CANADA

DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT

SHELTERBELTS IN THE GREAT PLAINS REGION OF THE UNITED STATES

by

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A tour was made in August 1966 to study and compare shelterbelt practices and related research in the Great Plains area of the United States with that being practiced in the corresponding area of western Canada.

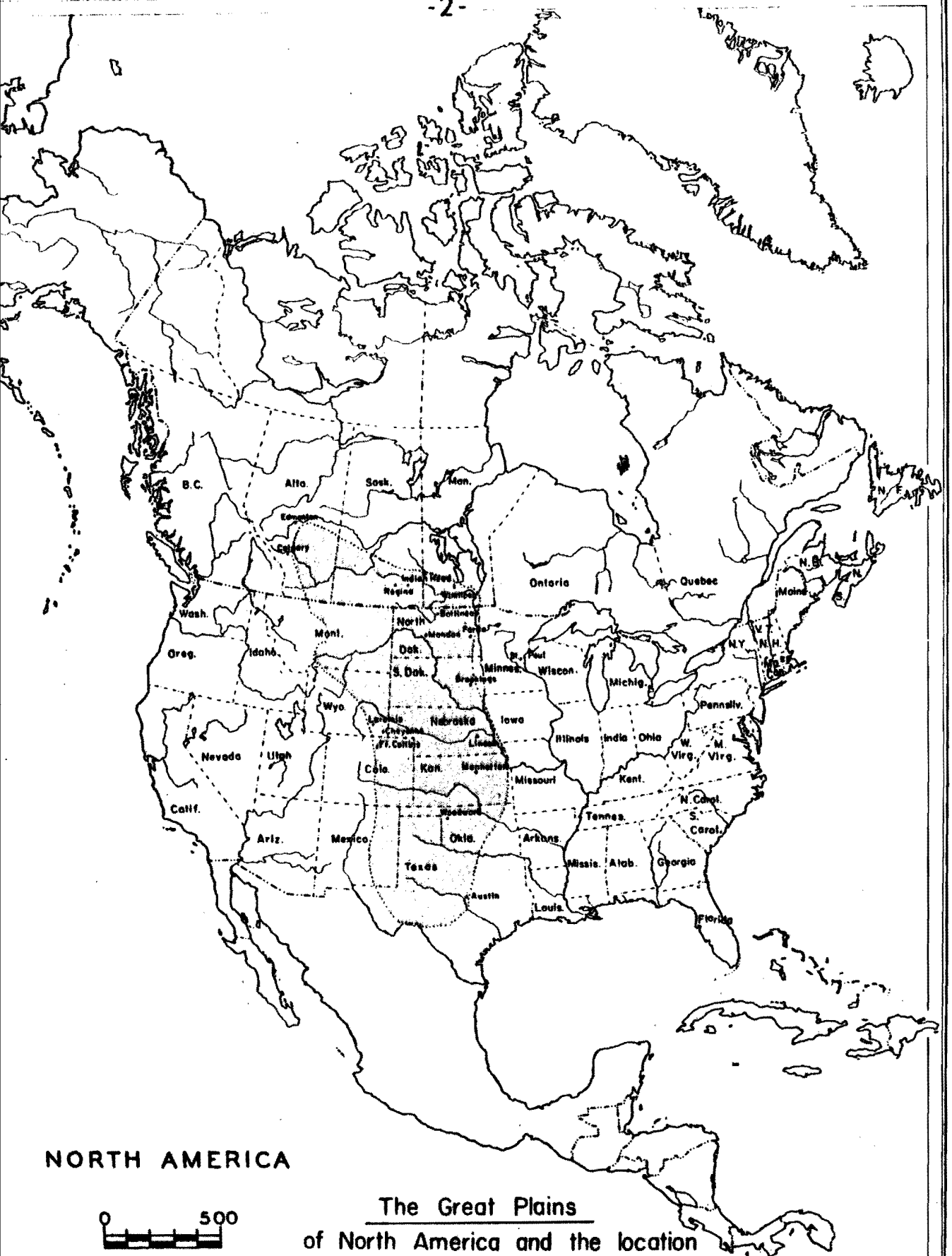
The historical background of shelterbelt work in the United States is somewhat similar to that of western Canada, except that in the United States government agencies have had a more active role. At present the organization of the practical aspects of shelterbelt plantation is more advanced in the United States in that more modern techniques are employed. Early plantations in the Great Plains area provide excellent material to observe the behavior and usefulness of many different tree and shrub species. At the present a total of 85 shelterbelt research studies involving over 15 institutions are active in the United States.

HISTORICAL BACKGROUND OF SHELTERBELT PROGRAMS

The Great Plains extend from San Antonio, Texas, to Edmonton, Alberta, a distance of about 1,700 miles in a band 500 to 800 miles wide (see map). Trees have been planted on the Plains since the first settlement. The program of tree planting and the cultural practices may be divided into four historical periods (7) as follows:

Period up to 1925

Limited assistance was given to the farmers by the United States Department of Agriculture (U.S.D.A.) Extension Service personnel in planning windbreaks. The farmers purchased most of the planting stock from commercial nurseries and were responsible for planting and maintaining



NORTH AMERICA

0 500

MILES

The Great Plains of North America and the location of Institutions involved in shelterbelt research.

their own shelterbelts. During this period certain States in the Great Plains allowed the farmer a tax exemption or provided a bonus for the establishment of a shelterbelt.

Period - 1925 to 1935

During the period 1925 - 1935, personnel from the U.S.D.A. field stations and County Agricultural Agents assisted farmers in the planning and protection of their plantations. The results of this work are still visible in a few counties where the County Agent took a particularly keen interest in his work. Most planting stock was provided at cost through the Clarke-McNary Act, established in 1924, administered by the U.S.D.A. and supervised by the Forest Service. Under this Act which is still operative the Secretary of Agriculture cooperates with the various States in the production and distribution of forest tree seeds and planting stock to establish forests, windbreaks, shelterbelts and farm woodlots on denuded or non-forested land. The Agricultural Colleges and universities of various States also cooperate by providing technical advice and demonstrations in the different aspects of the work.

