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Growth, Form and Survival of Plantation-Grown Broadleaf and Coniferous Trees in Southeastern Iowa

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Growth, Form and Survival of Plantation-Grown Broadleaf and Coniferous Trees in Southeastern Iowa[1]

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INTRODUCTION

Old fields and degraded forest lands in southern Iowa were acquired by the State of Iowa during the period 1935 to 1941. A forestation program was initiated in conjunction with the Civilian Conservation Corps. Hundreds of acres of conifers and broadleafs were planted, principally during the years 1937 through 1941, on eroded upland ridge tops, steep side slopes and narrow drainage basins in the vicinities of Chariton, Keosauqua and Farmington, Iowa. Because of insufficient knowledge and experience concerning forestation practices applicable in this area, the selection of species and planting procedures was approached experimentally.

A survey of these plantations was started in 1952 for the purpose of determining the adaptability of the various tree species to the sites on which they were planted and to provide a sounder factual basis for present and future forestation programs. This survey was supported by the Iowa Conservation Commission in cooperation with the Iowa Agricultural Experiment Station and the Forestry Department. The results of this survey and some of the studies made in connection with it are reported in this paper.[2]

Data were collected on 17 broadleaf species (137 plots) and 10 coniferous species (62 plots) during 1952 and 1953 (Table 1). The information obtained on each tree plot included species, age, height, diameter, merchantable length, crown size, form, vigor, disease and insect injuries and mortality. Site information included a description of the soil profile, percent slope, position on slope, aspect, degree of erosion and associated vegetation.

The absence of records on the source of seeds and seedlings, size, age class and condition of planting stock, former land use, ground preparation and plant competition, dates and methods of planting, and weather and injuries limit the conclusions, especially pertaining to survival, that can be drawn from the data. For many species only a few sample plots were available, therefore, information on their site requirements and growth responses was insuffi-

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[1]Journal Paper No. *2756* of Iowa Agricultural Experiment Station, Ames, Iowa. Project 1154.

[2]For more detail see Norman J. Hansen, Forest plantations in relation to sites in southeastern Iowa. M.S. Thesis. Library, Iowa State College, Ames, Iowa. 1954.

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Table 1

Number of sample plots and trees by species

Tree species: Common name	Tree species: Scientific name	Sample number: Plots	Sample number: Trees
(Conifers)			
Jack pine	*Pinus banksiana* Lamb.	18	637
Red Pine	*P. resinosa* Ait.	14	431
Ponderosa pine	*P. ponderosa* Laws.	10	315
E. white pine	*P. strobus* L.	6	176
Shortleaf pine	*P. echinata* Mill.	3	90
Virginia pine	*P. virginiana* Mill.	3	81
Austrian pine	*P. nigra* Arnold	1	30
Scotch pine	*P. sylvestris* L.	1	30
E. red cedar	*Juniperus virginiana* L.	5	138
Douglas fir	*Pseudotsuga menziesii* (Mirb.) Franco	1	29
		62	1,957
(Broadleaves)			
Black walnut	*Juglans nigra* L.	38	1091
Green ash	*Fraxinus pennsylvanica* Marsh.	36	1088
Red oak	*Quercus rubra* L.	14	385
American elm	*Ulmus americana* L.	9	246
Black locust	*Robinia pseudoacacia* L.	6	121/141[a]
Bur oak	*Quercus macrocarpa* Michx.	6	193
Sugar maple	*Acer saccharum* Marsh.	5	118
Osage orange	*Maclura pomifera* (Raf.) Schneld.	4	106
Black cherry	*Prunus serotina* Ehrh.	3	90
Butternut	*Juglans cinerea* L.	3	77
E. cottonwood	*Populus deltoides* Bartr.	3	66
Silver maple	*Acer saccharinum* L.	3	75/97[a]
Basswood	*Tilia americana* L.	2	60
Yellow poplar	*Liriodendron tulipifera* L.	2	48
Kentucky coffee tree	*Gymnocladus dioicus* (L) K.Koch	1	30
White oak	*Quercus alba* L.	1	30
Hybrid aspen-poplar	*Populus alba* x *P. grandidentata*	1	10/63[a]
		137	3834/3927[a]

[a]The first number refers to height measurements and the second to diameter measurements.

cient. Ash and walnut were sampled in greater detail than other broadleaves, because they were the most commonly planted. Jack pine, ponderosa pine and red pine were the major coniferous species.

Most plantations were only 12 to 15 years old. This is too short a period to judge the fitness of any species, particularly introduced species, because unusual climatic extremes, capable of causing serious injury, may occur but once or twice in a century. This was vividly illustrated during the last two years following the completion of the field work. Two seasons of abnormal weather have caused severe injury in formerly healthy stands of red pine and, to a lesser extent, in white pine, Scotch pine and jack pine in south central Iowa.

