PONDEROSA PINE--A RECLAMATION SPECIES FOR THE EAST?[1]

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Abstract.--Species trials involving ponderosa pine (Pinus ponderosa) for revegetating acid minesoils in Pennsylvania have met with variable success. The most extensive study, involving 49 provenances of ponderosa pine, was established in the spring of 1969. After 17 years, overall survival was 57 percent and mean diameter at breast height (DBH) was 2.7 inches. Most of the mortality had occurred within 2 years following planting, but mortality is increasing again as a result of infection by the western pine gall rust (Endocronartium harknessii). This disease was apparently present on a few of the seedlings at time of planting. Although the overall performance of the planting is only mediocre, certain seed sources had significantly better survival, growth, and/or disease resistance than others. The best four sources, at plantation age 17, had nearly 80 percent mean survival and 3.8 inches mean DBH. Performance of these sources approaches that of red pine (Pinus resinosa), the most consistently successful tree species for revegetating acid minesoils in Pennsylvania. Comparison of provenance performance plantings on non-mined areas, both in Pennsylvania and in the West, showed some similarities but did not show any consistent patterns. Although ponderosa pine has potential for reclaiming mine sites in the East, care should be exercised to ensure that the planting stock is disease-free and is from superior seed sources.

INTRODUCTION

Ponderosa pine, the most widely distributed pine in North America, has been the subject of numerous surface mine reclamation trials over the years. Within its natural range, it is a recommended species for sandy and silty soils (Thornberg 1982). To the east of its natural range, however, its utility is less certain. Clark (1954) reported 16-year-old ponderosa plantings in Kansas were severely infested with a needle cast disease. Early survival had been poor and the species was not recommended for further use. Poor survival and growth in several early plantings in Pennsylvania also discouraged additional testing (Hart and Byrnes 1960). A chance planting of ponderosa pine in 1955 produced much better results (Jones 1970).

Seed source differences may well have been responsible for the contradictory results achieved in the earlier trials. Therefore, the opportunity to participate in a range-wide provenance project developed by the USDA Forest Service was welcomed. Original objectives of the study were to determine which, if any, seed sources of ponderosa pine would give satisfactory survival and growth on Pennsylvania minesoils (Davidson 1977). The study was later expanded to include comparative resistance of the provenances to western gall rust.

THE STUDY

In the spring of 1969, 2,780 seedlings from 49 seed sources were planted on the test site. The seedlings were 2-1-1 stock that had been grown at the Bessey Nursery in Halsey, Nebraska.

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A sparsely revegetated surface mine in Clearfield County, Pennsylvania, was selected as the planting site. It is at 41°N latitude and 78° 12'W longitude and has an elevation of about 1,600 feet. Precipitation at the site averages 45 inches with about 25 inches occurring during growing season. The normal growing season is just over 100 days.

The area was mined about 10 years before the ponderosa pine study was established. Backfilling, grading, and planting were performed as required by the 1945 Pennsylvania Reclamation Act. Species included red pine, white pine (Pinus strobus) and Japanese larch (Larix leptolepis). Survival was so poor the entire area was planted again 2 or 3 years after mining. No grasses were planted. There were a few scattered trees and no volunteer vegetation on the site when the ponderosa pines were planted. An analysis of a composite soil sample showed these characteristics: pH--3.4, H+--6.7 meq/100 gm, conductance--0.44 µmhos/cm, SO_4--1,062 ppm, P--0.4 ppm. Particle size distribution was: greater than 2 inches, 8 percent; 1/4 inch to 2 inches, 47 percent; 2 mm to 1/4 inch, 19 percent; less than 2 mm, 26 percent.

The study design was a randomized complete block with a row of 10 trees from each provenance in each of six blocks. Seedlings were mattock planted at 6x6 foot spacing. Due to a shortage of seedlings in some provenances, only 40 sources were represented in all six blocks. The other nine sources were planted but were only present in two to five of the blocks. Three sources were omitted from the analysis because they were present in only two blocks. Table 1 lists the seed sources by ecotypes used in this study.

Height and survival measurements were made after 1, 2, 4, and 6 growing seasons. In the fall of 1985 (plantation age 17), height, diameter at breast height (DBH), survival, and incidence of western gall rust were measured. To better define mortality in 1985, each nonsurviving tree was put into one of three categories: dead and missing, dead with signs of galls, or dead with no signs of galls. The category of dead and missing consists of trees that died early and had completely decomposed.

