Evaluation of Ponderosa Pine Seed Sources for Windbreaks in the Central Great Plains of the United States

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Abstract. Ponderosa pine (Pinus ponderosa Laws.) has been planted widely in the Great Plains of the United States for windbreaks. Recommendations based on a 1968 study were to use material from south central South Dakota and north central Nebraska. A second test to further delineate seed sources (provenances) in this region was established in 1986. This paper reports results for survival, height, diameter, and D/H measurements in both Kansas and South Dakota, after 15 years. Results identify a wide range of suitable geographic provenances within the two-state region. A majority of the tested sources performed well in both states, thus verifying the original recommendations.

Key Words. Growth Characteristics; Pinus ponderosa; Ponderosa Pine; Provenance; Seed Source; Tree Selection; Windbreaks.

Ponderosa pine (Pinus ponderosa Laws.) is an important component of the windbreak agroforestry system in the Great Plains (U.S.). Its drought tolerance, dense crown form, and tall growth habit make ponderosa pine excellent for windbreaks, sight barriers, and ornamental plantings (Flint 1983). It is one of the few tall trees that grow in the region and also provides full year-round protection to fields and farmsteads because of its evergreen nature (Schaefer and Baer 1985). The natural range of ponderosa pine extends from British Columbia, Canada, southward into northern Mexico, and from California eastward into the Great Plains, except for Kansas (Crichfield and Little 1966). The tree has been widely planted in the plains region but has shown inconsistent performance.

Western pine tip moth (Rhyacionia bushnelli) has caused widespread damage in the plains (Kopp et al. 1987), but outstanding performance of some individual trees in the plains plantations suggests that proper seed selection could improve tree quality.

Early studies determined that trees grown from seed collected from the northeastern range of ponderosa pine performed best in most of the provenance test plantations (Deneke and Read 1975; Baer and Collins 1979; Read 1983; Schaefer and Baer 1985; Van Haverbeke 1986; Schaefer and Baer 1992). Also, six-year data from a Kansas plantation showed that early growth appeared to be climatically related to the elevation of seed provenances (Deneke and Read 1975). Therefore, plains nurseries have focused much of their ponderosa pine production on seed collections near Ainsworth and Valentine, Nebraska, and Rosebud, South Dakota. In addition, trees from Jordan, Montana, performed well in more than half of the early plantations (Read 1983).

In 1986, a second cooperative ponderosa pine study was initiated by the GP-13 Technical Committee of the Great Plains Agricultural Council in cooperation with the North Central and Rocky Mountain Forest Experiment Stations. The intent of the study was to more intensively sample recommended provenances identified in the 1968 study to locate a wider zone of collection for commercial plant material and/or breeding activities. Collection areas are from four states. Nine tests were established in Saskatchewan, Canada; and in the United States, Montana, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, and Minnesota. This paper reports data from the South Dakota, Nebraska, and Kansas tests. No additional tree improvement studies have been initiated in the United States since this effort. Recently, a genetic tree improvement effort was initiated in Argentina (Meier et al. 2004), with intention to establish seed orchards in Patagonia. Tree improvement studies have attributed approximately 2% of the total variation to differences among geographic locations in the southwestern United States (Yow et al. 1992). One generation of tree improvement may lead to gains in yield of 1%–15% or reduce rotations by 1–20 years in ponderosa pine in the Inland Empire Tree Improvement Cooperative in the northern Rockies of the United States (Hamilton and Rehfeldt 1994).

MATERIALS AND METHODS

The tree plantations reported here used seedlings representing 138 open-pollinated families from 13 geographic provenances (Figure 1; Table 1) and were planted in the field following standard provenance testing procedures. An individual tree factorial planting design with 5 to 8 replications and sized 1.3 × 2.4 m in South Dakota, or 3.7 × 3.7 m in Kansas plots. Spacing within each replication was represented by two (South Dakota) or five (Kansas) trees in single-tree, noncontiguous plots. Two border rows surrounded each plantation. Weeds were controlled by cultivation for the first three years. The Kansas plantation was near Milford Lake, and the South Dakota plantation was near Brookings, both located on alluvial sandy loam sites.
Superior height growth potential can be accurately identified at an early age [i.e., 5 to 15 years (Lambeth 1980; Read 1983; Van Haverbeke 1986; Schaefer and Baer 1992)]. In this analysis, data were also analyzed separately for each plantation. Analysis consisted of using the Mixed Model procedure of SAS (SAS Institute 2003) for height, trunk diameter, and D²H (a measure of trunk volume) Family × provenance was tested as a random factor. LSMEANS/Tukey multiple range test for mean separation and χ² for survival, stem crook, sweep, and number of terminal buds. In addition, correlations were determined among height, diameter, D²H, and latitude and longitude of each major geographic location. The 10 major geographic provenances were compared. Most of the sources were from north central Nebraska and southern South Dakota (Figure 1; Table 1).