Growth, Survival and Form

Figure 1 presents the minimum, mean and maximum annual height growth among plots by species.[1] The range for a given species was small for pines and large for broadleaves; for example the maximum average height growth per plot for ash was sixteen times greater than the minimum. These ranges in height growth indicated that the soil-site factors did not greatly affect the growth of pines up to age 15 but did influence markedly the growth of broadleaf species. On the uncultivated[2] and uneroded sites the height growth of many broadleaf species was considerably greater than the fastest growing pines; however, on old fields the broadleaves grew poorly and the pines grew rapidly (Figure 7).

The height above ground to an average top diameter inside bark of 3 inches was measured and the sum of all these heights per plot divided by the total number of trees gave the mean annual merchantable height growth per tree (Figure 2). The pines consistently made good merchantable height growth on all sites, whereas the broadleaves other than black locust attained merchantable heights only on the uncultivated and uneroded sites.

Figure 3 illustrates the minimum, mean and maximum annual diameter growth among plots by species. Again the pine varied the least and the broadleaves the most. However, the diameter increment of fast growing broadleaves and conifers was affected by stand density as well as site quality; therefore, diameter was not as good an indicator of site quality as height. On uncultivated and uneroded sites the average annual diameter increment of broadleaves such as cottonwood, silver maple, black cherry, ash and walnut was greater than 0.3 of an inch, but on old-field sites the growth was poor except for some black locust plantings. Conversely, the diameter increment of pine species was good regardless of site conditions, with the exception of ponderosa pine.

Basal area[3] per unit of land area is a measure of the degree of utilization of the growing space and of past growth. Table 2 compares the basal area among broadleaves and pines. The data demonstrates that pine species on old-field sites grow considerably more in basal area than broadleaf species on good sites. The ash with its narrow crown was the only broadleaf whose growth rate aproached that of pine.

Two crown widths per tree were measured and multiplied together to estimate the space occupied per tree of given diameter. Figure 4 shows the linear regressions which were fitted to the data.

[1]Plot means were based on approximately 30 tree measurements.

[2]An uncultivated site is land which has not been broken by plow for agricultural use.

[3]Basal area represents the sum of the cross-sectional areas of the tree stems measured at 4½ feet above ground.

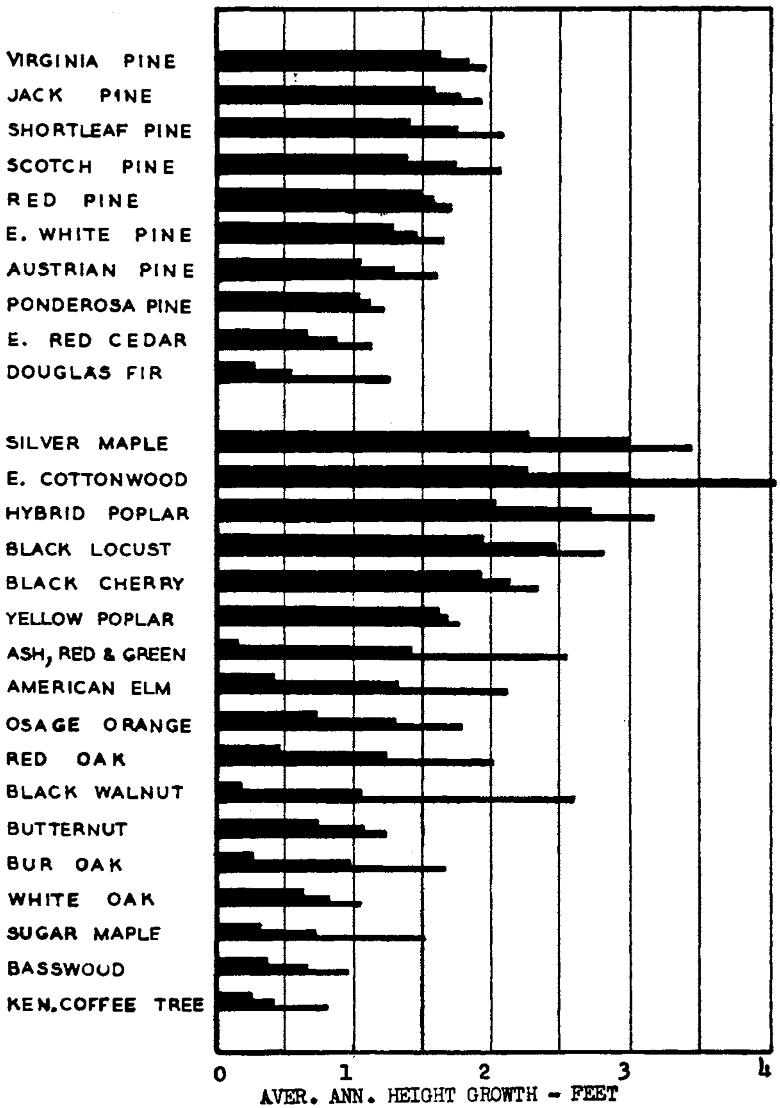

Figure 1. Comparison of the minimum, mean, and maximum average annual height growth among species.