Period - 1935 to 1942

The Prairie States Forestry Project which was actually a shelterbelt project administered by the Forest Service of U.S.D.A., had a tremendous influence on tree planting activities during the period 1935 - 1942. The aims of the program were two-fold; first to establish a network of field shelterbelts on agricultural lands from North Dakota to northern Texas, and secondly providing employment. The program was administered by a regional director, located in Lincoln, and a technical staff in the various States.

The project foresters reached a simple agreement with each landowner before planting. The landowner agreed to prepare the land, to fence the area and to maintain the plantings. The Forest Service provided the technical advice and planting stock; they also did the planting, replanting and controlled the weeds and insects, all free of charge.

During the 8 year period 18,600 linear miles of shelterbelts were planted involving 150 million trees and shrubs distributed on about 30,000 individual farms. These shelterbelts are now about 30 years old and are an excellent source for shelterbelt research.

In developing the shelterbelt network, the main objective was to establish at least two one-mile-long shelterbelts at half-mile intervals within each square mile. These basic belts usually consisted of 10 rows at intervals of 8 to 10 feet. Within the rows trees were spaced at intervals of 8 to 10 feet in the east and 12 to 14 feet in the drier areas to the west (6). Between and parallel to the basic shelterbelts, intermediate shelterbelts 5 to 7 rows wide were planted at intervals of 1/8 to 1/4 mile. For more complete protection, cross barriers of 3 to 5 rows each were planted at right angles to the basic and intermediate belts. The orientation of these belts depended on the prevailing wind direction, north-south in North Dakota and east-west in the remainder of the Great Plains.

Period - 1942 to the present

The Prairie States Forestry Project was terminated in 1942. At this time all shelterbelt work, including the tree nurseries, became the responsibility of the Soil Conservation Service. During this period the planting

of field shelterbelts on the plains gradually diminished with the exception of single-row shelterbelts in North Dakota. At the present time soil conservation technicians assist the farmers in the planning and selection of suitable tree species. The planting stock is obtained at cost either through the Clarke-McNary program administered by the State or Extension Forester or directly from the Soil Conservation District nurseries. Land owners prepare the land and do the maintenance. The Soil Conservation personnel usually do the planting and necessary spraying for weeds and then charge the landowner on a per tree basis. They are, however, reimbursed for up to 80% of the cost of tree establishment and maintenance under the Agricultural Conservation Program of U.S.D.A.

Although many shelterbelts have been planted not more than 5% of the lands in need of protection are adequately protected (2).

THE ORGANIZATION OF THE PRACTICAL ASPECTS OF SHELTERBELT PLANTATION

Productive soil, adequate water and well-managed woodlands are the foundation of agriculture. To protect these essential resources the Agricultural Conservation Program was developed and now serves on a shared cost basis to accomplish those projects which may not otherwise be attempted. Cost is shared only on satisfactorily performed conservation practices for which Federal cost-sharing was requested before the work was begun. Shelterbelts planted for wind and water erosion control are included in this program. To illustrate the minimum specifications for cost sharing the "Performance Requirements" for Nebraska are quoted (9).

"Site Preparation-Site preparation is required for tree or shrub plantings in accordance with the following provisions:

(1) For hardland areas (generally areas 1, 2, 4, and 5 of the Tree Planting Map) "(See Appendix I): "The site shall be prepared by plowing, discing, and harrowing before planting. It is recommended that the plowing be done the preceding fall, and the discing and harrowing in the spring just before planting.

(2) For light sandy soils (generally area 3 of the Tree Planting Map) or where plowing is not necessary: (a) For conifer plantings in grassland, plow a shallow furrow at the time of planting and plant in this furrow. (b) For broadleaf plantings in grassland, a 4-foot strip must be plowed and disced for each row (preferably the preceding fall). If this strip is subject to wind erosion, it should be planted to cover crop the year before planting or mulched after the trees are planted. (c) On cultivated land, trees and shrubs should be planted directly in the stubble or in a cover crop established the previous year and site preparation will be confined to tilling a strip approximately 4 feet wide to kill the weeds where the trees will be planted.

(3) In the arid areas of the State, in the summer fallow area, and in any area where the site has been devoted to legumes or sod, the following site preparation is recommended. Start the preparation of the site in the spring of 1966 for the planting to be made in 1967. In the summer fallow area, start the preparation of the site in the spring and fallow all summer, maintaining a rough trashy residue on the surface. Where legumes or sod are present, the site should be plowed in the spring

and fallowed all summer, keeping it free of excessive weed growth.

If sufficient stubble mulch is not present on the surface of the site to prevent serious wind erosion during the winter months, the county committee should require that a winter cover crop be planted thereon.

Planting Trees and Shrubs-Trees and shrubs must be planted in accordance with the following minimum requirements and must be protected from fire and livestock damage.

(1) Species of trees and shrubs to be used in the different areas of the State are shown in the following chart". (See Appendix I). " The use of other species must have the approval of the technician who makes the determination of need and practicability.

(2) Two- or three-row windbreaks must contain at least one row of conifers, and windbreaks of more than three rows must contain not less than two rows of conifers (except on sites which prohibit their use, such as very wet, saline, or alkali sites). Windbreaks which are located at the farmstead must contain two rows of conifers, or one row of shrubs and one row of conifers, on the north or west side of the windbreak.

(3) To obtain good tree growth, the rows should be spaced at least 12 feet apart.

(4) Cottonwood and Siberian (Chinese) elm shall not be used in the same planting. These and other fast-growing deciduous tree rows (such as Russian olive, willow, or boxelder) should be located at least 24 feet from pine rows.

(5) Multiple-row plantings of a single species of deciduous trees are not eligible for cost-sharing.

(6) Underplanting to increase the density of existing windbreaks will bedone with red cedar.

(7) One-row windbreaks will qualify for cost-sharing only if they are a part of a planned wind erosion control system.

(8) Shrub plantings, beneficial to wildlife, that control erosion on steep, erodible, or gullied areas are eligible for cost-sharing.

(9) Flowering shrubs are recommended to promote the "Natural Beauty of the Countryside."

(10) When selecting the site for a windbreak, farmers should be cautioned not to choose a site which will obstruct visibility or cause a snow hazard on main traveled roads.

(11) When selecting the site for a windbreak consideration should be given to locations which will screen unsightly areas.

Fencing-If fencing is required to prevent the entry of livestock until the stand is well established, cost-sharing may be approved for the construction of permanent fences necessary to protect the area seeded, excluding boundary and road fences.

