FACTORS AFFECTING THE VIABILITY AND GERMINATION BEHAVIOR OF CONIFEROUS SEED

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PART I

CONE AND SEED MATURITY, TSUGA HETEROPHYLLA (RAFN.) SARG.²

ABSTRACT

The following three papers show that both germination capacity and germination behavior are influenced markedly by maturity of cones and seed, and by various treatments, all of which can be controlled. Basic studies to discover the reasons for the radical changes in germination rate described herein are indicated.

Commercial cone and seed processing often reduces germination capacity and increases the absolute or relative rate of germination. Dewinging, particularly if prolonged or if done in the presence of hard and sharp debris, has a marked effect upon both seed characteristics.

High kiln temperatures (above 52°C.), impact, and other "drastic" treatments reduce viability and increase germination rate. Seed that has been affected in these ways usually produces germinates whose radicles are discolored and subject to decay in the incubator. The seed itself tends to darken abnormally during stratification and/or incubation, and usually becomes contaminated quickly during incubation. Commercial seed that shows evidence of harmful treatment is usually dull and dusty and produces similar symptoms of weakness during incubation.

It is well known that the seed of a number of coniferous species is highly variable from lot to lot in its germination behavior and its germinative capacity. One has only to study Toumey and Korstian's data (5, p. 196-8) for germinative capacity to realize that seed viability for any species may vary from nearly zero to almost 100 per cent. It is probable, however, that the presence of empty seeds is often responsible in part for the variation. The percentage of sound seeds can be manipulated during the final cleaning in many species of seed and it is possible to clean seed to a very fine point particularly for research purposes. Empty seeds that appear to be otherwise normal usually result from failure of pollination and possibly from self-pollination in some species or individuals.

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If all seed lots were cleaned perfectly and contained only sound seeds, they would still show considerable variation. This study was undertaken in the hope that some of the factors responsible might be discovered. A similar study with seed of *Pseudotsuga menziesii* (Mirb.) Franco has been completed with similar results.

Seed lots of any one species show considerable variation in germination behavior. One lot may germinate quickly and completely without any special pretreatment and another lot may be slow and erratic even though some individual seeds may germinate after only a few days of incubation. It is because of this variable behavior within a species that "stratification" has become a commonly used pretreatment in testing and in nursery practice (1; 2; 6, p. 36-8; 7, p. 54-6). Even after stratification, variation still exists. In the case of Douglas fir seed that has received a standard 6 weeks of stratification, one lot may show 95 per cent germination of the viable seed within 6 days whereas another lot may require 12 days to reach this same total. Most lots of Douglas fir seed give a "complete" test (within 2 per cent of capacity) in 14 days but occasionally a lot "misbehaves" and requires a longer period of incubation.

MATERIAL

Collections of western hemlock cones were made in 1953 by I. H. Schiedel from three trees at the University Forest near Haney, B.C. Samples were obtained at intervals beginning on September 15 and ending on December 3. The crop was small, however, and insufficient cones were available to provide a complete series from each tree.

The cones were air-dried at room temperature, extracted by careful hand shaking, dewinged by rubbing gently in a cloth bag, and finally cleaned of all debris and empty seeds in an adjustable air current. Cleaning was done carefully in order that all filled seeds would be retained and all empties blown over. In this way all lots were reasonably comparable for the purpose of the study.

Within a few days of the cleaning of each lot, it was tested, without pretreatment, at 20° C. constant on vermiculite in Petri dishes (3) using 5 samples each of 100 seeds for each lot. In some of the later collections the number of samples had to be reduced because of insufficient seed.

The remainder of the seed was stored in sealed glass vials at 0° C. and retested during the winter of 1955-56 both without pretreatment and following stratification for 2, 3, 4, or 6 weeks at 0° C.

In 1956, a second series of cone collections was made by J. Walters at the University Forest on another group of three hemlock trees. The size of the cone crop again made impossible a complete collection over several months. Collections were made between August 16 and September 30 at 2-week intervals. Methods of extraction and cleaning were the same as in 1953. Shortly after cleaning, the seed was tested both without pretreatment and following six weeks of stratification at 0° C. In most tests, 5 samples of 50 seeds each were used but, again, some tests had to be made on 3 or 4 samples because of limited seed.

