Number 75
July, 1980

NORTH DAKOTA
RESEARCH REPORT

Growth and Survival of Shelterbelts

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INTRODUCTION

The need for trees in the Great Plains was recognized during settlement in the late 1800's. The Timber Culture Act of 1873 provided for planting a timber culture entry of 40 acres for each quarter section (160 acres) of homestead. The act was amended several times to reduce acreage planted to trees. The Clarke-McNary Act of 1924 provided Federal assistance that made it possible for landowners to purchase planting stock at cost.

Governmental programs were developed in the 1930's to help relieve the effects of drought in the Great Plains. The Shelterbelt Program of 1935-1942 (later known as the Prairie States Forestry Project) was one of these programs. The purpose of the Shelterbelt Program was two-fold: (a) the planting of windbreaks throughout the eastern plains to reduce wind erosion and (b) to provide relief employment. The program was administered by the U.S. Forest Service until 1942, when responsibility was transferred to the Soil Conservation Service.

The purpose of the study was to inventory 20 Prairie States Forestry shelterbelts in Cass, Barnes and Ransom counties of southeastern North Dakota. The inventory would include tree and shrub species, growth data, vigor and the incidence and types of diseases and insects. The shelterbelts were chosen at random to obtain variation in species, orientation and planting sites. These belts ranged in length from one-quarter mile to one-half mile and from three to 20 rows in width.

LITERATURE REVIEW

According to Read (13), early planting experiments were conducted by the State Agricultural Experiment Stations of North Dakota, South Dakota, Oklahoma and Nebraska and by the U.S. Department of Agriculture, Division of Forestry at field stations at Mandan, North Dakota; Cheyenne, Wyoming; Akron, Colorado and Woodward, Oklahoma. The purposes were to test different tree and shrub species for adaptability and determine the best methods of planting, spacing and care of trees for production of shelterbelts.

The official beginning of the Shelterbelt Project, according to Roberts (14), was the issuance of an executive order by the President of the United States in 1934 to set aside one million dollars from the $528,000,000 appropriated by Congress for the relief of the inhabitants of the drought-stricken plains. From the onset of the proposed shelterbelt plan (13), residents of the plains and professional foresters expressed some doubt as to the practicality of the project.

The Prairie States Forestry Project (14) had a tremendous influence on the planting activities during the period 1935-1942. The aims of the program were to: (a) establish a network of shelterbelts from North Dakota to northern Texas and (b) to provide employment. The program was administered by a regional director of the Forest Service in Lincoln, Nebraska and a technical staff in other states.

In an agreement developed between the landowner and project forester, the landowner agreed to prepare the land, fence the area and maintain the plantings (14). The Forest Service provided technical advice, planting stock, planting, replanting where necessary and weed and insect control, all free of charge to the landowner.

The Shelterbelt Project operated chiefly in a zone about 200 miles wide (14). Within this zone in each state are considerable areas of deep sandy soils and high water tables, which were subject to wind erosion when under cultivation. This combination of sandy soil and high water table was the most suitable tree planting site.

Physiographically defined (14), the Great Plains include the interior plains sloping eastward from the Rocky Mountains to the central lowlands, and from San Antonio, Texas to Edmonton, Alberta.

Climatically, the Great Plains comprises the largest uninterrupted North American area with semi-arid climate. Annual rainfall averages less than 20 inches with a favorable seasonal distribution, but high rate of evaporation. Droughts are frequent and often prolonged. There are extremes of temperature in both summer and winter. The wind blows harder and more constantly on the Plains than in most other portions of the United States.

Most of the soils of the Great Plains Region, according to Sander (15), developed under grass, resulting in dark-topsoils with a zone of accumulation. The deep and medium to heavy soils in the north and east of the region are derived mainly from glacial till and loess. The more shallow and lighter soils in the western and southern regions are mostly derived from sedimentary materials.

The basic shelterbelt pattern (13), was to establish two belts, each one mile long, within a section of land. These belts were parallel at ½ mile intervals, on land survey lines. Most basic shelterbelts were oriented east-west to furnish protection against south winds during the growing season and northwest winds in the winter. Due to the westerly winds in North Dakota, nearly half were planted in a north-south direction.

The width or number of rows of shelterbelts has been a very controversial point (14). A three to four row shelterbelt would be adequate protection against wind erosion, particularly if one row was evergreens. However, in the spring and fall of the year, the soil is especially subject to blowing, and the hardwoods are then leafless. A dense growth of even leafless trees is effective in stopping the wind. In wider planted belts, gaps and holes may be filled more effectively, and forest conditions are established that are favorable to natural reproduction. Also, with the wider belts, effectiveness and appearance are not affected by the loss of one or two rows due to poor survival or disease problems.

With these points in mind (14), two rows of conifers are needed to achieve dense year-long protection. A row of shrubs is needed to protect the conifers until established, and because the conifers are slow growing, hardwoods must be planted for early protection. The rows of taller trees are necessary for the crest of the belt with the sides flanked by sufficient rows of intermediates to give wind resistance. This does not mean that narrow belts do not have a place in the shelterbelt plantings.

