# GROWTH AND WINTER INJURY OF DOUGLAS FIR IN A THREE-YEAR PROVENANCE DEMONSTRATION [1]

H. D. Gerhold[2]

Sixty-seven groups of 1-0 Douglas fir seedlings, and their seed source information, were received from J. W. Wright of Michigan State University in April, 1963s. The seedlings were planted early in May at Penn Nursery, near Potters Mills Penna., where they were used for demonstration purposes until large enough for field planting. For this reason they were arranged according to the latitude of the seed origin in three roughly longitudinal transects through the range of the species, representing the Pacific coast, interior Washington, and the Rocky Mountains, Each group was planted in one to several rows spaced 12 inches apart traversing the seedbed. Because the design purposely did not provide for replication or randomization, precise statistical analysis is not warranted. However, much of the observed variation in survival, height, and winter injury is believed to reflect real genetic differences, because the pattern confirms expectations based on replications of the same experiment at Michigan State University (5), and on previous provenance experiments in Pennsylvania, New York, and New Hampshire (1, 2, 3, 4).

The collection samples a large part of the range of the species, However, California and British Columbia are not represented; the latter region particularly deserves further study, for both applied and fundamental reasons.

The most significant data are recorded in table 1. Coastal sources were tallest, variable in survival, and severely damaged by winter injury: Those from interior Washington were somewhat slower growing and damaged less. The Rocky Mountain sources were quite variable in several ways. The Arizona and New Mexico sources were the tallest in this region, survived well, but had slightly greater winter injury than those from adjacent states. The Colorado and Utah sources were intermediate in height, had excellent survival, and were hardly damaged at all. In Wyoming, Montana, Idaho, and eastern Washington sources, growth was generally slow, over 80 percent of the trees showed slight signs of winter injury, and survival was fair to good. However, in sources from northern Idaho and the northwest corner of Montana (west of 115° longitude) growth rates were greatly superior to the remainder of the seedlots from these states, None of the seedlings were damaged by spring frosts, and thus no information was obtained regarding this important trait.

Outstanding seedlots include 1609 from Colorado, 1611 from Utah, 1615 and 1588 from Idaho, 1565 from Montana, and all of those from Arizona and New Mexico. Seed from the localities they represent can be expected to produce seedlings which are inherently faster growing and resistant to winter injury under conditions similar to those at Penn Nursery, This prediction could be extended to field conditions and until Christmas tree rotation age with somewhat less certainty, but fortified by prior experience. The risk way be greater in respect to the Arizona and New Mexico sources, because they have been tried less extensively in the East; but they must be regarded as very promising, also because they appear to branch profusely and have

[1] Partial financial support by Northeast Regional Research Project NE 27, USDA, is acknowledged.

[2] School of Forest Resources, University Park, Penna.

Table 1.--Performance of Douglas-fir from various origins at Penn Nursery.

Solid horizontal lines separate three longitudinal groups. Dashed lines direct attention to differences among provenance groups.

