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VARIABILITY OF GERMINATION IN DIGGER PINE IN CALIFORNIA

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Abstract: Seeds collected from 17 *Pinus sabiniana* Dougl. populations in California were tested for germination. Unstratified seeds germinated slower than stratified seeds. Germination of stratified seeds showed distinct population differences. Some populations started germination at 5°C. and reached a level of 60 to 70 percent after 30 days at 25°C. Less than 10 percent of the seeds germinated in 30 days at 25°C. in the slowest samples. Replication with seeds from "slow" and "fast" germinating populations showed that the type of response was similar for different samples within a local area, and from the same stand during different years. Seeds from populations in areas with cold winters germinated the slowest.

Oxford: 174.7 *Pinus sabiniana* [–232.315.3 + 181.524 + 181.525].
Retrieval Terms: Pinus sabiniana; germination behavior; seed dormancy; stratification; cold treatment.

Many aspects of ecotypic variation in forest trees have been investigated. But only a few studies have emphasized the intraspecific characteristics of seed germination. Those studies that include germination findings concerned widely distributed species. The germination behavior in a species—Digger pine *(Pinus sabiniana* Dougl.*)*—covering a smaller geographical area—part of the California foothills—is the subject of this note.

Only a few studies of seed germination in this species have been reported. And they are based largely on single collections.[1] Either individually or jointly, the published data provide only a limited picture of species variability in Digger pine. To add an estimate of population variability, this note reports results of seed germination under a variety of conditions, and variations between stands in an area and within a given stand during different years.

CONE COLLECTION AND SEED HANDLING

In California, Digger pine ranges in elevation from 200 feet in the Central Valley to over 5,000 feet in the north and 6,500 feet in the south.[2] While studying population samples from this distribution, I collected seed samples from 17 stands in 1960-1961 *(fig. 1).* These samples together represent Collection I. I cut mature cones from trees of comparable size within a fairly uniform habitat. Cones in the early samples were still closed. They were dried in a warm room (32°C.) for several weeks to complete opening. In later samples the cones had opened but many seeds still remained in the cones.

After hand extraction empty seeds were removed by floating in water. Filled seeds were put into composite lots for each stand and stored at room temperature (20-25°C.). Twenty-five-seed samples were taken from each lot, and ovendry weights of

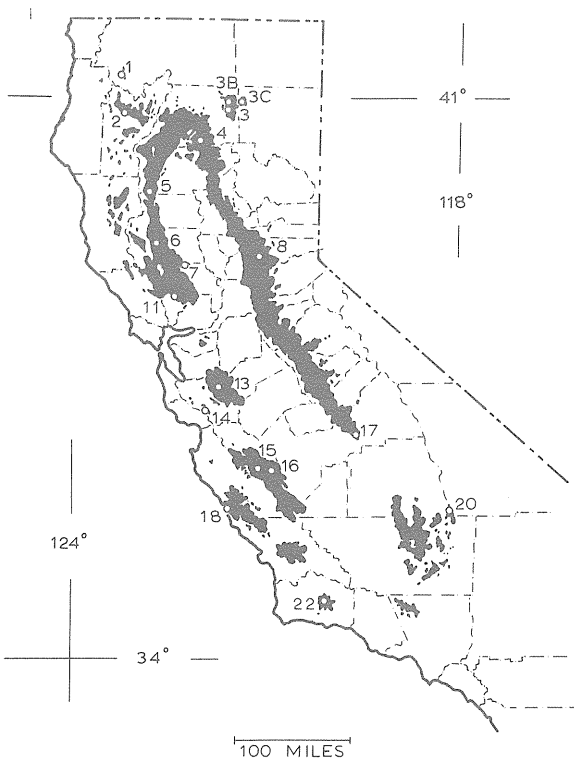

Figure 1—*For seed germination tests, Digger pine cones were collected from stands within the natural range of the species. In 1966, cones were collected from stands 3, 3B, 3C, 17, and 22. In 1960-61, they had been collected from all stands shown except 3B and 3C.*

seed coats, gametophytes, and embryos were individually determined.

