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Ponderosa Pine Family Growth Comparisons in the Central Great Plains of Kansas

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Ponderosa pine (Pinus ponderosa Laws.) has been planted widely in the Great Plains. 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 (provenance/families) in this region was established in 1986. This paper reports results for survival, height, diameter, and D2H measurements in Kansas at 15 years. Results identify a wide range of suitable families within the Great Plains region. A majority of the tested sources performed well especially those from central Nebraska. Those sources from eastern Montana and western Nebraska performed poorly where environmental or geographic conditions were the poorest, thus verifying the original recommendations.

Keywords: Ponderosa Pine, Pinus Ponderosa, Provenance, Seed Sources, Tree Selection, Growth Characteristics

Introduction

Ponderosa pine (*Pinus ponderosa* Laws) is an important component of the windbreak agroforestry system in the Great Plains. 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 & 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 & Little, 1966). It has been widely planted in the plains region, but has shown inconsistent performance.

Western pine tip moth (*Rhyacioniabushnelli*) 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 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 & Read 1975; Baer & Collins 1979; Read, 1983; Schaefer & Baer, 1985, 1992; Van Haverbeke, 1986). Also, 6-year datafrom a Kansas plantation showed that early growth appeared to be clinally related to elevation of seed provenances (Deneke & 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. Collection origins are shown in Figure 1. Nine progeny tests were established in Saskatchewan Canada, Montana, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, and Minnesota. This paper reports data from the Kansas tests. 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 in Argentina (Meier et al., 2004) a genetic tree improvement effort was initiated with intention to established 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.). One generation of tree improvement may lead to gains in yield of 1% - 15% or reduce rotations by 1 years - 20 years in ponderosa pine in the Inland Empire Tree Improvement Cooperative in the northern Rockies of the United States (Hamilton et al., 1994).

Materials and Methods

The tree plantation reported here used seedlings representing 75open-pollinated families from 13 geographic provenances

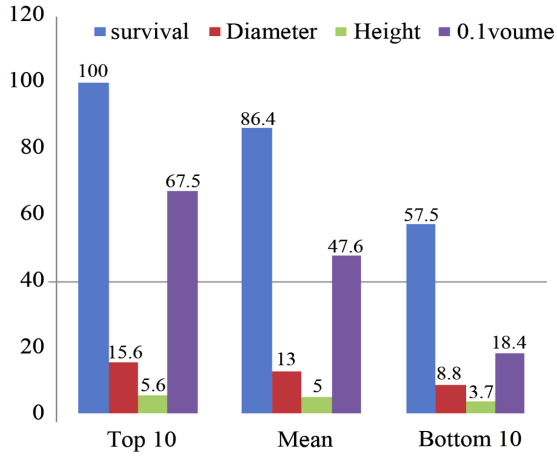

Figure 1.
Means of growth characteristics of the 10 *ten and bottom* 10 *families in the kansas.*

(Table 1) and were planted in an individual tree factorial planting design with 8 replications at 3.7 m × 3.7 m (12 × 12 ft) in Kansas for total of 1167 trees. Spacing within each replication was represented by five trees in single-tree, noncontiguous plots. Two border rows surrounded the plantation. Weeds were controlled by cultivation for the first 3 years. The Kansas plantation was near Milford Lake, Kansas, on an alluvial sandy loam site. Superior height growth potential can be accurately identified at an early age (i.e., 5 to 15years; Lambeth, 1980; Read, 1983; Van Haverbeke, 1986; Schaefer & Baer, 1992). In this analysis, data were also analyzed separately for the plantation.

Analysis consisted of ANOVA using the GLM procedure of SAS (SAS Institute, 2003) for height, trunk diameter, and D^2H (a measure of trunk volume—volume index); Duncan's multiple range test for mean separation; andchi-square for survival. In addition, correlations were determined among height, diameter, D^2H, and latitude and longitude. Seventy five seed sources (families) were compared. Most of the sources were from north central Nebraska and southern South Dakota (Table 1).

Results and Discussion

Fifteen-year survival and growth of the top 25% were from four provenances 757, 990, 994, and 996; generally at the edge of its natural range. Tests of effects are shown in Table 2 for dieter, height, and D^2H. Family performance differed signifyntly (<1%) level across the plantation (Table 3).Means for the top 10, mean, and bottom 10 are shown in Figure 1. Replicates were significant at the <1% level and interactions were mixed. No winter dieback or diseases were detected. Similar results in a 28 plantation study in the Canada and the United States showednorth central Nebraska sources were best as reported from a greater study (Read 1983).