| MSFG Seedlot No. 1/ | State | N. Lat. | W. Long. | Elev. | Survival 2/ in Nursery | Height 3/ Age 1-2 | Winter Injury 4/ |
|---|---|---|---|---|---|---|---|
| | | o | o | feet | % | cm. | % |
| 1634 | BC | 48.8 | 124.0 | 600 | 42 | 43 | 30 |
| 1617 | Was | 48.1 | 122 | 600 | 39 | 46 | 50 |
| 1620 | Was | 48.2 | 122.3 | 500 | 18 | 48 | 40 |
| 1623 | Was | 47.2 | 122 | 1300 | 55 | 51 | 35 |
| 1627 | Was | 47.2 | 123.4 | 300 | 62 | 50 | 25 |
| 1624 | Ore | 45.8 | 123.4 | 700 | 2 | 32 | 55 |
| 1621 | Ore | 45.2 | 122.2 | 100 | 40 | 45 | 25 |
| 1618 | Ore | 44.4 | 122.7 | 3400 | 20 | 34 | 15 |
| 1585 | Ore | 44.3 | 121.7 | 3500 | 52 | 34 | 20 |
| 1613 | Ore | 43.7 | 122.5 | --- | 13 | 35 | 35 |
| 1622 | Ore | 43.7 | 123 | 1300 | 17 | 37 | 25 |
| 1619 | Ore | 42.0 | 124.2 | 200 | 11 | 28 | 45 |
| 1651 | Was | 48.6 | 119.5 | 2500 | 74 | 18 | 2 |
| 1645 | Was | 48.6 | 119.7 | 2000 | 71 | 24 | 12 |
| 1646 | Was | 48.4 | 119.8 | 5000 | 41 | 18 | 9 |
| 1555 | Was | 46.8 | 120.7 | 3000 | 10 | 20 | 11 |
| 1596 | Alb | 51.1 | 115.0 | 4500 | 89 | 14 | 14 |
| 1595 | Alb | 51.0 | 115.0 | 5000 | 73 | 13 | 4 |
| 1556 | Was | 48.9 | 118.7 | 4100 | 41 | 12 | 4 |
| 1513 | Mon | 48.8 | 113.5 | 4500 | 94 | 12 | 9 |
| 1517 | Mon | 48.5 | 115.2 | 4000 | 83 | 28 | 15 |
| 1507 | Mon | 48.4 | 115.5 | 3800 | 93 | 22 | 9 |
| 1519 | Mon | 48.4 | 114.7 | 4000 | 69 | 16 | 5 |
| 1565 | Mon | 48.3 | 116.3 | 3500 | 68 | 27 | 3 |
| 1521 | Ida | 48.2 | 114.5 | 3000 | 64 | 14 | 4 |
| 1650 | Mon | 48.2 | 114.7 | 3500 | 76 | 18 | 10 |
| 1600 | Mon | 47.8 | 113.5 | 3700 | 86 | 18 | 9 |
| 1615 | Ida | 47.7 | 116.8 | 2400 | 77 | 36 | 3 |
| 1588 | Ida | 47.5 | 116.0 | 3000 | 93 | 29 | 8 |
| 1501 | Mon | 47.5 | 114.7 | 5000 | 45 | 11 | 10 |
| 1539 | Mon | 47.3 | 113.5 | 4600 | 63 | 12 | 13 |
| 1616 | Mon | 47.3 | 115.2 | 4000 | 73 | 20 | 9 |
| 1603 | Mon | 47.2 | 114.8 | 5000 | 14 | 10 | 13 |
| 1564 | Ida | 47.2 | 116.1 | 3000 | 27 | 24 | 9 |
| 1506 | Mon | 47.2 | 113.2 | 5000 | 76 | 16 | 4 |
| 1567 | Ida | 47.1 | 116.6 | 3500 | 93 | 22 | 4 |
| 1649 | Ida | 47.0 | 114.0 | 3500 | 87 | 17 | 6 |
| 1562 | Ida | 47.0 | 116.1 | 4500 | 81 | 20 | 4 |
| 1504 | Ida | 47.2 | 113.8 | 5000 | 64 | 13 | 10 |
| 1505 | Mon | 47.0 | 110.8 | 5000 | 73 | 13 | 10 |
| 1520 | Mon | 46.9 | 113.4 | 4000 | 70 | 15 | 19 |
| 1573 | Ida | 46.6 | 116.8 | 2500 | 45 | 22 | 15 |
| 1524 | Ida | 46.5 | 114.8 | 5000 | 87 | 18 | 10 |
| 1606 | Mon | 46.0 | 112.5 | 6500 | 57 | 15 | 5 |
| 1648 | Mon | 45.5 | 110.0 | 6000 | 67 | 12 | 4 |
| 1503 | Mon | 45.4 | 110.4 | 5600 | 84 | 11 | 4 |
| 1522 | Mon | 45.2 | 112.6 | 7500 | 13 | 6 | 5 |
| 1553 | Wyo | 44.9 | 109.8 | 6000 | 20 | 9 | 10 |
| 1636 | Col | 40.2 | 105.5 | 8800 | 93 | 16 | 4 |
| 1532 | Col | 40.2 | 107.9 | 8200 | 95 | 22 | 2 |
| 1635 | Col | 40.0 | 105.5 | 8000 | 76 | 15 | 3 |
| 1642 | Col | 40.0 | 105.4 | 8400 | 79 | 18 | 1 |
| 1612 | Col | | | | 64 | 16 | 1 |
| 1529 | Col | 40.0 | 106.5 | 8000 | 82 | 16 | 1 |
| 1609 | Col | 39.1 | 104.8 | 8000 | 100 | 29 | 1 |
| 1549 | Uta | 39.3 | 111.5 | 8000 | 79 | 12 | 1 |
| 1630 | Col | 38.2 | 107.6 | 9100 | 80 | 21 | 3 |
| 1611 | Uta | 37.6 | 112.5 | 8200 | 100 | 24 | 2 |
| 1525 | Col | 37.5 | 108 | 8500 | 93 | 34 | 3 |
| 1625 | Ari | 37.0 | 112.5 | 5000 | 93 | 25 | 2 |
| 1610 | NMx | 35.5 | 106.7 | 8500 | 81 | 30 | 6 |
| 1647 | Ari | 34.4 | 111.0 | 7000 | 74 | 30 | 4 |
| 1545 | Ari | 33.3 | 110.7 | 7800 | 77 | 38 | 6 |
| 1594 | NMx | 33.0 | 105.8 | 8700 | 47 | 35 | 2 |
| 1602 | NMx | 32.9 | 105.4 | | 95 | 36 | 6 |
| 1614 | NMx | 32.9 | 105.8 | 8300 | 100 | 40 | 5 |
| 1593 | Ari | 32.4 | 110.8 | 8400 | 91 | 40 | 7 |

1/ Sequence indicates arrangement in Penn Nursery, representing 3 N-S transects through the range. The nursery objective was demonstration, not experimentation; therefore, the design did not provide for replication or randomization.

2/ Percent of 1-0 seedlings planted 5/2/63 that were alive on 12/7/63.

3/ Average height of 3 typical trees measured 10/3/64.