Whenever cost-sharing is allowed for the construction of fences, such fencing must be constructed of new materials. Posts shall be of steel, cedar, Osage-orange, or black locust. Other wooden posts may be used if treated with a preservative. Wooden posts shall be not less than a nominal 3" top diameter (Osage-orange 2"). Posts shall be spaced not more

than one rod apart and carry at least three strands of standard barbed wire, or at the farmer's option the posts may be spaced not more than 20 feet apart and carry at least four strands of standard barbed wire, or a woven wire fence.

Weed Control-Except for grassland furrow plantings of conifers in light sandy areas, the planting shall be kept free from excessive weed growth during the year in which they are planted. On cultivated sandy soils, weed control will be confined to the tree row, leaving a strip of vegetation between the rows.

Where weed growth will create serious competition with the new planting, the county committee will require that weed control be continued in succeeding years until the trees attain sufficient growth that weeds cannot compete with them." The fulfillment of the specifications is usually checked by the Soil Conservation Service or State District Foresters.

The Soil Conservation Service of the U.S.D.A. is involved in the working program. District and Area Soil Conservationists provide professional advice on planning shelterbelts and selecting the proper tree species. The State Forester processes the applications for planting stock from County Agents, Soil Conservation Districts and individual farmers. The coniferous species are ordered from Federal and State nurseries. The broad-leaf species are ordered from private nurseries who ship the material to the government nursery where it is combined with the coniferous species into a single shipment. The shipment is packed in wax-lined boxes with wet moss and transported to the district stations in refrigerated trucks. Planting material

at the station is kept under refrigeration; only the amount required for a single day is removed at one time. If long distance transportation is needed the planting material is shipped by air. The actual planting is usually done by a crew hired by the Soil Conservation District.

TREE AND SHRUB SPECIES USED IN SHELTERBELT PLANTATIONS

Climatic and edaphic conditions vary considerably in the four states visited. The lack of water is usually the limiting factor for tree growth. Average annual precipitation increases from 16" to 30" from the semi-arid west to the east in North and South Dakota, and from 16" to 28" in Nebraska and Kansas. The considerable variation in tree growth and species composition observed between those two areas justifies the operation of the seed source testing projects.

According to Read (6), 5% of all the Prairie States Forestry Project shelterbelts have been destroyed, 18% are poor wind barriers, 29% are fair and 48% are good or excellent. The use of poor species or a poor combination of species is only partly responsible. The older windbreaks provide an excellent basis to judge the performance of species planted in a variety of conditions. Species which may be useful for the Alberta Region are discussed below.

Trees

Populus deltoides var. *occidentalis* - Plains cottonwood (Figs. 6 and 7)

It is surprising that this is the only poplar species widely propagated in shelterbelts. It is a native species which is free of any serious disease but survival and growth is good only on the lighter soils where the water table is within 15 feet. In heavy clay and dry sites this species would not survive longer than 10-12 years. The Sioux land

rust-resistant variety was developed to combat Melampsora occidentalis leaf rust which can cause considerable damage.

Since cottonwood is native in southeastern Alberta, an extensive trial on suitable sites would be justified as this species is a possible replacement for the widely propagated but disease-stricken hybrid poplars. Although most of the diseases and insects found on this species in the United States are also present in Alberta (1) no severe damage has been observed on any of the native stands.

Ulmus americana - white or american elm (Figs. 2 and 7)

This native species of the Great Plains grows well in any soil where adequate moisture is present. In deep sand and on shallow upland sites high mortality occurs from drought. The major problem with the species is the Dutch elm disease which was first discovered in one county of Nebraska in 1960, and is now rapidly spreading. In 1966 it was collected in 44 counties in Nebraska and Kansas.

White elm in Alberta is used mainly for ornamental plantings. Although Dutch elm disease is not present in the Province yet, there is always a danger of an accidental introduction. For this reason wide propagation of this species is not recommended.

Ulmus pumila - Siberian elm (or Chinese elm) (Fig. 9)

This species is listed under the fast-growing tall-species (6). It grows rapidly except on shallow upland sites, where it still grows taller than the other deciduous species. This species is drought-resistant, widely propagated and regenerates very well in many shelterbelts. According to Mr. Slabaugh, Bottineau (8), exposed trees may freeze back to the ground in North Dakota, and Chalaropsis thielavioides causes root rot in the nurseries. Slime flux, Erwinia nimipressuralis, occurs on older trees.

In Alberta, Siberian elm is rather slow growing and suffers from frost, which usually affects twigs and smaller branches. It is widely propagated because of its drought hardiness. The root rot has not been discovered in Alberta but a canker disease, Tubercularia vulgaris, has caused considerable damage in one shelterbelt at Brooks. Since the presently known pests of this species do not cause too much concern, wide propagation of the species is justified.

Fraxinus pennsylvanica var. subintegerrima - Green ash (Figs. 1,2, and 7)

This is a native species of the Great Plains and is widely propagated in shelterbelts. It is one of the best slow growing species from the standpoint of survival and adaptation. When green ash is stunted by heavy sod for a prolonged period it responds very well to release by sod removal in experimental shelterbelts (5). The ash borer, Podosesia syringae fraxini, is causing considerable damage. Heartwood decay, caused by Fomes fraxinophilus, is common even on young trees with 2-3" diameter.

Green ash is native to the southeastern corner of Alberta. It was planted in many shelterbelts but suppression by fast growing species due to improper spacing and grass competition have affected its growth. Since none of the above mentioned pests have been found frequently in Alberta, a wider propagation of this species, employing proper cultural practices, is desirable.

Celtis occidentalis - hackberry

This species performs best on deep, silty loam sites. Regardless of the depth of the soil it grows poorly on sandy soils. It grows slower than green ash. Since the northern Great Plains are too cold for this

species, it probably would not survive in Alberta.

Gleditsia triacanthos - honeylocust

It grows well on fertile clay soils. It is widely propagated but not preferred because of the suckering towards cultivated land. It is ineffective in shading out grasses because it has an open type crown with sparce foliage. The cultivation of this species in shelterbelts is limited.