Five levels of gall incidence were recorded: no galls, light (1 to 5 galls/tree); medium (6 to 20 galls/tree); heavy (21+ galls/tree); and dying. A tree was classified as dying if most of the needles were dead and it was unlikely that the tree would live another year. All the trees placed in this category had a large number of galls.

The data for growth, survival, and disease rate were averaged for each provenance in each of the six blocks. In the cases of disease rating, each category was given an approximate number of galls--light was given 3, medium was given 10, and heavy and dying were given 30. These averages were then used in an analysis of variance test to determine if the provenances were significantly different. The survival data were transformed using the inverse sine transformation before performing the analysis of variance test. Duncan's new multiple range test was then used to separate the various provenances. Regression equations were also calculated for 4-year versus 17-year growth and survival, gall infestation versus 17-year growth and mortality between 5 and 17 years, and 4-year mortality versus mortality between 5 and 17 years.

To rate the different seed sources for all three criteria, a system similar to one used by Van Deusen (1980) was applied. Each seed source was given a ranking from 0 to 5 for survival, growth, and disease resistance. To obtain survival ranking, the average survival for each provenance was divided by the average survival for the population. The range of these numbers was then divided into six equal groups with 0 representing the lowest group and 5 representing the highest group. The provenances were also ranked for growth and disease resistance in the same manner. The three ratings were then added together to give each provenance a rating that ranged from a possible low of 0 to a high of 15. The highest 20 percent; i.e. 9 provenances, were considered as superior.

RESULTS AND DISCUSSION

Survival

By the end of the first growing season, the average survival for seedlings by seed source ranged from 30 to 93 percent with an overall average of 66 percent. After 1 full year, average survival by source ranged from 23 to 90 percent and overall 61 percent. By the end of the fourth growing season, only a few additional seedlings had died (table 2); none died during the fifth and sixth years (Davidson 1977). Although measurements were not made again until 1985, the plots were visited annually, and appreciable mortality was not evident until the 1980's.

By 1985, an additional 4 percent, based on the total number of planted trees, had died and another 1.4 percent were dying. Almost all of the dead trees were still standing, lending support to the premise that this additional mortality occurred during recent years.

The average survival among all trees 17 years after planting was 57 percent. Analysis of variance of the survival data showed the provenances and the blocks were significantly different at the .01 level. The seed source with the lowest survival (23 percent) was 860 from the Colorado Plains, and the source with the best survival (88 percent) was 704 from the Black Hills and Plains area of

Table 1.--Climatological data for sources of ponderosa pine planted on bituminous strip-mine spoils[1]

Ecotype and source	State	Latitude north	Longitude west	Elevation	Annual precipitation	[2]Growing season precipitation	Growing season
				(feet)	- - - (inches)	- - -	(days)
Transition Zone							
754	MT	47°05´	110°50´	4,550	13.73	10.64	116
Central Montana							
815	MT	47°04´	109°15´	4,800	16.52	12.02	108
814	MT	47°03´	108°59´	3,700	16.52	12.02	108
813	MT	47°53´	108°33´	4,700	11.27	8.51	112
812	MT	47°30´	109°30´	3,400	12.85	9.15	131
[3]823	MT	46°05´	107°23´	2,900	14.44	9.32	135
829	WY	44°48´	107°20´	5,100	15.91	10.57	130
Central Rockies							
830	WY	44°37´	107°05´	7,000	15.91	10.57	130
831	WY	44°11´	106°50´	5,800	13.07	9.47	117
848	WY	42°35´	105°40´	6,900	13.74	9.76	124
847	WY	42°13´	105°15´	5,500	12.44	9.61	141
845	NE	41°30´	103°57´	5,100	14.37	11.01	127
760	CO	40°12´	105°32´	8,400	16.07	11.20	98
761	CO	39°59´	105°25´	8,000	18.57	12.30	125
763	CO	39°06´	105°06´	7,800	18.32	14.13	119
Black Hills and High Plains							
822	MT	46°15´	108°27´	3,800	10.93	8.22	141
824	MT	45°55´	106°36´	3,400	15.13	10.48	132
825	MT	45°41´	106°00´	3,600	15.13	10.48	132
827	MT	45°50´	104°28´	3,800	13.22	10.32	127
702	ND	46°56´	103°30´	2,500	15.42	12.11	111
701	ND	46°35´	103°27´	2,600	15.42	12.11	122
703	SD	45°51´	103°30´	3,200	13.52	11.11	135
704	SD	45°34´	103°11´	3,450	12.77	9.99	129
[3]832	WY	44°53´	105°33´	3,900	17.61	11.92	128
833	WY	44°39´	104°16´	4,000	16.32	11.56	120
834	WY	44°27´	104°26´	5,500	16.32	11.56	120
835	WY	43°54´	104°11´	5,080	13.58	10.00	134
836	WY	43°40´	104°05´	4,080	13.67	10.23	134
837	SD	44°17´	103°50´	6,300	23.81	16.28	129
838	SD	43°55´	103°38´	5,680	17.07	13.56	117
839	SD	44°10´	103°35´	5,400	22.23	14.85	93
854	SD	43°13´	101°43´	3,300	16.11	12.66	128
853	NE	42°56´	102°30´	3,600	16.11	12.66	128
852	NE	42°31´	102°29´	3,800	19.31	13.95	132
722	NE	42°39´	103°05´	4,300	19.31	13.95	132
851	NE	42°42´	103°35´	4,200	17.49	13.47	128
723	NE	41°46´	103°50´	4,600	14.37	11.01	127
Low-elevation East Plains							
757	SD	43°14´	100°58´	2,600	18.80	13.46	134
720	NE	42°41´	99°46´	2,300	20.31	15.72	149
[3]856	NE	41°26´	100°01´	2,900	19.79	15.28	154
Colorado Plains and Foothills							
759	NE	41°27´	103°05´	4,300	17.09	13.21	135
758	NE	41°13´	103°15´	4,500	17.35	13.33	137
858	CO	40°32´	105°08´	5,300	14.19	10.37	145
724	CO	39°06´	104°37´	7,400	19.41	14.27	119
860	CO	38°35´	104°56´	6,500	11.79	8.84	168
861	CO	37°55´	104°55´	6,600	14.93	9.73	131
Southern Rockies, NE New Mexico							
765	CO	37°19´	104°43´	7,000	16.20	11.32	167
862	NM	36°57´	104°18´	7,350	17.43	13.99	147
863	NM	35°50´	104°58´	6,400	16.56	12.99	155