**RESULTS AND DISCUSSION**

Ten-year survival and growth were best from those materials from eastern Nebraska as reported from a greater study (Read 1983); ponderosa pine from Nebraska and South Dakota are at the extreme eastern edge of the tree’s natural range. No winter dieback or diseases were detected. The top five sources for all variables were from eastern Nebraska. They came from the lower elevations (Table 1) between 710 to 800 m.

**Survival**

After 15 growing seasons, survival was good for all sources (Table 2). The mean survival of all provenances was 81.9%. Provenance survival ranged from 75.7% to 88.3%, while Kansas was 86.4% and South Dakota was 70.7%. The greater survival was from Kansas as expected as the climate is milder. The top provenances, listed in order of decreasing survival, are as follows: 721NE, 996NE, 995NE, 994NE, 990NE, 720NE. χ² tests indicated all provenances were significantly different at the 5% level. A similar test at age 10 showed 720 and 721 with 72% and 82% survival in the northern Great Plains in North Dakota.

**Diameter**

The mean diameter was 14.5 cm, ranging from 13.2 to 16 cm. All provenances were significantly different at the <1% level, using the mean contrast test. The top five were the same as listed for survival, except 995NE dropped to the bottom and 720 rose to the fourth position, not significantly different than any of top six (Table 2). Type 3 tests of effects are shown in Table 3 for diameter, height, and D²H. States were significant for diameter and D²H, but not height. Provenances were all significant at the <0.0001% level, state × provenance interactions were significant, and the family interaction with provenance were also highly significant.

**Height**

The tallest provenances were in the eastern half of the collection area (Table 2). All provenances were significantly different at the <1% level. The tallest trees listed in order of decreasing mean height are as follows: 721NE, 720NE, 990NE, 994NE, and 996NE. The mean height was 5 m, ranging from 4.7 to 5.8 m. A proceeding test to the current study (Kopp 1987), using a much larger number of provenances, found 720NE, 721NE, 855NE, and 856NE among the tallest seedlings at four years. A provenance test in North Dakota in 1968 and 1969 (Van Deusen 1980),
with many of the same provenances as in this study had similar results. At ages of 5 and 10 years, the best were 721NE, 757NE, and 720NE. Both provenances 720NE and 721NE were among the tallest in our study. Ponderosa pine from this area should maintain height growth superiority when planted in the central Plains States. Evidently these sources contain genes endowing them with a broad range of site tolerances (Read 1983). Deneke and Read 1975 found that the height of young trees was inversely related to elevation. In general, sources from lower elevations grew faster as reported by others (Mirov et al. 1952; Callaham and Hasel 1961; Squillace and Silen 1962; and Hanover 1963).

D\text{2H}
The trees with the greatest size were also found to have the greatest diameter and height, and provenances were significant at the 1% level (Table 2).

Seed source (provenances) performance differed significantly (1% level) for all the tested variables. Although trees were not permanently marked, foregoing the opportunity to make additional collections from them, collections from geographic locations in the near vicinity would provide materials from better sources as evaluated by numerous ponderosa pine studies in the past.

Other Characteristics
Crook, sweep, form, and number of terminal buds were evaluated only for the South Dakota plantation and were not significantly different.

Correlation Analysis
There was no strong relationship between elevation, latitude, or longitude, and neither was there a relationship between survival and diameter, height or D\text{2H}. Only D and H were significantly different, as well as D\text{2H} and H. Read (1983) and Schafer and Buer (1985) have found a close relationship between juvenile-mature correlations. Superior sources may be found at a fairly early age. Read (1983) noted that two- and three-year-old seedlings from the NE-SD areas are among the tallest in his nursery study.

SUMMARY AND CONCLUSION
Fast-growing trees are desirable for windbreak establishment in the Great Plains. Ponderosa pine is often planted in homestead and field plantings. Plains-wide studies conducted in the 1960s showed that provenances from south central South Dakota and north central Nebraska provided better planting material. The present study was conducted to further refine selection areas for ponderosa pine sources. Materials from 10 collection areas (provenances) and 71 individual trees were planted at two Central Plains sites for evaluation. Within this relatively small area, analyses indicated that geographic provenances affected growth of 15-year-old ponderosa pine. The better sources came from eastern Nebraska, as shown in many previous studies.

The five best collection zones were from the eastern part of Nebraska (720 - Ainsworth, 721 - Valentine, 990 - Springview, 994 - Bassett, and 996 – Sparks). Growth of the top 10 individual tree sources varied within the two states. Most grew well.

LITERATURE CITED


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