Table 2

Comparison of the average annual basal area growth among 14 year old pine and broadleaf species[a]

Species	Average number of live trees per acre	Average basal area per acre $(ft.)^2$	Mean annual basal area growth $(ft.)^2$
Virginia pine	1017	111.2	7.94
Red pine	836	89.3	6.38
Jack pine	1073	88.3	6.31
Ash, red & green	1091	81.7	5.84
Black walnut	816	50.8	3.63
Red oak	852	49.7	3.55

[a]The averages for broadleaves includes data only from the best plots on the uncultivated sites while averages for pine include data from all plots on the eroded, old-field sites.

The space occupied per tree of given diameter was greater for broadleafs than for pine. Red oak crowns occupied the most space. The smaller crown space per tree explains why more pine trees than broadleaves of given diameter can be grown per unit of land area.

The evaluation of survival data was difficult, because there were no records of mortality immediately following planting and during the intervening years. Figure 5 shows the estimated losses of trees up until the time of measurement. These data represent mortality in stands chosen primarily for species-site evaluation. They do not include mortality in stands that failed completely at the time of establishment or were later destroyed by fire, animals or other agencies. They represent estimates of mortality in established stands. There was no marked difference in mortality rate among conifer and broadleaf species. Usually, broadleaf species, particularly ash, survived well regardless of site conditions, which emphasized that early survival rates could not be used to judge species adaptability to site.

The bole form of conifers was superior to that of broadleaves. Seventy-eight percent of all conifers produced straight 12-foot boles while among broadleaves only 33 percent of the boles were straight. Seven percent of the conifers and 30 percent of the broadleaves were forked below 12 feet.

Evaluation of Individual Species and Sites

On the basis of this limited sample of young pine plantations in southeastern Iowa the soil-site characters were not of great importance in regard to the survival and early growth of pine. For