Survival

Survival after 15 growing seasons was good for all of the 75 families compared. The mean survival of all families was 86.4% with a range of 38.1% to 100%. The top 10 families are as follows: 99010, 72005, 72109, 75713, 99001, 99010, 99201, 99404, 99506, 99613. All are from the north central part of Nebraska. Most families had 100% survival. The five poorest families were far western sources from Jordan, Montana and one from South Dakota at 48.1%.They were significantly different (<1% level) from the other families. The other 74 sources were not. A similar test at age 10 among provenances showed 720 and 721 (central Nebraska) with 72 and 82 percent survival in the Northern Great Plains (Read 1983).

Diameter

The mean diameter was13.0 cm (6.0 in.)with a range from 17.2 cm - 5.3 cm (2.1 to 6.8 n). Mean diameters of the top 10 and bottom 10 families (Table 2) were 15.7 and 8.9 cm (6.2 and 3.4 in), respectively. Families from the 720 and 721 prove ances were among the best. A similar test at age 10 among provences showed 720 and 721 (central Nebraska) were the best in the Northern Great Plains (Read 1983).The largest 59 families were not significantly different ranging from 17.2 to 14.1 cm (6.8 to 4.9 in). Five families (provenance 811) from Jordan, Montana, had significantly smaller diameters than the other families (where environmental factors were poor having very low precipitation and low annual temperatures), whereas diameters of the poorest 10 families were significantly smaller than those of the best (Table 3).Trees with the largest diameters had the tallest heights (r = 0.77096 at the 1% level).

Table 1.
Collection zones (*provenances*) *of ponderosa pine seed sources.*

Geographic origin(#)	Tree additions (families)(#)	Local area (town/state)	Annual precipitation((mm)(in))	Annual mean temp. C^0 (F^0)	Elevation m (ft)	Latitude (^{0}N)	Longitude (^{0}W)
720	02 - 11	Ainsworth NE	579 (22.8)	8.6 (47.6)	780 (2560)	42.59	100.00
721	01 - 11	Valentine NE	495 (19.5)	8.4 (47.2)	800 (2625)	42.88	100.55
757	01 - 40	Rosebud SD	955 (37.6)	8.5 (47.7)	850 (2789)	43.25	100.82
811	13,15 - 16,19,22	Jordan MT	327 (12.9)	6.9 (44.5)	808 (2625)	47.31	106.89
990	01 - 10	Springview NE	573 (22.7)	8.3 (47.0)	740 (2428)	42.82	99.75
991	01 - 05	Kilgore NE	516 (20.3)	8.3 (47.0)	800 (2625)	42.94	100.97
992	01 - 04	Drinkwater NE	495 (19.5)	8.3 (47.0)	859 (2800)	42.47	101.07
993	01 - 07	Nenzel NE	526 (20.3)	9.0(48.3)	950 (3117)	42.93	101.11
994	01 - 05	Bassett NE	635 (25.0)	9.0 (48.3)	710 (2329)	42.60	99.54
995	01 - 06	Snake River NE	495 (19.5)	8.3 (47.00	866 (2840)	42.71	100.97
996	01 - 14	Sparks NE	495 (19.5)	8.3 (47.0)	800 (2625)	42.94	100.24

Table 2.
Test of source effects on 15*-year-old ponderosa pine families.*

Effect		Pr > F		
	DF	Diameter	Height	D^2H
Family	74	<0.0001	<0.0001	<0.0001
Replicate	5	0.0020	0.0436	0.1047
Family X replicate	345	0.02262	0.03992	0.2912

Table 3.
Ranking of the 10 *top and bottom* 10 *families at* 15 *years in Kansas.*

