numbers 102, 30, 54, and 7) is 3.45, and less than 7 percent of similar twin samples would yield proportional differences as great or greater than that observed were tongue rolling ability not in fact influenced by hereditary factors. The data are inconsistent, therefore, with the hypothesis of chance fluctuations, and we conclude that hereditary factors strongly influence tongue rolling ability ($P < 0.07$).

The fact that only 88.5 percent of monozygous twin pairs are concordant would indicate 5.75 percent (half of 11.5 percent) lack of penetrance. This frequency might be due to either hereditary factors or environmental factors such as the learning component previously mentioned.

An even stronger case for genetic influence is exhibited when the twins in the third group—parenthesized in Table I—are eliminated from the analysis. The numbers in Table I then become 96, 24, 51, and 3 with a chi-square of 5.97. Now $P < 0.025$, and 94.4 percent of the monozygous twin pairs are concordant, with 2.8 percent of these subjects exhibiting a lack of penetrance.

**Notes**

**Summary**

Data were collected from 193 pairs of twins on their tongue rolling ability. This sample population included 61 pairs of monozygous twins. The data were then analyzed for concordance and discordance among monozygous and dizygous twin pairs by the chi-square method. It was found that the data were inconsistent with the hypothesis of chance fluctuation and that the ability to roll the tongue is strongly influenced by hereditary factors. The data further indicated a lack of penetrance of 5.75 percent using the entire population sample, and 2.8 percent if the doubtful group (19 individuals exhibiting intermediate expression) was eliminated. This lack of penetrance may be due to either hereditary factors or to environmental factors such as a learning component.

**Literature Cited**


**"White Seedling": A Pigment Mutation That Affects Seed Dormancy in Douglas-fir**

FRAnc C. SORENSEN

THIS note describes a chlorophyll-less mutant of Douglas-fir and its association with speed of germination. Recessive chlorophyll mutants have been frequently observed in plant species (e.g., Gustafsson with regard to forest trees). In maize, it has been observed that the lack of pigmentation often has been accompanied by premature germination or absence of dormancy. There appear to have been no observations linking lack of chlorophyll or carotenoids with germination characteristics in other species, however. This may be because the traits are not associated in most other species, or because it is difficult, at least in many plants, to distinguish the albino from the normal seedling at the onset of germination, and the association has been missed. In the present case, germinating white seedlings could be distinguished from their normal siblings at the time the radicle was first visible, which made the relationship between albinism and speed of germination readily apparent.

**Materials and Methods**

Two trees, designated in our laboratory as Lac-2 and XWC-8, growing about 30 miles apart in the Willamette Valley of western Oregon and which previously had been identified as carriers of the same recessive white seedling gene, were self- and reciprocally cross-pollinated in the spring of 1968. Seeds were collected in the fall, and germination tests were made in the next winter and spring. Test seeds were those containing white seedling embryos. Control seeds were from the same progeny and contained normal embryos.

Initially, germination tests were made under our standard conditions for Douglas-fir of 16- to 20-hour water soak at room temperature, 2-week stratification at $5^\circ$ C, and germination at $30^\circ$ C day and $20^\circ$ C night temperatures with 12-hour photoperiods. Subsequently, some samples of seeds were germinated without stratification and with stratification at $0.5^\circ$ C and $7.5^\circ$ C. The purpose of $0.5^\circ$ C temperature was to provide stratification at a temperature at which little or no embryo elongation would be likely to occur. Purpose of the $7.5^\circ$ C temperature was to stratify at a temperature...
that was known to be above optimal for Douglas-fir.

Seeds were checked each day for new germination. A seed was tallied as germinated when any of the radicle could be seen. White seedlings could be distinguished at this time, but all germinated seeds were still held for a few days to make sure of correct identification. Germination proceeded rapidly for these lots and a germination test was considered complete when two days passed without any seeds germinating. Germination was, in most cases, 95 to 100 percent complete at this time.

Rate of germination is expressed by simply determining the average number of days from the time a sample of seeds enters the germinator until germination is completed. For example, if one seed germinated in 8 days, a second seed in 9 days, and a third in 11 days, the average number of days to germination for the three seeds would be 9.3.

Results

Description of mutant

The white seedlings, when allowed to develop in the light, had neither green nor yellow pigmentation. However, if the seedcoat was removed prematurely, the freshly exposed portions of the cotyledons of many seedlings showed varying intensities of green, from pale to quite dark. (Some germinating seedlings were without green pigmentation even in freshly exposed portions of the cotyledons. Proportion of seedlings showing green coloration under the seedcoat was not determined.) Green color faded after a few hours exposure to light. Yellow pigment was not noticeable in either the portion that had been exposed to light or the portion that had been protected from the light. The white seedlings developed until seedcoat was shed or nearly shed. At this point the cotyledons started to wither, and the entire seedling withered within 3 to 7 days.