Pinus ponderosa - ponderosa pine (Fig. 8)

Ponderosa pine is a native tree in the western fringe of the southern and central Great Plains. It is one of the most commonly planted of the drought-hardy coniferous species. Although it stagnates at the beginning it grows fast once established. The results of a recent progeny test should determine the best seed sources of ponderosa pine for shelterbelt use in the different regions of the Great Plains (Fig. 5). A pine tip moth, Rhyacionia frustrana bushnelli, commonly damages the leaders and slows down height growth. Dothistroma pini, needle blight and Diplodia pinea, pine twig blight, also cause some damage, but both can be controlled by chemicals.

Ponderosa pine has never been planted in shelterbelts in Alberta. However, a 50 year old group of 10-15 trees in Rich Valley, north of Gun, and individual oramental trees in Edmonton ranging from 10 to 30 years of age exhibit excellent growth without serious pest problems. The pests causing concern in the United States have not been collected on native pine in this Region. Ponderosa pine is an excellent coniferous species for shelterbelts and should be tried in Alberta.

Pinus nigra - Austrian pine

Austrian pine is an introduced species which grows very well on the Plains. The density and form of crown is superior to ponderosa pine

and since it is not affected by the tip moth, the height growth is more uniform than that of ponderosa pine. However, it is also susceptible to Dothistroma and Diplodia blights.

Austrian pine prefers sites with a high lime content. A group of trees growing in the Mount Pleasant Cemetery, Edmonton exhibit good growth. This is another species which should be properly tested in Alberta.

Pinus sylvestris - Scots pine

Scots pine was rarely planted in American shelterbelts but a wide provenance study emphasizes the possible future importance of this species. In the northern Great Plains (Denbigh Forest) trees from a Siberian seed source grew 10 feet in 5 years (Fig. 4). In Nebraska (Horning Farm) trees from Vosges Mountain, southeastern France, are exhibiting the best growth characteristics of the provenances tested there (Fig. 12). The major pests are the tip moth and the two blights.

During the early days Scots pine was planted more often in Alberta than in American shelterbelts. Good 35-40 year old shelterbelts prove the usefulness of this species in Alberta (Larson farm, south of Provost, Severtson farm, Enchant, etc.). Poorly performing plantations of unknown origin in the foothills emphasize the importance of a good seed source. A stand of approximately 80 trees in Rich Valley from a west Russian (Leningrad) seed source are growing extremely well. Scots pine should be more broadly planted in Alberta than it is at present.

Shrubs

Juniperus scopulorum and J. virginiana - Rocky Mountain and red juniper (Figs. 4,6,7 and 11)

Both junipers were planted mainly in the outside rows constituting the shrub layer. Their unexpected height growth (up to 30 feet within 25 years) and good low crown density provide an excellent shelterbelt tree to be used for dual purposes (shrub and conifer row). Phomopsis and Cercospora blights cause damage in nurseries as well as in shelterbelts, but they can be controlled with chemicals containing phenylmercury (3), and Bordeaux mixture respectively.

Junipers have not been planted in Albertan shelterbelts. Rocky Mountain juniper is native in the high mountains of western Alberta. Seed from the southeastern extremes of its distribution would be more suitable for Albertan conditions. Both of these species should be tried in the Region.

Eleagnus angustifilia - Russian olive (Fig. 1)

Russian olive has been widely propagated in shelterbelts. It grows well for the first 20-25 years but than collapses. However on alkaline sites it was sometimes the only surviving species. It was always planted in the shrub row, next to conifers, but because of its early fast growth, the slower growing conifers suffered from suppression. An unidentified canker was discovered recently which gradually kills an infected tree. The first symptom of the disease is a wilting of the foliage and gum exudation from branches and stem. Since the canker is not a typical sunken type, it is difficult to locate. The distribution of the disease in the Great Plains has not been completely determined. The conclusion is that this species has only limited usefulness in shelterbelts.

Russian olive is gaining popularity in Alberta but the above mentioned limitations justify its replacement by one of the native shrubs such as Shepherdia argentea - Silver buffaloberry. Its cultivation should be

restricted to alkaline sites.

Prunus virginiana and P. americana - chokecherry and American plum

Chokecherry is commonly used in outside rows. The recently discovered Western X virus (4) and Dibotryon morbosum black knot disease may limit its use in American shelterbelts. American plum produces superior low level density compared to chokecherry. In combination with ponderosa pine or Austrian pine a belt is almost impenetrable. It sprouts towards cultivated fields. Necrotic ring spot virus, brown rot and plum pockets caused by Sclerotinia fructicola and Taphrina communis are the most common diseases of plum. Considerable decline and death of American plum has been observed in shelterbelts recently. Since the described diseases, with the exception of viruses, have been found in Alberta, these shrub species are not recommended for trials in Alberta.

THE ORGANIZATION OF SHELTERBELT RESEARCH

A number of federal and state agencies are conducting shelterbelt research with co-ordination provided through a Forestry Committee of the Great Plains Agricultural Council. Within the United States Department of Agriculture there is a Forest Service Shelterbelt Laboratory at Bottineau, North Dakota and another at Lincoln, Nebraska. These stations have a co-ordinated program of research into tree improvement, nursery methods, windbreak establishment, tree growth-site relationships, and tree and nursery pest problems. Currently, seven scientists with support staff are involved and further expansion is planned. Research has been conducted at these stations since 1930, and 1953 respectively.

Another U.S.D.A. agency is the Agricultural Research Service with four stations actively involved in studies of windbreak influences on climate, crop production, soil erosion and other ecological factors. These stations are located at Mandan, North Dakota; Cheyenne, Wyoming; Manhattan, Kansas; and Woodward, Oklahoma. The Mandan station is the oldest. It has been involved in research since 1916. Yet another agency is the Soil Conservation Service which carries out limited research on site-windbreak performance in Lincoln, Nebraska. The U.S.D.A. Extension Service has an educational function in co-operation with State agricultural colleges.

There are six state agricultural experiment stations involved in various shelterbelt research work. These are located at Fort Collins, Colorado; Manhattan, Kansas; Lincoln, Nebraska; Brookings, South Dakota; Fargo, North Dakota and Laramie, Wyoming. The Stations in Kansas, Nebraska, and South Dakota have one research forester each. Their work is co-ordinated with that of the Forest Service Shelterbelt Laboratories.

The State forestry personnel are mainly involved in the administration of the practical shelterbelt work rather than in research.