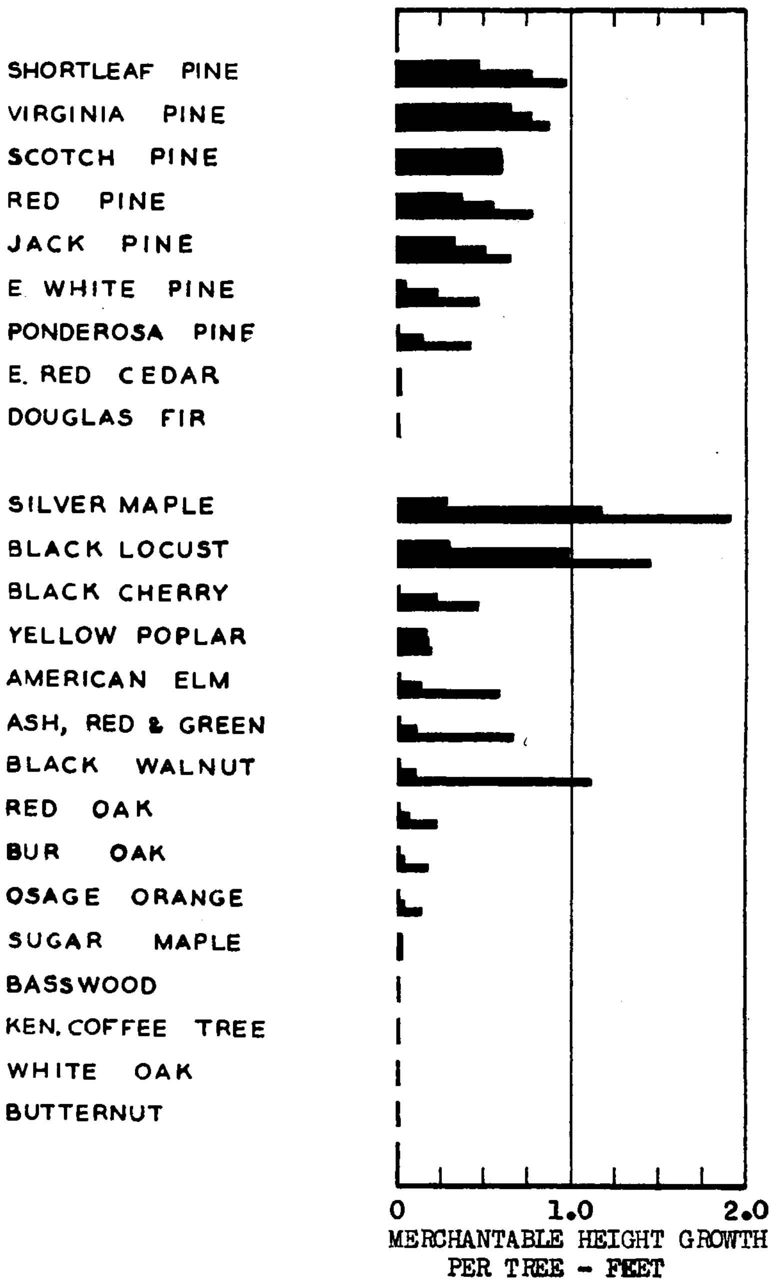

Figure 2 Comparison of the minimum, mean, and maximum annual merchantable height growth per tree among species.

broadleaf species, though, soil-site factors affected the growth but not the survival.

BROADLEAVES

One practice of selecting trees for planting is to use the indigenous species. Many of the native broadleaf species were used for planting, but their early development on old-field sites was poor. However, on uncultivated sites the broadleaves grew satisfactorily.

Green ash grew rapidly on the uncultivated and uneroded sites, made fair growth on old pastures and poor growth on old fields. Several soil factors were definitely correlated with growth. Height and diameter growth was directly correlated with the percent nitrogen in the leaflets. Fast growth and high leaf nitrogen were associated with the uncultivated and uneroded sites generally located around old farmsteads. The protected cove-like sites with their deeper rooting zones and greater soil moisture were most favorable. The darker colored surface soils were indicative of superior sites as opposed to lighter colored soils. Growth appeared to be associated with the Great Soil Groups. Brunizen soils[1] and colluvial complexes supported the best ash stands. Gray-Brown Podzolic soils were intermediate and Planosols the poorest.

In total the following seven soil-site factors were combined for estimating ash site quality for uplands in southeastern Iowa: degree of erosion, depth to impermeable subsoil, Great Soil Group, color of surface soil, exposure, aspect and cultural treatment (cultivated, pastured and uncultivated). The latter seemed to be of first importance. A highly significant correlation existed between the combined site quality index value based on these seven factors and the average annual height growth of ash (Figure 6).

Ash seedlings are easy to grow in the nursery, easy to plant and survive well. Animals cause very little injury to young trees. Ash has about the smallest crown and root space requirements in youth of any broadleaf species, hence its wood volume growth per unit area is high. In many of the plantations the boles tended to be crooked and often forked, but some plantings exhibited straight, unforked boles which suggested a possible genetic variance among seed sources.

Walnut growth was very erratic in the area studied (Figure 8). The planting of walnut in this area is a big risk. However on a few good sites walnut grew rapidly in height and diameter when the crowns were not crowded, but tree form was usually poor.

Site classification for black walnut was based on soil moisture regime, aeration and color of soil—all in combination with thickness of rooting zone. The linear regressions obtained by plotting

[1]Formerly called Prairie soils.

