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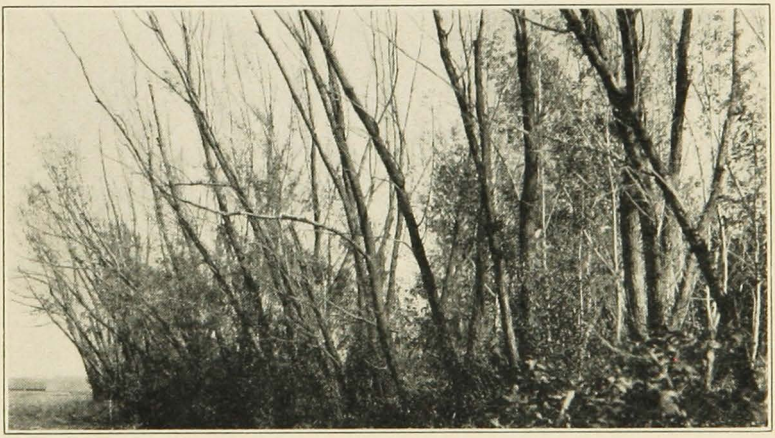
Division of Forestry



Typical Drouth Injury to Willow at The West Central Station

UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

DROUTH DAMAGE TO PRAIRIE SHELTERBELTS IN MINNESOTA

M. E. Deters and Henry Schmitz[1]

INTRODUCTION

During the spring and summer of 1934, Western Minnesota experienced one of the most severe drouths since the settlement of that region. The destructive effects of greatly subnormal precipitation were intensified by hot dry winds which occurred with great frequency throughout the entire growing season. Also for a number of years prior to 1934, the precipitation in the prairie region of Minnesota was somewhat below normal. During these years, the soil moisture supplies were gradually depleted. The extreme losses that occurred during the summer of 1934 can not therefore be attributed solely to the severe drouth of that year. More properly should they be regarded as the result of a series of successive dry years culminated by the most critical conditions, insofar as vegetation is concerned, experienced in a long period of time.

Until 1929, tree plantations in the prairie regions appeared to be in relatively good condition, with no severe losses in any particular year. Since 1932, however, the losses have been heavy. In 1934, in certain parts of the prairie region, it seemed that only a comparatively small number of plantations would survive.

In the spring of 1934, the Division of Forestry in cooperation with the West Central and Northwest substations undertook a study of the conditions of the shelterbelts in western and southern Minnesota. The determination of the extent to which trees in the region had died was not the only, or the chief, objective of the study. Interesting and important tho these data may be, it was felt that the effect of the drouth upon tree planting in the prairie region might be regarded as a great natural experiment, not as well controlled as may be desired in scientific work, but nevertheless one from which might be obtained the information necessary to develop sound principles and practices for tree planting in the prairie region. The trees that remain in the region have been subjected to a most severe test, and the survival figures in a general way furnish a satisfactory basis for the choice of tree species and planting and cultural practices.

[1] The authors wish to express their appreciation for helpful suggestions given by Mr. Ernest George, Assistant Silviculturist, Northern Great Plains Field Station, Mandan, N. D., and Prof. E. G. Cheyney, Division of Forestry, University Farm, St. Paul, Minnesota.

The authors are also indebted to Prof. J. A. Anderson, West Central Experiment Station, Morris, Minn., and Prof. T. M. McCall, Northwest Experiment Station, Crookston, Minn., for their continued interest and active cooperation in this study.

METHODS AND PROCEDURE

The prairie region of Minnesota comprises an area of about 18,000,000 acres. About 2,000,000 acres of this total consist of scattered small areas of prairie within the general boundary of the forest region and of the so-called prairie-forest transition belt. This study was limited to approximately 16,000,000 acres of prairie exclusive of the scattered prairie and of the prairie-forest transition belt.

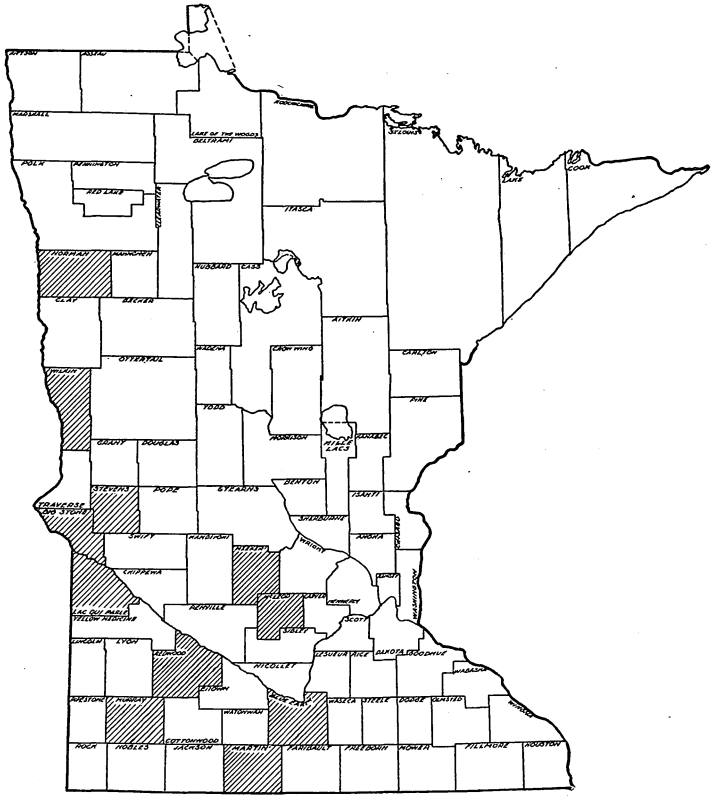


FIG. 1. IN EACH OF THE SHADED COUNTIES, A SAMPLE TOWNSHIP WAS STUDIED

In order to sample adequately a region as large as this with the funds and facilities available, it was necessary to select sample townships distributed more or less uniformly in the general prairie region. Eleven such townships were selected and studied, one in each of the following counties: Martin, Blue Earth, Murray, Redwood, McLeod, Meeker, Lac qui Parle, Bigstone, Stevens, Wilkin, and Norman. (See Fig. 1.)

An attempt was made to record all of the tree plantings on every farm within each township selected for study. Records were obtained for 665 farms in the 11 townships, which is equivalent to approximately

0.834 per cent of the total number of farms within the prairie region covered by the survey.

Each tree in the shelterbelts studied was examined and classified as to species, size, and condition. Notes were also taken on each shelterbelt on the age, site, spacing, arrangement, care, and other pertinent factors. In all, data were collected for 179,703 trees on the 665 farms studied. This amounts to an average of 270 trees per farm. Only planted trees were tabulated, except where naturally occurring trees formed an integral part of a shelterbelt. Ornamental plantings around buildings, field border plantings, and woodlot plantings were included. Only standing trees were considered, and no record was made of trees that had died and had been cut or removed prior to the time of actual examination. Because of the fact that severe losses had occurred in 1933 and earlier and because much of the dead timber had been removed, the losses of the five-year period 1929-1934 actually were much greater than the data indicate. The results recorded in this discussion present the condition of prairie plantings as it existed in the summer of 1934.

The data for the entire region were computed on a basis of 79,705 farms.

The Drouth of 1934 and Preceding Years

There are many reasons for the extremely heavy losses of trees in shelterbelt plantings in the prairie region of Minnesota during recent years. Without question, however, by far the most important and decisive factor was inadequate moisture resulting from subnormal precipitation.

