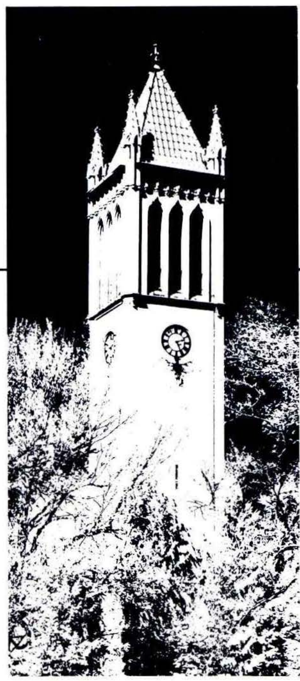
Tree Survival and Growth on Iowa Coal-Spoil Materials



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CONTENTS

SUMMARY

An evaluation was made of 7- to 8-year survival and growth of 15 tree species of conifers and hardwoods planted on several classes of coal-spoil materials in southeastern Iowa. The more important results were:

1. Green ash survived better than all other species on a variety of coal-spoil materials and appeared best adapted to the more moist sites on the moderately acid to calcareous spoils.
2. Cottonwood grew much faster than all other species on a variety of coal-spoil materials and grew to more than double the height of green ash.
3. Survival and growth of eastern redcedar were best on the calcareous coal-spoil materials. This species is drouth resistant and can be planted on the drier sites.
4. Survival and growth of all pine species tested were very poor on the calcareous coal-spoil materials; apparently, these pines should not be planted on calcareous shales and glacial tills.
5. Of all species tested, jack and Virginia pine appeared best adapted to the dry sites on the strongly and moderately acid spoil materials. Pitch pine was adapted to the same materials but probably should be planted on more moist sites.
6. Red and eastern white pine were best adapted to the slightly acid, more fertile, moist, well-drained sites, and plantings of these species probably should be limited to these locations.

Tree Survival and Growth on Iowa Coal-Spoil Materials[1]

by P. L. Lorio, Jr., G. E. Gatherum and W. D. Shrader[2]

Strip-mining for coal in the United States had resulted in the need for reclamation of one-quarter of a million acres of land by 1947 (Chapman 1947). Thirty-two-thousand acres had been stripped in Ohio by that time. Fourteen years later, more than 180,000 acres had been stripped (Lowry 1961).

According to Limstrom (1948), Iowa had the lowest total stripped acreage of all states in the Central States Region but had the largest percentage of toxic spoil (pH 4.0 or less). Einspahr (1955) estimated that 38 percent of the 5,000 acres of spoil banks in Iowa were toxic to plant growth.

The interrelationships of all the factors affecting plant growth on coal-spoil materials are extremely complex. Successful attempts to classify these materials in relation to plant growth have been limited. Limstrom (1948) developed a general classification based on the texture and acidity of coal-spoil material. The textural part of the classification is limited to three divisions from sand to clay, thereby precluding its use for more specific descriptions of coal-spoil materials. The actual causes of poor plant growth under acid soil conditions are not always known, and plants at times seem to grow well under conditions of extreme acidity as indicated by pH measurements. More detailed information is required concerning tree growth and spoil factors to permit formulation of more meaningful classification schemes and, hence, more reliable recommendations.

The very nature of strip-mine spoil banks makes their characterization difficult. From region to region, and even within short distances, composition of the spoil banks is quite variable. Shavilje (1941) concluded that spoil banks were composed of shale, till, clay, soil, sand, gravel, limestone, minerals and waste coal, mixed in any proportion. Aside from the materials themselves, the manner in which they are deposited on the landscape has a definite influence on the type of spoil bank produced.

The cause of the extreme acidity often found on coal-spoil banks has interested several investigators (Croxton 1928, Einspahr 1955, Kohnke 1950). Croxton noted that the oxidation of iron pyrites in coal-spoil materials in Illinois was the cause of the acidity found in his studies. Kohnke observed that roof coal and other strata of carboniferous age contained pyrites and other forms of iron sulphide and that the oxidation of these compounds, with the production of sulphuric acid, led to extremely acid conditions.