Other agencies such as the Colorado Game, Fish and Parks and Texas Parks and Wildlife Department have limited programs in shelterbelt-wildlife habitat studies.

Finally there are a number of universities including North Dakota State University, North Dakota School of Forestry, School of Forestry, University of Minnesota which have co-operative and independent research projects dealing with shelterbelt problems.

ACTIVE RESEARCH PROJECTS AND FUTURE PLANS

The Forestry Committee of the Great Plains Agricultural Council conducted a survey of present research programs and future research needs. The results of this survey were published (2) and 85 active research projects are listed providing a summary of the present status of knowledge in each subject and an estimate of further work required. Besides listing 52 different problems where the Committee believed additional research is needed, they also estimated the number of man years of work required on each problem. According to these calculations, 1,430 man-years of research is needed in Windbreak Forestry and Wildlife Plantings which should be undertaken in the next 20 years. To meet this objective 76 full time scientists will be needed, nearly 4 times the present staff. Windbreak Forestry is subdivided by the Forestry Committee into the following subjects: Windbreak influences, Trees and shrubs for windbreaks, Windbreaks and the Plains environment, Production of planting materials, Windbreak establishment, Windbreak protection, and Windbreak management.

Wildlife planting problems are discussed separately from Windbreak Forestry and the work is conducted by the different State Fish and Game Departments. Outdoor recreational problems are also included.

CONCLUDING REMARKS

Shelterbelt research is urgently needed in the Alberta region. Much of the work from the United States, particularly that from the Northern Great Plains, is probably applicable to the Alberta region but the slight soil and climatic differences which occur, make it adviseable that their

results be tested under Alberta conditions.

The following priorities for research are recommended:

The soil variations in the previously defined zones (1) should be investigated and suitable tree and shrub species for the different soil types in these zones should be selected. The effects of spacing and of species composition on survival, growth and effectiveness of shelterbelts should also be studied in the different zones.

A fast growing and pest resistant poplar species is required for the Dry Prairie and Parkland Regions. Various seed sources of Rocky Mountain and red juniper, lodgepole pine, ponderosa pine, Austrian pine, Scots pine, and spruce should be tested to select drought and frost hardly provenances of coniferous species with suitable form and growth characteristics. Similar work should be done with slow growing deciduous tree and shrub species.

The major practical problems in existing shelterbelts in Alberta arise from the use of single species, usually poplar hybrids, the overcrowding and excessive herbaceous competition. It is therefore urgent to find suitable methods for rehabilitating existing shelterbelts, more specifically to find improved methods to transform single species shelterbelts into belts of mixed species composition, to release selected components in mixed belts, to remove competing herbaceous vegetation, and to replace rows or portions of shelterbelts which have died or are seriously diseased.

Since survival has been low during the past years (1) in Alberta, research is therefore necessary to improve nursery, storage, transportation and planting practices, to increase survival and reduce costs.

Regional research work in Alberta should be coordinated with that of Dr. W. H. Cram, Indian Head and the Manitoba-Saskatchewan Region.

ACKNOWLEDGMENTS

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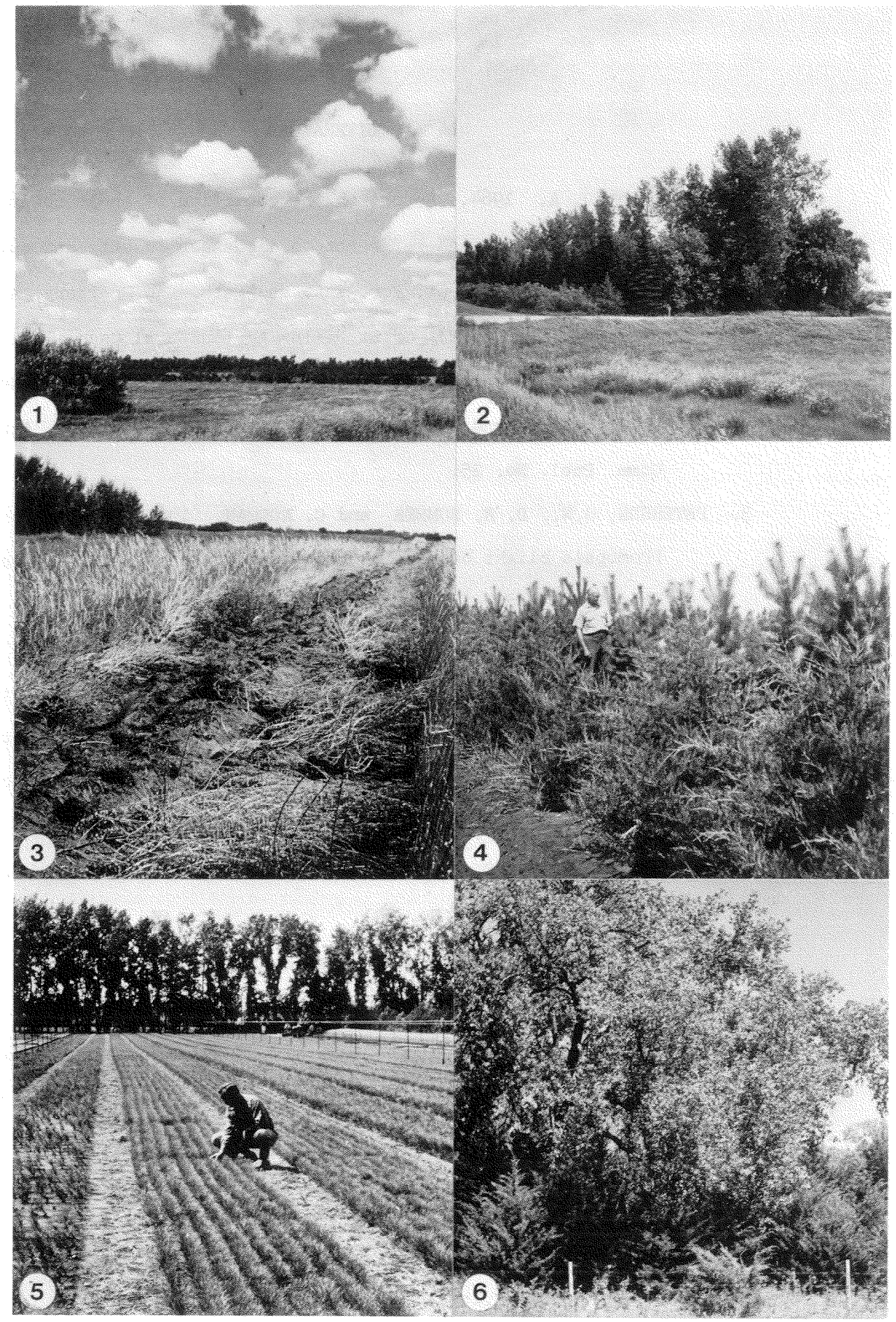
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1. Single row field shelterbelts west of Bottineau, N. Dakota. Russian olive, green ash and Siberian elm rows, spaced approximately 40 chains apart.