Germination tests

Table I, which gives results of germination tests, shows that seeds yielding white seedlings germinate much more rapidly than normal siblings. Rapid germination of white seedlings occurred with or without stratification; in fact, it even occurred in stratification when the stratification temperature was a little higher than normal. In addition to more rapid germination regardless of pretreatment, the results also indicate that the seeds containing "white embryos" lack the response to moist chilling that most Douglas-fir seeds seem to show.

The more rapid germination characteristic can be seen in all the tests, but is perhaps best illustrated by the Lac-2 and XWC-8 seeds that were stratified at 0.5°C. At this temperature, little or no embryo elongation can be expected during stratification. The fact that the mutants germinated more rapidly under these conditions shows that the white embryo grows faster at the germination temperature.

The lack of response to moist chilling (i.e., lack of dormancy) by the mutant embryos is best seen by comparing seed lots for Lac-2 X XWC-8, which were unstratified, with those that were stratified at 0.5°C. Normal seedlings responded to stratification by germinating more rapidly with stratification than without. White seedlings, on the other hand, germinated at about the same rate with or without stratification. A similar comparison can be made between Lac-2 X XWC-8 seed lots that were stratified the same length of time (14 days) but at 5°C and 7.5°C. Normal seedlings responded to lower stratification by germinating more rapidly after stratification at 5°C than after stratification at 7.5°C. Seeds containing mutant embryos "responded" to the higher stratification temperature by germinating in stratification. That these seeds germinated more rapidly when stratified at 7.5°C than at 5°C, and normal seeds did not, indicates that the former lacked a chilling requirement and, instead, simply responded to higher temperature with more rapid elongation of the embryo.

Discussion

Occurrence of the mutant

Although lack of pigment and lack of dormancy would seem to be a peculiar combination of characters, the combination may be quite frequent. The phenotype was apparently first reported in maize where the absence of seed dormancy aspect was stressed under such names as "germinating seeds"16, "primitive sporophyte"17, "premature germination"18, and "viviparous"19. Recently, the combination of traits also has been observed in western white pine (personal communication, R. T. Bingham, Forestry Sciences Laboratory, Forest Service, U. S. Department of Agriculture, Moscow, Idaho 83843) and in ponderosa pine (Sorensen, unpublished).

Lack of pigment and lack of dormancy requirements are not always associated. Many albino mutants have been reported in maize20, 21; however, it is only those that are also associated with white or pale yellow endosperm that show vivipary22. But even among these, not all are viviparous.

Table I. Germination of white and normal green seedlings from several segregating Douglas-fir families

<table>
<thead>
<tr>
<th>Family</th>
<th>Length</th>
<th>Temperature</th>
<th>Days to germination*</th>
<th>White seedlings</th>
<th>Normal seedlings</th>
</tr>
</thead>
<tbody>
<tr>
<td>XWC-8 X self</td>
<td>14</td>
<td>5</td>
<td>2.6</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>Lac-2 X self</td>
<td>14</td>
<td>5</td>
<td>3.5</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>XWC-8 X Lac-2</td>
<td>14</td>
<td>5</td>
<td>1.4</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Lac-2 X XWC-8</td>
<td>14</td>
<td>5</td>
<td>1.5</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>Lac-2 X XWC-8</td>
<td>14</td>
<td>7.5</td>
<td>2.4</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td>Lac-2 X XWC-8</td>
<td>15</td>
<td>5</td>
<td>4.4</td>
<td>16.5</td>
<td></td>
</tr>
<tr>
<td>Lac-2 X XWC-8</td>
<td>15</td>
<td>5</td>
<td>4.5</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Lac-2 X XWC-8</td>
<td>25</td>
<td>5</td>
<td>3.7</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

* Average number of days to germination of all seeds which germinated. Test was considered complete when 2 days passed with no new germination. Day on which seeds went into germination was called 0.

† Of 29 white seedlings, 27 germinated while seeds were in stratification, but on the day called 0—hence, days to germination less than one.
Comparative description of mutant

Among albino-viviparous or albino-rapid germinating mutants in maize and conifers, the pigment phenotypes are remarkably similar. In general, the mutant seedlings are white, lacking both chlorophylls and carotenoids. Many of the Douglas-fir white seedlings have some green color until the colored tissue is exposed to light, but it then bleaches out. Similarly, maize viviparous-albino mutants are green or tinged with green when germinated in the dark or in dim light but bleach in the light. Western white pine mutants are described as pink albino (personal communication, R. T. Bingham); ponderosa pine mutants are pink albino or white. Pink albino seedlings are known in corn, and they are viviparous (personal communication, D. S. Robertson, Iowa State University, Ames 50012).