TABLE 1
RATE OF GERMINATION (R) AND GERMINATION CAPACITY (G) OF 1953 WESTERN HEMLOCK SEED,
FRESH AND UNTREATED, STORED AND UNTREATED, AND STORED FOLLOWED BY STRATIFICATION

Tree No.	Date of Collection	Test of fresh seed untreated			Test of stored seed untreated			Test of stored seed stratified		
		R	Signif. of diff. in R	G	R	Signif. of diff. in R	G	R	Signif. of diff. in R	G
1	Sept. 15	13.9	1	99.2	12.9	1	70.4	7.9	1	53.4
	Nov. 26	7.0		90.8	11.6		58.4			
2	Sept. 15	18.4	1	92.6	17.1	1	94.6	12.6	1	93.6
	Sept. 24	15.7	2	97.4	15.5		94.2	9.9		99.8
	Oct. 1	15.4	1	96.4		1			1	
	Oct. 7	12.6		94.8	14.5		96.4	9.0		89.2
	Oct. 17	12.6	1	85.8		1			1	
	Nov. 12	10.9		85.0	13.5		84.8	7.1		77.6
	Nov. 17	10.9		95.2		1	81.0			
	Nov. 26	10.6		86.0	15.5					
3	Dec. 3	9.9		80.5						
	Sept. 24	17.0	1	92.4	15.2	2	96.6	10.0		93.2
	Oct. 1	16.3		95.4	14.7	2	95.8		1	
	Oct. 7	15.8	1	95.8	14.2	1	99.2			
	Oct. 17	14.5		89.2	13.3		84.8	8.5		84.2
	Nov. 12	13.5	1	97.0		1			1	
	Nov. 17	10.7		92.0						
	Nov. 26	11.7		86.0	16.8		66.8	13.5		61.3

R—"rate of germination"—No. of days to attain 50 per cent of germination capacity
G—germination capacity in per cent, tested at 20°C. constant.

1—significant at the 1 per cent level

2—significant at the 5 per cent level

3—insufficient samples to be reliable

RESULTS

Fresh untreated seed

The results obtained from the two series confirmed one another quite well. In both, the September 15 collection showed a very high germinative capacity (about 95 per cent) but germinated relatively slowly.

For the purpose of comparing rates of germination, an arbitrary measure was used—"R", the number of days required to attain 50 per cent of the ultimate germinative capacity. This value does not give any specific indication of the shape of the germination curves but it does have the advantage of being objective and useful for statistical comparisons among lots.

Using **R** as a measure of rate of germination, it can be shown that the later the collection from September 15 onward, the lower the value of **R** and the faster the germination. For example, in the case of tree No. 2, **R** was 18.4 days from the September 15 collection, and it dropped steadily to a low of about 10.6 for the November 26 collection. Table I gives the values of **R** for the various seed lots by tree number and collection date. Lack of balance in the sampling makes a complete statistical analysis difficult but partial analyses indicate a high degree of significance between the **R** values for most of the dates of collection between September 15 and mid-November (see Table I).

In the 1956 collection, **R** for the September 15 data was 18.8, 16.4, and 17.8 for tree Nos. 4, 5, and 6 (see Table II). Corresponding values for trees 1, 2, and 3 in 1953 were 13.9, 18.4, and 17.0. The September 30 collection in 1956 gave **R** values of 15.9, 13.8, and 16.9, corresponding reasonably well to the 1953 values for trees 2 and 3 of 15.4 and 16.3, respectively.

Differences in **R** are significant at the 1 per cent level among trees in both 1953 and 1956, and among most dates in both years for individual trees. The downward trend of **R** after about September 15 is consistent but prior to September 15 (1956 data) no particular trend is evident. This may be explained by the fact that seed collected earlier than September 15 is definitely "immature" and that rates of germination for it cannot properly be compared with those for seed that shows a high germinative capacity. The very nature of **R**, based as it is on germinative capacity, makes questionable its use for seed that is "immature" as judged by its germinative capacity.

It can be concluded that rate of germination of fresh untreated seed under the conditions present is affected both by parentage and by date of collection. The apparent effect of inheritance, as among trees, may represent largely the differences in maturity that exist among several trees on a given date. Unfortunately, the phenological characteristics of the six sample trees have not been studied.