Ten rows of trees was considered a standard belt because of added winter protection, the need for proper wind uplift, the development of a microclimate and better chances of survival (13). About 40% of the belts contained ten rows, with width ranging from 80 to 120 feet, depending upon distance between rows. Nearly half were intermediate belts (5-7 rows) with the remainder either narrow (3-4 rows) or very wide (11-21 rows).

General length of individual shelterbelts was from one-quarter to one-half mile, with some being ¾ to 1 mile long and others continuous for several miles (13). Distance between rows was generally 8-10 feet with an increase to 12-14 feet in the far western Great Plains. Tree spacing within rows was 6-8 feet apart and shrubs 3-4 feet apart.

A number of shelterbelt species were selected for use in all states with some variation from north to south (13). The basic shelterbelt design included tall, fast growing deciduous trees, conifers and shrubs planted so to be symmetrical when grown, with the height in the center. In 1937 this design was changed so that all fast growing trees were placed on one side to facilitate removal of dead, fast growing, short-lived trees.

Position of the windward or conifer side of the belt depends upon fields to be protected; i.e., conifers were placed on north and west sides to protect against winter and spring winds; otherwise they were placed on the south side to protect the fields from hot south winds during the growing season (1) (3).

Shelterbelts are now considered an essential feature of Great Plains agriculture (17). The species used in the Great Plains Shelterbelt Program were described by several researchers (2) (5,6,7) (11) (12,13) (14) (16,17), as to growth rate, soil preference, adaptability and use. These are presented according to growth rate and tree type.

—Tall, fast growing deciduous trees, functioning to provide maximum height in the shortest time: cottonwood; white willow and Siberian elm.

—Tall, medium to slow growing deciduous trees which are expected to grow slowly into tall trees and are longer living: common hackberry; green ash; bur oak and American elm.

—Short, fast growing deciduous trees functioning to create low barrier density in place of shrubs and to fill in rapidly between tall growing species: boxelder and Russian olive.

—Deciduous shrubs, used on one or both sides of the belt to reduce wind velocity: common caragana; Tatarian honeysuckle; American plum; common chokecherry and common lilac.

—Conifers that are used throughout the region as long-lived, dense wind barriers effective year round: Rocky Mountain juniper; eastern red-cedar; Colorado spruce and ponderosa pine.

Orientation, height, length, density and frequency are important factors to shelterbelt plantings (14). On the leeward side of the belt the wind is dissipated by branches and foliage and uplifted by the design of the belt, with the actual area protected lying between the barrier and 10-20 barrier heights out on the lee side. On the windward side the backwash is effective to five heights. Belt length is also very important. The shorter the barrier, the quicker the air meets around the ends, which is the same effect when gaps or breaks are present in the barrier. If a gap must be present, it should be placed in a zig-zag pattern.

A tight shrub row will lift the surface wind upward and the sloping bank of trees will partly absorb and dissipate the wind's force, reducing velocity and surface evaporation. Shelterbelts cool and raise the humidity of air passing through and create a microclimate. Some other benefits from shelterbelts are: soil protection, increased crop yield, wildlife protection and aesthetic value (14).

The trees' seed source is important in that it may influence growth rate, form, longevity, insect and disease resistance, temperature tolerance and reproduction (14). The seed should be collected and progeny planted within each zone, but it is possible to obtain seed stock from one zone and plant in an adjoining zone, or even in some cases, safely planted several zones away.

During the first 8 years of shelterbelt work (13) more than 200 million trees and shrubs were planted in patchwork patterned windbreak strips along survey lines, totalling 18,600 miles on 30,000 farms. The planting zone lies between 96° and 101° longitude and from Texas to North Dakota.

In a preliminary survey in 1938, Read (12) states region-wide survival was 61% for all species. The 39% loss was due to faulty cultivation, insect and rodent damage, small planting stock, faulty handling and planting and a small percent of miscellaneous causes.

In 1944 Munns and Stoeckler (11) of the Forest Service made sample survey of 93 counties and 1079 belts from North Dakota to Texas to determine how they had fared. Most of the plantings were not mature enough to be fully effective as wind barriers, but the results were highly favorable: 78% of the belts were rated good or better as potential windbreaks; 11% rated fair; 9% poor to very poor and 2% had been destroyed. Livestock damaged 8% of the plantings.

In general the species used were highly satisfactory. Cottonwood was erratic due to high mortality caused by leaf rust. Ponderosa pine left large gaps in the belts due to low initial survival. Species planted on droughty, shallow, sandy soils appeared unhealthy due to a lack of adaptation to the conditions.

This survey (11) included 203 belts in North Dakota with conditions rated as follows: 75% good to better; 21% fair to poor and 4% destroyed. The belts averaged 16 feet high, with cottonwoods tallest and the shortest being conifers.

Anderson (1) and Bates (3) stated that cultivation was the single most important factor in determining success of plantings. Well cultivated plantings were generally vigorous and tall and rated good or better as potential windbreaks.

In the summer of 1954 the survey of 10 years earlier (11) was repeated by Read (12) on 938 shelterbelts from North Dakota to Texas. The objectives were: (a) to gather data on the tree and shrub species in the past decade; (b) to appraise their usefulness for windbreaks and (c) to isolate evident problems in all plantings. New estimates of survival, height, DBH, vigor and crown-spread were made, along with classification of groundcover and vegetation density. The 1954 resurvey windbreaks were rated solely on appearance, rather than survival and the possibilities of producing effective barriers as in the 1944 survey.