Numerous investigations of the effects of acidity, as measured by pH, have been conducted on the survival and growth of trees and forages planted on spoil banks (Bramble 1952, Bramble *et al.* 1948, Croxton 1928, Deitschman and Lane 1952, Einspahr 1955, Finn 1958, Grandt and Lang 1958, Knudsen and Struthers 1953, Limstrom 1948, Limstrom and Merz 1949, Lowry 1956, 1958, Potter *et al.* 1951 and Tyner *et al.* 1948). Limstrom and Merz (1949) observed that spoils with pH 4.0 and lower were toxic to most trees. Deitschman and Lane (1952) reported that the growth of pine plantations did not appear influenced by variations in acidity above pH 4.5 but that the growth rate of pine was decreased significantly at lower pH levels. Tyner *et al.* (1948) found poor plant survival on acid to extremely acid spoil material that had been limed at the rate of 5 tons of $CaCO_3$ per acre.

Bramble *et al.* (1948) found that several forest species grew well, at least to 10 years of age, over a wide range of acidity (pH 3.5 to 5.0). Spoil banks with pH less than 3.5, however, were difficult to plant successfully with any species. Lowry (1958) reported that pine would survive to produce adequate stocking on sandy spoils with pH above 3.2. On silty clay spoil, he suggested a pH of 4.0 as a more suitable lower limit.

In general, a relation between acidity, as measured by pH, and the survival and growth of trees on coal-spoil materials has been shown to exist. Limstrom (1948) developed a system of classification of coal-spoil materials, based largely on pH. This classification has been use-

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ful in the location of areas of doubtful value in tree planting programs, but fundamental investigations are needed to explain some of the anomalies that occur. For example, vegetation sometimes exists on quite acid spoils in one area but not on less acid spoils in other areas (Knudsen and Struthers 1953).

Since 1952, the Forestry and Agronomy departments of the Iowa Agricultural and Home Economics Experiment Station, in cooperation with the Iowa Coal Research Association, have made studies of the revegetation of strip-mined land in southeastern Iowa. Einspahr (1955) surveyed the area involved, classified the spoils and made early survival and growth studies with various tree and forage species. Burton (1958) studied the effects of modifying the microclimate on early survival of conifers planted on spoil materials.

This study was concerned with a later evaluation of the survival and growth of 15 tree species of conifers and hardwoods planted in 1952 and 1953 by Einspahr (1955) on six classes of coal-spoil materials. The objective was to determine 7- to 8-year survival and growth of the 15 tree species on the various classes of spoil material and to make this information available to landowners and strip-mine operators for future coal-spoil reclamation. As discussed by Einspahr, the goals of Iowa coal-spoil reclamation may be as diverse as erosion control, aesthetic improvement, game cover and food supply, water production, Christmas tree production, wood production, recreation, etc. Therefore, information on tree species adaptability is obtained to provide some of the biological data that may be used by the landowners and strip-mine operators, in conjunction with economic and institutional considerations, to establish goals in coal-spoil reclamation.

METHODS AND PROCEDURES

Locations and Descriptions of Experimental Areas

The experimental areas, all within 10 miles of the Des Moines River, are located in five counties of southeastern Iowa— Marion, Mahaska, Wapello, Davis and Van Buren. The topography consists of irregular rows of low, cone-shaped mounds from 10 to 50 or more feet in height and with 20- to about 50-percent slopes. For months or years following stripping, the land surface essentially is devoid of vegetation. On the more favorable sites, cottonwood, boxelder and American elm gradually encroach. Some banks have been seeded with sweetclover, orchardgrass, timothy and bromegrass, but, within any stripped area, forage stands range from very poor to good.

In 1952, near the towns of Pershing, Bussey and Kirkville, three areas were planted with 13 tree species. Einspahr (1955) described the predominant spoil materials at these locations as follows:

Pershing — loess, till, buff shale mixture, pH 6.0 to 6.5, southeast aspect, 10- to 40-percent slope.
Bussey — buff shale material, pH 6.0, north-south running ridge, 10- to 40-percent slope.
Kirkville — till, gray shale material, pH 4.0 to 6.0, north aspect, 10- to 50-percent slope.