Seeds were stratified in moist vermiculite at 5°C. All seeds were germinated on the surface of moist vermiculite flats at 25°C. Surface molds were common on both unstratified and stratified seeds in the loosely covered flats. Light conditions were not controlled because Digger pine seed dormancy is not influenced by changes in photoperiod or light quality.[3]

Seeds were counted as "germinated" when their radicles extended 5 mm. At the end of each test the remaining seeds were cracked. The "soundness" of these ungerminated seeds was checked by continuing germination with seedcoats removed. If the massive outer seedcoat and thin inner layer (including nucellar cap) are removed, many seeds will germinate. Small lots of unstratified seeds from several stands were also germinated with seedcoats removed.

For several years I tried to repeat seed collections from fast and slow germinating populations, but cone crop failures precluded adequate sampling. In 1961 a small sample was obtained from the southern California stand No. 22. In 1963 I gathered small samples on the western edge of the Modoc Plateau in northeastern California. One sample came from the original stand No. 3. Two new samples came from ecologically comparable stands (Nos. 3B, 3C) several miles away *(fig. 1)*. Finally in 1966 I obtained large enough samples for another direct comparison of fast and slow germinating populations *(table 1)*. These samples represent Collection II.

GERMINATION RESULTS

Collection I

In a small-scale test at five controlled temperatures—1°, 9°, 17°, 25°, 32°C.—unstratified seeds from all 17 stands germinated poorly. The highest germination after 5 months was 31 percent at 9°C. (stand No. 18). These results were confounded since seeds rotted at the higher temperatures. This rotting makes tests with unstratified seeds difficult to interpret. Surface sterilization will not keep the seedcoats free of mold for the long periods required. Also, external sterilization does not affect the internal putrification of uncracked seeds. In stratified seeds germination is prompt enough to reduce the effects of contamination.

Table 1—*Cone sampling details, seed treatments, and germination test conditions for cones collected in 1960-61 and in 1966*

Tests	Collection I	Collection II
Sampling:		
Stands . . . . . No.	17	5
Trees per stand . . . . No.	10 to 20	5 to 10[1]
Dates	9-17-60 to 2-11-61	9-29-66 to 10-15-66
Storage before tests:		
Days at room temperature . . . . . No.	180	0, 60, 120
Unstratified seed tests:		
Seeds/stand/ treatment . . . . . No.	45	300
Temperature . . . . . °C.	1, 9, 17, 25, 32	25
Stratified seed tests:		
Stratification at 5°C. . . . . days	120	60, 120
Seeds/stand/ treatment . . . . . No.	200	300
Temperature . . . . . °C.	25	25

[1]Exception: one tree in stand 3C.

Table 2—*Germinability after 30 days at 25°C. of stratified Digger pine seeds collected from 17 stands in California, 1960-61*

Stand	Germination value[1]	Total germination	Ungerminated sound seed[2]
		Percent	*Percent*
17	98	64	2
22	75	70	6
5	49	43	20
18	25	34	28
14	19	36	2
11	16	27	15
15	15	29	6
4	5	23	24
6	3	20	35
8	2	12	34
16	1	11	45
7	1	10	16
2	0.5	10	41
13	.1	3	10
3	.02	4	54
20	.008	1	9
1	.002	0.5	47

[1]Calculated by method of Czabator (see Notes Section).
[2]All seeds cracked at end of test.

Preliminary work with stratified seeds had shown striking differences in germination behavior between some populations. These results were supported by the results of this study of Collection I seeds. The speed and total amount of germination are summarized by "germination values"[4] for all stands *(table 2)*. Even after the 120-day cold treatment, many seeds from some stands were still dormant. Stratification may have altered relative dormancy patterns, but it certainly did not eliminate them.

External molds did not appear to be serious, but internal contamination of some lots lessened the validity of these data. Thus, stand No. 20 had only 1 percent germination, but 90 percent of its seeds rotted during the test. In other cases the results are clear. For example, stand No. 3 still had predominantly dormant seeds. Only 4 percent germinated, and at least 54 percent remained sound.