Each windbreak was rated excellent, good, fair, poor or destroyed. The ideal barrier should be continuous and moderately dense at all height levels. An excellent barrier consisted of a full stand of trees and shrubs, continuous from one end to the other. Poor windbreaks consisted of sparse, scattered clumps of trees and shrubs and lacking in lower level continuity.

Region-wide (12), 48% of the 938 sample windbreaks rated good and excellent, 29% fair, 18% poor and 5% had been destroyed.

Considerable differences in ratings between states were apparent. Northern North Dakota had many good and excellent plantings because most samples were in the Red River Valley lowlands, whereas most sampled windbreaks in southern North Dakota were on uplands.

The 1954 survey (13) also evaluated individual species and adaptation. Cottonwood was found to be satisfactory on lowlands, with Siberian elm being superior to cottonwood on uplands, but slower in height growth. White willow was superior to cottonwood on lowlands, but exhibited less height growth.

Of the slower growing deciduous species, green ash was found to be most consistent in survival and height in-

crease. Bur oak was good on all sites, but slower in height growth.

Russian olive was the only short, fast growing tree used throughout the region and was satisfactory except in the southern plains. Boxelder was superior to Russian olive in the northern plains.

American plum was the only shrub used throughout the region and was excellent except on dry shallow sites. Caragana was second only to plum in the northern plains.

Common lilac was an outstanding shrub, producing a dense barrier even on dryer sites.

Eastern red-cedar proved to be not only the best conifer but the best adapted tree.

MATERIALS AND METHODS

Shelterbelts studied in this survey included those in Cass, Barnes and Ransom counties in southeastern North Dakota. One shelterbelt for each year of the plantings from 1935-1942 was surveyed in each county. Whenever possible, the belts were chosen to obtain variation in soil type and topography.

Information on the original shelterbelt sites was obtained from the Rocky Mountain Forest and Range Experiment Station at Bottineau, North Dakota (16). Maps and soil types for 1935-1942 and rainfall and temperature data for the year of planting were obtained from the Soils Department at North Dakota State University (18). Other pertinent information was obtained from the Horticulture and Forestry Department at NDSU (8,9) (10) (19).

The original belt sites surveyed were plotted on a map from each county according to the year of planting. The data collected for each shelterbelt included date of planting, size (number of rows and length), orientation, composition of understory, diameter breast height (DBH) of trees sampled, tree height, vigor and distances of trees between and within rows. A Haga altimeter was used to measure height of the selected trees. The DBH was taken in an area of the trunk free of twigs and branches. On multiple trunked trees, the largest trunk was measured. The sampled trees were marked, using orange paint or orange plastic strips placed on the trunk horizontal to the DBH to facilitate identification. Increment borings of 2 or 3 trees of each species per row were made to calculate growth for the last 10 years.

A systematic method of sampling was used after consultation with Dr. Robert Carlson (4) of the Entomology Department at NDSU. The trees were numbered and counted in increments of 20, with every 20th tree in each row being sampled. If any tree sampled was less than 1 inch DBH, broken off or dead, either the 19th or 21st was checked.

North-south oriented belts were sampled moving from east to west and east-west oriented belts were sampled from the north to the south. The rows were numbered according to the number occurring in each belt.

A comparative rating system as suggested by Heintz (9) and Lana (10) was used to express vigor of the sampled trees by a number from 1 through 4, 1 indicating poor condition, 2 indicated fair condition, 3 good condition and 4 an excellent condition. DBH, height, physical appearance, disease rating and insect rating were factors considered in rating the vigor.

A rating system was developed for estimating insect damage, numbered 1 through 4, and disease damage, numbered 1 through 5. Leaf gall insects were given the code number 1, mites number 2, chewing insects number 3 and leaf rolling insects number 4.

Many of the green ash and American and Siberian elm were found to have anthracnose infection, which was indicated by number 1. Black Spot was found on some elms and was designated as number 2. Bacterial blight was found on some cottonwoods and was indicated by the number 3. A fourth, needleblight, *Dothistroma pini,* was found on ponderosa pine and designated by the number 4. *Phomopsis* and *Cercospora* blight found on some junipers was noted as number 5.

If the disease or insect infestation found was slight, the letter (s) was used; if the infestation was moderate the letter (m) was used and the letter (h) was used if the infestation was heavy.

RESULTS AND DISCUSSION

Shelterbelt Design

Shelterbelts encountered in this survey varied from 3 to 20 rows but generally were ten rows wide. The original idea of the narrow belt was that not more than 5 per cent of the land concerned would contain trees. This type of belt was usually found on 40 and 80 acre farms. The belts wider than ten rows were usually planted by farmers who desired extra rows for woodlot purposes or for a greater variety of trees.