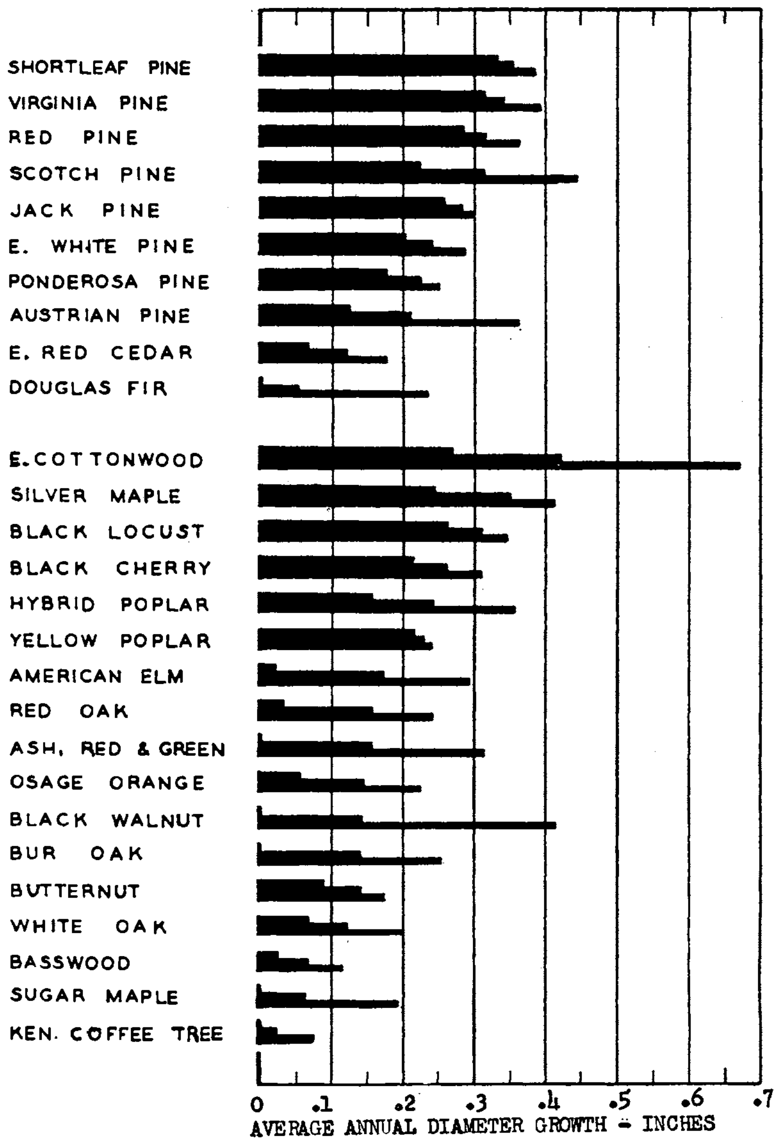

Figure 3. Comparison of the minimum, mean, and maximum average annual diameter growth among species.

average annual height growth over calculated index values were highly significant for moisture regime, soil color and the composite index (moisture regime + soil color + aeration). The linear regression of the aeration index was significant. However, correlation coefficients were low in all cases. Only about one-half or less of the variation in height growth could be accounted for by any one or combination of the above site factors.

Red oak grew moderately fast on uncultivated sites, but the majority of the trees, even in the best stands, were crooked, forked and coarsely limbed. The undesirable form of red oak might be improved by denser planting (5 x 5 or 4 x 4 foot spacing), by planting in mixtures, or by selection of genetically better strains. The maximum rate of height growth on good sites approximated that of fast growing pines. The bole is stiff and does not sway much in the wind. Therefore, red oak and other native oak species might be good companions in mixed pine-oak plantations. Such a combination should reduce the hazard from oak-wilt and possibly other diseases. Deer and rabbits have a fondness for young red oak stems.

White oak planting has fallen into disfavor. Most of the plantations were complete failures. Seedings fail because rodents eat the acorns. Trees that survived on old-field sites were slow growing and poorly formed. If new planting techniques can be discovered, which would insure adequate stocking, the white oak might then be a desirable species to plant on uncultivated sites.

Bur oak plantations were established successfully, but growth and form were poor on old-field sites. Bur oak on an exposed, upland ridge in uncultivated prairie soil was growing satisfactorily and exhibited good form. It is a species which tolerates poor soil aeration and from this standpoint is probably a desirable species to plant on the heavy textured and poorly drained prairie soils.

Black locust arrested gully erosion and grew rapidly, but often the trees were destroyed by insects before they could be utilized as posts and poles. The practice of planting locust contiguous to pine is dangerous, because the locust can spread rapidly into the pine plantings by root sprouts and then outgrow, overtop and kill the pine. Black locust can still be recommended for erosion control, but pine may often do the job better. More knowledge on tending black locust stands and on control of its insect pests must be obtained before this species can be recommended as a crop capable of consistently yielding high quality posts and poles.

Cottonwood on suitable sites produces the greatest wood volume in the shortest period of time of any broadleaf species in Iowa. Medium textured soils in lowlands and moist to wet upland soils are suitable sites. However, tall weed competition during the first or second year after planting limits the establishment of successful

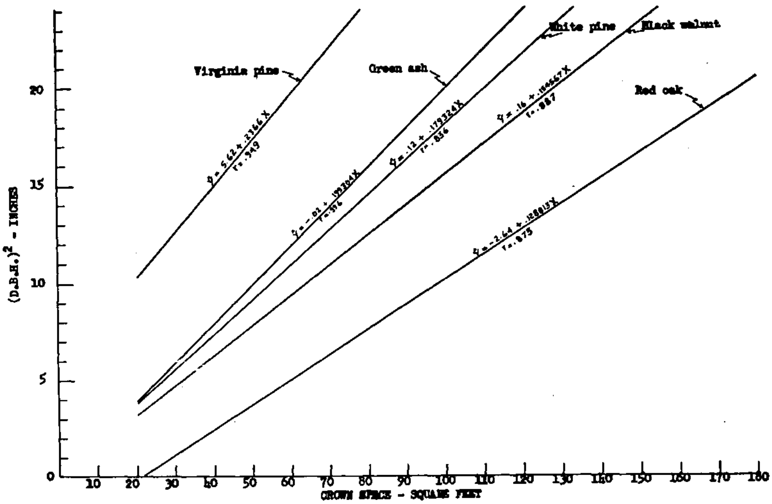

Figure 4. Relation of stem size to crown size for coniferous and broadleaf species.

plantations. A natural occuring aspen-poplar hybrid in southeastern Iowa promises to be a desirable species on uneroded moist upland sites.