[1]Supplied by R.A. Read, Rocky Mtn. For. Range Exp. Stn., Lincoln, Nebr.
[2]April through September.
[3]Not included in the analysis.

Table 2.--Average [1]survival and total height after four and six growing seasons, by seed source

Ecotype and source	State	Survival	Height 4 years	Height 6 years	6-year height as percentage [2]of mean
		(percent)	(centimeters)		(percentage)
Transition Zone					
754	MT	58	35	67	74
Central Montana					
815	MT	52	48	90	99
814	MT	84	51	95	104
813	MT	79	45	77	85
812	MT	85	50	90	99
829	WY	50	45	79	87
Central Rockies					
830	WY	50	40	72	79
831	WY	64	44	76	84
848	WY	68	48	85	93
847	WY	62	44	77	85
845	NE	62	42	77	85
760	CO	70	46	79	87
761	CO	80	45	81	89
763	CO	87	45	78	86
Black Hills and High Plains					
822	MT	58	59	104	114
824	MT	58	63	107	118
825	MT	85	63	113	124
827	MT	68	53	94	103
702	ND	67	46	80	88
701	ND	35	52	96	105
703	SD	73	45	77	85
704	SD	90	64	113	124
833	WY	60	53	88	97
834	WY	77	55	97	107
835	WY	66	56	95	104
836	WY	47	55	93	102
837	SD	77	54	92	101
838	SD	73	43	73	80
839	SD	54	49	90	99
854	SD	43	52	92	101
853	NE	38	63	114	125
852	NE	58	51	89	98
722	NE	77	50	84	92
851	NE	32	55	92	101
723	NE	57	46	84	92
Low-elevation East Plains					
757	SD	78	73	140	153
720	NE	51	62	118	130
Colorado Plains and Foothills					
759	NE	63	44	79	87
758	NE	48	44	79	87
858	CO	48	52	89	98
724	CO	43	52	98	108
860	CO	23	47	89	98
861	CO	72	47	80	88
Southern Rockies, NE New Mexico					
765	CO	43	63	114	125
862	NM	33	61	104	114
863	NM	60	67	122	134

[1]No mortality in fifth and sixth growing seasons.
[2]Average height at 6 years as percentage of mean for entire plantation.

South Dakota (table 3). Provenances 825, 763, and 761 also had high survival. A large number of provenances, with mean survival between 50 and 65 percent, varied significantly only from the very high and very low survival rates.

There was no relationship between early and late mortality among provenances; i.e. provenances with high early mortality were no more likely to experience high late mortality than those with low early mortality. Evidently, causes of mortality differed between the two periods. Most of the early mortality was probably caused by incompatibility with the environment, whereas most of the recent mortality was probably caused by disease.