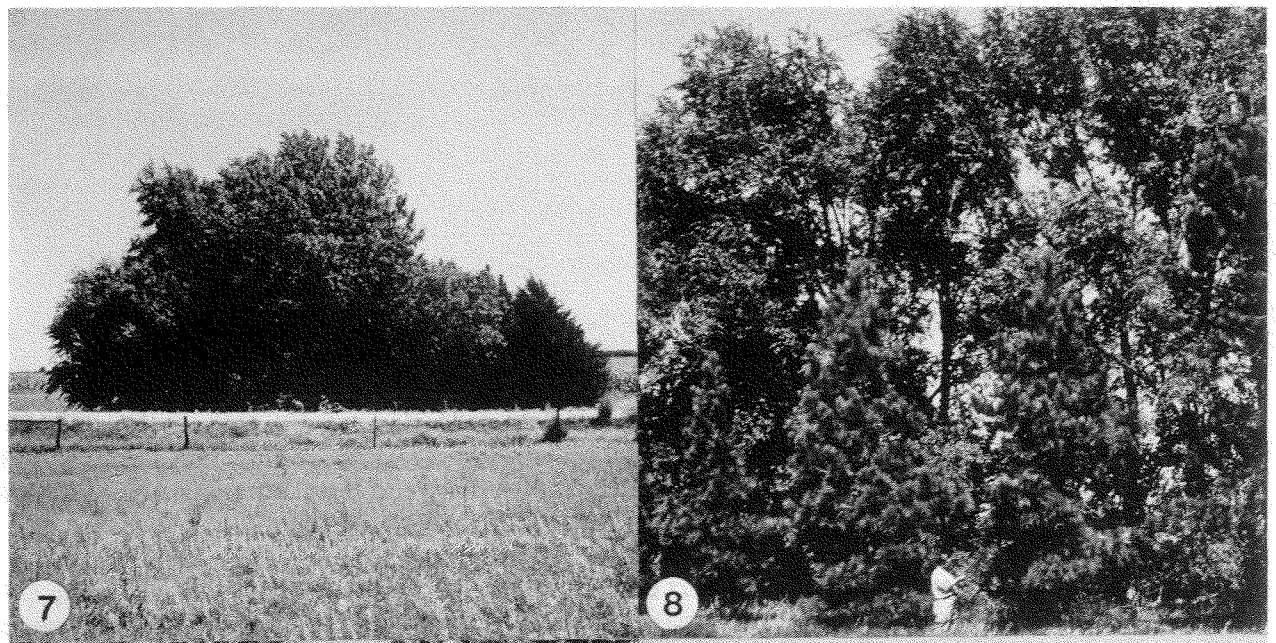
2. Thirty year old shelterbelt west of Willow City, N. Dakota. Proper spacing provided ample growing space for the trees. Species composition from left to right: honeysuckle, Rocky Mountain juniper, blue spruce, green ash, white elm, cottonwood, boxelder, Russian olive.

3. Herbaceous wind barrier. Winter rye sown in 4 - 6' wide strips to protect ponderosa pine plantation. Denbigh, N. Dakota.

4. Five year old Rocky Mountain juniper and Scots pine in a nursery windbreak, Towner, N. Dakota. The Scots pine is from a Siberian seed source.

5. Ponderosa pine progeny study, Towner, N. Dakota. Seedlings from 83 seed sources.

6. Native cottonwood and juniper stand in the Platte River valley, Nebraska.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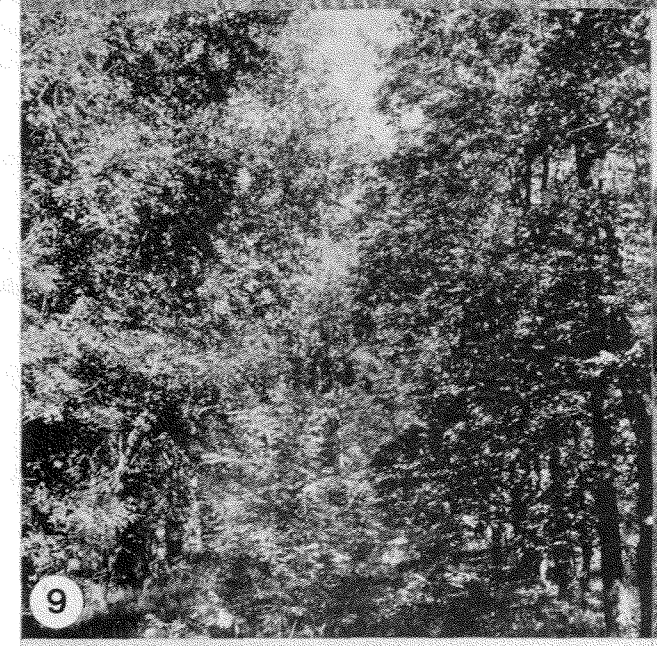
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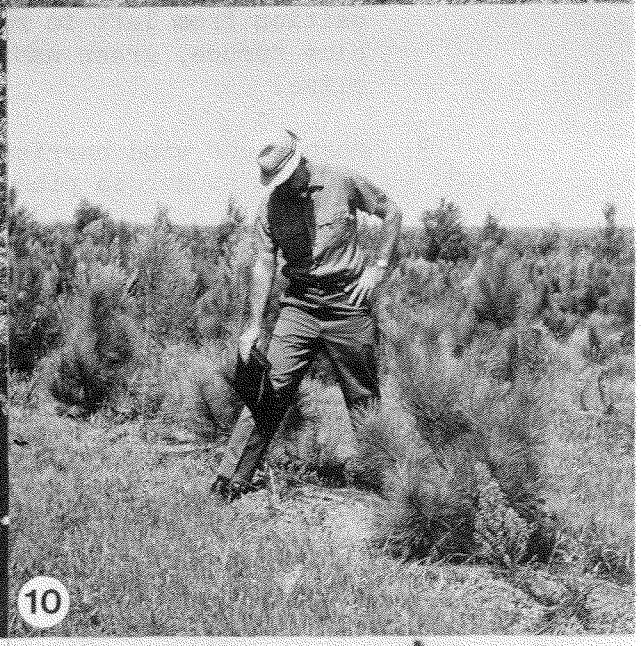
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7. Good shelterbelt near St. Paul, Nebraska, planted in 1941. Composition from right to left: red juniper, ponderosa pine, green ash, black walnut, white elm, cottonwood, Siberian elm, Russian mulberry. Juniper is 30' high and cottonwood is 80'.

