ABSTRACT

Provenance tests established in Minnesota show that ponderosa pine (Pinus ponderosa, Laws.) from south of 40°N latitude and west of 112°W longitude should be avoided to ensure adequate survival and reduce climatic injury. Materials from southern and eastern Montana and the eastern high plains-low elevations grew tallest and had adequate survival and freedom from climatic injury.

Plantings of ponderosa pine in Minnesota have frequently been less than satisfactory because of poor early survival, excessive winter injury and slow juvenile growth. Given the geographically and climatically diverse natural range of this species, the use of seed from inappropriate origins may have contributed to these problems. Insight into this possibility is now being obtained from provenance tests established as a part of the North Central Regional Tree Improvement Project (NC-99) at University of Minnesota field stations. These tests were established in 1968 at the University's West Central Experiment Station at Morris (45.6°N, 95.9°W), Southwest Experiment Station at Lamberton (44.2°N, 95.3°W), and the Cloquet Forestry Center (46.8°N, 90.7°W), and in 1970 at the North Central Experiment Station at Grand Rapids (47.2°N, 93.5°W). Materials tested were grown from seed from 74 stand collections made by the Rocky Mountain Forest and Research Experiment Station USDA, from the high plains west to the foothills of the Rocky Mountains and in a few scattered locations in the western part of the species range (Table 1). With a few exceptions, the seedlings used to established all 4 tests represent the same stand collections and all tests are the same age from seed. Tests are randomized complete blocks with from 3 to 9 replications.

RESULTS

Survival - Survival percentages are based on the total number of trees planted, including replacements made between 1968 and 1971. Survival in the Cloquet and Grand Rapids plantings exceeded 90 percent in the first year following planting and was approximately 80 percent in 1973. Losses in these two plantings have been dramatic since 1973. The Cloquet plantation suffered almost complete mortality during the winter of 1975-76 and survival in the Grand Rapids planting fell to 60 percent by 1978. Because of excessive losses, the Cloquet planting was abandoned in 1977. The high losses probably reflect the effects of a drought in 1975-76 and increased exposure of trees as they outgrew the protection provided by snow cover. The two prairie region plantings (Lamberton and Morris) were characterized by low early survival (35-39%), in part due to a summer drought in 1968, but losses of only 2 to 5 percent between 1973 and 1978.

In Table 1, the 74 stand collections represented in the plantings have been combined into 10 regional groups suggested by R. A. Read/1 on the basis of a cluster analysis of three-year nursery data. A Chi-square test indicates a relationship between survival and these groups. There was a consistent trend in all plantations for higher
survival among northern origins. A significant deviation was the poor survival of the western materials from Washington and Idaho (region 5). These sources are from the western side of the continental divide and appear to have adapted to different environmental conditions. The data suggest that survival in Minnesota can be increased by avoiding materials from south of 40°N latitude and west of 112°W longitude.

Survival of individual stand collections varied greatly among test sites. For example, the average values for survival in the Lamberton, Morris, and Grand Rapids tests of stand collections from the Black Hills ranged from 24 to 67 percent.

Climatic injury - Extensive needle browning was observed in the three active tests during the 1977 growing season (Table 2). No fungi which could cause the injury were isolated in culture of the needles and the injury is assumed to have been caused by climatic factors.

For each tree in each plantation the percent of the previous year’s needles showing browning was estimated to be the nearest quartile. The percent of trees with 75 percent or more of the previous years foliage free from browning is given by regional group and test site in Table 2.

Needle damage was most extensive in the Morris planting and occurred at a moderate level in the Grand Rapids test. The Lamberton test was almost free from such injury. Comparing regional groups, injury was greatest in southern and western origins. Avoidance of materials from south of 43°N latitude and west of 112°W longitude would effectively reduce this type of injury.

Variation among stand collections within regions was large (Table 2). Stand collections in which 80 percent or more of the trees had less than 25 percent of their foliage browning at Morris and Grand Rapids were found in all regions except the Central High Plains, the Southern Rockies and Far West (regions 5, 8, and 10).

A second type of injury was noted. Buds on terminals and lateral shoots either had not flushed or expanded abnormally. This injury was most common in the Morris test and its pattern paralleled that of needle browning.

Height Growth. Mean 1977 heights in the active test are given by regional group in Table 3. Data were evaluated using the means of four-tree field plots. Analyses of variance indicated that differences among regions were significant (.05 level) at each test location and for the combined analysis containing the 66 seedlots common to the three tests. At Morris there were significant differences among stand collections within regions and a significant interaction was found between test site and regional groups in the combined analysis.

The interaction between test site and regional groups is apparent when the rankings of regional means at test locations are compared. However, materials from Southern and Eastern Montana and the Eastern High Plains-low elevations (regions 3 and 7) performed best at all test sites and appear to be the most promising materials for planting throughout Minnesota. North central Montana and central Montana (regions 1 and 2), also performed well. At Lamberton, north central Montana was significantly shorter than regions 3 or 7. Therefore, materials from this region should be avoided in southern Minnesota. Central Montana contained only two sources which exhibited large height differences, 186 and 220 cm. This area shows potential but further screening is needed. Variation among stand collections within regions was large and the range of heights for stand collections given in Table 3 indicates that this level of variation should be considered.