In 1953, six additional areas were planted with five coniferous and five broadleaved tree species near the towns of Selma, Eldon, Pershing, Otley, Pella and Oskaloosa. The descriptions of the predominant spoil materials at these locations as given by Einspahr (1955) are:

Selma — leached glacial till, pH 6.4, east aspect, 3- to 5-percent slope.
Eldon — light gray shale material, pH 4.5 to 4.8, ridge top, 0- to 10-percent slope.
Pershing — sandy buff shale material, pH 6.4, southeast aspect, 25- to 30-percent slope.
Otley — brown shale material, pH 4.0 to 4.5, south aspect, 20- to 25-percent slope.
Pella — calcareous glacial till material, pH 7.5 to 7.9, southeast aspect, 20- to 30-percent slope.
Oskaloosa — black calcareous shale material, pH 7.2 to 7.7, east aspect, 25- to 35-percent slope.

The following species were included in the plantings at these nine locations:

Coniferous species:

Eastern white pine. . . . . *Pinus strobus* L.
Red pine . . . . *Pinus resinosa* Ait.
Jack pine . . . . . . *Pinus banksiana* Lamb.
Pitch pine . . . . *Pinus rigida* Mill.
Virginia pine . . . . *Pinus virginiana* Mill.
Scotch pine . . . . *Pinus sylvestris* L.
Table-mountain pine. *Pinus pungens* Lamb.
Japanese larch . . . . *Larix koempferi* Sarg.
European larch. . . . . *Larix decidua* Mill.
Eastern redcedar . . *Juniperus virginiana* L.

Broadleaved species:

Black locust. . . . *Robinia pseudoacacia* L.
Green ash .*Fraxinus pennsylvanica* Marsh.
Cottonwood. . . . *Populus deltoides* Bartr.
American elm. . . . . . *Ulmus americana* L.
River birch . . . . *Betula nigra* L.
Sycamore . . . . . . *Platanus occidentalis* L.

Experimental Designs

In 1952, a randomized block design was established in which single-row plots of each species were planted in each of three or five blocks in each area at a 6- by 6-foot spacing. Because of the wide spacing, the plantings extended over more than one type of spoil material. The number of replications varied (three at Pershing and Kirkville, and five at Bussey), and the number of trees planted per row were variable (Einspahr 1955).

In 1953, a randomized block design was established in which three-row plots of each species were planted in each of three blocks in each area at a 2- by 2-foot spacing. Each row contained 10 trees. The closer spacing reduced the variability of the spoil material within each plot.

Measurements and Analyses

Tree survival and growth were determined in each of the plots in 1959-60. Percentage survival was based on the number of trees originally planted. Tree height was measured with an extension pole, and average tree height for each species was calculated.

Analysis of variance of survival was calculated for all species planted in 1952, except for larch and black locust. Larch establishment was extremely low, and black locust was not considered sufficiently desirable for further evaluation because of its susceptibility to the locust borer (*Cyllene robiniae*). To normalize the sample, percent survival was converted to $\sin^{-1}$ (percentage)$^{1/2}$ before analysis. The data for the Kirkville area were limited to two replications because the third had been disturbed by mining equipment. Duncan's multiple range test (Duncan 1955) was used to evaluate differences among species.

Analysis of variance of survival was calculated for all species planted in 1953, except where establishment was low. Duncan's multiple range test was used to evaluate differences among species.

RESULTS

Survival

Eight years after planting

Average 8-year survival of the 10 tree species planted on (a) the Pershing loess, till, buff shale mixture, (b) the Bussey buff shale and (c) the Kirkville till, gray shale ranged from 26 to 91 percent. Survival of green ash was better than that of all other species and was more than twice the survival of all coniferous species except jack pine. Survival of cottonwood and jack pine was approximately 1½ to 3 times greater than survival of the remaining species (table 1).

Table 1. Average 8-year tree survival percentage[a] on the Pershing, Bussey and Kirkville spoil materials.

Species	Pershing[b] loess, till, buff shale	Kirkville[c] till, gray shale	Bussey[d] buff shale	Average of all spoils
Green ash	91	88	95	91
Cottonwood	86	73	69	76
Jack pine.	76	68	52	65
Red pine	74	44	13	44
E. redcedar	59	32	26	39
Pitch pine	41	43	27	37
Scotch pine	51	32	24	36
E. white pine	39	44	8	30
Virginia pine	26	38	18	27
Table-mt. pine	44	20	14	26
Av., all species	59	48	35	47

[a] Based on a variable number of trees planted.
[b] Three replications.
[c] Two replications.
[d] Five replications.

