Seed were placed in polyethylene bags upon collection and returned to the laboratory where they were sorted by hand to remove damaged and weevil-infested acorns. Seed diameter and average moisture content (over-dry weight basis) at collection were determined on samples of ten randomly selected seeds per tree:

Source	Moisture Content (percent) Mean	Moisture Content (percent) Tree-to-Tree Range	Seed Diameter (mm.) Mean	Seed Diameter (mm.) Tree-to-Tree Range
Northern	64	62-72	16	13-18
Appalachian, High Elevation	80	62-93	19	16-20
Appalachian, Low Elevation	70	60-100	21	19-24

Mean seed size of samples from the three sources was significantly different. However, further study will be necessary to determine if this variation represents actual population differences, since some size selection probably occurred during collection.

Collections from each tree were divided into seven 80-seed samples and treated as follows:

(1) One was further divided into four 20-seed subsamples, each of which was given one of the following treatments and immediately planted:
   (a) Control: Seed soaked for 24 hours in water.
   (b) Cracked: Pericarp cracked, then seed soaked 24 hours in water.
   (c) GA: Seed soaked for 24 hours in 100 ppm GA_3.
   (d) GA-Cracked: Pericarp cracked, then seed soaked for 24 hours in 100 ppm GA3.
(2) Three were stratified in moist sand at 4°C.
(3) Three were stored at 4 °C. in polyethylene bags at collection moisture content.

After 4, 10, and 16 weeks' storage, one sample from (2) and (3) above was subdivided, treated, and planted as for (1) above.

Two 10-seed replicates of each tree-treatment combination were planted in sand flats arranged randomly on a greenhouse bench. Seed from each source were stored as soon as possible after collection; therefore, planting dates differed among sources after any given storage period. Greenhouse conditions were reasonably uniform throughout the test, and these planting date differences are believed to have had little influence on variation in germination behavior among sources. During the study, greenhouse temperature averaged 21°-24°C. and ranged diurnally from 18° to 29 C. A 16-hour photoperiod was maintained with incandescent and fluorescent lighting.

To obtain a record of germination over time, seed were noted as having germinated when the shoot apex appeared above the sand surface; sufficiently frequent observations were made to obtain a record of germination pattern. Final germination data also include a few

[1] *Suszka, Boleslaw.* 1971. First Annual Report on Studies on the Long-Term Storage of Acorns. E21-FS-44, FG-Po-253. Polish Academy of Science, Inst. of Dendrology and Kornik Arboretum.

seed which exhibited only a radical growth when the tests were dismantled. Length of the initial flush of stem growth was measured on all seedlings in trials after 0 and 4 weeks storage and on at least five seedlings per replicate in the other trials. Final germination percent (arcsin transformations), peak value (a measure of germination speed developed by Czabator, 1962), and height were subjected to an analysis of variance. To obtain a record of height increment pattern, some seed from a number of low elevation trees were treated and planted in pots after the several storage periods; their heights were recorded at two- or three-day intervals throughout the first two flushes of shoot growth.

RESULTS

Germination Percent

Total germination of controls increased as expected from less than 20 percent for freshly collected seed to over 80 percent after storage for 10 and 16 weeks (Table 1). The greatest dormancy release (i.e., increase in germination) occurred between four and ten weeks. Simply cracking the pericarp increased germination modestly for seed stored 0 or 4 weeks, but was not as effective as cracking followed by GA_3 treatment. Treatment effects were of no practical significance after 10 and 16 weeks of storage.

Table 1. Final germination percent of northern red oak seed as influenced by test factors

Storage Period (weeks)	Storage Condition	Treatment: Control	Control Cracked	GA	GA Cracked
0	—	8	16	22	38
4	Dry	12	27	33	66
	Moist	12	28	28	68
10	Dry	83	88	89	96
	Moist	82	85	90	88
16	Dry	94	93	89	91
	Moist	95	94	92	96

Storage in polyethylene bags at collection moisture content was as effective as stratification in breaking dormancy. Stratified seed from some trees had cracked pericarps after 10 and 16 weeks and therefore germinated more rapidly than unstratified seed, though germination percents for both storage conditions were the same.

Source effects were nonsignificant with one exception: Seed from low altitude trees in east Tennessee germinated much less than seed from other sources when planted immediately after collection and after four weeks storage. Tree-to-tree differences were statistically significant, but not large enough to be of practical importance except after 0 and 4 weeks storage.

Germination Speed

An analysis of peak values revealed significant, though sometimes minor, effects of all test factors and their interactions. These effects are illustrated in Figure 1, in which cumulative germination is plotted over time for stratified and dry-stored seed given Control and GA-Cracked treatments. There was little difference in germination pattern of seed from the two storage conditions, though germination of stratified seed typically began slightly earlier and was consistently a few days ahead of dry-stored seed. GA effects on germination speed were greatest after 0 and 4 weeks storage; they were negligible after 10 and 16 weeks for low-elevation seed. Northern and high-elevation seed, on the other hand, exhibited a major difference in germination speed between 10 and 16 weeks storage treatments; the GA-Cracked treatment tended to decrease this difference by stimulating germination of seed stored ten weeks.