4/ Percent of trees that showed any sign of winter injury on 4/16/65, at age 1-2, multiplied by estimated average percent of dead foliage, on injured trees only. None were injured the previous winter, during which they were protected by snow cover much of the time.

very blue needle color, Selected Colorado (and perhaps also Utah) sources are probably still the most reliable, while the above indicated localities in Idaho and Montana are also worthy of consideration,, especially when more desirable seed is not available. It has been known for some time that the Coastal sources are generally unsuitable in the East because of their extreme susceptibility to winter injury.

Much remains to be learned, both about these trees as they grow older, and about variation in the species related to geographic source of seed. It is becoming ever more apparent that large differences can occur over small distances. Although similarities can be described for regions the size of one or several states, considerable and significant variation occurs within these. For example, at age 3, MSFG 1609 was nearly twice as tall and sustained a fraction of the winter injury in comparison with MSFG 1635, the two locations being only 70 miles apart in Colorado,

In view of the fairly large chance of obtaining genetically inferior seed even when reasonable care is taken to assure a desirable origin ; and because of the uncertainties presently involved in seed procurement, it would seem prudent for Christmas tree growers and nurserymen to take steps to provide further safeguards.. Two temporary measures that would provide quick benefits can be suggested:

1. Arrange for the establishment of seed production areas at previously tested locations in western forests. This would probably require the cooperation of the U. S: Forest Service to set aside appropriate areas for this purpose and to rogue out undesirable trees. A sale procedure could be instituted to permit private seedsmen to bid for the privilege of collecting the seed. Improved and more abundant seed would become available during the first good seed year after roguing is completed.

2, Establish grafted seed orchards in the East by propagating cone-bearing trees selected in previously tested western forest stands. The author has observed within western stands considerable phenotypic variation in needle color, branching characteristics, abundance of cones, and growth rate, Opportunities for selecting outstanding trees in the best localities appear to be very promising. The species is easily grafted and thereafter grows well, It should be possible to start harvesting useful quantities of seeds within 5 to 10 years- if the most suitable techniques are employed. In my opinion, considerably greater improvement in needle color and branching characteristics could be anticipated than with the first suggestion.

It is also recommended that such temporary measures be integrated with a continuing effort to breed varieties that would be even better suited to cultivation,

## LITERATURE CITED


1. Baldwin,, H. I. and D.. Murphy. 1956. Rocky Mountain Douglas-fir succeeds in New Hampshire, Hillsboro, N. H. Fox Forest Note No. 67.
2 and D. A. Rock, 1961. Douglas fir as a New Hampshire Christmas tree.Hillsboro,;N. H., Fox Forest Note No. 80.
3. Byrnes, W. R,., H. D. Gerhold, and W. C.. Bramble. 1958. Douglas fir varietal tests for Christmas tree plantations in Pennsylvania. Penna, State Univ., Coll. Ag. Prog. Rpt. 198: 1-6.
4. Heit, C.. E. 1965, Douglas fir seed source studies covering a 15 year period at Geneva, New York. Am., Christmas Tree Growers Jour. 9 (2): 33-35.
5.. Wright, J. W. 1963. One-year report on Douglas-fir geographic origin study, Forestry Dept., Mich. State U., E. Lansing, Mich. 5 pp. mimeo.

## DISCUSSION[1]

LARSSON Have you located any high quality larch phenotypes?

CHANDLER Good phenotypes of American larch were located at Wingdale. We have three hybrid seedlings with Japanese and European larch crossed with American larch which are too young for a critical evaluation.

STAIRS - I might add something to that. We have a letter from some research people in Germany who have a small stand of putative hybrids between *laricina* and European larch. They're not completely sure of the origin of these, but they feel on the basis of their observations that it is this hybrid, and they think it's particularly well-growing, a good-growing hybrid, and they want to do some more work with it, and they're asking us for materials.

WATERS - Was there any natural crossing of the American larch at Yonkers or Wingdale with European or Japanese strains?

CHANDLER - Only American larch was growing at Wingdale so there was no chance for natural crossing with other species, No germination was obtained from open-pollinated seed collected from trees at Yonkers,

WATERS - Is the seed source of either the Wingdale or Yonkers trees known?

CHANDLER - The Wingdale trees are growing in a natural stand 50 miles north of Yonkers. They are not my seedlings, They are large trees which must be 30 or 40 years old or perhaps older, We know that they produce viable seed because there is excellent natural regeneration in this stand; and it is here also that we have our first evidence that this "wobbly" characteristic which is so common in Japanese larch may be genetically inherited. Among these natural seedlings of American larch we do find under one tree which is "wobbly" many seedlings which exhibit this characteristic, while under the best straight trees the seedlings were all nice and straight, just like the trees under which they were growing. The seedlings of *L. laricina* that I studied at Yonkers were 10-12 years old from seed obtained from Dave Cook.

WATERS - The effect of "site" cannot be assessed, of course, unless reciprocal plantings were made of the trees in the two sites. The very marked meiotic: malfunctions you show in the Yonkers stock would seem to indicate a highly selective site factor, if this be the case, since no other tree species were affected. Isn't it more likely that the observed abnormalities are a genetic character of that particular stock?