Silver maple grew rapidly on moist, uncultivated upland sites. Natural pruning was good. Planted seedlings tend to form sprout clumps which should be thinned out to one good stem per clump. Boles are often crooked and leaning.

Black cherry has potentialities, but not much is known about its site requirements. The Iowa black cherry tends to have spiral grain which is undesirable for certain wood uses. Thus a good strain must be located. This species is capable of making rapid growth, of providing wood of high utility and of furnishing food for birds and animals.

Basswood has great potential, though not much is known about its site requirements in the area studied. It has been a difficult species to germinate and grow in the nursery. In natural stands basswood develops best on the cooler and more moist aspects on well-drained soils, especially in the coves and at the base of long slopes.

Osage orange is another species which makes poor growth on old-field sites but grows satisfactorily on uncultivated land. Although the wood is very useful as posts, the trees tend to be bushy and the stems crooked. Osage might best be used as a living fence around plantations to provide summer wind protection and to serve as cover and food habitat for wildlife.

CONIFERS

The use of conifers for reforestation in southern Iowa required the introduction of species not indigenous to the region, except for eastern red cedar. White pine, however, occurs naturally in parts of eastern Iowa. Present knowledge suggests that the planting of pine and other coniferous species should help to improve forestry in the state.

Conifers yield products desired by the wood industries; they increase production on degraded forest land; they can be established successfully on sites unsuited to native broadleaf species; and they might alter poor sites to the extent that desirable indigenous species could be re-established later.

Jack pine and Virginia pine have grown satisfactorily on all upland sites in southeastrn Iowa. However, jack pine does not appear to be growing as well on the poorly drained upland flats (Planosols) as on the sloping and better drained sites. These species

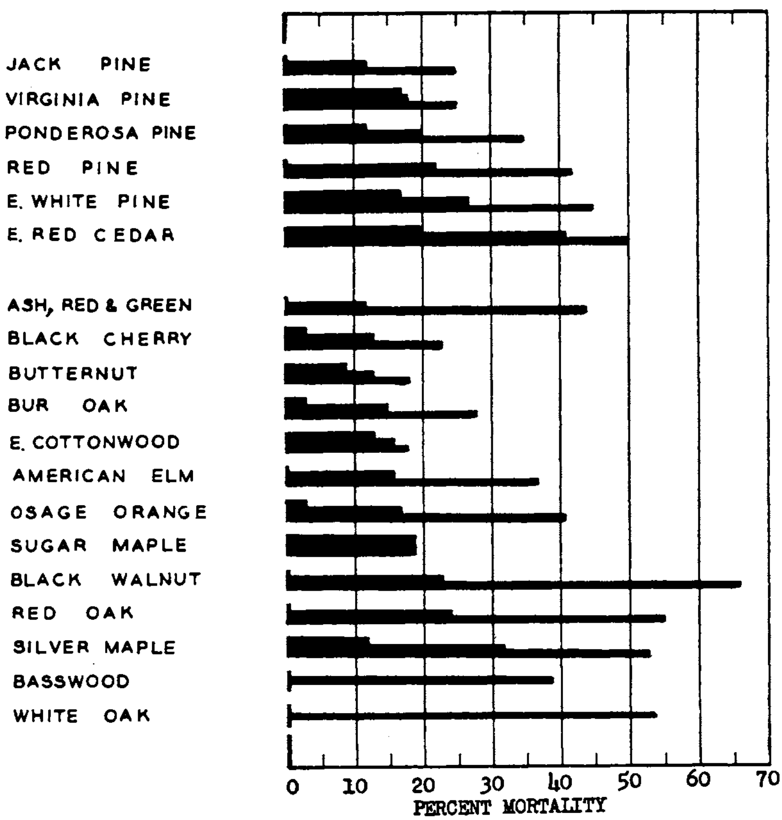

Figure 5. Comparison of the minimum, mean, and maximum mortality within plots among species.