Because of the size and geographic location of the region covered by the survey, it is to be expected that there would be considerable variation in the precipitation received by different parts of the region. In Table 1 is given a detailed record of mean annual precipitation of nine stations in the region covered by the survey. It is apparent from Table 1 that the severity of the drouth from 1931 to 1934, inclusive, varied within quite wide limits. Insofar as tree growth was concerned, conditions appeared to have been most critical in west central Minnesota and decreased in intensity to the north, east, and southeast. If the death of trees is to be ascribed largely to a deficiency in precipitation, then the heaviest losses would be expected to occur in the west central part of the state. As will be pointed out later, this was precisely the case.

Composition of Shelterbelts by Species

Thirty-six species of trees were found in the shelterbelts of the region, but only 28 species were represented by a sufficient number of individuals to warrant their being given consideration. The scientific and

Table 1. Detailed Record of Mean Annual Precipitation for 11 Stations in The Prairie Region of Western and Southern Minnesota

(Data Based on Records of the U. S. Weather Bureau, Minneapolis)

Year	Fairmont, Martin County	Mankato, Blue Earth County	Redwood Falls, Redwood County	Willmar, Kandiyohi County	Artichoke Lake, Bigstone County	Beardsley, Bigstone County	Morris, Stevens County	Campbell, Wilkin County	Ada, Norman County
1920	25.69	27.66		29.06	26.41	23.79	25.04	21.74	15.61
1921	33.09	24.82	20.41	23.07	17.81	17.28	24.06	29.11	23.79
1922	23.13	26.10	16.99	19.97	15.73	15.98	21.08	21.80	24.15
1923	22.32	20.49	18.63	13.78	14.24	16.03	20.45	20.81	17.92
1924	26.37	24.14	27.50	23.22	23.93	24.09	26.64	23.92	21.33
1925	24.97	26.35	22.55	20.92	16.61		21.60	24.27	21.90
1926	27.90	27.60	24.29	28.10	23.16		21.63	25.87	17.26
1927	25.88	27.13	27.05	22.13	18.71		21.78	30.15	19.73
1928	26.92	28.11	25.31	28.83	16.81	19.09	23.43	24.57	23.42
1929	24.03	27.97	24.66	25.36	17.56	18.53	24.41	21.42	15.13
1930	22.65	22.97	24.44	23.23	21.52	21.36	25.08	16.84	18.63
1931	26.14	27.75	18.65	19.34	17.56	16.49	19.22	23.58	20.00
1932	25.11	27.88	20.33	23.16	18.19	17.11	19.70	17.24	13.95
1933	20.45	22.94	22.35	13.67	13.72	14.85	15.31	16.02	18.07
1934	22.29	22.04	17.71	15.85	12.93	13.42	15.87	12.12	17.45
Average 1931 to 1934, inclusive	23.50	25.15	19.76	18.00	15.60	15.47	17.52	17.24	17.37
Average from year of establishment of station to 1930	28.18	27.79	25.06	24.25	19.11	22.89	23.78	23.76	20.58

common names of the 28 kinds of trees occurring in the shelterbelts of the prairie region of Minnesota are given, in the order of their frequency, in the following tabulation.

Order of frequency	Scientific name	Common name
1	*Acer negundo*	Boxelder
2	*Salix sp.*	Willow
3	*Fraxinus pennsylvanica lanceolata*	Green ash
4	*Acer saccharinum*	Silver maple
5	*Populus deltoides virginiana*	Southern cottonwood
6	*Ulmus americana*	American elm
7	*Populus sp.*	Poplar
8	*Pinus sylvestris*	Scotch pine
9	*Picea glauca*	White spruce
10	*Ulmus pumila*	Chinese elm
11	*Quercus macrocarpa*	Bur oak
12	*Gleditsia triacanthos*	Honey locust
13	*Populus alba*	White poplar
14	*Picea excelsa*	Norway spruce
15	*Juniperus virginiana*	Eastern red cedar
16	*Catalpa speciosa*	Hardy catalpa
17	*Juglans nigra*	Black walnut
18	*Elaeagnus angustifolia*	Russian olive
19	*Caragana arborescens*	Siberian pea tree
20	*Pinus ponderosa*	Ponderosa pine
21	*Abies balsamea*	Balsam fir
22	*Picea pungens*	Blue spruce
23	*Larix europea*	European larch
24	*Picea mariana*	Black spruce
25	*Thuja occidentalis*	Northern white cedar
26	*Pinus strobus*	Northern white pine
27	*Robinia psuedoacacia*	Black locust
28	*Pinus resinosa*	Norway pine

Figure 2 shows the composition of shelterbelts by species and clearly indicates the great importance of six common native species of trees in shelterbelt plantings. The five leading species, boxelder, willow, green ash, silver maple, and cottonwood, make up about 90 per cent of all trees occurring in shelterbelts. If American elm is added to the group, the six leading species total about 93½ per cent. If the various species of poplar, Scotch pine, western white spruce, and Chinese elm are also added to the group it will be found that these 10 leading species make up approximately 97½ per cent of the total. The other 26 species of trees occurring in shelterbelt plantings make up only about 2½ per cent of the total. The six leading tree species found in shelterbelt plantings are all native to the region.

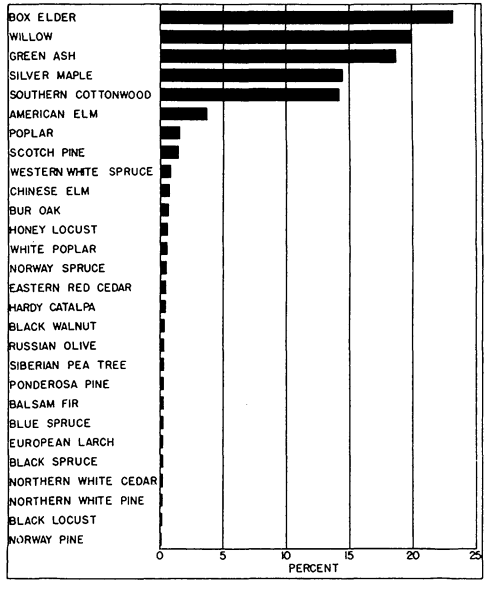


FIG. 2. PERCENTAGE COMPOSITION OF SHELTERBELTS BY SPECIES

Of the 28 kinds of trees included in Figure 2, only seven — boxelder, willow, green ash, silver maple, cottonwood, American elm, and bur oak—occur commonly in or adjacent to the prairie region. All the other kinds of trees were introduced from outside the region, a number of them not occurring naturally in North America. Because these introduced kinds of trees were less well known and were usually sold as ornamental stock at relatively high prices, they were planted only in limited numbers. During recent years, when introduced kinds of trees were readily available, relatively few plantings have been made.

The Age of the Trees in the Shelterbelts

The age of the trees in the shelterbelts was not determined in all cases because of the practical impossibility of cutting sample trees. However, the age of trees can be determined in a general way from their diameters. Because most stands were planted densely and were never thinned, the trees are suppressed and the diameters are less than would

be expected for any given age. A great majority of the trees 25 to 50 years of age are in the 4–6-inch and 6–8-inch diameter classes.