Survival		Diameter		Height		D^2H - - volume index	
Family	(%)	Family	cm (in)	Family	m (ft)	Family	Volume
			Top 10 families				
72004	100a	99010	17.2 (6.8a)	72109	6.0(19.6a)	72109	926a
72005	100a	72109	16.5 (6.5ab)	72103	5.8(19.1ab)	99010	906ab
72109	100a	99305	16.4 (6.5abc)	99101	5.8(18.9abc)	99305	815abc
75713	100a	96601	15.7 (6.2a-d)	72104	5.6(18.3a-d)	99006	698bcd
99001	100a	72004	15.2 (6.0a-f)	75710	5.5(18.2a-)	72004	687b-d
99010	100a	75710	15.2 (6.0a-f)	72004	5.5(18.2a-f)	75710	678b-f
99201	100a	75704	15.2 (6.0a-f)	99305	5.5(18.2a-f)	72104	676b-g
99404	100a	72104	15.0 (5.9a-f)	99404	5.5(18.1a-f)	72103	676c-g
99506	100a	99090	15.0 (5.9a-e)	99002	5.5(17.7a-h)	99008	647c-g
99613	100a	75707	15.0 (5.9a-e)	99405	5.4(17.5a-h)	72011	647fc-g
			Bottom 10 families				
99102	71.4a-c	75719	10.7 (4.2o-s)	75719	4.3(14.0p-o)	75735	282p-x
81119	70.0a-d	75718	10.2 (4.0o-s)	75718	4.3(14.0p-o)	99501	240q-x
99006	68.8a-d	99501	9.9 (3.9p-s)	75735	4.2(13.7o-q)	99101	240q-x
99204	68.2a-d	99302	9.9 (3.9p-s)	99501	4.2(13.7n-q)	99302	235r-x
99502	63.6a-d	81113	9.9 (3.9p-s)	99302	4.1(13.5n-q)	75718	224t-x
81115	56.2b-d	99101	9.7 (3.8r-t)	81119	3.4(11.2r)	81113	187t-x
81116	50.0cd	81119	8.1 (3.2r-t)	81115	3.4(11.2r)	81115	180u-x
75718	50.0cd	81115	7.1 (2.8t-u)	81113	3.3(10.7r)	81119	155v-x
81122	38.9d	81116	6.9 (2.7u-v)	81116	3.1(10.3r)	81111	116w
81113	38.1d	81122	5.3 (2.1v)	81122	2.9((9.4r)	81112	80w
N	1167		1167		1167		1167
Mean	86.4		13.0 (6.0)		5.0 (16.5)		476
Sign.	< 1%		<1%		<1%		<1%
Range	38.1 - 100		5.3 - 17.2 (2.1 - 6.8)		2.9 - 6.0 (9.4 - 19.6)		80-906

Height

The tallest families were from central Nebraska. They were significantly different (<1% level) from the other families. Mean height of all sources was 5.0 m (16.5 ft) with a range of 2.9 to 6.0 m (9.4 to 19.6 ft). The top 10 sources (Table 3) differed by 0.6m (2.13 ft). Five sources from Jordan, Montana, (provenance 811) were significantly shorter than all of the remaining sources. The poorest 10families ranged in height from 2.9 to 4.3 m (9.4 to 14.0 ft) and were significantly shorter (1% level) than the best 71. There were no significant differences in height among the best 55 families.

A proceeding test to this one (Koop, 1987) using a much larger number of provenances found 720, 721 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 721, 757, 720. Many families from provenances 720 and 721 were among the tallest in our study. Ponderosa pine from this area should maintain height growth superiority whenplanted in the central Plains States. Evidently these sources contain genes endowing them with a broad range of site tolerances (Read, 1983). Sources from lower elevations grew faster as reported by others (Mirov et al., 1952; Callaham & Hasel, 1961; Squillace & Silen, 1962; Hanover, 1963), but we did not observe this trend.

D^2H (Volume Index)

The trees with the greatest size were the same as found for both diameter and height.

Volume index among sources, indicated by D^2H values, was significantly different (1% level; Table 3). Mean D^2H of all sources was 476 units with a range from 80 to 926. The best 51 sources differed significantly from the shortest24.Five sources from Jordan, Montana, were among the 10 sources with the smallest volume.

Correlation Analysis

Environmental factors did not influence tree growth as there was no strong relationship between annual precipitation and temperatures or elevation, latitude, and longitude. Diameter, height, and D^2H values were highly significant; diameter and height at 0.77096, and 0.9345with D^2H while height was 0.8056 with D^2H. Read (1983) and Schafer & Baer (1985) have found a close relationship between juvenile-mature correlations.

Superior sources may be found at a fairly early age. Read (1983) noted that 2- and 3-year-old seedlings from the NE-SD areas among the tallest in his nursery study.

Summary and Conclusion

Fast-growing trees are desirable for establishment in the Great Plains. Ponderosa pine is often planted in homestead and field plantings in the Central and Northern Plains. Plains-wide studies conducted in the 1960s showed that sources from south central South Dakota and north central Nebraska were the best planting material. The present study was conducted to test a greater number of families to further refine selection areas for ponderosa pine sources. Materials from 75 individual trees were planted in the Central Plains sites for evaluation. Within this relatively small area, analyses indicated that ponderosa pine provenances affected growth of this 15-year-oldplantation. The best families came from central Nebraska. Environmental or geographic factors did not influence growth.

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