Height of First Growth Flush

Average heights of seedlings developed from seed stored 10 or 16 weeks were 30 to 40 percent greater than those from seed stored 0 or 4 weeks (Table 2). Northern seed produced smaller initial flushes after all chilling periods than those from either of the Appalachian sources, which did not differ significantly. No consistent difference in height due to storage conditions was noted. GA treatments promoted a 30- to 40-percent average increase in shoot length over controls after all storage periods.

Pattern of Early Shoot Growth

Control and GA-treated seedlings from partially chilled seed (four weeks) typically made additional flushes of growth after 20 to 30 days of quiescence, but these flushes were abnormally short and their leaves did not fully develop. These plants were still stunted when discarded in early summer. Seedlings from seed chilled 10 and 16 weeks made two to three apparently normal flushes of growth during winter and spring. The initial two flushes are illustrated by curves (Figure 2), which are based on measurements of six to 10 seedlings each.

Table 2. Initial flush length (cm.) of northern red oak shoots as influenced by test factors

Seed Source	Treatment: Control	Control Cracked	GA	GA Cracked
	0 Weeks Storage			
Northern	6	7	8	10
Appalachian, High Altitude	9	9	14	17
	4 Weeks Storage			
Northern	9	7	9	9
Appalachian, High Altitude	9	10	12	15
Appalachian, Low Altitude	11	10	12	14
	10 Weeks Storage			
Northern	9	8	11	14
Appalachian, High Altitude	14	12	15	18
Appalachian, Low Altitude	14	14	16	17
	16 Weeks Storage			
Northern	10	9	13	16
Appalachian, High Altitude	13	12	16	18
Appalachian, Low Altitude	14	15	17	20

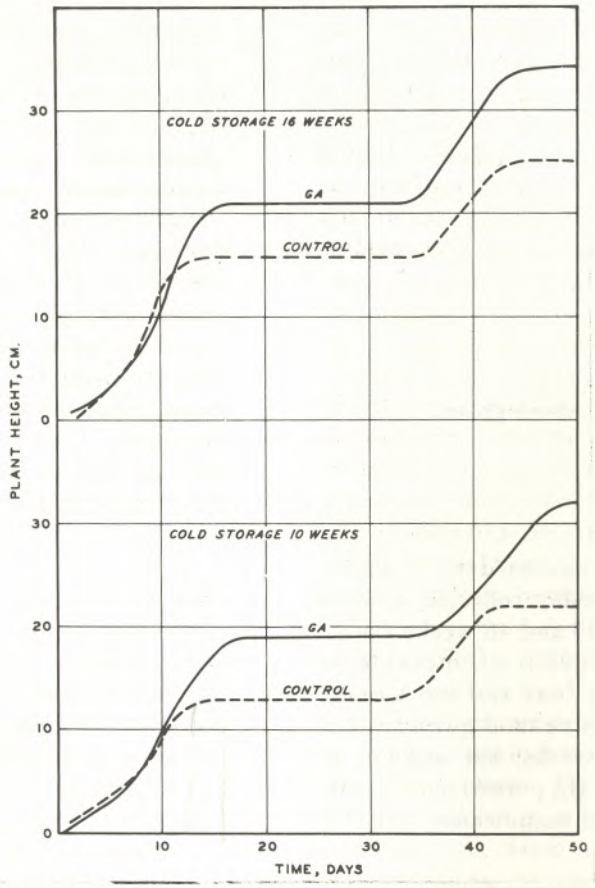

Figure 1. Cumulative germination of northern red oak over time as influenced by test factors.