CHANDLER - It is certainly possible that this abnormal meiotic behavior may be genetic and that these Yonkers seedlings are weak plants obtained from seed produced through selfing. The fact still remains that these trees are growing poorly and meiosis proceeds abnormally.
that you select excellent trees for your breeding and not use pollen just because it is pollen from the species you want to use in your hybridization work, and the importance of evaluating your pollen very carefully,.

[1] Transcripts of the discussion were sent to each of the participants for editing with the specific request not to change the contents of their remarks.

SCHREINER - Many years ago I built a house in Maine and transplanted a native larch out of a swamp to gravel fill near the edge of a 25-foot slope; the fill came out of the cellar excavation, Although this was a rather dry site because of excessive drainage, the tree grew very well and produced a lot of good seed. We think of our native larch as a wet-land species, but I believe they grow on such sites because they seldom get a chance to take over on drier upland sites, I wonder whether atmospheric contamination in Yonkers, with all the automobile and other air pollution you have there, might be responsible rather than the dry soil.

CHANDLER - If it were air contamination, I would expect it to have an effect on other species as well, Why would just the American larch be susceptible to the air conditions there?

HUNT - Dr. Chandler, your suggestion that drought conditions at the Yonkers site enhanced the formation of abnormal pollen prompts me to ask if only those trees in swamps or moist areas at Wingdale produced viable pollen. Wouldn't trees growing on dry, upland areas experience conditions similar to those encountered in Yonkers?

CHANDLER - Seeds could be dispersed on the hills in the Wingdale area and some small seedlings were observed on these dry areas; however, no material was available for meiotic studies,

HUNT - The spring period when meiosis occurs coincides with soil moisture levels normally close to field capacity: Are you planning to compare pollen formation on both relatively dry and moist sites?

CHANDLER - Some of these Wingdale seedlings were transferred to our Dutchess County property where they are planted on a dry hillside, These seedlings produced flowers the following year while those at Wingdale did not flower. Root pruning of the transferred seedlings could have induced flowering or it could be the unfavorable site which initiated flowering, This material will be available for further studies

SVUKSTS - Have you considered the possibility that temperature conditions might be slightly different between the two areas, and whether fluctuations in one area, such as freezing and thawing during parts of the winter, may be partially responsible for what you observed?

CHANDLER - These observations were not completed in a single year but extended over a period of about five years- Temperatures may have been slightly lower at Wingdale than at Yonkers which delayed the meiotic stages a week to 10 days. We did not have more drastic drops in temperature at Yonkers than at Wingdale

WAKELEY - I'd like to ask Dr, Chandler two questions about her American larches, with abnormal meiosis, at Yonkers: First, did the abnormality occur in one specimen only, or was it characteristic of several? Second, if it occurred in more than one specimen, what was their parentage? That is, were they by any chance half-sibs, with the abnormality possibly attributable to the common female parent?

CHANDLER - The seeds were planted in 1948; they came from Mr. Cook, There are 20 seedling trees, Material was collected from seven of these seedlings and all showed abnormal meiosis,

WAKELEY - And you collected material from several of the twenty, and found the abnormality in each one from which you collected?

CHANDLER - Yes.

WAKELEY - Then the abnormal meiosis isn't limited to just one seedling tree?

CHANDLER - No, it's all the trees.

GERHOLD - Are the seedlings that exhibit irregular meiosis all siblings? Could the cause be genetic rather than environmental?

COOK - I think I can trace the source of Dr. Chandler's trees through my records; I will look it up and send it to the editor for insertion in the record. The following statement was received by the editor from Mr. Cook: "Dr. Chandler's acquisition data indicate that the seed came from Cooxrox Forest; November 6, 1948. My notes for that day say that I 'stripped the lower part of the American larch opposite the driveway'. This tree is a wildling dug at Taplins Pond, only four miles to the southwest. Over the years, it has suffered severely from squirrel-clipping and from summer droughts--it is a poor specimen indeed! In 1948 the only possible source of tamarack pollen was one tree in European larch No. 1, 350 feet to the south. The odds would have been one tamarack against 550 very vigorous Europeans. Dr. Chandler's trees show no trace of hybridity with European or Japanese; must be presumed to have been the result of selfing.")

BALDWIN - I think Ernie mentioned that our native larch might be restricted to swamps because of inability to compete with upland species, which have greater tolerance of shade. Now as far as I recall, natural American larch stands in both northern New York and northern New England, the best development has been on upland where they have seeded in naturally in pastures where there was not this competition with other species. You will find some very fine stands in Maine and northern New Hampshire, possibly elsewhere, which seem to be reproducing on the site as well, and presumably they are able to grow very well indeed on upland sites. I think in the IUFRO plantation that you've got near Saratoga, Eli, there are one or two rows of American larch that are certainly not up to the European, but they're doing better than the same source would do in a swamp.

HOUSTON - You indicated that the presence of crooked seedlings growing beneath crooked parents was evidence that this character was inherited. Could not this be due also to local site condition? In other words, local site condition (soil minerals, etc.) that might have influenced growth of parents, could influence the growth of progeny in the same way.