The 0–2-inch class may be taken to represent roughly the 0–10-year age class. Of the trees occurring in the shelterbelts, only cottonwood commonly exceeds two inches D.B.H.[2] before 10 years. The 0–2-inch diameter class represented only 9.8 per cent of the total number of trees, and of this 3.6 per cent consisted of willow coppice (sprout growth). The actual planting during the last 10 years, therefore, amounted to only 6.2 per cent of the present total number of standing trees. If it be considered further that there have been heavy removals of larger trees, especially during the last five years, which have resulted in an appreciable reduction in the total number of trees in the region, the deficiency in the 0–10-year age class is even more marked.

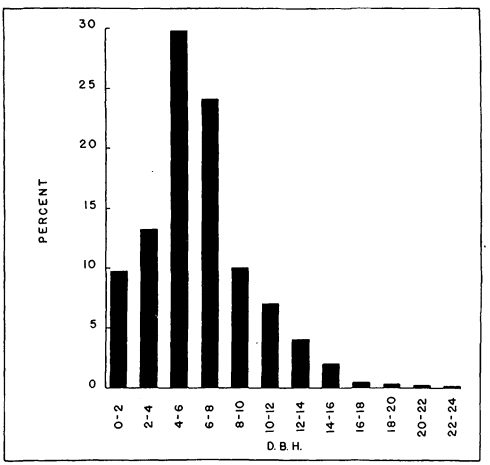


FIG. 3. THE PERCENTAGE DISTRIBUTION OF DIAMETER CLASSES IN THE SHELTERBELTS OF THE PRAIRIE REGION

The distribution of the various diameter classes for all species is shown in Figure 3. This figure indicates clearly the markedly abnormal condition which existed in the distribution of tree sizes and ages in the shelterbelts. The number of trees in the 4–6-inch and the 6–8-inch diameter classes (25-50 years of age) was disproportionately large, while both the number of trees in the smaller and the larger diameter (age) classes was insufficient even to maintain the existing shelterbelts.

Normally the 0–10-year age class should be represented by the largest number of trees. In the successively higher age classes should be successively smaller numbers of trees. Because of the fact that very few trees over 50 years of age were found in the shelterbelts, the trees may be grouped in five 10-year age classes for the purpose of determining the number of trees that must be planted each year merely to maintain the present stands. In order to maintain the present shelterbelt plantings, the number of trees in the 0–10-year age class should com-

[2] D.B.H. = Diameter breast high.

prise approximately 25 per cent of the total. Assuming this figure to be essentially correct, there is a deficit in the region based on the present number of trees of about 15 per cent or more than 4 million trees in the 0–2-inch diameter class.

Survival and Condition of Different Kinds of Trees in the Shelterbelts

The condition of the 28 most important kinds of trees in the shelterbelts is shown in Figure 4. For the leading 10 kinds of trees, the results are probably quite reliable. Because the other kinds of trees are represented by a very much smaller number of individuals, the data dealing with these are less reliable. Nevertheless, by giving adequate consideration to this fact and by considering other factors involved, fairly satisfactory conclusions can be drawn concerning the condition and the drouth resistance of even those kinds of trees that occur in the shelterbelt plantings only in limited numbers.

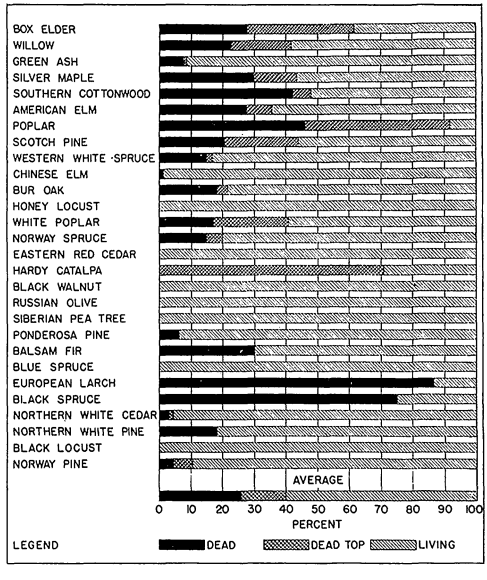


FIG. 4. THE CONDITION OF MOST IMPORTANT TREES IN THE SHELTERBELTS OF THE PRAIRIE REGION

The trees of each kind were classified as far as their condition was concerned in one of the three groups as follows: (1) dead, (2) dead tops, and (3) living. Dead trees and those with dead tops may for convenience be grouped together as dead or dying, because it is believed that it is quite improbable that many of these trees will fully recover even with a return of normal growing conditions. It was found that 25½ per cent of all the trees examined were dead and that 14½ per cent had dead tops. Thus 40 per cent of all the trees examined may be considered dead or dying at the end of the summer of 1934.

An examination of the condition of the six important native trees occurring in shelterbelts shows a relatively high percentage to have been dead or dying. The outstanding exception was the green ash, only 8 per cent of which were found to be dead or dying. The comparative

weakness, under conditions of extreme drouth, of boxelder, willow, silver maple, and cottonwood, especially in the older age classes, is well illustrated. The trees that occur naturally in the region along river borders appear to be relatively poorly suited for planting on the drier upland prairie land. Green ash, bur oak, and American elm, which occur naturally on drier upland sites, in general appear to be the most suitable native species for shelterbelt plantings in the prairie region.

Some kinds of trees introduced into the region appear to have withstood successfully the severe drouth conditions of 1934, while others have suffered severely. The survival of introduced kinds of trees is shown in Figure 4.

In general, all of the 28 kinds of trees listed on page 6 will grow satisfactorily throughout much of the prairie region of Minnesota during periods of normal or above normal precipitation. However, only a comparatively few kinds of trees are able to endure protracted periods of drouth. A first requisite of any kind of tree to be planted extensively in the prairie region is that it be capable of enduring the severe drouth conditions which have occurred and will occur from time to time in the region.

Unfortunately, the kinds of trees best adapted to the region have not been planted most extensively. Of course, a number of characteristics other than drouth resistance must be considered in evaluating the merits and limitations of different kinds of trees for planting in the prairie region. First and foremost, a suitable tree must be able to withstand all the variations in the climate and weather of the region. Rate of growth, shape and form, length of life, character of the foliage, quality of the wood, freedom from disease, and insects must also receive due consideration in the choice of trees for prairie planting.

It is perfectly apparent that in the choice of trees for planting in the prairie region, adequate consideration has not been given to their ability to withstand extreme drouth conditions. In Table 2, 13 species of hardwoods and 12 species of conifers are listed in the order of their general suitability for prairie planting. The actual order in which they occur in the region, on a numerical basis, is also given.

The wide difference between the actual and recommended order of trees in the prairie region is shown in Table 2. For example, boxelder was the most commonly occurring hardwood tree; yet it is probably the least desirable of the 13 hardwoods considered. The most desirable tree for prairie planting, green ash, is third in order of actual occurrence.

Similar differences are to be noted among the conifers. The most commonly occurring coniferous tree, Scotch pine, is given a preference rating of 10, whereas the most desirable coniferous tree, Ponderosa pine, is sixth in order of actual occurrence.