Survival differences among species and location by species interactions were significant at the 1- and 5-percent probability levels (fig. 1 and appendix table A-1). Apparently, the very low survival rates of red pine and eastern white pine on the buff shale spoil material and the relatively high survival rates of these species on the loess, glacial till and buff shale mixtures and on the glacial till, gray shale mixture, accounted for this significant interaction. Disturbances by man and animals probably affected survival of several species. All pine species had suffered from "topping" for Christmas trees, attempts to dig them out, or both. Rodent dens were found at Bussey, and the boles of many trees were damaged 1 to 2 feet above the ground.

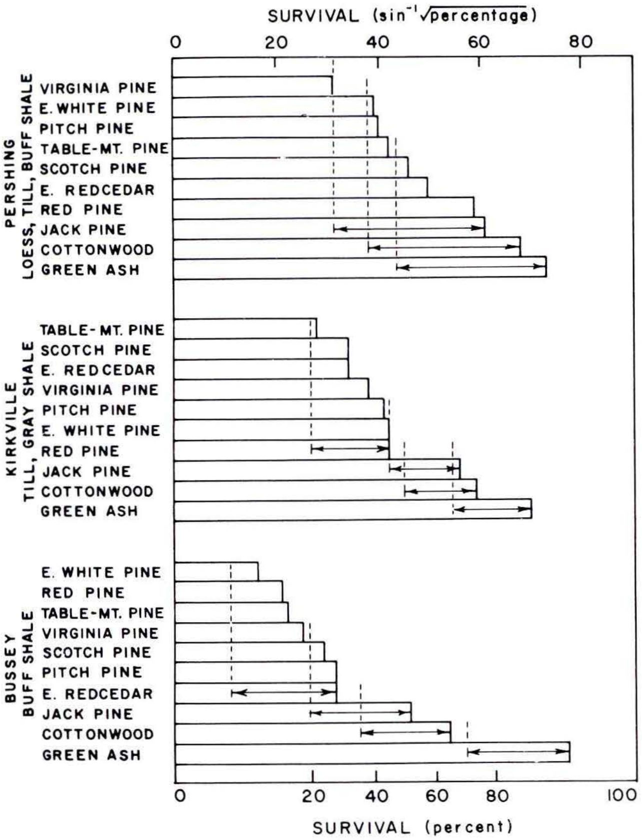

Fig. 1. Average tree survival 8 years after planting; comparisons based on Duncan's multiple range test (Duncan 1955). Survival does not differ at the 1-percent level for species grouped by an arrow.

Seven years after planting

Average 7-year survival of the nine tree species planted at six locations on coal-spoil materials, ranging from extremely acid to calcareous, varied from 2 to 52 percent. Damage by browsing animals was noted at several locations and may have affected the survival of the broadleaved species and red pine.

All pine species tested failed on the black calcareous shale at Oskaloosa and on the calcareous glacial till at Pella. The broadleaved species, except American elm, did not survive on the acid light gray shale at Eldon. Average tree survival was greatest on the leached glacial till spoil material at Selma and second greatest on the acid sandy buff shale at Pershing. Survival on these spoil materials was approximately 2 to 8 times greater than survival on the other spoils. Among species, average survival of green ash and eastern redcedar was approximately 2 to 26 times greater than survival of the other species (table 2).

Survival differences among species were significant on the acid sandy buff shale, the calcareous black shale and the leached glacial till (appendix table A-2). Survival of green ash was at least 3 ½ times greater than survival of all pines and cottonwood on the acid sandy buff shale. On the calcareous black shale, green ash survival was approximately 5 and 36 times greater than survival of American elm and cottonwood. On the leached glacial till, survival of eastern redcedar was approximately 2 and 14 times greater than survival of jack pine and sycamore. Survival of all other species ranged from 6 ½ to 13 times greater than survival of sycamore (fig. 2). Variation in survival on two of the planted areas is shown in figs. 3 and 4.