Hart and Byrnes (1960) rated species that had 61 to 100 percent survival on minesoils as "good" and those with 41 to 60 percent as "adequate." Accordingly, for the ponderosa pine planting as a whole, ponderosa pine would only be considered "adequate" for planting on strip mines. However, if the provenances are considered separately, 20 of the provenances fall into the "good" category. Thus, based on survival alone, ponderosa pine from the proper provenance can be classified as a "good" species for reclamation.

Growth

The average DBH of the provenances varied from a high of 3.63 inches for 825 to 1.95 inches for 847 (table 3). Individual tree diameters varied from 0 to over 5 inches, with an average of 2.71 inches. In the analysis of variance of DBH, it was again shown that provenances and blocks were significantly different at the .01 level. Provenances 825, 704, 701, and 814 had the largest diameters.

The fastest growing provenances are located in the western South Dakota and eastern Montana areas. However, slower growing provenances are also from this area. It is therefore difficult to generalize on provenance suitability based on geographic location alone.

Tree heights were the only growth data collected through plantation age 6. In order to determine if early growth patterns were consistent with later growth, a regression was formed with the 17-year mean DBH for each provenance to its mean height at 6 years (figure 1). There is a direct relationship between the two that is significant at the .01 level (r=0.665). The provenance with the highest mean 6-year height had the largest mean DBH at 17 years, and the provenance with the second lowest height had the lowest DBH.

Impact of Western Gall Rust

This disease was accidentally introduced into Pennsylvania from the West. Its status and history in the Northeast have been reviewed by Merrill and Wenner (1985). Merrill et al. (1986) recently made a detailed study of the incidence of galls in the plantation under study. Since western gall rust is not native to Pennsylvania, it was probably imported to the site with the seedlings. However, the presence of galls was not noted until the 6-year measurements, and therefore probably had little or no impact during the first few years. At age 10, 91 trees had galls. By 1985, galls were common throughout the plantation, occurring in 58 percent of the trees. All provenances contained both heavily infected trees and trees with no galls. Of the trees with galls, 37 percent were in the heavy-gall class. Almost half of the standing dead trees had such a high incidence of galls that the disease was probably the

Table 3.--Performance of seed sources at age 17 by survival, growth, and disease rating

Seed source	Survival (%)	DBH (in.)	Galls/tree No.	Rating
704	88	3.33	6.1	14
814	76	3.33	4.5	14
825	82	3.63	11.6	12
757	72	3.25	6.0	12
827	67	2.97	1.8	12
834	72	3.01	7.4	11
760	67	2.93	5.9	11
813	68	2.83	4.7	11
835	62	2.99	7.3	10
832	73	2.90	10.2	10
824	58	3.05	9.1	10
815	45	3.16	5.6	10
761	78	2.44	9.6	9
837	77	2.22	7.4	9
838	72	2.24	5.2	9
831	62	2.37	5.3	8
703	68	2.33	8.0	8
722	68	2.03	4.7	8
863	57	3.07	13.4	8
754	55	2.79	7.5	8
723	50	2.80	10.2	8
830	48	2.95	9.3	8
763	83	2.14	12.0	7
833	57	2.60	11.1	7
839	53	2.13	2.6	7
822	52	2.24	5.5	7
848	63	2.24	10.4	6
845	57	2.74	13.6	6
852	52	2.69	12.1	6
854	38	2.47	6.7	6
701	37	3.33	16.6	6
861	62	2.43	14.7	5
758	47	2.77	15.6	5
829	47	2.24	12.2	5
720	45	2.78	13.8	5
858	43	2.79	14.0	5
724	42	2.81	13.3	5
836	45	3.02	16.8	5
765	40	3.15	18.1	5
853	32	2.63	9.1	5
702	65	2.12	15.1	4
860	23	2.87	14.9	4
847	56	1.95	17.0	3
759	53	2.38	18.2	3
851	32	2.81	18.4	3
862	30	2.80	16.2	3