Table 2. The Relationship Between the Suitability of Different Kinds of Trees for Prairie Planting and Their Actual Occurrence in the Prairie Region Plantings

	Hardwoods			Conifers	
	Order of preference	Actual occurrence		Order of preference	Actual occurrence
Green ash	1	3	Ponderosa pine	1	6
Southern cottonwood	2	5	Eastern red cedar and Rocky Mt. Juniper	2	5
American elm	3	6	Blue spruce	3	8
Chinese elm	4	8	White spruce	4	2
Bur oak	5	9	Western white spruce	5	3
Honey locust	6	10	European larch	6	9
Willow sp.	7	2	Norway spruce	7	4
Black locust	8	17	Northern white pine	8	12
Russian olive	9	14	Norway pine	9	13
Siberian pea tree	10	15	Scotch pine	10	1
Black walnut	11	13	Balsam fir	11	7
Soft maple	12	4	Northern white cedar	12	11
Boxelder	13	1			

The Relationship of Diameter and Age to Drouth Resistance

The relationship between the age of trees and their drouth resistance is shown in Figure 5. In the preparation of Figure 5, all species of trees found in shelterbelts in the region were grouped together to

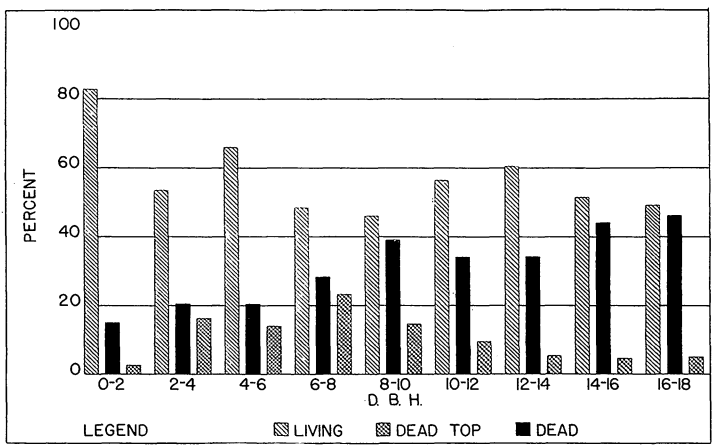


FIG. 5. THE RELATIONSHIP BETWEEN THE DIAMETER OF TREES (AGE) AND THEIR DROUTH RESISTANCE IN THE PRAIRIE REGION

show the relationship between the diameter of the trees and their drouth resistance. It is fully recognized that such a grouping is a questionable procedure, and too much confidence should not be placed on any but broad general relationships. The trees of all species were grouped because the data for any single species were inadequate for the purpose. The most obvious and at the same time probably the least questionable relationship brought out by Figure 5 is the comparatively low percentage

of trees in the 0–2-inch diameter class killed by the drouth. It seems clear that young trees, once well established, are better able to survive drouth conditions than are the large, more mature trees.

In general, there was an increase in the percentage of dead trees with an increase in age, at least until a diameter of 8 to 10 inches was reached. This relationship is somewhat concealed because most of the trees above 10 inches in diameter are cottonwood, whereas a large number of different kinds of trees are included in the groups below 10 inches.

If age had been used instead of diameter in the preparation of figures, the same trends undoubtedly would have been shown. It is difficult to conclude from the data available whether age or diameter is the better indication of the change in drouth resistance. Both older and larger trees appeared to be in good condition in many places, even in the driest parts of the area, when they were favorably situated and not subjected to excessive crowding and competition from other trees. The heaviest losses occurred invariably in dense stands of medium- or large-sized trees. In many cases medium-sized trees, because of crowded conditions, were mature. The size of trees is greatly influenced in crowded stands. In more open stands, where there was less competition among the trees, losses were much less severe and trees grew to larger sizes. Competition as well as age and diameter therefore appears to influence the resistance of trees to drouth.

Variation in Drouth Losses in Different Parts of the Prairie Region

Attention has already been called to the fact that drouth conditions during 1934 and several preceding years were most critical in west central Minnesota. It is only to be expected, therefore, that the losses would be greatest in the same locality.

In Figure 6 the average percentage of dead and dying trees is given by counties. Losses varied from 72.30 per cent in Bigstone County to 21.80 per cent in Norman County. There was a close, but not exact, correlation between the losses and drouth severity. For example, in Bigstone county, where the heaviest losses occurred, the average precipitation for the years 1931 to 1934, inclusive, was about 15½ inches, the lowest precipitation received by any of the counties for which precipitation data were available and which were included in the survey. On the other hand, however, the average precipitation for the period 1931 to 1934 was a trifle lower in Norman County, where the losses were low, than in Stevens County, where the losses amounted to 63 per cent of the total number of trees. It should be noted, however, that in Norman County the average precipitation of the period up to 1930 was 20.58 inches. In other words,

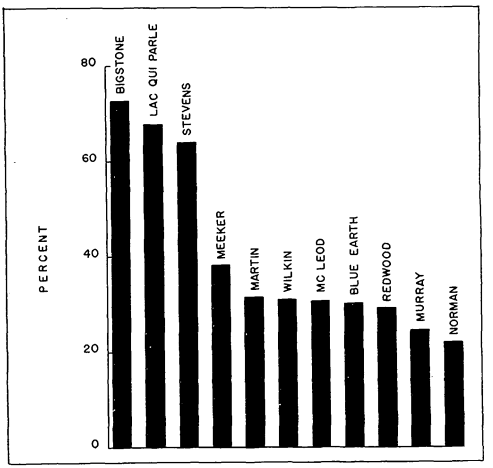


FIG. 6. VARIATION IN THE PERCENTAGE OF DEAD AND DYING TREES IN THE DIFFERENT COUNTIES OF THE PRAIRIE REGION

the average annual deficiency in Norman County was only 3.21 inches, while in Stevens County it was 6.26 inches. Furthermore, the distribution of precipitation, especially during the growing period, together with the dryness of the soil in the late fall and winter, probably also influenced the severity of the losses.

The somewhat lower normal precipitation in Norman County also apparently influenced the particular kinds of trees planted in that county. For example, the drouth-susceptible silver maple, which was almost exterminated in Stevens County, apparently had not been planted in Norman County, because of its probable lack of hardiness in that county.

Factors Other Than Drouth Which Have Adversely Affected the Growth of the Trees in the Prairie Region of Minnesota

Attention has already been called to the fact that, altho drouth probably has been the most decisive factor, certain other factors also have influenced the death of trees in the prairie region during the last years.

Probably the most important of these secondary factors is the age of the trees. Even during the years when climatic conditions were favorable for the growth of trees, a certain number of trees died each year. During drouth years, the precentage mortality among the larger, older trees was higher than among the smaller, younger trees.

The average life of trees growing under prairie conditions appears to be much less than that of the same tree growing under natural forest conditions. The indications are that from 50 to 100 years is about the maximum age of most tree species in the Minnesota prairie region. Often it is much less than this. Natural death due to old age and maturity is and has been causing losses of trees for some time. Because many of the trees in the region have been planted 40 to 50 years ago, they have now reached maturity and are dying a "natural" death. To be sure, the drouth

of the last few years has hastened greatly the death of many trees which under more favorable conditions would have continued to live for some time.

Table 3. Percentage Survival of the Six Most Commonly Planted Kinds of Trees by Counties

County	(Boxelder) *Acer negundo*	(Willow) *Saiix sp.*	(Green Ash) *Fraxinus lanceolata*	(Silver Maple) *Acer saccharinum*	(Cotton-wood) *Populus deltoides*	(American Elm) *Ulmus Americana*	All species
Bigstone	4.60	5.30	69.30	2.90	7.60	33.20	27.20
Lac qui Parle	10.20	16.00	88.30	3.30	33.20	35.90	32.40
Stevens	16.50	17.40	96.00	0.35	32.30	100.00	36.00
Meeker	60.00	56.20	92.10	44.50	75.30	100.00	61.80
Martin	67.50	60.00	99.80	100.00	68.50	98.00	68.50
Wilkin	42.00	52.70	98.00	00.00	43.90	100.00	69.00
McLeod	84.40	79.90	95.20	72.20	32.40	98.30	69.40
Blue Earth	67.10	57.70	100.00	75.80	78.10	100.00	69.90
Redwood	82.70	58.30	100.00	72.70	77.60	94.50	70.80
Murray	60.30	51.60	99.90	75.00	77.10	100.00	75.40
Norman	80.50	79.10	97.50	.....	75.50	100.00	78.20

Too close spacing without thinning to provide adequate growing space for the remaining trees also has been an important factor in the deterioration of shelterbelt plantings in Minnesota. Commonly trees were planted 4x4, 4x6, or 6x6 feet and occasionally even more densely. In the past, thinnings have seldom been made. When planted so densely, trees grow well only for a short time; competition then becomes so strong that the trees stagnate and many die at an early age.