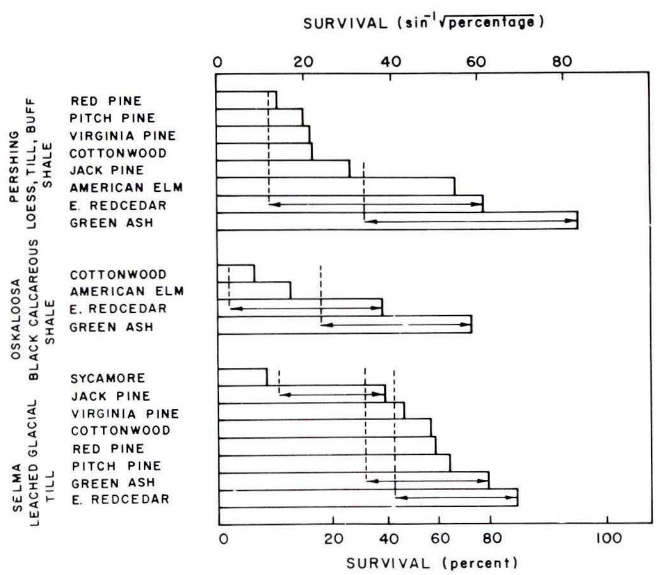

Fig. 2. Average tree survival on three coal-spoil materials 7 years after planting; comparisons based on Duncan's multiple range test (Duncan 1955). Survival does not differ at the 1-percent level for species grouped by an arrow.

Table 2. Average 7-year tree survival percentage[a] on the Selma, Pershing, Eldon, Oskaloosa, Otley and Pella spoil materials.

Species	Selma leached glacial till	Pershing sandy buff shale	Eldon light gray shale	Oskaloosa black calcareous shale	Otley brown shale	Pella calcareous glacial till	Av. of all spoils
Green ash.	78	97	0	73	34	27	52
E. redcedar	87	76	33	40	4	18	43
Pitch pine	63	14	54	0	2	0	22
Jack pine.	40	27	42	0	8	0	20
American elm.	0	67	16	14	9	7	19
Virginia pine	47	18	18	0	2	0	14
Red pine	59	9	14	0	1	0	14
Cottonwood	57	18	0	2	1	0	13
Sycamore	6	0	0	0	9	0	2
Av., all species	49	36	20	14	8	6	22

[a] Average of three replications based on the original number of trees planted per plot (30).

Fig. 3. Replication III of the 7-year-old Pershing sandy buff shale plots. Red pine, Virginia pine, eastern redcedar, pitch pine, jack pine, American elm, cottonwood, river birch, green ash and sycamore were planted, left to right. Survival of eastern redcedar, American elm and green ash was very good. The spoil material was slightly acid, pH 6.5, and exchangable aluminum was not detected.

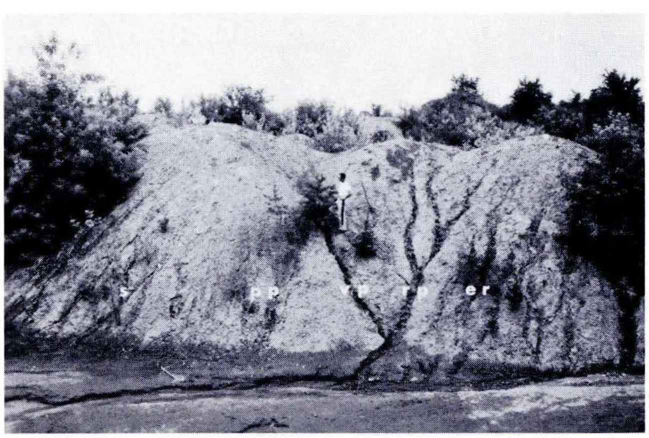

Fig. 4. Replication I of the 7-year-old Otley brown shale plots. Sycamore, pitch pine, Virginia pine, red pine and eastern redcedar were planted, left to right. The spoil material was extremely acid, pH 3.0, and exchangable aluminum was very high (approximately 532 parts per million). Erosion increased plant losses.

Growth

Eight years after planting

Average 8-year tree height was obtained for each species planted (a) on the Pershing loess, till, buff shale mixture, (b) on the Bussey buff-shale and (c) on the Kirkville till, gray shale. Cottonwood averaged 22 feet in height on the loess, till, buff shale mixture and attained a greater height than all other species on each class of spoil (fig. 5). The average height of cottonwood was approximately twice the height of green ash (figs. 5 and 6). Jack pine height was 3 to 6 feet greater than the height of all other conifers.