CHANDLER - Of course, I can't say very much about that because I have not propagated these vegetatively and placed them in randomized block plantings in the field, and until that is done, I don't think you can say it's site location or anything.

CONNOLA - I would like to ask Dr. Chandler if the American larch at Yonkers was the same stock as that at Wingdale.

CHANDLER - No, they are not the same stock.

CARLSON - Dr. Chandler, I would like to know what time of day was best for collecting to get the diakinesis stage.

CHANDLER - Oh, you don't have to be particular about the time of day; you'd better be concerned with which day of the week you're going to pick them. The vegetative nucleus of the pollen grain goes through all stages for the divisions within about 24 hours, So there you do have to watch, but it doesn't make any difference when you cut your material; it isn't like Spirogyra that at 9:30 in the morning or 9:30 at night, some mechanism says you divide, and everything divides.

GENYS - Dr. Baldwin, what is your opinion about Polish larch? Mr. Cook mentioned that this larch was not good at the Cooxrox Forest, but if I remember correctly it was doing quite well at your IUFRO plantations.

BALDWIN - Well, I wouldn't be able to answer that from any personal knowledge. I do know that we have some of the Polish larch that Dave Cook sent me in a plantation now about 7 or 8 years old, and it doesn't seem to be doing as well as some of the other sources. But I think the statement I made in my paper was that trees from the general area of the Silesian, Polish, Sudetan, and Carpathian sources were, in general, superior to the Alpine ones. To go in more detail, I think you would have to study the literature much more carefully than I have done, or discussed in my paper. I don't know whether that answers your question or not; you know the background of it probably better than I do.

GENYS - Published data suggest that Polish larch should be one of the most rapidly growing strains of European larch, but it was seldom compared to other larch species. I think Mr. Cook would be kind to comment more about it.

COOK - Yesterday I showed you one Polish larch that was a selection at the level of about 1 to 10,000 in the 2-0 seedbed, from Seed Lot X-9 (Mark Holst's 82501) from Scarzysko, Latitude 50° 15', elevation 1300'. I have another stand (S.L.X-44) from the Pieniny Mountains; it tends to be scrawny, thin-foliaged and rather lacking in stiffness of stem, so that it has been hurt by snow-bending. Our experience with Polish larch is limited and what I have said applies mostly to Cooxrox Forest. It is not that the species is no good, but that it is not as good as the heavier-foliaged Japanese and hybrids.

SCHREINER - In reference to Dave Cook's suggestions on spacing, I would like to point out that he's dealing with seedling varieties. If he were dealing with synthetic multiclonal hybrid varieties he could space wider and avoid an early thinning. This is just another "plug" for the possibilities of clonal varieties.

ANONYMOUS - Why would wider spacing to avoid early thinning be possible with a clone mixture?

SCHREINER - Because we could expect less genetical variation between trees on any particular site, We would have the same clones represented by a number of ramets; a random mixture of identical genotypes.

HUNT - I see no need to plant the same clonal mixture on every acre, I would assume thorough clonal testing (replicated on all probable planting sites) will precede large-scale commercial plantings. This allows a silviculturist to select the clones proven best for a given site. If he expects snow or insects to be a problem, those clones that have proven least susceptible to such damage should be utilized.



SCHREINER - That's right; the tests in various regions or on various sites would be combination progeny and clonal tests. For use in commercial Multiclonal varieties, selection would be on a clonal basis; the first selections based on at least half rotation, and later selections up to full rotation.

STONE - Your assumption is, though, that one of your big reasons for thinning is to select trees on the basis of their genetic interactions, whereas a great part of the damage occurs after the initial stages of sorting out, as from snow break or something of that sort. You may still need that number to have sufficient straight stems.

SCHREINER - I'm not advocating reducing the number of trees planted to the final crop-tree number. But this is what they do in Europe with hybrid poplars in monoclonal cultures on 10- to 25- and even 50-year rotations. I would suggest that we should plant at least 10 to 20 percent more trees than we expect to harvest. This would still be less than we would probably plant if we use seed-reproduced varieties; but even in such a seedling plantation there could be severe (possibly even 100 percent) damage from snow breakage or other catastrophe.

NIENSTAEDT - Considering the question of the dangers and advantages of uniformity, I want to inject the idea that the manufacturers are particularly interested in uniformity in the raw material they use. Lack of uniformity usually complicates manufacturing. Therefore, in spite of the fact that uniformity, biologically speaking, might entail certain dangers it is, from the standpoint of the manufacturer, highly desirable.

GENYS - Dr. Schreiner, I am interested in your suggestion on inducing apomixis and producing apomictic clones. However, I wonder if these clones, resulting from reproductive abberrations, will be normal with respect to their fertility and growth habits.

SCHREINER - For practical use--commercial planting--we would not be interested in the sexual fertility of the selected clones. Since clones would be selected for growth habit on the basis of adequate clonal tests such selections would be superior to the average; they would be selected for the superior qualities or characters desired for commercial use.