8. Coniferous release in a shelterbelt planted in 1941 near Grande Island, Nebraska. The original Russian olive, hackberry rows and alternate ponderosa pine were cut in 1958.

9. Deciduous release in a shelterbelt planted in 1939 near Seward, Nebraska. The row of honeylocust was cut in 1959 to release Siberian elm and hackberry. Sprouts of honeylocust increased the density at the lower level.

10. One application of "Simazine" controlled weeds for the season. Red pine provenance study, Horning, Nebraska.

11. Single row shelterbelt with alternating Rocky Mountain juniper and burr oak planted in 1961, Horning, Nebraska.

12. Scots pine provenance study, planted in 1962. First row from central Siberia, second row Vosges Mountains, Haguenau Forest, France. Horning, Nebraska.

APPENDIX I

Tree and Shrub Species for Nebraska. Tree Planting Map.

SPECIES	*AREA (see map)					Remarks on site
	1	2	3	4	5	
SHRUBS**						
American plum	2	2	1		2	Spreads by root suckers
Cotoneaster	1	1	1	1	1	
Lilac	1	1	1	1	1	
Tatarian honeysuckle	1	1		2	1	
Western chokecherry	1	1	1	1	1	
Purple osier willow	2	1	1		2	Lowland sites only
Multiflora rose	2	2				
CONIFERS						
Eastern red cedar	1	1	1	1	1	Shade tolerant
Rocky Mt. Juniper	2	2	2	2	2	
Ponderosa pine	1	1	1	1	1	
Austrian pine	1	2	2		1	
DECIDUOUS (Med. to tall)						
Slow Growing						
Green ash	1	1	1		1	Use next to conifers
Honey locust	1	1	1	1	1	
Hackberry	1	1			1	
Fast Growing						
Cottonwood	1	1	1	1	1	Water table 15' or less
Siberian elm (Chinese)		2	2	1	2	Highland sites only
Golden willow	2		1		2	Lowland sites only
White willow	2		1		2	Lowland sites only
DECIDUOUS (Short)						
Boxelder	2	2	2	2	2	
Russian olive	1	1		2		
Russian mulberry	1	1			2	
Diamond willow	2	2	1		2	Lowland sites only

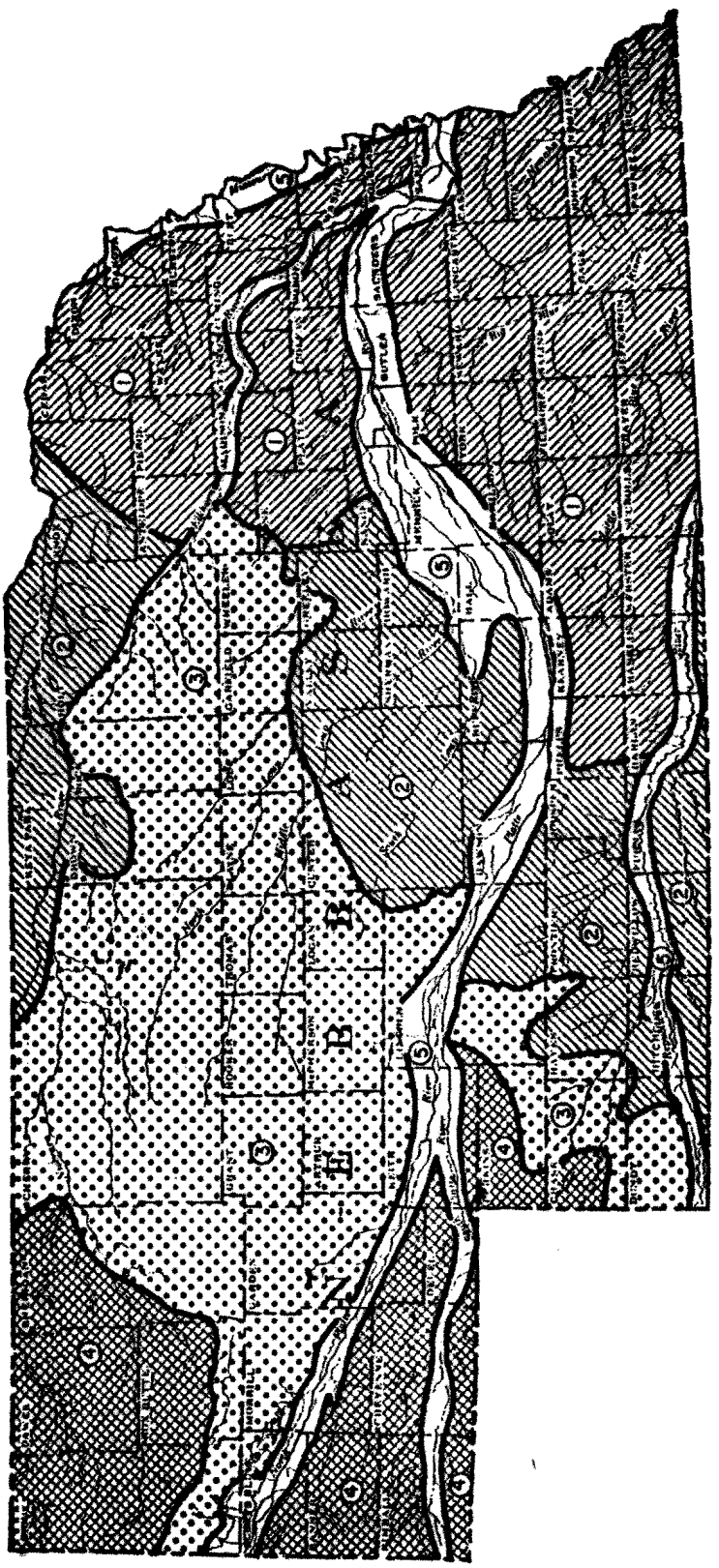
*"1" First choice; "2" Second choice; etc.
Division of the State into five major areas is intended only as a general guide, for within these areas tree planting sites will differ widely.