No clear relationship existed between seed size and germination value. The average seed size of stand No. 17 with the highest germination value was similar to that of stand No. 3 with a low germination value. Stand No. 22 had the largest embryos; they averaged 0.035 g. Stand No. 1, which seemed to have many internally contaminated seeds that rotted quickly, had the smallest embryos—0.018 g.

My limited trials with treating seedcoats of Collection I seeds supported Hermann's[1] suggestion that the hard seedcoat was an important part of the dormancy problem. But cracking the seedcoat or just removing the outer shell did not increase germination as much as removing the nucellar cap. In one extreme example from stand No. 8 no intact, unstratified seeds in a sample of 45 germinated in 90 days at 25°C. In a test with seedcoats and nucellar caps removed, all 20 seeds germinated in 17 days at 25°C. A few seeds without seedcoats germinated in 4 days. After the first week, molds and bacterial rot usually obscured the results of these tests, and I can not compare the seedcoat effect in different stands.

Another small-scale test with the 1961 collection from stand No. 22 resulted in 76 percent germination. Germination with the Collection I seeds the previous year had been 70 percent. The germination response with stratified seeds in this southern California stand was at a high level 2 years in a row.

Collection II

Unstratified seeds from all stands in the Collection II tests failed to germinate. This occurred regardless of whether seeds were fresh, dry-stored for 60 days, or dry-stored for 120 days. In trials with seed from stand No. 22, one seed from the fresh lot and one from the lot dry-stored for 60 days each started but did not complete germination. These uniformly negative results with unstratified seeds were as expected. The 4 months of dry storage had no effect on dormancy. No more than 5 percent of the seeds from any lot rotted in the tests. The unstratified seeds were dormant under test conditions.

Germination trends in seeds stratified for 60 days supported previous results *(table 3)*. Seeds from stands 17 and 22 started germination during the 30-day test, while those from the Modoc Plateau did not.

Doubling the length of cold treatment increased the amount of germination in all stands, but the basic trends did not change. Fewer seeds from stands 17 and 22 germinated during the 120-day stratification with Collection II seeds than with Collection I seeds. But as soon as the stratified seeds were put in at 25°C. germination quickly reached expected levels.

Germination response was similar within the Modoc Plateau stands. In the 120-day test one stand (No. 3B) replication had more quick-germinating seeds, but it was still below the level of either stands 17 or 22. Sample No. 3C replications were unusually uniform, probably due to sampling from only one tree *(table 1)*.

A minor year-to-year comparison with stand No. 22 seeds was mentioned earlier. A more detailed comparison can be made within the Modoc Plateau

Table 3—*Germinability of Digger pine seed lots after 30 days at 25°C. collected in five stands in California, and stratified at 5°C., 1966*[1]

Stand No. and 100-seed lot	Stratified for . . .		Sound seed at end of test
	60 days	120 days	
	Percent		
Stand 22:			
Lot	12	59	19
Lot	14	77	20
Lot	16	79	11
Stand 17:			
Lot	9	52	40
Lot	10	66	20
Lot	13	74	9
Stand 3:			
Lot	0	11	83
Lot	0	12	80
Lot	3	17	79
Stand 3B:			
Lot	0	12	86
Lot	0	22	75
Lot	1	32	66
Stand 3C:			
Lot	0	2	96
Lot	0	2	97
Lot	0	3	93

[1]All unstratified seeds failed to germinate, whether in trials with fresh seed, seeds dry-stored for 60 days or for 120 days. One seed started but failed to complete germination in trials with fresh seed and with seeds dry-stored 60 days from stand No. 22.

population. The average percent germination with seeds stratified 120 days was:

Stand No.	*3*	*3B*	*3C*
	Percent		
Special samples (1963)	14	13	7
Collection II (1966)	13	22	2

Thus, three stands in this population had relatively low germination in two different years. Stand No. 3 had low germination three different years when Collection I seeds are considered. Modoc Plateau Digger pines had significantly slower germination response than stands 17 and 22.