Spacing variation was noted between species and shelterbelts. Most shelterbelts had spacing between the rows of 8 to 10 feet, although 12 feet was encountered. One belt had 16 to 18 feet spacing between the rows and 4 to 6 feet in the tree row. The narrow spacing was to provide a fast-closed canopy. The spacing allotted between rows in most cases was determined by the width of the farmer's equipment to be used for cultivation. Generally, trees were spaced 6 to 8 feet in the row and shrubs from 3 to 4 feet. Conifers were generally spaced the same as the larger deciduous trees. The reason for this type of spacing was to get the trees to grow together as soon as possible in order to shade weed growth and eliminate cultivation. The densely shaded and protected ground cover collected and held forest litter which retained moisture instead of permitting it to run off. It also reduced evaporation and created conditions favorable for natural reproduction. These conditions were also necessary for growth in the early stages of development to provide quick height for good protection.

Location and orientation was also a very important factor in planting shelterbelts. Protection of cropland is needed primarily from north, west and south winds. Most of the belts were planted in an east-west direction and ranged from 0.2 to 0.5 mile in length.

Pests and Pesticides

Insects and diseases were noted in all belts surveyed. This varied from belt to belt and from tree to tree. The damage and infestations were not serious in any given shelterbelt. Only on a few individually sampled trees did disease and insects affect the growth of the tree to any extent.

Spray damage largely from herbicides was evident in a few belts. This caused considerable dieback and leaf browning, especially on the Siberian elm. Boxelder also showed noticeable indications of spray damage.

The collected data for each shelterbelt will be discussed individually. The rainfall totals and mean temperatures presented for each shelterbelt are for the year the belt was planted. Data were also collected on species present for spacing within and between rows, per cent survival, DBH, height, vigor, insect and disease ratings and diameter growth the past 10 years.

Ransom County

Seven belts were surveyed in Ransom County. The total county planting was 159.75 miles and 2081.3 acres of shelterbelts during the period 1936-42. 1935 was the only year a shelterbelt was not planted in this county.

The data in Table 1 indicate that 1936 was the driest year of the planting series and 1941 received the most rainfall. Mean temperature of 3.9 degrees F was the extreme between 1937 and 1938 and that of 1941. The soil type varied from loam to loamy sand and the terrain from level to slightly level. All belts had an east-west orientation. Only one belt exceeded .3 of a mile in length. Most of the belts planted in Ransom County were wide belts of 10 rows or more. Data on planting date, location, climatic data, soil type, orientation, row length and number of rows of each shelterbelt surveyed in Ransom County is presented in Table 1.

Table 1. Planting Date, Location, Climatic Data, Soil Type, Orientation, Row Length and Number of Rows of Each Shelterbelt Surveyed.

Ransom County

Year	Location	Rainfall in Inches	Mean Temp. (F)	Soil Type & Terrain	Orientation	Length (miles)	Row Width (trees)
1936	Sydna Township NE ¼, Sect. 16, Twp 133 N., R 54W	8.77	40.1	Sandy loam Sand & Gravel Substrate Level	E-W	0.3	6
1937	Tuller Township SW ¼, Sect. 17, Twp 136 N., R 56W	23.31	40.1	Loam West-Rolling East-Low	E-W	1.2	10
1938	Rosemeade Township W ½, Sect. 2, Twp 133 N., R 53W	21.01	43.2	Loamy Sand Sandy Substrate Gently Rolling	E-W	0.3	13
1939	Northland Township NE ¼, Sect. 19 Twp 135 N., R 58W	19.95	43.5	Sandy Loam Sand and Gravel Substrate Nearly Level	E-W	0.4	10
1940	Alleghany Township NE ¼, Sect. 9, Twp 133 N., R 57W	19.84	42.3	Loam-Clay Loam Slightly Rolling	E-W	0.4	10
1941	Owego Township SE ¼, Sect. 15, Twp 135 N., R 53W	26.05	44.0	Loamy-Sand Slightly Rolling	E-W	0.4	3
1942	Coburn Township NW ¼, Sect. 1, Twp 136 N., R 53W	23.96	42.3	Loam-Loamy Sand Sandy Substrate Level	E-W	0.4	10

Sydna Township. NE ¼ of Sect. 16, Twp. 133 N., Range 54W — Planted 1936.

The care of this belt for the first 4 years was cultivation with horse-drawn equipment. The understory at the time of the survey consisted of Siberian elm, green ash, bromegrass, Kentucky bluegrass and leafy spurge.

Species survival for cottonwood and boxelder was relatively poor. Survival of common lilac was exceptional. The spacing between rows was quite wide. Spacing within the Siberian elm row is only 4 feet. This close spacing did not hinder the elm growth and the survival and vigor were good for this species. The shrub row of common lilac is very dense and uniform. The last 100 feet of this section was planted to plum. The plum section is less dense and survival not as good as the lilac. Table 2 presents the data collected on survival and growth.

Table 2. Survival and growth data for shelterbelt surveyed in Sydna Township, Ransom County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Lilac	1	16	4	97.0						
Siberian Elm	2	16	4	45.5	8.0	33.5	3.2	1^{s}	1.1^{s-h}	2.5
Boxelder	3	16	6	23.9	4.5	19.3	2.3	1^{s-m}	0.6^{s-m}	2.6
Cottonwood	4	16	6	17.8	11.2	44.5	2.5	0	0	2.7
Boxelder	5	16	6	18.2	3.8	16.5	1.0	1^{m-h}	0	
Siberian Elm	6	16	4	53.0	6.1	27.5	2.6	0.9^{s}	1.2^{s-h}	

Tuller Township. SW ¼ of Sec. 17, Twp. 135 N., Range 56 W — Planted 1937

The original care of this belt was not known. The understory at the time of the survey consisted of bromegrass, buckbrush, Kentucky bluegrass, chokecherry, green ash, bur oak, Siberian elm and Russian olive. Survival and growth data is shown in Table 3.