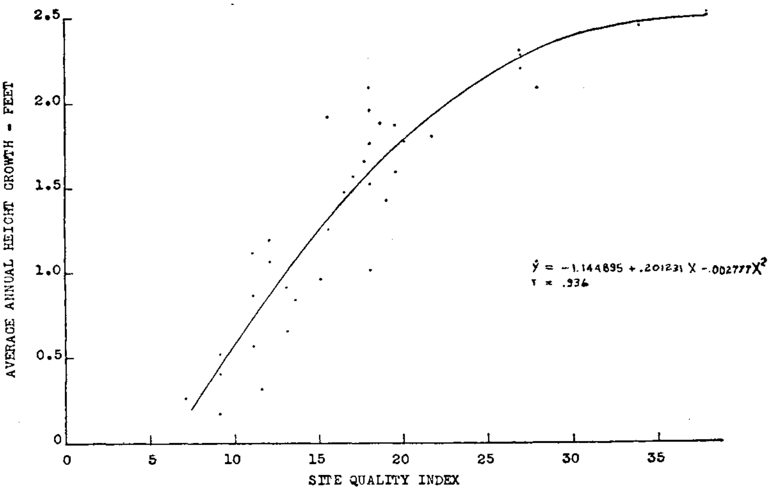

Figure 6. Regression of the average annual height growth on the calculated site quality index of ash. Site quality index is based on (1) degree of erosion, (2) depth to impermeable subsoil, (3) Great Soil Group, (4) color of surface soil, (5) exposure, (6) aspect and (7) cultural treatment.

probably should be planted on the drier sites where more desirable species are not adapted. Dry sites include the upland ridge tops and southern and western aspects. Jack and Virginia pine occupy the site rapidly and provide good ground cover and watershed protection. Within 12 to 15 years they are large enough to be harvested as posts and small poles. Both species tend to be limby and crooked, hence the spacing probably should be 6 x 6 feet or less.

Red pine looked very promising until 1953 and 1954. Now, in south central Iowa, high mortality indicates that red pine planting should be restricted at least to protected sites, preferably the lower slopes of northern and eastern aspects where insolation is the least or to sandy soils which permit deeper rooting. In extreme southeastern Iowa red pine has not suffered excessive mortality on fine textured upland soils but discretion suggests confining future planting to the cooler, moister and more porous sites. This species developes rapidly in youth, exhibits good form, provides good ground cover, and starts to supply posts and small poles within 15 years (Figure 9). The best stand development occurs in plantations with a spacing of 6 x 6 feet or greater. For planting economy and ease of management an 8 x 8 foot spacing is recommended.

White pine mortality was higher and its early growth was less than that of the hard pines. But past experience indicates that on suitable sites its growth may be expected to eventually exceed that of other northern pine species. Many white pine died on fine textured soils with shallow rooting zones on the exposed upland sites following the dry years of 1953 and 1954. Hence, white pine planting in southern Iowa should be restricted to the fresh or moist sites which permit deep rooting and preferably to the cooler and protected sites with northern or eastern aspects. For economy in planting and tending of young plantations a spacing greater than 6 x 6 feet may be desirable because small products are not readily marketed.

Ponderosa pine planted in southern Iowa was usually unhealthy, its growth and form was inferior and its mortality rate was generally high. A needle disease not yet identified caused premature leaf drop. As the severely infected trees become weaker each year, they gradually die. The poor development might be attributed partly to site because the trees are growing on fine-textured, poorly-drained soils. Tarrant[1] reported that ponderosa required well drained sites. This species has been recommended in the past because of its drought resistance.

Shortleaf pine was studied in two plantations. Its performance suggests further trail in the lower one or two tiers of counties in southeastern Iowa. This species has grown rapidly and has excellent form in a plantation near Keosauqua. Its growth near Lucas in south central Iowa was much poorer. If shortleaf continues to show resistance to frost, snow, ice and insects, it might be a good species for planting on the drier and hotter sites in southern Iowa.

One mixed plantation of Scotch pine and jack pine on a ridge at Lucas demonstrated that the early diameter growth of Scotch pine was considerably greater than the diameter growth of jack pine, though the two species were equal in height growth. However, a number of Scotch pine and several jack pine died following the two years of drought. Therefore, future plantings probably should be restricted to the cooler and more moist sites.

Eastern red cedar is a native of southern Iowa and thrives in its natural state, but the dense, pure plantations were very unhealthy. Consequently, it is inadvisable to plant pure stands of red cedar until more is known about the requirements of this species. It might be desirable to plant as a border around pine plantations to provide protection from wind and sun as the pines grow tall. Red cedar should not be planted around fruit orchards. This species does provide winter feed, cover and nesting habitat for birds.