The growth of all vegetation on the loess, till, buff shale mixture and on the buff shale was generally better than on the till, gray shale (figs. 7 and 8). Trees on the loess, till,

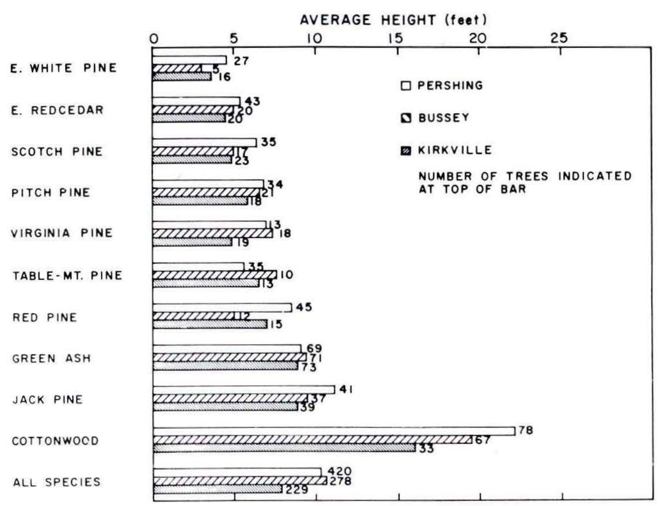

Fig. 5. Average 8-year tree height on the Pershing loess, till, buff shale mixture; Bussey buff shale and Kirkville till, gray shale.

Fig. 6. Eight-year-old plantings on the Kirkville till, gray shale. Left to right are black locust, jack pine, green ash, white pine and cottonwood. The extension pole is at 17 1/2 feet. Note the difference in height between cottonwood and green ash.

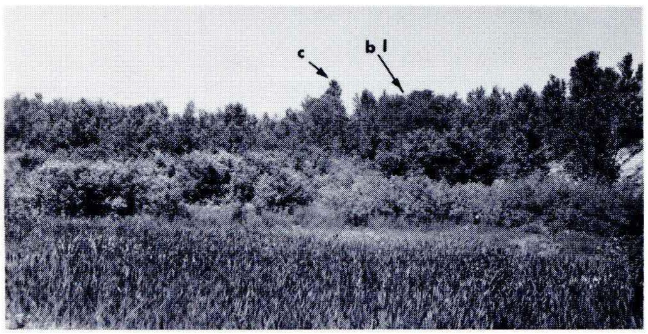

Fig. 7. General view of the 8-year-old plantings on the Pershing loess, till, buff shale mixture. Cattails are in the foreground, and volunteer boxelder is in the middle. Rows of black locust and cottonwood may be distinguished in the background. Much volunteer cottonwood has obscured the original plantings.

Fig. 8. General view of the 8-year-old plantings on the Kirkville till, gray shale. Rows of cottonwood and conifers are easily distinguished. Invasion of the plantings by volunteer species has been light. Rows of black locust are seen at either end of the plantings.

buff shale mixture and the buff shale averaged approximately 10 ½ feet, while those on the till, gray shale averaged approximately 8 feet. Eastern redcedar, eastern white pine, Scotch pine, pitch pine, red pine, jack pine and cottonwood attained their greatest heights on the loess, till, buff shale mixture, while Virginia pine, table-mountain pine and green ash reached their greatest heights on the buff shale.

Seven years after planting

Average 7-year tree height on the Otley, Pella, Pershing, Oskaloosa, Eldon and Selma spoil materials was extremely variable (table 3). Average cottonwood height of 8 feet was greater than all other species, twice the height of green ash and 3 feet more than American elm. Jack and Virginia pine reached about the same average height, 5 ½ feet, and exceeded the other pine species by 1 ½ to 3 feet.

Eastern redcedar, green ash and cottonwood attained heights of 5 ½, 6 and 13 ½ feet on calcareous black shale at Oskaloosa. All pine species, except red pine, attained greatest heights on acid light gray shale material at Eldon where Virginia pine averaged 6 ½ feet. Red pine, with an average height of 2 ½ feet, grew slowly on all spoil materials. Browsing damage to the leaves and needles may have reduced the growth of the broadleaved species and red pine. Rabbit and other rodent damage may have reduced the growth of all species. Relative differences in height growth are indicated in figs. 9, 10 and 11.