Table 3. Survival and growth data for shelterbelt surveyed in Tuller Township, Ransom County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Russian olive	1	10	4	38.6	6.9	18.0	3.5	0	0	1.6
Boxelder	2	10	6	88.1	8.3	19.0	2.3	1^{s}	0.6^{s}	2.0
Cottonwood	3	10	7	54.7	5.5	24.9	3.3	2.1^{s-m}	0.6^{s-m}	2.5
Cottonwood	4	10	7	29.3	10.8	44.2	2.5	0	0	2.3
Siberian Elm	5	10	6	74.4	6.8	33.2	3.2	0.9^{s}	0	1.6
Green Ash	6	10	6	93.2	5.9	31.0	4.0	1.4^{s}	0.7^{s-m}	1.1
Green Ash	7	10	6	97.7	5.7	23.9	3.1	0.6^{s}	0.5^{s-h}	2.4
Bur Oak	8	10	7	88.0	4.2	18.2	2.5	0.6^{m}	1.7^{s-m}	1.5
Eastern Red cedar	9	10	6							
Russian olive	10	10	6	48.3	6.2	20.0	3.2	0	0	2.8

The overall condition of this belt exhibited a very good vigor and survival rate. The low area of the east end had been planted to white willow, which was in good condition. White willow would have been sampled only if they fell in exact row sequence. The white willow present in the belt area made a very important fill-in for complete effectiveness.

The east side had a row consisting of Eastern red cedar and plum existing in very poor condition. This row of Eastern red cedar and possibly plum may have been the ninth of the belt because of the large spacing between the rows of bur oak and Russian olive. This was the only belt where bur oak was present. The oaks were in good condition, and had a good survival rate.

The Russian olive took the place of the shrub row. It was less effective as a border because of the low survival rate. The vigor of Russian olive was exceeded only by green ash. The diameter growth for Russian olive in Row 10 for the last 10 years was superior to that of any other species in this belt.

Rosemeade Township. W ½ of Sec. 2, Twp. 113 N., Range 53 W — Planted 1938

The original care consisted of hoeing by the W.P.A. for 3 to 4 years. The understory at the time of this study consisted of buckbrush, Kentucky bluegrass, sage, green ash, Russian olive, thistle, anemone, leafy spurge and sweet clover.

The overall condition of this belt was poor. Cattle grazing was evident on the east two-thirds of the planting. The west end was low and wet.

A very sparse belt resulted because of the poor survival in the numerous rows of cottonwood and other species. Height of cottonwood was comparable with that of the other belts. DBH of cottonwood showed considerable variation between rows. The individual condition of the cottonwood trees remaining was good.

Ponderosa pine had the greatest survival rate and cottonwood had the best diameter growth rate and vigor, followed by boxelder. Table 4 presents the survival and growth data.

Table 4. Survival and growth data for shelterbelt surveyed in Rosemeade Township, Ransom County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Russian olive	1	8	5	32.8	5.7	21.8	2.8	0	0	1.2
Ponderosa Pine	2	8	6	39.4	5.0	22.5	2.0	0	4.0[s]	2.0
White Willow	3	8	6	32.2	7.1	33.2	2.5	0	0	2.1
White Willow	4	8	6	21.2	7.0	35.0	3.0	0	0	
Cottonwood	5	8	7	20.4	16.0	63.5	3.5	0	0	
Cottonwood	6	8	7	22.1	17.0	69.0	3.5	0	0	
Cottonwood	7	8	7	23.9	17.4	60.0	3.5	0	0	3.4
Cottonwood	8	8	7	20.6	8.0	45.0	1.5	0	0	2.9
Cottonwood	9	8	7	17.7	15.1	63.0	3.0	0	0	
Cottonwood	10	8	7	12.4	10.5	54.0	3.0	0	0	
White Willow	11	8	6	16.3	7.5	32.5	3.0	0	0	
White Willow	12	8	6	30.3	8.6	31.2	3.0	0	0	
Boxelder	13	8	5	28.4	7.7	29.5	3.0	1.5[s]	0.5[s]	2.8

Northland Township. NE ¼ of Sec. 19, Twp. 135 N., Range 58 W — Planted 1939

The original care for this belt was not known. The understory consisted of bromegrass, Kentucky bluegrass, leafy spurge, buckbrush, green ash and common lilac. Data collected on survival and growth are shown in Table 5.

Table 5. Survival and growth data for shelterbelt surveyed in Northland Township, Ransom County.