STONE - Just to switch back to the sense of what I take your purpose to be here, of putting out mixtures of desirable individuals; it's pleasant to see that forestry is not as far behind agriculture in this as it frequently is. This is what they are doing with some of the new varieties of legumes, which are synthetic hybrids; and there is a good deal of discussion about mixing grain varieties to reduce the degree of susceptibility in comparison with a single genotype. The problems of breeding are very different among the grains, so that oats and corn, for example, are entirely different things. But that hasn't prevented them from recognizing the value of a diverse population in providing security against some of the fungus diseases.

GENYS - I wonder if we can learn more about some methods of inducing apomixis from the scientists in other research fields, and what was their success.

SCHREINER - To my knowledge no one has yet developed a method for inducing apomixis on even a semi-commercial scale. Forage breeders have made some progress toward the breeding of synthetic apomictic varieties.

GENYS - My interest in the subject is only from the basic, cytologic point of view. I appreciate Dr. Schreiner's suggestions giving us new ideas.

FARNSWORTH - I think the point you make is an excellent one. We do not have experience, but what Dr, Schreiner is urging, and I think what's implied in your statement, is that we need to select this as an area of intensive investigation to determine what the validity and what the lines of procedure should be.

CHANDLER - I would like to ask the plant breeder on western larch, how he's going to tell that this pollen that he has stored during the winter or during this period of time, how he is going to tell what's viable before he takes it to the field to use in his pollination work next year.

CARLSON - This is an excellent question and one that we did consider. We did test the pollen before doing our artificial pollinating.. We tested the pollen by putting it in distilled water at about $70^{o}$ F. for three days, and at the end of this period we counted the number of pollen grains that had germinated.

CHANDLER - I'd like to ask if you got actual tubes from these pollen grains.

CARLSON - Yes, pollen tubes.

CHANDLER - I haven't tested the western larch, but I havent been able to germinate pollen of any of the larch that I have worked with on artificial media. I've tried water like they use for pine, but I've never seen tubes protruding from the pollen grains, and I have germinated pollen of other types of plants for forty years

BLAKE - We were not aware of any difficulties associated with the germination of larch pollen. However, we had no problems germinating either western larch or subalpine larch. Maybe you should try some western larch.

CHANDLER - I have western larch pollen at Yonkers now.

STAIRS - I would like to add a comment here. Pollen germination is not an absolute indicator of pollen viability. While it is a good indicator, what we really need is a method for obtaining tube divisions in conifers as we are able to do in many angiosperm plants. This would then indicate the state of nuclear viability, for we know from radiation studies and from heat-killing experiments with pollen that tube growth may only be an expression of cytoplasmic viability.

SCHREINER - I recall that someone from Placerville has reported that although laboratory germination of pollen seems good, its actual effectiveness in fertilization can be quite a lot lower than the germination tests would indicate. This would not necessarily apply to one-year-old pollen because I think they used pollen stored several years. Perhaps Bob Callaham can give us more detail on this report from California.

CALLAHAM - That is right. Germination tests may not indicate ability to set seed. The results of this pollen storage work have been reported by Stanley in Silvae Genetica in 1962. I would like to ask Mr. Carlson whether he has any evidence for genetic barriers between these larch species as would be evidenced by reduced seed set.

CARLSON - The approximate germination for the western larch we collected was 30 percent and for the Alpine larch was approximately 15 percent, and of the hybrids was near 30 percent.

CALLAHAM - My question referred to the number of sound seeds set per cone after controlled crossing within the species and between the species.

NIENSTAEDT - In your controlled pollination, did you find any indication of incompatibility between the species?

CARLSON - We have not observed any genetic barriers yet. We just made the reciprocal cross using western larch as the female parent this year, but last year we made the cross using Alpine larch as the female parent and as far as we can tell, everything went fine.We have not made any controlled self-pollinations.

WATERS - Is it possible that light to moderate defoliation, by an insect say, would actually be beneficial to a tree under moisture stress?

STONE - As a way of reducing the moisture demand, I guess the only answer is a on-the-one-hand or other-hand sort of thing- I wouldn t know whether we ever could wind up with an advantage from defoliation except under quite extreme conditions when it might make the difference between survival and non-survival. I could imagine producing such an effect experimentally,

WATERS - In the Northeast, we have a great diversity of hardwood defoliators, a relatively small number of which are considered serious pests because of observed or assumed damage caused by them. Some of these accomplish their feeding late in the growing season--in August, or even September--when drought conditions often occur, Since the trees have put on most of their actual growth by then, perhaps this sort of defoliation is really beneficial in the long run.

STONE - Too many things enter in to give an open and shut answer to that. The tree has to produce those leaves with a drain on its reserves; it's got to store a certain amount of reserves ; it has some tolerance of drought. I have no answer.

McQUILKIN - My question is directed to Dave Cook, or anyone else who can answer: What has been the experience in direct seeding the larches? I raise the question because, on three occasions, I have made small seedings of either European or Jap larch alongside red and pitch pines, and in each instance the larch was almost a total failure, whereas good catches of the pines occurred under the same conditions. The larches appeared definitely to be more sensitive to the rigors of field conditions when starting from seed.