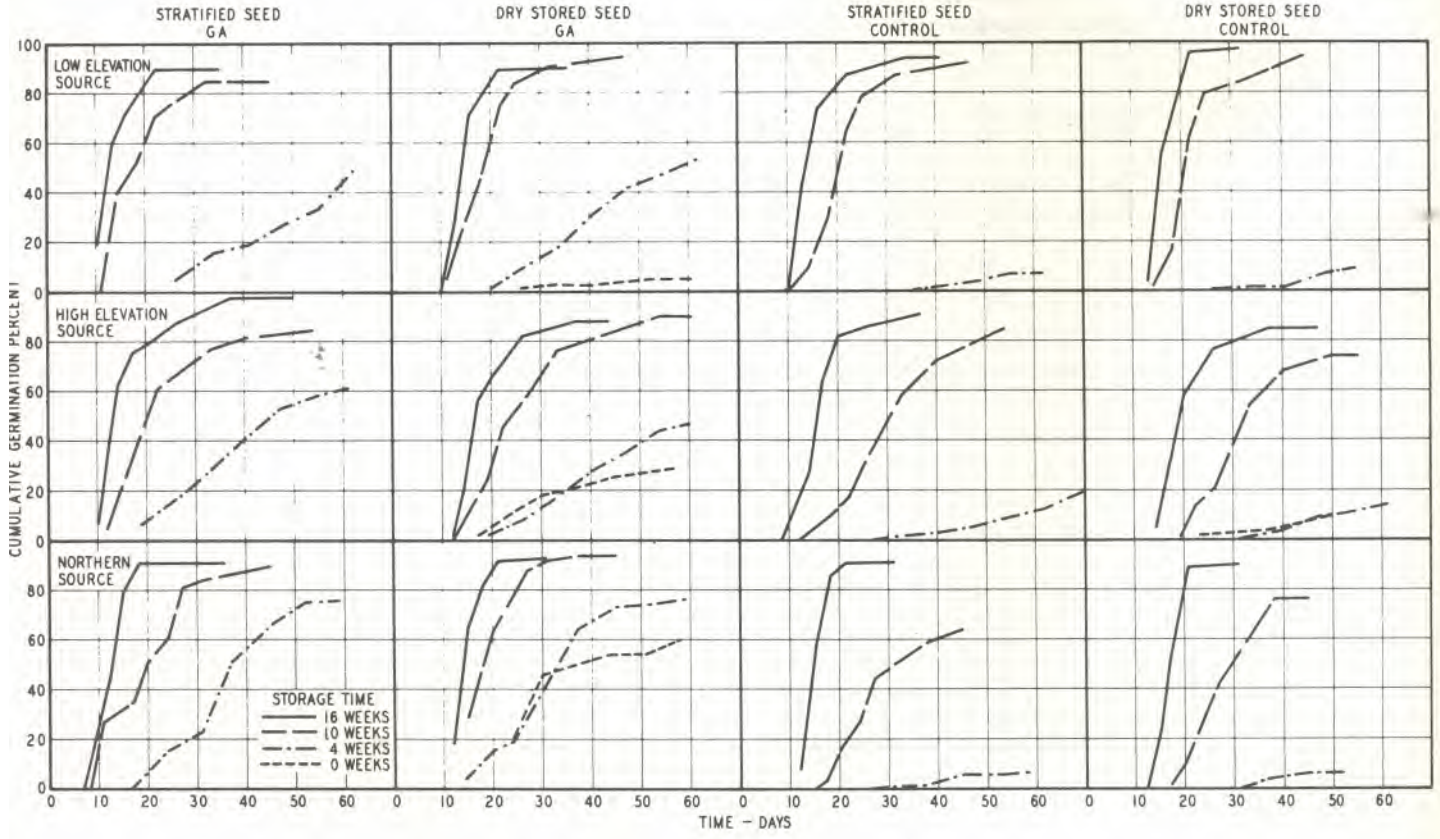

Figure 2. Cumulative height increment of northern red oak seedlings.

Several features of these growth curves are notable: Growth rates during flushing for GA and Control seedlings were almost identical at about 1 to 2 cm. per day. The greater height of GA-treated plants is thus a result of continued elongation after height growth cessation by control plants. The plateau period was about 20 days between flushes regardless of treatment. GA effects extended to the second flush but were considerably less than for the initial flush.

DISCUSSION

Germination data in this study indicate that (1) cold storage at collection moisture content was as effective as stratification in breaking dormancy; (2) GA stimulated germination of dormant seed as has been previously noted for northern red oak (Vogt, 1970); (3) cracking did not greatly stimulate germination of unchilled or partly chilled seed; (4) germination speed was largely a function of chilling time rather than storage conditions.

These observations support Korstain's (1927) conclusion that northern red oak has embryo dormancy, though the possibility of chemical inhibitors in seedcoats warrants more investigation. Typical moisture content at collection (60-100 percent, oven-dry weight basis) appeared to be sufficient to allow operation of the biological clock controlling dormancy release. This relationship could account for premature germination under some storage conditions. More detailed information on the relationships between moisture content and functioning of the dormancy release system may be useful in solving storage and germination problems.

The fact that seed from a low-elevation Appalachian source exhibited a more rapid germination response after ten weeks chilling than seed from northern and high altitude sources suggests that seed from the latter provenances may have a longer chilling requirement. Source differences in germination after 0 and 4 weeks storage probably reflect variable levels of dormancy at collection. Though tree-to-tree differences in germination were statistically significant, they were not of major practical importance.

Observations of the initial growth flush tend to support the above conclusion on embryo dormancy since height was positively correlated with chilling time. Vogt (1970) noted this correlation, but did not state whether growth consisted of single or several flushes. GA treatment tended to overcome this reduction in height due to partial chilling as well as to enhance elongation after chilling requirements were fulfilled. Percentage increases in elongation in this test were slightly lower than those noted by Vogt (1970) for equivalent GA concentrations, probably due to our less effective application technique. GA treatment appears to be a practical procedure for producing large greenhouse container stock, although it still appears desirable to chill seed for eight to ten weeks before planting.

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