Fig. 9. Pitch pine in Replication III of the plantings at Eldon. Seven years after planting, the pine species were making fair growth on the strongly acid, pH 4.0, light gray shale material.

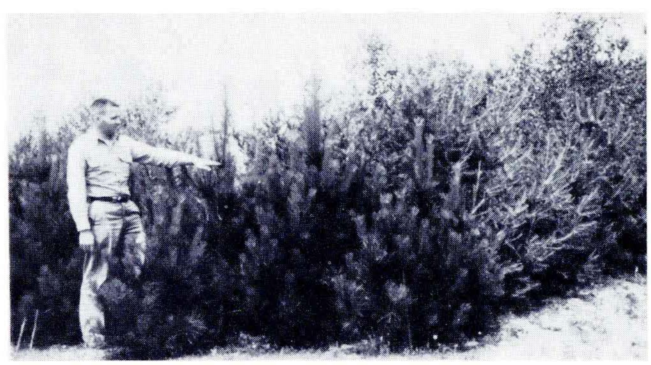

Fig. 10. Red pine in Replication III of the plantings on the Selma leached glacial till. Seven years after planting, this species was making very poor growth. Damage by browsing animals was severe in the spring of 1961.

Table 3. Seven-year average tree height in feet on the Oskaloosa, Pershing, Eldon, Selma, Pella and Otley spoil materials.

Species	Oskaloosa black calcareous shale		Pershing sandy buff shale		Eldon light gray shale		Selma leached glacial till		Pella calcareous glacial till		Otley brown shale		All spoils	
	No. of trees	Av. ht.	No. of trees	Av. ht.	No. of trees	Av. ht.	No. of trees	Av. ht.	No. of trees	Av. ht.	No. of trees	Av. ht.	No. of trees	Av. ht.
Cottonwood	23	13.6	25	5.2	--	--	51	6.9	--	--	20	8.0	119	8.0
Virginia pine	--	--	18	6.0	39	6.6	50	4.8	--	--	5	3.6	112	5.6
Jack pine	--	--	27	5.5	52	5.9	39	5.5	--	--	12	3.6	130	5.5
American elm	--	--	38	5.9	--	--	--	--	23	4.7	34	3.8	95	4.9
Pitch pine	--	--	18	3.5	61	4.6	58	4.0	--	--	12	3.3	149	4.1
E. redcedar	77	5.7	84	4.4	56	1.8	86	3.6	76	4.3	23	2.5	402	4.0
Green ash	88	6.0	88	5.4	--	--	83	2.1	66	3.1	55	2.5	380	4.0
Sycamore	--	--	--	--	--	--	10	1.4	--	--	21	4.4	31	3.4
River birch	--	--	--	--	10	2.4	--	--	--	--	2	7.6	12	3.3
Red pine	--	--	12	1.6	22	2.5	58	2.7	--	--	3	1.7	95	2.5
Av., all species	188	6.8	310	5.0	240	4.3	435	3.9	165	3.9	187	3.7	1,525	4.5

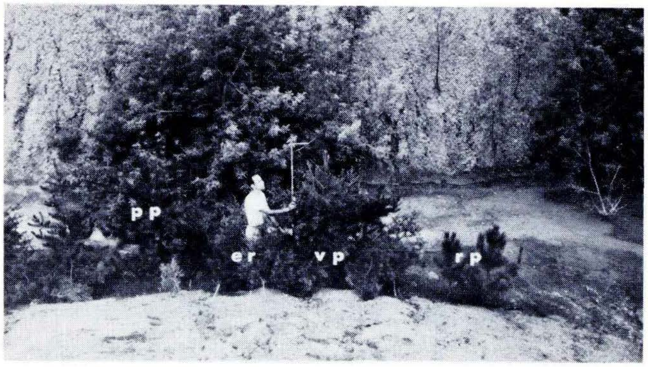

Fig. 11. Part of Replication III of the plantings on the Otley brown shale. Few of the original 30 trees per species remain. From left to right, pitch pine, eastern redcedar, Virginia pine and red pine may be seen. The pole is at 7 1/2 feet.