Species	Row No.	Between Rows	Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Lilac	1	10	4	97.7						
Ponderosa Pine	2	10	6	36.4	7.0	24.2	2.8	0	1.3^{s}	3.0
American Elm	3	10	6	68.2	2.6	11.0	1.2	1.1^{s}	1.5^{s-m}	1.4
Green Ash	4	10	6	73.9	5.4	27.3	2.9	1.5^{s}	0.8^{s-m}	
Green Ash	5	10	6	89.5	5.1	28.1	2.9	0.1^{s}	0.7^{s-h}	1.7
American Elm	6	10	6	73.0	5.5	26.3	2.2	0.9^{s-m}	1.8^{s-m}	1.9
Cottonwood	7	10	8	30.3	10.2	43.5	2.2	0	0	2.6
Cottonwood	8	10	8	34.9	10.7	53.0	2.7	0	0	
Boxelder	9	10	5	56.2	5.3	22.5	2.4	1.4^{s}	0.4^{s}	1.8
Common Caragana	10	10	4	95.5						

The overall condition of this belt was good. Row three (American elm) exhibited the poorest condition of this species encountered in any of the belts in this study. This row was stunted and the last 40 trees had been broken off. The belt was otherwise effective with sufficient rows and an ideal arrangement of species. A few Eastern red cedar were incorporated in the ponderosa pine row, none of which seemed to have good vigor. The ponderosa pine had good vigor and the best diameter growth rate. The shrub row showed excellent survival. The fourth and fifth rows of green ash had good vigor and survival rate. The ash, overall, were somewhat better in quality than the American elm. Cottonwood survived rather poorly but has good diameter growth rate.

Alleghany Township. NE ¼ of Sec. 9, Twp. 133 N., Range 57 W — Planted 1940

The original care of the shelterbelt was not known. The understory consisted of bromegrass, Kentucky bluegrass, green ash, Siberian elm, American elm, boxelder, chokecherry, buckbrush, thistle and anemone. Table 6 presents the survival and growth data.

Table 6. Survival and growth data for shelterbelt surveyed in Alleghany Township, Ransom County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	10	3	21.3						
Eastern Red cedar	2	10	6	25.3	5.0	16.0	2.5	0	1.25^{s}	1.8
Ponderosa Pine	3	10	6	25.3	8.1	30.7	3.0	0	4.0^{s-m}	2.7
Green Ash	4	10	6	75.9	6.3	28.0	2.3	0	0.5^{s}	2.2
American Elm	5	10	6	65.3	6.4	27.0	2.3	1^{s-m}	1.3^{s-h}	2.8
Siberian Elm	6	10	6	44.6	7.8	32.7	2.9	0.4^{s}	0.3^{s}	2.6
Cottonwood	7	10	8	47.2	13.9	57.8	2.7	0	0.7^{s}	3.3
Cottonwood	8	10	8	46.1	13.5	53.6	2.6	0	0.6^{s}	
Boxelder	9	10	6	66.8	7.1	27.4	2.9	3^{s}	0	3.2
Russian olive	10	10	4-5	37.2	6.6	17.9	2.4	0	0.9^{s-m}	2.1

This belt was one of the most dense in the survey. It was exceptionally fine looking. Green ash, American elm and boxelder had the best survival and the two conifers and common caragana the poorest survival. Tree height for the cottonwood was exceptional. Vigor for ponderosa pine was the best, followed by the boxelder and Siberian elm. The diameter growth rate was the greatest in cottonwood, followed by boxelder, American elm and ponderosa pine. Insect and disease infestation was generally low. The low wet areas in the conifer rows were replanted to white willow, which grew well and prevented serious gaps. No data were collected on these white willow replacements. Common caragana survival was poor in the low areas. Common caragana showed a heavy infestation of blister beetle. This belt was mature as indicated by the type of understory present.

Owega Township. SE ¼ of Sec. 15, Twp. 135 N., Range 53 W — Planted 1941

The original care of this belt was not known. The understory at the time this study was made consisted of bromegrass, Kentucky bluegrass, caragana and buckbrush. Survival and growth data is presented in Table 7.

Table 7. Survival and growth data for shelterbelt surveyed in Owego Township, Ransom County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	10	3	19.1						
White Willow	2	10	6	59.1	7.3	28.6	2.4	0	3^{s-m}	2.3
White Willow	3	10	6	51.7	9.5	37.1	3.3	0	1^{s-m}	

There was evidence of grazing in this belt and the per cent survival and condition of the species were undoubtedly adversely affected by grazing.

Comparing the two white willow rows, the outside row showed more growth with larger DBH, greater height, better vigor and less disease. These differences may be due to the fact that the center row received competition from the two outside rows. Per cent survival was less in the outside white willow row.

The overall condition of the belt was fair to good. This shelterbelt was the narrowest surveyed.

Coburn Township. NW ¼ of Sec. 1, Twp. 136 N., Range 53 W — Planted 1942.

The original care of this belt was not known. The understory consisted of bromegrass, leafy spurge, Solomon's seal, green ash, chokecherry, buckthorn, white willow and Russian olive.

About one-third of the west end of this shelterbelt was a low wet area. The boxelder had been damaged by excess moisture and a number of the trees were dead. The other species were not so affected. Overall, this was a very effective and dense belt. The survival of cottonwood, green ash, American elm and Eastern red cedar was especially good as was the vigor of ponderosa pine, cottonwood and Russian olive. Arrangement of species and composition were good. Ponderosa pine was exceeded in height only by cottonwood and has put on more diameter growth in the last ten years than any other species.