The data for germinative capacity of the 1953 seed show that seed collected on September 15 was "mature". It germinated practically as well as seed from later collections and stored perfectly for two years. Differences in germinative capacity that show in Table I are not significant for trees 2 and 3.

The data for the 1956 seed overlap the 1953 data and cover the period from August 16 to September 30. Indications are that seed collected on August

TABLE 2

RATE OF GERMINATION (R) AND GERMINATION CAPACITY (G)
OF 1956 WESTERN HEMLOCK SEED AS AFFECTED BY DATE OF COLLECTION

Tree No.	Date of Collection	Untreated				Stratified 6 Weeks			
		R	Signif. of diff. in R ¹	G	Signif. of diff. in G ¹	R	Signif. of diff. in R ¹	G	Signif. of diff. in G ¹
4	Aug. 15	16.2		4.8		—		0.4	
	Aug. 30	15.9		81.2	1	7.9		74.4	1
	Sept. 15	18.8	1	97.6	1	6.1	1	97.2	1
	Sept. 30	14.8	1	97.3		5.2	1	99.0	
5	Aug. 15	—		0.0		—		2.0	
	Aug. 30	13.8		42.4	1	7.5		20.8	1
	Sept. 15	16.4	1	96.5	1	7.3		97.5	1
	Sept. 30	14.1	1	92.4		6.1	1	97.6	
6	Aug. 15	—		0.0		—		0.0	
	Aug. 30	16.9		81.6	1	9.6		79.6	1
	Sept. 15	17.8	1	97.6	1	9.4		96.8	1
	Sept. 30	15.2	1	95.0		5.7	1	95.0	

R—"rate of germination"—No. of days to attain 50 per cent of the germination capacity

G—germination capacity in per cent at 20°C. constant

¹—significant at the 1 per cent level

30 or earlier is "immature" and has a considerably lower germinative capacity than has seed collected later. The evidence suggests, too, that individual trees vary widely in the date of seed maturation. For example, tree No. 4 gave 73 per cent, tree No. 5—20 per cent, and tree No. 6—78 per cent on August 30. On August 15 only one tree had any viable seed and it was a small fraction of the total collected. On the other hand, seed from another tree was collected on August 5 and this gave 11.6 per cent germination. Again, the effects of collection date and inheritance on maturity (germination capacity) are indicated.

It might be concluded, therefore, that a tentative "safe" date to begin hemlock cone collections is September 15. However, locality and weather conditions must be taken into account. The suggested date probably applies only to localities similar to the University Forest in years similar to 1953 and 1956. In principle, however, the findings have significance in any area and any year.

Fresh, stratified seed

Stratification hastened germination very definitely and consistently as reported by Bientjes (4). In every case the R value dropped to one-half or less after stratification. For example, for tree No. 4, R for September 15 seed dropped from 18.8 to 6.1 days.

Furthermore, the later the collection the less was the time required to reach 50 per cent of germinative capacity. In the case of tree no. 4, the August 30 value of R was 7.9, the September 15 value was 6.1, and the September 30 value was 5.2 (see Table 2). Figure 2 shows the change of rate for seed of tree No. 5. The same behavior was shown in the case of seed from all three trees although the actual R values differed among trees.

A similar result was obtained with the 1953 seed after storage, followed by stratification (see Table 1 and Figure 1). Evidently date of collection (maturity) affects the rate of germination or relative dormancy rather permanently so that neither storage nor stratification entirely eliminate the differences that exist in the fresh untreated seed. The more effective the pretreatment, however, the closer the R values came together (see Figure 1) and the greater the argument for using such a pretreatment in setting up standards for seed testing.

Figure 1. Effect on rate of germination " R " of date of collection, storage, and duration of stratification following storage.
Western hemlock, Tree no.2, 1953.

In other words, collection before the seed has fully matured imposes on the seed a form of dormancy or retarded germination that cannot be easily erased. Hence, in seedlots containing mixed stages of maturity, it is difficult to establish pretreatment and test conditions that will meet the needs of all of the seeds and yield consistent results for all or nearly all seedlots.