COOK - Let me pass the question to Eli; he knows vastly more about that than I do.

ELIASON - There is very limited experience in the direct seeding of larch, However, if conditions were right for successful germination with other species, I see no reason why it would not be as well with larch. In fact, due to its deciduous nature, early juvenile growth and ability to recover even with one live bud, larch might be more successful than other species in that critical period following germination

McQUILKIN - Do you actually have any successful field seedings?

ELIASON - No

WINIESKI - In regards to direct seeding of the larches, a small attempt at direct seeding was made on the Greenland Tract, Weiser District in Pennsylvania. Three pounds of Jap larch and one pound of European larch seed were sown by hand on March 12, 1958. The area was a cut-over site III (poor) oak site that had been root-raked. There was a heavy snowfall after sowing and both species germinated well, The resulting larch saplings are competing favorably with the sprout vegetation.

COOK - Wherever you're getting natural regeneration, you're getting direct seeding, not in strict silvicultural sense, but you're certainly getting direct seeding; and we have numerous cases in New York where all three of the larches have done very well at natural seeding. I have no idea what the loss is, but I can say this, that as far as mass use of direct seeding, larch seed is too scarce and too expensive to make it possible at this stage of the game.

DOLGAARD - Observing the plantations during yesterday's field trip, and listening to the panel's presentation and discussion from the floor, am I correct in saying, if a planting program of larch is proposed, the best species would be Japanese or the Dunkeld hybrid?

COOK - I'll go along with that; the best thing about the Dunkeld hybrid is some of its Japanese characteristics, high volume production and very rapid growth.

LAMBERT - Have you had any natural regeneration from any of your larches and under what conditions?

COOK - I have some reproduction at Cooxrox Forest; the Cranston larches at Stephentown reproduce aggressively; Eli has some on Montgomery State Forest No. 1--a most unlikely place. There is abundant natural reproduction from the old larches at Bovina, Delaware County. I do not know specifically where you might get natural reproduction, but I would expect it almost anywhere where seed and seedbed are available.

BALDWIN- I'd like to ask Dave Cook if he's tried fall planting. In New Hampshire we've been digging larch in the spring when the snow is on the ground and having very good success with spring planting when it was done the way he recommended it, However, for several years we've been putting in comparable tests of fall planting from the same seedbed as the spring planting, and I've planted them right up until the ground freezes, sometimes the first week in December. Reviewing all the results it would appear that we get a better survival with fall planting than we do with spring planting,

COOK - The first problem is the nursery one. It is difficult to get the larch seedlings to shed their needles, and then to get them out of the ground and then back into the ground and still beat an early frost, because our nurseries tend to be at lower elevations than the planting sites. I would say that Cooxrox Forest Plantation No. 19, which I showed you yesterday, was planted on November 9, 1935 and it did right well--initial survival about 90 percent. But I beat the snow by only one day--it snowed the day after and I would have been in difficulty if I had been a day later.

STONE - My intention was not to shut off that discussion but simply invite Dave's further comment to Mr. Dolgaard's question: Jap would be the species except as you move into the drier areas, drought susceptible areas, where European might be a better bet?

DOLGAARD - I recognized during the discussion that site would influence choice of stock for planting, that European appeared best for the drier sites. I did want some expression of what the panel would recommend.

COOK - Let me say this about larch. The man who plants larch in the field will take what the nurseryman can provide. It is up to the nurseryman to get the best seed he can. If and when we get good European larch seed, we allocate the stock to some of our drier areas. If we can get Jap or good hybrid, that will go on the better sites. But "hybrid" is a very tricky business; you cannot be sure that you are getting real hybrid seed, and it is not a commercial product.

DORN - You mentioned in your proposal for the use of synthetic multiclonal varieties that we plant 10 to 20 percent more trees than we expect to harvest and that artificial pruning be definitely planned if we want clear boles. Aside from the merits of natural versus artificial pruning, if you mean we start with 10 to 20 percent more than we want as final crop trees, I would suggest we are not utilizing the full potential of the site with such wide spacing. Development of clear boles and provision for selection during the rotation are not the only reasons for close initial spacing. Provided, of course, that we have a market for thinnings, stand closure early in the rotation will produce a greater volume of wood.

SCHREINER - I agree, I would plant close provided the cost of clonal planting stock (or apomictic seed for direct seeding) made such close planting economically feasible, However, I will continue to mention possibilities of wide spacing of select clones because most foresters fear that vegetative propagation is going to be so expensive that we will not be able to afford their use for timber production. And I don't want to discourage research on vegetative propagation.

ANONYMOUS - Wide spacing would provide less control of weeds.

MORROW - In this age of chemicals and weed-killers, there is little excuse for controlling weeds by close spacing of trees. In most cases chemical weed control is cheaper than planting the required additional trees for weed control.

SCHREINER - That's a good point, Since 1951, when I first studied spacing of hybrid poplars in Europe, I have pointed out that spacing is not necessarily a biological problem; it's an economic problem. We can grow trees at dense stocking or we can grow them at wide spacing. It's a question of how we can produce the desired product and make the most profit.