It was observed that with 4x4-foot spacing the maximum diameter development was from 4 to 6 inches; with 6x6-foot spacing, it was 6 to 8 inches; and with 8x8-foot spacing, it was 8 to 10 inches. Irrespective of the age of the stand, these diameters were rarely exceeded except in the case of cottonwood or in mixed stands in which one kind of tree was more aggressive than its associates.

In closely planted stands of a single species, natural crowding out of some trees to permit adequate growth of the remaining dominant trees as a rule does not occur in prairie plantings. In such plantations, the trees usually develop more or less uniformly and are approximately equal in their ability to compete for light and moisture. Development of trees to satisfactory sizes does not occur, and the stands become decadent at an early age. Early maturity and shortened life appear to result from crowded, closely planted stands.

Because height growth is important in shelterbelt trees and because crowding stimulates height growth, it is desirable to have close spacing during the early life of the plantings. Thinnings should be made in such stands while the trees are still vigorous and before growth has slowed down because of intense competition. Except under unusually favorable

conditions, such thinnings ordinarily need not be made before the trees have attained an age of 20 years or more.

In general, initial spacing about 4x8 feet is recommended, altho single or double rows of trees may be spaced even more closely because there is no crowding on the free sides. Spacing of 4x8 feet will permit adequate development of the individual trees until diameters of 4 to 6 inches are attained. Then thinnings should be made in order that the

FIG. 7. A FIVE-YEAR-OLD PLANTING OF GREEN ASH AT THE WEST CENTRAL STATION, MORRIS, MINNESOTA

Despite the drouth, these trees are thrifty and grew rapidly.

final spacing of the trees will be about 8x8 feet. If trees larger than 10 to 12 inches in diameter are desired, wider spacing will be necessary.

Once the stand is closed, the windbreak values of fairly widely spaced plantings are just as great or greater than from closely spaced plantings. In addition, the individual trees grow more rapidly and produce fuel or wood products in a much shorter time.

The pasturing of shelterbelts and woodlots is probably only second to severe drouth as a cause of the death of trees in the prairie region of the state. Even light pasturing of shelterbelts and woodlots is definitely harmful, and heavy pasturing soon results in the death of some trees and a consequent reduction in shelterbelt values. Pasturing of all kinds results in packing the soil to such an extent that penetration of moisture is greatly retarded and aeration of the soil reduced. The penetration of moisture is of first importance and anything that tends to decrease absorption during drouth years is bound to be detrimental. Forage values under a good stand of trees are small if not negligible. Because of this fact and because pasturing is definitely harmful to tree growth in the prairie region, it must be discontinued if the trees are to survive.

Insects played an important tho minor rôle in the destruction of shelterbelt trees during the drouth period. The boxelder aphids were unusually abundant during the dry years and did much to lower the vitality of that tree. Canker worms, forest tent caterpillars, and woolly aphids of elm took a heavy toll in sporadic outbreaks in various parts of the prairie region.

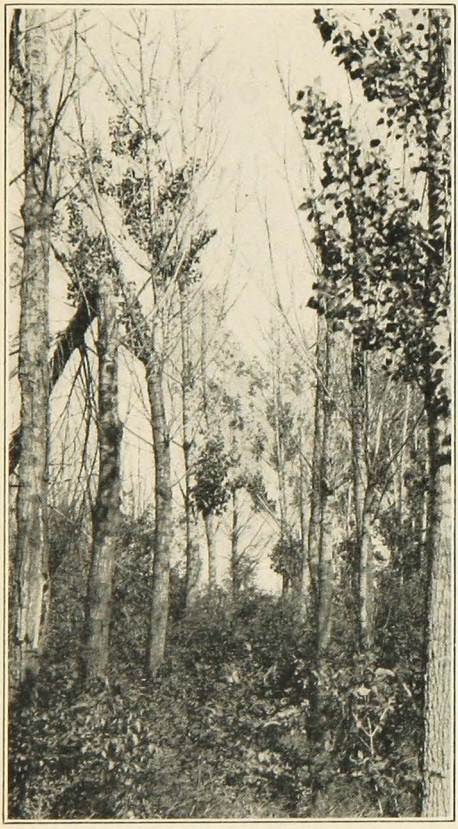


FIG. 8. A STAND OF HYBRID POPLARS IN WESTERN MINNESOTA SHOWING TYPICAL DROUTH EFFECTS

Shelterbelts and windbreaks in the prairie region have suffered greatly from overcutting, especially since 1930. In many sections, the trees have been cut much faster than they have been planted or have grown, thus resulting in a marked depletion in the amount of timber in these sections. Not only have the dead and dying trees been cut for fuel, but green living trees as well.

It is estimated that fully half of the volume of timber in the shelterbelts of the region in 1929 had been used for fuel during the period 1929-1935. It is obvious that this situation cannot long continue if the shelterbelt resource is to be saved from complete exhaustion.

Volume of Timber in Shelterbelts

If the data collected for 665 farms in 11 townships in the prairie region are representative of the entire region, it may be assumed that there were a total of approximately 21½ million trees in Minnesota prairie shelterbelts or an average of 270 trees per farm. The size of these trees is shown in Figure 3.

Considering only trees about four inches D.B.H., there was represented a volume of approximately 1,142,000 cords. Of this total, almost

457,000 cords consisted of dead and dying trees, and approximately 685,000 cords were living trees. There were an average of 14.5 cords per farm, of which 5.8 cords were dead or dying timber. The average volume of timber in shelterbelts for the region as a whole was only 0.071 cords per acre.

The available volume of timber in shelterbelts is wholly inadequate to meet the fuel and other wood requirements of the region. It represents about a two years' supply of fuel wood at the present rate of consumption, and were all the farmers in the region limited to the local wood supply for fuel, the entire stand would furnish about one year's supply.

The natural forest areas along rivers and lakes and planted woodlots supplement the local shelterbelt timber supply. The total volume of wood in these natural forest areas and in planted woodlots is probably as great or greater than that in the shelterbelts. However, the timber supplies in these natural woodlands are being depleted rapidly. Trees are cut for fuel and other uses, and little new growth is taking place to maintain the stands. The situation makes it doubly important that shelterbelts and woodlots be re-established to provide continuously the needs of the region. The present large deficit of trees in the younger age classes has, and will continue to have, an important influence on the volume of timber in the region. Within a comparatively few years much of the timber in the larger diameter classes will be cut, and there will be too few younger trees to replace them.

Planting and Care of Shelterbelts

Many plantings have failed in the past because of improper planting methods and care. Planting in the region is best done in the spring, but may also be done in the fall after the end of the growing season. Good planting stock is the first requirement. Preferably it should be grown in the region, and stock grown in seedbeds or nurseries will generally be found more satisfactory than stock collected from the woods. The stock should be planted as soon as possible after digging and should not be exposed to drying or heating. The root especially should be kept moist at all times.