Stored, untreated seed

The 1953 seed, stored for 2 years at 0°C. in sealed vials, showed less variation in rate than it did when fresh. The range of R for tree No. 2, for example, was from 18.4 (Sept. 15) to 10.6 (Nov. 26) for fresh seed, whereas untreated stored seed gave R values between 17.1 and 13.5, a drop in range of about 4 days (see Table 1). Surprisingly, storage for 2 years speeded up the slower lots and slowed down the faster lots, not enough, however, to change the relationships of the germination curves to one another (see Figure 2).

Figure 2. Course of germination of western hemlock seed collected on 3 different dates, fresh and following 2 years' storage, untreated. Tree no. 2, 1953.

Stored, stratified seed (1953 lot)

Stratification speeded up germination and **R** dropped to one-half or less after 4 or 6 weeks' stratification (see Figure 1 and Table 1). The September 15 collection of tree No. 2, for example, had an **R** value of 18.4 when fresh, 17.1 after 2 years' storage, and after storage followed by stratification for various periods the following: 2 weeks' stratification—12.65, 3 weeks'—10.7, 4 weeks'—7.9, and 6 weeks'—about 5.0. The last value is questionable because of very limited seed but the others are reliable. Similar trends were found consistently in every collection except that in the later ones the **R** value increased during dry storage and then decreased with length of stratification. Only after 4 and 6 weeks' stratification did the **R** values for early and late collections come close together. At least 4 weeks of stratification seem to be necessary to reduce differences to a reasonable level, 6 weeks is better, and 8 weeks as recommended by Bientjes (4) may be close to optimal.

SUMMARY AND CONCLUSIONS

- (1) Hemlock cones were collected on various dates from 3 trees in 1953 and from 3 other trees in 1956. Seed was hand processed carefully in all cases and cleaned until only the sound seed remained in each sample.
- (2) The 1953 seed was tested fresh without pretreatment. The unused seed was stored for 2 years at 0°C. in sealed vials and then tested both untreated and following stratification.
- (3) The 1953 seed collected on September 15 showed high germinative capacity, perfect storage for the 2-year period, but a slower rate of germination than did later collections. Both storage and stratification reduced the variation in rate of germination but did not eliminate the differences associated with collection date.
- (4) The 1956 seed provided data that confirmed September 15 as a suitable date to begin collecting cones. Collections of August 30 showed a considerably lower germinative capacity and a great deal of variation among parents. Some trees would yield considerable good seed on August 30 and others almost none.
- (5) Variation in maturation is undoubtedly related to inheritance but for the collection area and the 2 years in question, September 15 represents approximately the date when almost all seeds have matured sufficiently to germinate and to store well. On this date the cones are green and hard and should be handled carefully.
- (6) Results indicate that dates of collection can influence both viability and germination behavior of hemlock seed. This has a bearing on seed testing since any collection may contain seeds in various stages of maturity, and hence, with variable rates of germination and ability to germinate under test conditions. Stratification reduces the variation in rate and hence is useful as a means of standardizing seed tests for species such as western hemlock.
- (7) "Immature" seed appears to suffer somewhat as a result of stratification.

Poor lots of seed often show a similar reduction, possibly because of immaturity or weakness of some seeds. A reduction in germinative capacity following stratification may indicate that a seed lot contains immature or otherwise weakened seeds.

REFERENCES

1. ALLEN, G. S. 1941. A standard germination test for Douglas fir seed. *For. Chron.* 17: 75-78.
2. ALLEN, G. S. and W. BIENTJES. 1954. "Naked stratification" key to improved seed testing and increased nursery production. *British Columbia Lumberman*: 38 (4): 112, 114.
3. ALLEN, G. S. and W. BIENTJES. 1954. Studies on coniferous tree seed at the University of British Columbia. *For. Chron.* 30: 183-196.
4. BIENTJES, W. 1954. The effects of temperature, seed moisture, and stratification on the germination behavior of western hemlock seed. U.B.C. Forest Club, Research Note No. 11, pp. 7. University of British Columbia, Vancouver, Canada.
5. TOUMEY, J. W. and C. F. KORSTIAN. 1948. Seeding and planting in the practice of forestry. John Wiley & Sons, Inc. New York.
6. U.S. Forest Service. Woody-plant seed manual. 1948. U.S. Dept. Agric. Miscell. Public. No. 654, Washington, D.C.
7. WAKELEY, P. C. 1954. Planting the southern pines. Forest Service, U.S. Dept. Agric., Agric. Mon. no. 18. Washington, D.C.