In maize, vivipary is also associated with white or pale yellow rather than yellow endosperm. However, there is no comparable pigmented tissue in the conifers.

Examination of several albino maize mutants reveals that they produce protochlorophyllide and protochlorophyll during germination and growth in the dark and convert these pigments into chlorophyll and chlorophyllide in the light. Chlorophyll production is normal or nearly so; but carotenoids are reduced or absent, and all mutants bleach with continued illumination. Levels of chlorophyll and carotenoid production are not known for Douglas-fir, except that some chlorophyll is frequently formed, that it is rapidly bleached in the light, and that yellow carotenoid pigmentation is not apparent.

It is more difficult to compare the dormancy phenotypes because of differences between conifers and maize, both in the expression of the mutant and in reproductive behavior. Two points in particular should be mentioned.

In maize, seeds are produced from double fertilization. Therefore, both the embryo and the nutritive endosperm tissue contain sets of paternal chromosomes. Dormancy control could be in the endosperm or in the embryo. However, Robertson produced single maize seeds with different genetic constitutions in the embryo and endosperm and showed that the viviparous allele affected dormancy through the embryo only. In conifers, the nutrient tissue for the embryo is the female gametophyte, which is maternal. Since green and white full siblings germinate at different times, dormancy control here also must be in the embryo.

A second possible point of difference is that viviparous maize and other grains are viviparous (personal communication, D. S. Robertson). It is more difficult to compare the dormancy due to a single gene, or to linkage that must be pleiotropic effects were responsible for the two traits appearing together. Recombination has been observed, but this could be the result of heterofertilization rather than recombination. Also, there are some “viviparous” loci not associated with albinism, and vice versa.

In Douglas-fir data presented above, the white seedlings have averaged more rapid germination than have the seeds yielding normal seedlings. However, there is some overlap in the two classes. A small percentage of green seedlings in almost every germination test appears before the appearance of the last white seedling. This is probably chance distribution of the classes, but it could indicate that some of the green seedlings are carrying the allele for rapid germination and some of the white seedlings are not—that there has been some recombination between the two classes.

Several white pine carrying the same gene for white seedlings have been identified (personal communication, R. T. Bingham). In the majority of the progenies from these trees, seeds containing normal and white embryos germinated contemporaneously. But in the selfed progeny of one tree, and perhaps another, seed with white embryos germinated more rapidly or with less stratification than did seeds with green embryos. This could be interpreted as evidence for separate genes. However, subtle environmental differences in cone and seed handling, or in germination conditions, could produce the same result, particularly if the albino-rapid germinating mutants were exceptionally sensitive to drying and wetting conditions (personal communication, D. S. Robertson).

Conclusion

The genetic association between pigment production and a dormancy control mechanism may be rather widespread in the plant world. There is evidence that the association may sometimes be due to linkage. Usually, however, it appears to be due to a single gene, or to linkage that must be very tight. In either case, the fact that the effects have been located together in Douglas-fir, pine, and at several points in the maize genome indicates that some basic relationship between the dormancy mechanism and pigment formation exists. Eyster remarked that continuous development of white sporophytes was strongly influenced by environmental factors, especially moisture. In fact, he was able to induce dormancy by prematurely drying the ear. Varis and Manner also reported that sprouting in the
Inheritance Of a Dwarf Character in Sericea Lespedeza

J. D. Miller and E. D. Donnelly

**Sericea, Lespedeza cuneata** (Dumont) G. Don, has been used for many years as a forage and soil-conserving crop. This study reports the inheritance of a dwarf internode character that was discovered in selfed progeny of an irradiation-induced sericea mutant.

Hanson and Cope reported inheritance of a dwarf mutation in sericea that was characterized by shortened internodes, small leaves, and light green color. This trait was conditioned by a single recessive gene. A second dwarf mutation in sericea was reported that had longer and fewer internodes but attained a height of not more than 15 cm.

Summary

A white seedling mutant in Douglas-fir and its association with speed of germination are described. Mutant seedlings appeared to lack all carotenoid pigment; green pigment, though initially present in some germinating seedlings, bleached rapidly in the light. Comparisons of seed lots after exposure to several combinations of stratification temperatures and periods showed that seeds containing mutant embryos apparently do not have a stratification (moist chilling) requirement and germinated more rapidly than their nonmutant siblings. Union of white albino or pink albino seedling trait and vivipary, or rapid germination, has also been reported several times in maize and in western white and ponderosa pines.

**Literature Cited**