It is often necessary, and always desirable, to cultivate the young trees after planting. The small trees suffer from the competition of sod and weeds. A heavy sod may kill trees if given sufficient time. All sod-forming grasses and perennial weeds should be thoroly eradicated by bare fallow or cultivated crops before the land is fit for trees. Cultivation should be continued until the trees develop sufficient shade to keep down grass and weeds.

There is considerable difference of opinion concerning the advisability of mulching tree plantings in the prairie region. In some cases it is probably undesirable, in others desirable. In winter, mulch sometimes attracts rodents, especially mice, which may girdle small trees. Mulch also constitutes a fire hazard during the dry part of the year. For these reasons, it is perhaps best not to mulch very small trees. If a good litter of leaves and brush is present, there is, of course, no need for mulching. However, sod, which is frequently unfavorable to tree growth, may be controlled by a mulch of leaves or straw. Where the ground in shelterbelts is bare of litter or ground cover, a mulch will aid in conserving soil moisture and add valuable organic matter to the soil. In fact, a mulch of protecting litter may be just as important to shelterbelts as to natural forests.

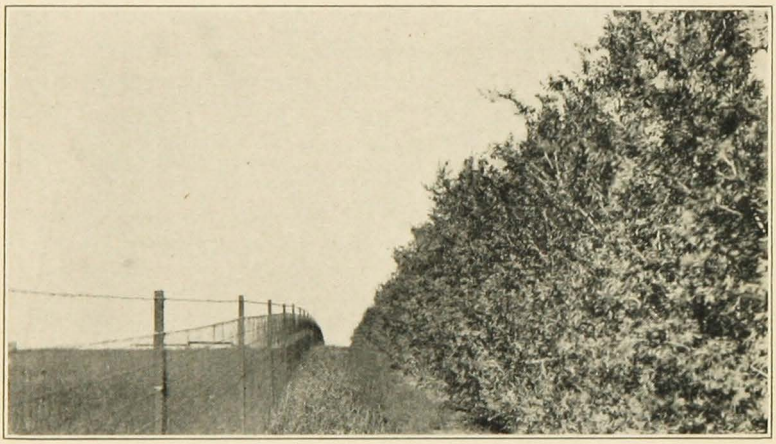


FIG. 9. A FIVE-YEAR-OLD PLANTING OF CHINESE ELM AT THE WEST CENTRAL STATION, MORRIS, MINNESOTA

Thinnings are absolutely essential to the proper development of shelterbelts and woodlots where the original plantings were made closer than 8x8 or 6x10 feet. Unless such plantations are thinned, the trees stagnate and deteriorate. The proper thinning of a shelterbelt or forest plantation is an art. Unless thinnings are properly made, they may result in far more harm than good. It is quite difficult, if not impossible, for one not trained in the work to apply general thinning rules to specific stands. Advice and instruction concerning thinning methods may be obtained from the Extension Forester, University Farm.

The trees remaining after thinning will grow rapidly, and ordinarily the stand will close after a few years. The size a tree can attain is limited by the amount of growing space available, and it therefore is necessary to give a tree sufficient room through thinning operations if it is to attain to merchantable size.

A Program of Tree Planting Adequate to Meet the Present and Probable Future Needs of the Prairie Region

Every farm in the prairie region of Minnesota would and should have an adequate shelterbelt and woodlot to provide protection against the cold winter winds and the hot summer winds, to supply continuously necessary fuelwood and the other wood requirements, to enhance the beauty of the countryside in general and the individual farm in particular and to improve the environment for birds and other wild life.

At no time in the past has the number and extent of tree plantings in the prairie region been adequate to meet the existing needs.

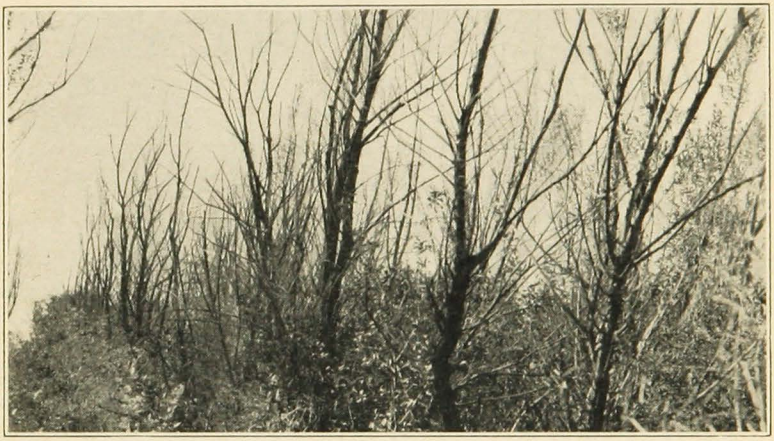


FIG. 10. DROUTH INJURY TO A WILLOW SHELTERBELT, STEVENS COUNTY, MINNESOTA

The wood requirements of the region have been supplied in a large measure by natural forest growth within the region, and this supply has now been largely depleted.

It is believed that the present and probable future minimum requirements of the region could be met if on the average five per cent or eight acres per farm were devoted to tree growth. Plantations of cottonwood and other rapidly growing tree species should average, with good care, approximately a cord per acre per year on a 30- or 40-year rotation. Many of the existing plantations have far exceeded this rate of growth. On the average, then, there would be available on each farm about eight cords of wood per year on a sustained yield basis.

It is assumed that approximately 1,000 trees would be planted per acre. On a 40-year rotation, it would be necessary to plant annually in the whole region approximately 22,000,000 seedlings or cuttings. It would be necessary to plant approximately this number of trees each year

for 40 years in order to plant five per cent of the area or 900,000 acres in trees. In general, no final cuttings would be made in these new plantations for 50 years, but thinnings would provide a large amount of wood. Because of the fact that there is little or no natural restocking in prairie plantations, it will be necessary to continue to plant annually approximately 22,000,000 trees to maintain the plantations on a sustained yield basis.

It would be in the public interest to establish tree plantings in the prairie region at a much faster rate. If five per cent of the area were to be planted to trees on a 10-year program, it would be necessary to plant 90,000,000 trees annually during the 10-year period. If the area were to be planted on a 25-year program, it would be necessary to plant annually during the 25-year period 36,000,000 trees or cuttings.

Because of the fact that very few trees now growing in the region will be living 25 years hence, the 25-year planting program suggested above is more desirable than a longer planting program because the longer period would leave the region with very inadequate wood supplies and inadequate protection against winds for a long period of time. The more rapid the rate of planting at the present time, the less critical will be the situation 25 years hence.

It will be unnecessary to reduce appreciably the present cultivated area in order to have five per cent of the area in trees. By replanting the old shelterbelt areas, woodlots, and cut-over natural forest areas, and by planting ditch banks, certain roadsides, and unused waste land an area equivalent to and even greater than that recommended would be in timber. However, because of the fact that it would be advantageous to crop production to plant narrow belts of trees along field borders and fence rows to serve as windbreaks or shelterbelts, a small area of land now cultivated could be devoted to tree planting most advantageously. Doing this would probably not reduce the yields of cultivated crops, but actually increase them.

As has already been indicated, several distinct types of plantings are recommended for the area. Trees can be planted in various ways to meet different conditions and serve different purposes.