Injurious Agencies

Various injurious agencies were important in some of the plantations. Animals directly influenced survival and growth. Field

[1]R. F. Tarrant. 1953. Soil moisture and the distribution of lodgepole and ponderosa pine (a review of the literature). Pacific Northwest Forest and Range Expt. Sta. Research Paper No. 8.

mice completely destroyed a 6 year old plantation of Virginia pine and first year plantings of yellow popular. Gophers killed patches of pine by eating the lateral roots. Deer and rabbits have injured young hardwood trees, especially red oak.

Fungi were of minor importance, but *Fomes rimosus* (Berk.) Cke., a spongy yellow heart rot, was ruining some merchantable black locust trees. Unhealthy eastern red cedar trees were infected with *Phomopsis juniperovora* Hahn, *Gymnosporangium juniperi-virginianae* Sch., and *G. clavipes* Cke. & Pk., Basswood stems on poorly drained sites were necrotic. Foliage disease of ash and walnut on poor sites resulted in premature leaf fall, and needle disease of ponderosa pine greatly reduced the amount of live crown.

Insect damage occurred in some plantations. The locust borer, *Megacyllene robiniae* (Frost.), has severely damaged the majority of the merchantable black locust stands. An unidentified sawfly, thought to be the European sawfly, *Neodiprion sertifer* (Geoff.), defoliated red pine and jack pine plantations at Keosauqua during May 1953 and again in 1954. The periodical cicada, *Magicicada sp.,* has severely injured the stems and branches in young broadleaf plantations, especially on the poorest sites.

The relation of climate on the health of pine has become paramount since the abnormally dry seasons of 1953 and 1954. In the Lucas-Chariton plantations red, white and Scotch pine began to show crown injury during the dry season of 1953 and increasing injury and death during 1954. Red pine was the most seriously injured species (Figure 10). However, very little injury occurred to any of these species in the plantations near Keosauqua and Farmington, though the precipitation was approximately the same for 1953 and 1954.

The difference in precipitation between the Keosauqua-Farmington vicinity and the Chariton-Lucas vicinity during the past 15 years is a possible explanation for the greater height growth of some pine species in the Keosauqua-Farmington area. Precipitation records show that the average annual rainfall at Keosauqua for 1937 through 1952 was 35.67 inches, at Chariton it was 33.39 inches. The average monthly temperature was 53.8°F. and 50.2°F., respectively.

Mixtures

Intimate mixing of different species, though silviculturally desirable is hazardous unless the species are known to be compatible. Compatibility means that, for trees of the same tolerance, the height growth and crown development must be equal for given soil-site conditions. Among species of different tolerances, the least tolerant must be the fastest grower, and the crown of the slower growing and more tolerant species must be capable of

Figure 7. Growth superiority of jack pine over green ash and sugar maple on an old-field site.

Figure 8. Response of 16 year old black walnut to changes in soil type and micro relief. Mean height of trees on left is 3.8 feet and on the right 25.4 feet. Demonstrates sharp change in bottomland soil-site factors.

Figure 9. Red pine posts harvested in the first thinning 16 years after planting. Unpeeled on left, and peeled and treated with pentachlorophenol in right foreground.

Figure 10. Red pine dying in plantations around Chariton, Iowa, after the unusually dry growing seasons of 1953 and 1954. The soils are fine textured with shallow rooting zones. Sites are exposed to southerly winds and high insolation.

withstanding the lower light intensities and the mechanical friction and abrasive action of the overtopping trees. Small group-wise mixtures, which are planted according to species-site requirements, possess several possible advantages over large single-species plantations. The diversification of species in group-wise mixtures hedges against unforseen calamities to a particular species such as permanent or temporary loss of market outlets; changes in economic value; and climatic, disease, insect, animal or fire injury.

Summary and Conclusions

This paper presents results of a forest plantation survey aimed at finding out what species were planted and how they were growing in southeastern Iowa on old and highly weathered loess and till soils characterized by poorly drained and impervious subsoils. The planting sites were usually old fields abandoned as unsuitable for agriculture. Data were collected for 17 broadleaf species (137 plots) and 10 coniferous species (62 plots) during 1952 and 1953. Tree information included the species, age, height, diameter, merchantable length, crown size, form, vigor, injuries and mortality. Site information included a description of the soil profile, percent of slope, position on slope, aspect, degree of erosion and vegetation.

On eroded, old-field sites in southeastern Iowa the growth of pines was good, and the growth of broadleaves was poor. On the uncultivated and uneroded sites, chiefly around old farmsteads, the growth of several broadleaf species was good. Merchantable products, posts and small poles, could be harvested within 12 to 15 years from practically all of the pine plantations but from very few broadleaf plantations. In 10 to 15 years after planting the pine species provided good ground cover and watershed protection, but the broadleaf species failed to do so.

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