Table 8 presents the data collected on survival and growth.

Table 8. Survival and growth data for shelterbelt surveyed in Coburn Township, Ransom County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Russian olive	1	9	5	36.7	6.4	18.0	2.9	0	0.4[s]	1.9
Eastern Red cedar	2	9	5	42.7	3.6	15.2	2.1	0	4.4[s-m]	2.3
Ponderosa Pine	3	10	5	29.4	8.0	35.0	3.3	0	3.3[s-m]	2.9
Green Ash	4	10	6	86.9	4.8	29.1	2.4	1.2[s-h]	0.3[s]	
Green Ash	5	10	6	85.8	4.7	27.9	2.3	1.4[s-h]	0.3[s]	1.4
American Elm	6	10	6	67.6	3.9	21.2	2.1	1.1[s]	1.3[s]	1.6
Cottonwood	7	10	6	41.8	13.9	67.3	3.3	0	0	
Cottonwood	8	10	6	34.1	13.5	54.7	2.8	0	0	2.8
Boxelder	9	10	6	34.1	4.0	19.0	1.8	1.3[s-h]	0	2.4
Russian olive	10	10	5	37.9	6.3	20.1	3.0	0	0	

Cass County

Cass County contains shelterbelts of all the years of planting except 1935, 1937 and 1938. This county also contains the largest number of belts planted, 265.87 miles and 3,308.26 acres planted with trees for the year 1935-1942. Data on planting date, location, climatic data, soil type, orientation, row length and number of rows of each shelterbelt surveyed in Cass County is presented in Table 9.

Table 9. Planting Date, Location, Climatic Data, Soil Type, Orientation, Row Length and Number of Rows of Each Shelterbelt Surveyed.

Cass County							
Year	Location	Rainfall in Inches	Mean Temp. (F)	Soil Type & Terrain	Orien-tation	Length (Miles)	Number of Rows
1936	Leonard Township SW ¼, Sec. 33, Twp. 137 N., R 52W	9.07	37.2	Loam-Sandy Loam Level	E-W	0.5	10
1939	Wheatland Township NE ¼, Sec. 27, Twp. 140 N., R 53W	11.88	42.8	Loam-Clay Loam Level	N-S	0.3	10
1940	Gunkel Township NE ¼, Sec. 2, Twp. 142 N., R 51W	22.05 Level	42.1	Clay-Loam Till Substrate	E-W	0.3	10
1941	Leonard Township NW ¼, Sec. 22, Twp. 137 N., R 52W	22.10	43.8	Loam-Clay Loam Level	N-S	0.5	7
1942	Walburg Township NW ¼, Sec. 28, Twp. 138 N., R 53W	22.82	42.7	Loam-Clay Loam Sandy Loam to South Level	N-S	0.5	5

This shelterbelt planted in 1936, is located in Section 33 of Leonard Township, Cass County.

The year 1936 was the driest and coolest of the five years belts were established. The soil types varied from sandy loam to clay loam. The orientation was varied, with three of the five belts planted in a north-south direction and the remainder east-west. The length varied from three- to five-tenths miles. The shelterbelts planted in 1936, 1939 and 1940 were 10 rows wide with the remaining two, seven and five rows wide.

Leonard Township. SE ¼ of Sec. 33, Twp. 137 N., Range 52 W — Planted 1936.

The original care of this belt was not known. The understory consisted of bromegrass, Kentucky bluegrass, thistle, wild grape, honeysuckle, buckthorn, boxelder, Siberian elm and green ash.

The overall vigor of this shelterbelt was good, except for possible spray damage in the boxelder and Siberian elm rows. White willow was planted in a low area of the Colorado spruce row and neither species showed good vigor in this location. Colorado spruce had better vigor than ponderosa pine but the survival and growth rate for the last ten years was less.

Colorado spruce was sampled in one other belt. These Colorado spruce rows seemed quite comparable to each other and to pine rows in vigor and survival. The remaining portion of the row was honeysuckle and chokecherry. The quality of this row is good and very few gaps were present. Overall survival was good considering the initial dry summer and the following cold winter. Table 10 presents survival and growth data.

Table 10. Survival and growth data for shelterbelt surveyed in Leonard Township, Cass County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Russian olive	1	10	5	42.0	8.1	17.0	3.4	0	0	1.3
Boxelder	2	10	6	51.0	7.7	28.9	3.3	2.1[s-h]	0.2[s]	2.1
Cottonwood	3	10	9	50.0	13.7	63.1	3.3	0.9[s]	1.7[s]	2.8
Cottonwood	4	10	9	64.0	14.5	52.3	3.3	0	0.8[s]	
Siberian Elm	5	10	6	41.0	7.8	39.6	3.4	0.3[s]	0.9[s-m]	2.1
American Elm	6	10	6	70.0	5.2	26.9	2.8	1.6[s-h]	1.6[s-h]	2.3
Green Ash	7	10	6	84.0	7.3	39.5	3.2	1.5[s-h]	0.3[s-m]	2.1
Ponderosa Pine	8	10	9	62.0	6.1	23.5	2.6	0	3.6[s-m]	2.0
Colorado Spruce	9	10	7	49.0	7.2	24.5	3.1	0	0	1.1
Common Lilac	10	10	4	97.0						

Wheatland Township. NW ¼ of Sec. 27, Twp. 140 N., Range 53 W — Planted 1939.