One of the outstanding needs of the prairie region is adequate protection from winter and summer winds. Such protection may be best obtained by the planting of trees.

The shelterbelt is primarily for wind protection, especially for the protection of farm buildings. Altho the terms "shelterbelt" and "windbreak" are often used interchangeably, a shelterbelt is more commonly considered to be a relatively wide strip of trees with a definite form or arrangement, the purpose of which is not only to break the force

of the wind but to trap the snow. The windbreak, on the other hand, is more commonly considered to be a narrow strip of trees two to six rows wide and designed solely to give protection from wind.

A woodlot is established primarily for wood production and may be of any size or shape. It may, and in many cases should, serve to provide protection against the wind as well as to provide wood supplies. When suitable for the growth of trees, abandoned or unused land may be used for woodlots.

Field border plantings consist usually of one or a few rows of trees. In general, two to six rows of trees are usually sufficient for a field border planting, depending somewhat on the type of protection desired and upon the growth habits of the species to be used. It is only through an extensive system of such field border plantings that an effective shelterbelt or windbreak system can be obtained.

In the prairie region of Minnesota, there are hundreds of miles of ditches. Along many of these ditch banks, cottonwood has been established naturally. However, there are still many ditches along which trees have not established themselves and which are in need of planting. These ditch banks are probably the most favorable areas for tree growth in the entire region. An adequate moisture supply is always available from the ditches and the danger of losses due to drouth is negligible. Cottonwood and willow are especially suitable for ditch bank planting.

APPENDIX

RECOMMENDED HARDWOOD TREES FOR PRAIRIE PLANTING

Green Ash, *Fraxinus pennsylvanica lanceolata*

Green ash appears to be the outstanding hardwood tree for planting in the prairie region. Ninety-two per cent of the trees examined have survived the severe drouth of 1934, the highest survival record of any tree in the region. It grows well under practically all conditions encountered in the prairie region and is extremely resistant to drouth. The tree grows rapidly and the wood is hard and of good quality. Up to the present time, green ash has been practically free from serious fungous diseases and insect pests. For general prairie planting, no tree can be recommended more highly than green ash.

Cottonwood, *Populus deltoides*

Altho mature cottonwood suffered heavily during the severe drouth, this species has many desirable qualities for prairie planting. In youth, it appears to be quite drouth-resistant. It is the largest and most rapidly growing of all trees on the prairie. It produces wood at least twice as fast as the next most rapidly growing prairie tree and reaches merchantable size in 20 or 30 years.

When cottonwood is planted on sites where the moisture supply is supplemented by run-off water, such as along ditch banks or on low places, there is little danger of drouth damage. On dry upland sites, it may suffer severely from drouth when old.

Cottonwood is the only species of the genus Populus that can be highly recommended for planting in the Minnesota prairie region. Other species and varieties, such as Norway, Northwest, Russian, and Canadian poplars failed almost completely, 90 per cent either having been killed or dying. Furthermore, these varieties of poplars are also very susceptible to certain fungous diseases. Despite their rapid early growth, these trees are short-lived and possess few characteristics to warrant large-scale planting.

American Elm, *Ulmus americana*

The American elm is one of the most desirable trees for general prairie planting in Minnesota. It makes an excellent shade tree, attains large size, and is both hardy and drouth-resistant. It grows best when given plenty of growing space. With the exception of green ash, it has withstood drouth conditions better than any other species of major importance.

Chinese Elm, *Ulmus pumila*

It is difficult to make definite recommendations concerning the use of Chinese elm, because it has not been grown and tested for a sufficiently long period of time to show just how valuable a tree it is. It seems clear, however, that there are various varieties of Chinese elm, some of which are desirable and some of which are undesirable for prairie planting in Minnesota. The most desirable varieties of Chinese elm, which unfortunately have not yet been definitely determined, appear to be very promising trees for this region. Their remarkable drouth resistance combined with rapid growth are the chief advantages. They do not reach so large a size as the American elm and for this reason should not be given preference over American elm on the better sites. On the poorer sites, however, and in the drier parts of the region American elm is only moderately satisfactory. There the Chinese elm appears to be the better species to plant. During the winter of 1935-36 Chinese elm appears to have suffered badly in certain parts of Minnesota as many trees were injured and even killed by the prolonged low temperatures.

Honey Locust, *Gleditsia triacanthos*

Honey locust has been planted only to a limited extent in the prairie region of Minnesota, but in all places where it was encountered it appeared to be in excellent condition. Even in parts of the most seriously affected areas, almost 100 per cent of these trees survived. Honey locust grows rapidly and is a beautiful tree. The wood is hard and durable. It should be planted more extensively than in the past in the southern half of the state, where it appears to be well adapted. It may not be entirely hardy in the northern part of the state.

Bur Oak, *Quercus macrocarpa*

Most of the natural upland forest of the prairie region consists of bur oak, but it has been planted only to a very limited extent. Bur oak is difficult to transplant, because of its well-developed tap root, but it can be grown easily by planting the acorns in the fall soon after they are ripe. Altho bur oak is a slow-growing tree, it is one of the best adapted and most desirable trees for the region. It should be used in replanting natural forest areas or where permanent plantings are wanted. It is probably the longest lived of all trees in the Minnesota prairie region.

Willow, *Salix* sp.

Willows, largely the white willow, *Salix alba,* and the almondleaf willow, *Salix amygdaloides,* rank second in abundance in the shelterbelts of the region. They are used commonly as outside border rows around shelterbelts or for field border plantings. The willows grow rapidly,

but are short-lived and suffer severely from drouth, especially if densely planted. However, they sprout rapidly and usually can be maintained by cutting back to the stump.

Willows are desirable for temporary shelterbelts where rapid growth is a primary consideration. They are well adapted for planting on moist sites.

Black Locust, *Robinia pseudoacacia*

Black locust has been planted to a limited extent in the southern part of the region, where it was found to be making satisfactory growth and to be drouth-resistant. It is not hardy in the northern part of the region. Because of the fact that black locust suckers abundantly from the roots, it is not recommended for general planting. However, where it is hardy, it is a most valuable tree for control of soil erosion. The wood of black locust, because of its great durability, is valuable for fence posts.

Russian Olive, *Elaeagnus angustifolia*

Russian olive is a small- to medium-sized tree well known for its ability to withstand drouth and alkali. It is well suited for border rows of shelterbelts and is of high ornamental value.

Siberian pea tree, *Caragana arborescens*

This species commonly grows in bush form and is used chiefly for hedges and border rows of shelterbelts. It is quite drouth-resistant, but probably not very long-lived. For ornamental and hedge purposes, the Siberian pea tree should be used more widely than at present.

Black Walnut, *Juglans nigra*

Black walnut has been planted widely in the prairie region, but it is hardy only in the southern part. Usually it requires more moisture than the upland prairie region affords, but it will do well on selected sites. It should be sheltered from winds, but not crowded by other trees, serving best as a yard tree where it can be given necessary care. Black walnut is commonly used for road and field border plantings. Its wood is of high quality and its fruit is the common black walnut.

Silver Maple, *Acer saccharinum*

Altho silver maple has been used very extensively for prairie planting, it is not well suited for this purpose. In that portion of the prairie region where the drouth was most severe, silver maple was almost completely wiped out. This tree seldom lives to be over 50 years old, and many plantings were found to be decadent before 40 years. If used at all, silver maple should be used sparingly. Because of the fact that silver maple is not drouth-resistant, its use should be confined to the east-

ern part of the prairie region where rainfall is generally more favorable than in the western part.