Individual seed and embryo weights were not recorded in Collection II, but lots (each with 100 seeds) were weighed for all stands. Seed weights were similar to weights recorded for Collection I and showed little relation to germination. The average air-dry weights of Collection II seeds were:

Stand No.	*22*	*17*	*3*	*3B*	*3C*
Weight (g.)	0.93	0.65	0.88	0.89	0.72

DISCUSSION

My results confirm suggestions in the literature that Digger pine seeds germinate very slowly if given no cold treatment. After cold moist exposure, two contrasting patterns emerged.

In the first pattern, a large proportion of seeds germinate quickly after some minimum cold treatment. Stands 17 and 22 illustrate this pattern. Though rot was a factor in Collection I, stands 5, 14, and 18 might be put in this group. Johnstone's and Clare's[1] best trial with stratified seeds was 80 percent germination (50 days on ice, 60 days in soil), and it appears to fit into this pattern. Their southern California seeds probably were ecologically comparable to those from stand No. 22.

The second pattern is prompt germination of a small fraction of the stratified seeds followed by a slow rate of germination over a period of many months. Drastic treatments, such as removal of the seedcoat, are necessary to accelerate germination. Stands 3, 3B, and 3C illustrate this pattern. Stand 2 probably would be in this category.

Hermann[1] stratified his small sample of northern California seeds for 42 days. After these seeds were put in at 32°C. they did not start to germinate until after 4 weeks. His seeds seem to follow the same trend as my Modoc Plateau samples.

In many stands my germination results showed little relation to climatic variables. But in the extremes emphasized earlier, germination pattern did coincide with different climates. Near stands 3, 3B, and 3C the mean January temperature is about 2°C. But days with temperatures from 10-15°C. can be followed by lows of -25°C. Seeds germinating during a mild period in winter could be subject to repeated freezing. The long stratification requirements of these populations is likely to have adaptive value by preventing germination until late spring.

This situation resembles that which Fowler and Dwight[5] found in southern provenances of eastern white pine *(Pinus strobus* L.*)*. Their seed collections, which came from areas subject to mild winter temperatures followed by cold periods, had strong stratification requirements.

In contrast, stands 17 and 22 have a milder climate. Mean January temperatures are probably near 8°C. to 10°C. Frost is common but prolonged sub-freezing conditions are infrequent. The prompt germination (after some minimal cold exposure) may permit these seeds to take advantage of favorable germinating and growing conditions during mid-winter. At lower elevations or in southern latitudes

the hazard to young seedlings from winter cold may be less than that from spring and summer drought.

NOTES

[1]Everett, P. C. *A summary of the culture of California plants at the Rancho Santa Ana Botanic Garden 1927-1950.* Rancho Santa Ana Bot. Garden, Claremont. 223 p. 1957.

Forest Service, U.S. Department of Agriculture. *Woody plant seed manual.* U.S. Dep. Agr. Misc. Publ. 654. 416 p. 1948.

Hermann, R. K. *Germination of Digger pine.* Tree Planters Notes 21. 12 p. 1970.

Johnstone, G. R., and T. S. Clare. *Hastening the germination of western pine seeds.* J. Forestry 29: 895-906. 1931.

Mirov, N. T. *A note on germination methods for coniferous species.* J. Forestry 34: 719-723. 1936.

Vabre-Durrieu, A. *La froid et les graines de quelques abietaces.* Trav. Lab. Toulouse 1(5): 23-29. 1956.

[2]Griffin, J. R. *Cone morphology in Pinus sabiniana.* J. Arnold Arboretum 45: 260-273. 1964.

[3]Unpublished data by S. L. Krugman, on file at Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif.

[4]Czabator, F. J. *Germination value: an index combining speed and completeness of pine seed germination.* Forest Sci. 8: 386-396. 1962. This is a composite value of total germination (represented by percentage of full-seed germination at the end of test divided by number of days) multiplied by speed of germination (represented by peak value, the maximum daily germination at the break in the typical sigmoid germination curve). Germination value varies directly with total germination and speed of germination.

[5]Fowler, D. P., and T. W. Dwight. *Provenance differences in the stratification requirements of white pine.* Canadian J. Bot. 42: 669-675. 1964.

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