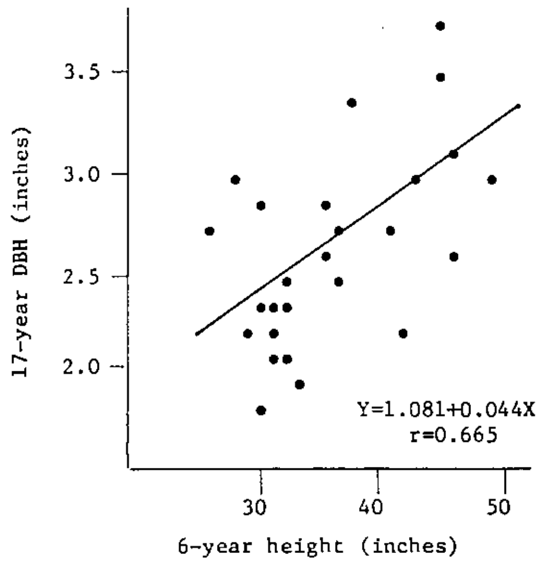

Figure 1.--Mean DBH of various ponderosa pine provenances after 17 years compared with heights after 6 years.

cause of death. Therefore, it appears that each provenance contains susceptible and resistant trees, and the differences in provenance susceptibility is caused by the frequency of resistant trees in a population.

When the gall classifications were averaged among all trees in each provenance, 827 had the fewest galls, 1.8 per tree, and 851 had the most, 18.4 per tree (table 3). The overall average was 10.4 galls per tree. Mean number of galls per tree differed significantly among provenances (.01 level) and among blocks (.05 level). Of all the provenances, 827, 839, and 814 had the least amount of galls.

No significant correlation was found between gall incidence and either recent mortality or mean diameter in analyses by provenances. However, since western gall rust does stress a tree and causes eventual mortality, it probably deserves equal weighting with survival and growth when provenances are rated.

Combined Performance

From table 2, it is evident that provenances with superior survival did not necessarily have superior growth and disease resistance. Therefore, a rating system adopted from Van Deusen (1980) was applied to select superior provenances on the basis of all three criteria. The provenances in the upper 20 percent were 814, 704, 825, 827, 757, 813, 834, 760, and 835. With the exception of provenance 760, all are located in a band from central Montana to south central South Dakota. Although this area contains superior provenances, it also contains other provenances that are unsuitable for planting. Interestingly, seven of the nine provenances with superior performance were also considered as superior performances by Davidson (1977) based only on 6-year survival and height data without consideration of western gall rust.

Comparisons With Other Studies

When other studies using the same provenances are compared, there are some provenances that consistently do well. Of the nine superior provenances in this study, 757 and 825 also had a combination of superior growth and survival in a planting on former agricultural land near State College, Pennsylvania. Provenances 757 and to a lesser extent 704 were also successful in other studies (Deneke and Read 1975; Van Deusen 1980; Schaefer and Baer 1985). However, the other provenances did not do exceptionally well in other studies. In many of the other studies, 720 did well, but it performed poorly on Pennsylvania minesoils and was very susceptible to western gall rust.

CONCLUSIONS

While ponderosa pine has been considered a poor strip mine species in the past, the results of this study show that ponderosa pine from an appropriate seed source can be planted successfully. However, the areas from which seed should be obtained are not well defined. Within a single geographic area, there may be provenances that are very adaptable to minesoils and provenances that will fail on mined lands. For example, the northern part of the east-low elevation of South Dakota contains both a recommended source and a source that has a poor rating. To ensure adequate survival and growth, care must be taken to obtain seed from a precise provenance.

One of the major problems with finding an adequate seed source is the possibility that it might be highly susceptible to western gall rust. While this disease does not seem to have a great effect on early growth and survival, it will take its toll as galls become very numerous (Merrill and Wenner 1985). Disease susceptibility is not confined to a group of provenances or a geographic area, but is apparently present in all provenances. Also, individual trees within a provenance appear to vary in their susceptibility. Therefore, care should be taken to collect seeds from ponderosa pine trees without western gall rust since these trees may be more resistant to the rust. However, since the planter usually has no control over the individual seed trees, it is best to get seedlings from the areas where the most resistant trees occur and from nurseries without a history of infected nursery stock.

Western gall rust is present in the superior provenances identified in this study, but it is limited in number of galls and number of trees infected, except for provenance 825. This provenance had the best growth and third best survival among the 46 provenances, but its gall incidence was somewhat higher than the average for all provenances combined. This provenance should be planted on eastern strip mines only if the nursery stock is disease-free, since the most likely way for a plantation to become infected is for the pathogen to be brought in with the seedlings.

If care is taken to obtain seedlings from an appropriate area and sanitation is maintained in the nursery, ponderosa pine can be used effectively in reclaiming poorly vegetated strip mines even in the East. However, we do not have sufficient information to make recommendations concerning its use for strip mines with topsoil replaced and covered with grasses and legumes as required by current reclamation laws and practices.

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