**All of these shrubs are both beneficial to wildlife and add to the beauty of Rural America.

APPROXIMATE SPACING BETWEEN TREES IN THE ROW

Outside row of shrubs or red cedar .....3 to 4 feet.
Conifers .....6 to 8 feet.
Deciduous (short) .....6 to 8 feet.
Deciduous (tall) .....8 to 10 feet.

TREE PLANTING MAP



APPENDIX II

Some Recent Publications Relating to Shelterbelt Work in North America.

An annotated bibliography has been prepared by R. A. Read (Bibliography of Great Plains Forestry, Rocky Mt. For. and Range Exp. Sta., For. Serv., U.S.D.A., St. Paper No. 58, 1961) includes the world literature until 1959.

Some of the papers published in North America since 1959 are listed below:

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2. _____. 1965. Chemicals for controlling weeds near shrubs and trees in windbreaks, forest, ornamental and orchard plantings. Dept. of Hort. and For., Coll. of Agric., Univ. of Nebr., Lincoln, Nebr. Mimeo.

3. _____. 1966. Chemical weed control reduce tree failure, increase growth. Nebr. Agr. Exp. Sta. Farm, Ranch and Home Quarterly. 13: 18-20.

4. Baranyay, J. A. 1964. Report on the condition of shelterbelts in Alberta with special references to diseases, insects and cultural practices. Inf. Rept. For. Ent. and Path. Lab., Calgary, Alberta.

5. Boldt, C. E. and Teja Singh. 1964. Root development of ponderosa pine transplants at Lincoln, Nebraska. Forest Service, Rocky Mt. For, and Range E. S., U.S.D.A., Res. Note RM-20.

6. Canada Department of Forestry and Rural Development. 1966. Man-made forests in Canada. A statement prepared for the World Symposium on man-made forests and their industrial importance. Apr. 24-25, 1967, Australia. For. Br. Ottawa, Ont.

7. Clegg, A. G. 1963. Organic matter important in field analysis of soil texture. Forest Service, Lake State F.E.S., U.S.D.A., Res. Note LS-9.

8. Conley, W. T., D. H. Dawson and R. B. Hill. 1965. The performance of eight seed sources of ponderosa pine in the Denbigh Experimental Forest, North Dakota. Forest Service, Lake State F.E.S., U.S.D.A., Res. Note LS-71.

9. Cram, W.H. 1960. Performance of seventeen poplar clones in south central Saskatchewan. For. Chronicle, 36: 204-209.

10. _____. and G. A. Morgan. 1961. Survival and growth of shelterbelt trees at three spacings. For. Chronicle, 37: 187-191.

11. Dawson, D. H. and P. O. Rudolf. 1966. Performance of seven seed sources of blue spruce in central North Dakota. Forest Service, North Centr. F.E.S., U.S.D.A., Res. Note NC-5.

12. Forestry Committee (The), Great Plains Agricultural Council. 1966. A forestry research plan for the Great Plains. Great Plains Agr. Counc. Publ. No. 25.

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14. _____. 1966. Shelterbelts for the northern Great Plains. Farmers' Bul. No. 2109, U.S.D.A. (Revised Nov. 1966).

15. Goss, R.W. 1960. Mycorrhizae of ponderosa pine in Nebraska grassland soils. Nebr. Agr. Exp. Sta. Res. Bul. 192.

16. Greb, B.W. and Al. Black. 1961. Effect of windbreak plantings on adjacent crops. Jour. Soil and Water Cons. 16: 223-227.

17. Grover, R. 1963. Chemical weed control in shelterbelt plantings. Mimeo. Speech presented at 15th meeting, Forestry Comm., Great Plains Agr. Counc., Nemo, So. Dak.

18. _____. 1963. Bibliography of weed control research in tree and woody ornamental nurseries, and forest and shelterbelt plantations. Publ. No. 26. For. Nurs. Sta., Can. Dept. of Agr., Res. Br., Indian Head, Sask.

19. Howard, G.S. 1964. Shelterbelt tree and shrub species under dry land culture in the central Great Plains. U.S.D.A., Prod. Res. Rpt. 78.

20. _____ and G. B. Brown. 1963. Seven species of broadleaf deciduous trees for windbreaks - effect of spacing distance and age on their survival and growth at Cheyenne, Wyo. U.S.D.A., Tech. Bul. 1291.

21. Lehans, J. J. and K. F. Nielsen. 1961. The influence of field shelterbelts on climatic factors, soil drifting, snow accumulation, soil moisture and grain yields. Mimeo. Exptl. Farm, Swift Current, Sask., Canada.

22. Loerch, K. -- . Chemical weed control in windbreaks. Ext. Service, Univ. of Nebr. Coll. of Agr. E.C. 60 - 1733.

23. Peterson, G.W., D. Nuland, and J. L. Weihing. 1960. Test of four fungicides for control of cedar blight. Plant Disease Reporter, 44: 744-746.

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26. _____. 1963. Diseases of conifers in Nebraska. Am. Nurserymen, 118: 71.

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38. _____. 1964. "Hybrid" pines, a matter of....time, patience, research. Nebr. Exp. Sta. Quarterly, Winter 1964.

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Leaflet 1. How to use trees to protect land and crops.
" 2. How to select trees and shrub species.
" 3. How to arrange and space trees and shrubs.
" 4. How to prepare land and plant trees.
" 5. How to maintain new tree plantings.
" 6. How to protect them from damage.
" 7. How to manage established plantings.

Forest Service, Rocky Mt. For. and Range E. S., U.S.D.A.

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47. Staple, W. J. 1961. Vegetative management and shelterbelts in evaporation control. Paper presented at Second Canadian Hydrology Symposium.

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