DISCUSSION

Results of 7- to 8-year tree survival and growth studies indicate that green ash and cottonwood offer the most promise among the broadleaved species for reclamation of the various coal-spoil materials. Over-all survival of green ash was superior to cottonwood, but the abundance of natural cottonwood, which has invaded many coal-spoil sites, indicates that better results might be expected in future plantings. Cottonwood grew much faster on a variety of sites and, on the average, grew to more than double the height of green ash.

Green ash appears best suited for the moderately acid to calcareous coal-spoil materials where competition is not extreme and nutrient levels are more favorable. North and east aspects and protected coves that offer favorable moisture conditions are the best planting sites for green ash (fig. 3).

Cottonwood invaded sites on all classes of coal-spoil materials. It grew best on the moderately acid and calcareous materials and on sites where competition for moisture, nutrients and light was not great. Competition for moisture and light may limit cottonwood survival and growth more than competition for nutrients on these sites. Many volunteer cottonwood trees survive and make fair growth on coal-spoil materials usually considered toxic (pH 2.7 to 4.0). Other vegetation is very sparse. It might be desirable to encourage volunteer cottonwood on the more acid and toxic materials if moisture conditions are favorable. The trees may hasten amelioration of the surface materials so that more demanding species could be established in subsequent plantings.

Eastern redcedar survival and growth were best on the calcareous coal-spoil materials. Some redcedar survived on the acid spoils, but the best possibilities for this species appear to be calcareous sites. However, limited plantings on moderately acid coal-spoil materials, such as the acid buff shale at Pershing, appear feasible (fig. 3). Eastern redcedar is relatively drouth resistant and will grow on drier sites.

Response of the pines was erratic. Survival and growth were very poor on the calcareous materials; apparently, these pines should not be planted on the calcareous shales or glacial tills. In general, the pines appear tolerant of strongly acid and dry site conditions. Jack and Virginia pine seem best suited for the strongly to moderately acid spoil materials and dry sites. Pitch pine is adapted to the same materials but probably should be planted on more moist sites. Red pine and eastern white pine plantings should be limited to the fertile, slightly acid materials and moist sites. Red pine suffered severe browsing damage; grazing animals, apparently, prefer its long needles over the shorter and less brittle needles of jack, Virginia and pitch pine.

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APPENDIX

Table A-1. Analysis of variance of average 8-year tree survival on the Pershing, Bussey and Kirkville spoil materials.[a]

Source[b]	df	Sum of squares	Mean square	F	F'
Total	99	29,398.54			
Locations	2	4,175.33			
Species	9	21,954.13	2,439.35		11.09**
Locations x species	18	3,269.08	181.62	2.20*	
Pooled error	70		82.41		

[a] Survival percentage transformed to $\sin^{-1}(\text{percentage})^{1/2}$
[b] Analytical method from Cochran and Cox 1957, p. 555.
** Significant at 1-percent level.
* Significant at 5-percent level.

Table A-2. Analysis of variance of average 7-year tree survival percentage converted to $\sin^{-1}(\text{percentage})^{1/2}$ on six coal-spoil materials.

Location		Source of variation: Total	Replication	Species	Error
Pershing sandy buff shale	df	23	2	7	14
	Sum of squares	15,880.50	198.59	13,277.83	2,404.08
	Mean square			1,896.83	171.72
	F			11.05**	
Selma leached glacial till	df	23	2	7	14
	Sum of squares	9,108.35	1,069.86	6,361.81	1,676.68
	Mean square			908.83	104.79
	F			8.67**	
Oskaloosa black calcareous shale	df	11	2	3	5
	Sum of squares	6,049.18	134.26	4,623.41	1,291.51
	Mean square			1,541.14	358.30
	F			5.97*	
Otley brown shale	df	26	2	8	16
	Sum of squares	4,467.58	1,745.20	1,467.52	1,254.86
	Mean square			183.44	78.43
	F			2.34	
Eldon light gray shale	df	17	2	5	10
	Sum of squares	4,380.02	53.68	2,061.24	2,265.10
	Mean square			412.25	226.51
	F			1.82	
Pella calcareous glacial till	df	8	2	2	4
	Sum of squares	2,889.02	1,589.14	187.51	1,112.37
	Mean square			93.76	278.09
	F			-----	

** Significant at 1-percent level.
* Significant at 5-percent level.