NIENSTAEDT - We must keep in mind that spacing must be kept within certain limits in order to permit silvicultural manipulation of stands. We, as geneticists, can bring about improvement in many characteristics--quantitative as well as qualitative--but sound silviculture and tree improvement should go hand in hand, and open-grown trees cannot be manipulated silviculturally.

SCHREINER - That's right, Hans; I have an example of a poplar clone that at 14 years was 28 inches in d.b.h and about 75 feet in height when grown at wide spacing in Philadelphia, The same clone at 15 years in a 6 x 6 planting in Maine, was 70 to 75 feet in height,'and the average diameter was about 8 inches, The volume of wood per acre was practically the same for wide spacing as for the 6 x 6 spacing. But think of the difference in taper. What product do we want, pulpwood, lumber, or veneer? I agree with you that the geneticists can't do it all. I've said that time and time again, particularly in my 1958 paper on improvement of utilization potentials of forest trees.

MORROW - I agree. At Cooxrox there are markets for larch pulpwood. As we all saw, a 6 x 10 foot spacing produced an ample supply of good stems per acre. At locations where there is no pulpwood market, a wider spacing may be best. On the other hand, spacings closer than 6 x 10 feet are uneconomic even for pulpwood since the stand will biologically need thinning before a commercial cut of pulpwood is available. I have commented further on economic and other aspects of plantation spacing in Tree Planters' Notes No, 67 (Sept, 1964). Included is discussion of upper limits of tree spacing with consideration for tree quality growth.

CALLAHAM- Have provenance tests with Japanese larch progressed far enough to suggest good sources of seed?

STAIRS - I believe that our information is somewhat limited at this time. In studies where we have replication over several environments, a significant interaction component has usually been observed.. Thus, we can say that present data is based on juvenile performance and is probably valid only for the region where the study is being conducted.

CALLAHAM - Then what seed sources can be recommended to land managers at the present time. Would you recommend that they collect seed from the better Japanese larch stands growing in their areas in preference to buying seed from Japan?

STAIRS - I would suggest that if a suitable plantation is available, it is a better source of seed than resorting to commercial seed lots. Provided, of course, that you do not have suitable information from provenance tests conducted in a chosen region. For this very reason, I believe that it is important to include local plantation seed lots in provenance studies. You then have an opportunity to evaluate your local (and potentially more bountiful) seed source with others under consideration.

CALLAHAM - Japanese larch seems to have great promise and comprehensive second generation provenance tests with numerous outplantings seem warranted, Is such research planned?

STAIRS - I don't know of any well-organized, region-wide study in this area, although there is a need for such study, We could consider two approaches to these second-generation studies; either a mass selection scheme among the best seed lots, or an inter-source breeding scheme. I would favor beginning breeding studies under both approaches as quickly as we can

STONE - My general speculative question was already foreshadowed by Dr. Baldwin's comments on the European larch. I've always heard that the population of Japanese larch in the homeland did consist of those isolated populations. I wonder how much of this is actually an artifact of the long activity of man in separating what might have been a more continuous distribution? The lack of marked differences among populations of different origins may be in part a result of mixing prior to the separation of those populations by man,

BALDWIN - I think that in the case of John Genys' analysis of the IUFRO sources that he segregated the ones which were from perfectly natural stands, and there were some included which were either doubtful or from planted stands. I certainly would emphasize what Dr. Stone has said that you have mixed and extended the range so that it is very difficult in central Europe, for instance, always to be sure that you have an entirely native race, The IUFRO studies have labored under that difficulty.

STONE - My question was actually with respect to Japanese larch because we have less knowledge of the activity of man in that country.

STAIRS - I would say that my ability to read Japanese is somewhat like your own. I am sure that this language barrier restricts our full appreciation of the past history of Japanese larch as reported in the Japanese literature. Nevertheless, the pattern of land development, as you suggest, must have been a factor in the isolation of small populations Occasional crossing between these small populations would affect gene frequencies and result in greater variation within the populations. In the reference I quoted from, the populations appear to be distinctly allopatric, but I assume that one would need to qualify this by an on-the-ground inspection.

In general, I believe we do find considerable variation within seed-lots of Japanese larch in addition to the differences between sources: Additional studies are needed to compare the magnitude of these two primary sources of variation.

WATERS The relatively large amount of variation within seed sources is to be expected--despite the limited geographic range--if the stands are semi-isolated with limited crossing between them Heterogeneity would be maximized by genetic drift within these subpopulations coupled with occasional gene flow among them.

STAIRS - That may well be a point, although many of the natural populations are located on mountain tops and thus there would seem to be considerable isolation between respective sources

ANONYMOUS - What is the present status of larch sawfly?

WINIESKI - We had moderate to complete defoliation of several hundred acres of Japanese and European larch plantations in Pennsylvania by the European sawfly, Pristiphora erichsonii, in 1964 and 1965. Talking to other participants here the past few days, I fid that no one seems to be having as much trouble with this insect ns we are in Pennsylvania.