Correlations. Average survival, freedom from winter needle injury, and height growth were found to be positively correlated when the combined data from the three active tests were examined. Statistically significant Spearman’s Coefficients of Rank Correlation for combinations of these traits were: .79 for freedom from winter injury and survival, .72 for survival and height, and .63 for freedom from winter injury and height.

CONCLUSIONS

The differences with seed source for survival, freedom from winter injury, and height, and the favorable correlation among these traits, indicates that the use of appropriate seed could significantly increase the success of ponderosa pine planting in Minnesota. The pattern of variation observed, significant differences among geographic regions as well as among stands within regions, is consistent with results elsewhere (Wang and Patee, 1976; Barr and Collins, 1979).

We recommend that ponderosa pine planted in Minnesota originate from areas with the highest probability of yielding well-adapted materials (regions 3 and 7). This is a minimal step. In any substantial planting program, efforts should be made to obtain seed from specific stands identified as superior in these tests or to identify additional exceptional stands through screening. An indication of the potential for improvement using this approach is found in the average performance of the 5 tallest seed lots.
### Table

<table>
<thead>
<tr>
<th>Stand Nr.</th>
<th>Region</th>
<th>Height (cm)</th>
<th>Survival (%) trees</th>
<th>75 percent plus freedom from needle browning (%) trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>826</td>
<td>3</td>
<td>246</td>
<td>65</td>
<td>85</td>
</tr>
<tr>
<td>822</td>
<td>33</td>
<td>236</td>
<td>51</td>
<td>82</td>
</tr>
<tr>
<td>821</td>
<td>33</td>
<td>244</td>
<td>60</td>
<td>87</td>
</tr>
<tr>
<td>721</td>
<td>77</td>
<td>236</td>
<td>71</td>
<td>100</td>
</tr>
<tr>
<td>720</td>
<td>77</td>
<td>231</td>
<td>79</td>
<td>71</td>
</tr>
<tr>
<td>All Stands</td>
<td>--</td>
<td>188</td>
<td>40</td>
<td>62</td>
</tr>
</tbody>
</table>

*a* Lamberton, Morris, and Grand Rapids tests.  
b* Lamberton and Morris tests only.

### LITERATURE CITED


Table 1. Origin and survival of ponderosa pine in Minnesota provenance tests.

<table>
<thead>
<tr>
<th>Regional Group</th>
<th>Origin</th>
<th>1977 Survival in Percent of Trees Planted by Test Location</th>
<th>Lamberton, Morris, and Grand Rapids Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Stands</td>
<td>Number of Collections</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Represented</td>
</tr>
<tr>
<td>1. No. Central Montana</td>
<td>17,1-17.9</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2. Central Montana</td>
<td>174-181</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3. S. &amp; E. Montana</td>
<td>177, 181, 212-282</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4. SW North Dakota &amp; SW South Dakota</td>
<td>76-192</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>5. Far West</td>
<td>89-101.1</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>6. Black Hills</td>
<td>82-860</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>7. E. High Plains (low elev.)</td>
<td>872, 890-950</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>8. Central High Plains</td>
<td>872, 890-950</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>9. Central Rockies &amp; Plains (high elev.)</td>
<td>76-192</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>10. Southern Rockies</td>
<td>32-37.3</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2. Percent of surviving trees with 75 percent or more of the previous year's needles free from browning by plantation and regional group.

<table>
<thead>
<tr>
<th>Regional Group</th>
<th>Percent of Surviving Trees</th>
<th>Combined: Morris &amp; Grand Rapids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lamberton</td>
<td>Morris</td>
</tr>
<tr>
<td>1. No. Central Montana</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2. Central Montana</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3. South &amp; East Montana</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4. SW North Dakota &amp; SW South Dakota</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>5. Far West</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>6. Black Hills</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>7. E. High Plains (low elev.)</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>8. Central High Plains</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>9. Central Rockies &amp; Plains (high elev.)</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>10. Southern Rockies</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

Table 3. Mean heights in centimeters by regional group and test planting of ponderosa pine in Minnesota.

<table>
<thead>
<tr>
<th>Regional Group</th>
<th>Mean Heights in Centimeters</th>
<th>Combined: Morris &amp; Grand Rapids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lamberton</td>
<td>Morris</td>
</tr>
<tr>
<td>7. E. High Plains (low elev.)</td>
<td>229</td>
<td>232</td>
</tr>
<tr>
<td>3. S. &amp; E. Montana</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2. Central Montana</td>
<td>214</td>
<td>216</td>
</tr>
<tr>
<td>1. N. Central Montana</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>10. Southern Rockies</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6. Black Hills</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>9. Central Rockies &amp; Plains (high elev.)</td>
<td>173</td>
<td>176</td>
</tr>
<tr>
<td>5. Far West</td>
<td>126</td>
<td>128</td>
</tr>
</tbody>
</table>

Published as Misc. Jour. Series No. 1786 of the Univ. of Minn. Agr. Expt. Sta.

THE UNIVERSITY OF MINNESOTA IS AN EQUAL OPPORTUNITY EDUCATOR AND EMPLOYER.