Boxelder, *Acer negundo*

Boxelder has been planted more commonly in the prairie region of Minnesota than any other tree, despite the fact that it is not very well suited for this purpose. It is only moderately drouth-resistant and it is short-lived. Approximately only 40 per cent of the trees were found to be in good condition during the summer of 1934. Trees in stands 40 to 50 years old were invariably found to be decadent and in need of replacement. Many boxelder shelterbelts only 30 years old were found in poor condition.

Except for fuel, boxelder wood is of low quality. In general, boxelder trees have a poor shape and are subject to disease and insect attack. There are few, if any, situations in the prairie region where a better tree than boxelder can not be used.

RECOMMENDED CONIFERS

Ponderosa pine, *Pinus ponderosa*

Ponderosa pine, altho not very extensively used in the past, appears to be one, if not the most, desirable coniferous tree for general use in the prairie region. It should be emphasized, however, that there are numerous varieties of geographic races of Ponderosa pine, and as far as is known, only the so-called Black Hills variety and varieties from the Eastern foothills of the Rocky Mountains are satisfactory. These varieties of Ponderosa pine are very resistant to drouth, make a satisfactory growth, and have a desirable form. Ponderosa pine makes an effective windbreak, but it should not be planted in too dense stands or shaded by other trees. The foliage of young trees is very dense, but gradually thins out as the trees become older.

Juniper or Red Cedar, *Juniperus virginiana* and *Juniperus scopulorum*

Juniperus virginiana, the Eastern red cedar, and *Juniperus scopulorum,* the Rocky Mountain juniper, are grouped together here because of the similarity of their habits. Both species appear to be drouth-resistant, the Rocky Mountain juniper somewhat more so than the Eastern red cedar. Here again there appears to be a considerable number of geographic races of Rocky Mountain juniper, and only that race occurring on the eastern slopes of the Rocky Mountains appears to be suitable for prairie planting.

Altho junipers grow somewhat slowly, they are excellent for border rows and low windbreaks. They appear to be fairly long-lived under prairie conditions.

Certain junipers, and especially the Eastern red cedar, are the alternate hosts of apple rust, an important disease of the apple. These trees may be, therefore, an important menace to commercial apple orchards and other apple trees in the immediate vicinity.

Colorado Blue Spruce, *Picea pungens*

Colorado blue spruce appears to be the most drouth-resistant of the various species of spruce grown in the state. Colorado blue spruce has not been planted as extensively as its characteristics would seem to justify, probably largely because of the high cost of planting stock. Green specimens of Colorado blue spruce, however, are much cheaper than the blue specimens. It makes an excellent shelterbelt tree, especially while young, because of its dense foliage. As the tree reaches maturity, and particularly if partially shaded, the foliage thins out. The age limit of blue spruce in the prairie region appears to be 40 or 50 years.

White Spruce, *Picea glauca*

During recent years white spruce has been difficult to establish, and heavy losses occurred even in young plantings. White spruce should not be planted extensively in the western part of the prairie region, but may be used on the better sites in the eastern part of the region.

Western White or Black Hills Spruce, *Picea glauca albertiana*

Western white spruce is a variety of the ordinary white spruce. There appears to be little reason for believing it to be superior to white spruce in drouth resistance. Both suffer badly from extensive drouth.

European Larch, *Larix europea*

European larch is a more satisfactory tree for prairie planting than the survival data in Figure 4 would indicate. The 84.8 per cent mortality shown in that figure is influenced somewhat by a large stand of this tree in the heart of the critical drouth area. This stand was heavily pastured, and 90 per cent of the trees had been killed. Wherever European larch was encountered elsewhere in the region, it appeared to be highly drouth-resistant. This tree grows rapidly and in appearance closely resembles the native tamarack. It deserves to be widely planted as a shelterbelt tree, but consideration must also be given to the fact that it loses its needles in the fall of the year.

Norway Spruce, *Picea excelsa*

Norway spruce, a European tree, is about equal to white spruce for prairie planting. It is not sufficiently drouth-resistant for planting in the western part of the region, but does quite well in the eastern part. It grows more rapidly than white spruce, but after middle age its foliage

begins to thin out. Forty to 50 years is the usual life span of Norway spruce on the prairies.

Northern White Pine, *Pinus strobus*

Under the best conditions, in the eastern part of the prairie region white pine makes excellent growth. If exposed, it will not withstand extreme periods of drouth. White pine is an admirable tree for the eastern part of the region, but it is not recommended for planting in the western part.

Norway Pine, *Pinus resinosa*

Norway pine occurs commonly and does well in shelterbelts in the eastern part of the region, but does not appear to be satisfactory for planting in the western part. It appears to be somewhat similar to white pine in its ability to withstand drouth conditions. Like the white pine, it makes an effective and beautiful shelterbelt, but it is inferior to Ponderosa pine.

Scotch pine, *Pinus sylvestris*

Scotch pine is the most extensively planted evergreen in the region, but its performance does not warrant its wide popularity. Almost 44 per cent of the Scotch pine was dead in the summer of 1934. It is possible that some varieties of Scotch pine are well adapted for prairie planting, but until this fact has been definitely determined, Scotch pine should be planted sparingly, if at all, in the prairie region, except where past experience indicates it will be satisfactory.

Balsam Fir, *Abies balsamea*

In most of the prairie region, balsam fir has failed almost completely. Only under favorable conditions in the eastern part of the region has it made satisfactory growth. Even there it should be planted only on sheltered moist sites.

Northern White Cedar, *Thuja occidentalis*

Northern white cedar (arbor vitae) has been widely planted, but it does not withstand the drouth satisfactorily. While Figure 4 shows only small losses for northern white cedar, the living trees were represented largely by yard trees and special care undoubtedly contributed greatly to the high percentage survival. Northern white cedar is known to have suffered severely from drouth even before 1934 and only a comparatively small number of trees remain in the region. The general failure of northern white cedar throughout the entire southern part of the state indicates clearly that it is not suited for prairie shelterbelt planting.

Coniferous transplant stock is relatively expensive, but seedlings are comparatively cheap. Farmers who are not in position to purchase a sufficient amount of transplanted stock to get a fair proportion of these species in their shelterbelts or woodlots may wish to purchase seedling stock and line it out the same in nursery rows for one or two years before moving to a permanent position.

OTHER SPECIES

Some species of trees have been planted only to a very limited extent in the Minnesota prairie region. Altho an insufficient number of specimens were available to serve as a basis for final recommendations, certain of these trees appear to be very promising.

Hackberry, *Celtis occidentalis*

Only a very few specimens of hackberry were encountered in the survey, but such specimens as were encountered appeared to be drouth-resistant and thrifty. Hackberry has been planted elsewhere in the prairie region and is considered a valuable species. It is recommended for planting in the Minnesota prairie region. Seed for growing hackberry in this region should be obtained from trees known to be adapted to prairie conditions.

Douglas Fir, *Pseudotsuga taxifolia*

Douglas fir has been used in Minnesota for shelterbelt planting only during recent years. Good varieties of Douglas fir appear to be very promising, but it is quite likely that only seed collected from trees on the dry eastern slopes of the Rocky Mountains will develop trees capable of withstanding prairie conditions.

Silverberry, *Elaeagnus argentea*

Silverberry is a medium-sized shrub occurring naturally in western Minnesota. It appears to be very hardy and drouth-resistant, altho sufficient information concerning these points is not available. Silverberry should be a satisfactory shrub for hedges and border row planting.