The original care of this belt was not known. Understory consisted of bromegrass, Kentucky bluegrass, green ash, common caragana and plum. Table 11 presents the data collected on survival and growth.

Table 11. Survival and growth data for shelterbelt surveyed in Wheatland Township, Cass County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	10	4	76.0						
Ponderosa Pine Eastern Red cedar	2	10	6	28.0	7.2	24.0	3.3	0	1.3[s]	2.6
Green Ash	3	10	6	69.0	5.7	31.3	3.0	2.2[s-m]	0.6[s]	1.8
Green Ash	4	10	6	71.0	5.2	29.8	2.7	1.7[s]	0.3[s]	
American Elm	5	10	6	56.0	5.1	27.4	2.3	0.9[s-h]	1.1[s-h]	1.2
American Elm	6	10	6	58.0	3.8	21.7	1.9	0	2.0[m-h]	
Siberian Elm	7	10	6	58.0	6.7	32.7	2.7	0.9[s]	1.1[s-h]	1.9
Siberian Elm	8	10	6	55.0	7.5	33.6	3.3	1.7[s]	1.4[s-h]	
Green Ash	9	10	6	71.0	5.2	29.4	2.9	1.3[s-h]	0.7	
Russian olive	10	10	6	66.0	5.6	18.1	2.9	0	0	1.2

The overall condition was good for the entire shelterbelt. This was one of the few belts without cottonwood. The green ash on the west side had somewhat better vigor than the American elm or ash on the east side. There seemed to be no apparent reason for this growth difference, unless the competition of the Siberian elm may have been too great. The ponderosa pine showed good vigor. The juniper mixed in the row did not have good vigor. Ponderosa pine had the best diameter growth for the last 10 years.

Two-thirds of the shrub row was common caragana which had good vigor; however some of the plants had extensive yellowing of the foliage. The remaining one-third was mostly American plum with several chokecherry intermixed.

Gunkel Township. NE ¼ of Sec. 2, Twp. 142 N., Range 51W — Planted 1940.

The original care of this belt was not known. The understory consisted of bromegrass, leafy spurge, nettle, Kentucky bluegrass, thistle, green ash, boxelder, hackberry, common caragana and plum.

Overall condition of this belt was good. The survival of the green ash was excellent. White willow and cottonwood survival was poor. There was no apparent reason for the poor survival. The surviving trees had good vigor. Boxelder had good survival and vigor in this belt.

Hackberry was found in only two belts of this study. In this belt hackberry had good vigor. The placement of the hackberry in this belt may have been the reason for its condition. It was on the south side next to the conifer row and did not have the competition from the other fast-growing species. The common caragana shrub row had some large open areas and considerable blister beetle damage was evident. The last 200 feet of this row was planted to plum which had good vigor. Data collected on survival and growth are shown in Table 12.

Table 12. Survival and growth data for shelterbelts surveyed in Gunkel Township, Cass County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	10	3	51.0						
Eastern Red cedar	2	10	6	39.0	5.1	16.2	2.6	0	3.0[s]	1.9
Hackberry	3	10	6	65.0	4.2	17.9	2.4	2.4[s-m]	0	1.4
Green Ash	4	10	6	94.0	7.3	30.4	3.4	1.6[s]	0.3[s]	2.2
Green Ash	5	10	6	87.0	6.3	29.1	3.0	2.1[s-m]	0	
White Willow	6	10	6	5.0	11.5	25.0	4.0	0	0	2.8
Cottonwood	7	10	8	5.0	1.0	(no sampling done on this row)				
Cottonwood	8	10	8	11.0	14.5	45.0	3.0	0	0	3.3
Boxelder	9	10	6	67.0	6.5	20.0	3.1	2.1[s-m]	0	2.2
Russian olive	10	10	6	33.0	5.7	19.2	2.8	0	0	2.5

Leonard Township. NW ¼ of Sec. 22, Twp. 137 N., Range 52 W — Planted 1941.

Original care for this belt is not available. The understory consisted of bromegrass, Solomon's seal, leafy spurge, green ash and Russian olive. Table 13 presents the survival and growth data.

Table 13. Survival and growth data for shelterbelt surveyed in Leonard Township, Cass County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Boxelder	1	10	6	65.0	6.1	22.5	2.9	1.3^{s-m}	0	2.0
Cottonwood	2	10	8	79.0	14.7	66.1	3.5	0	0	2.7
Cottonwood	3	10	8	82.0	11.5	53.7	2.8	0	0.2^{s}	
American Elm	4	10	8	73.0	5.4	24.8	3.1	2.3^{s-m}	1.2^{s-m}	1.6
Green Ash	5	10	6	87.0	5.7	29.9	3.1	1.0^{s-m}	0.6^{s-m}	1.2
Eastern Red cedar	6	10	6	80.0	4.9	16.1	2.8	0	2.5^{s-m}	1.8
Russian olive	7	10	4	33.0	5.7	17.5	3.2	0	0	1.5

Overall vigor was good, with excellent survival except for the Russian olive. The cottonwood had the best vigor and growth rate for the last 10 years. This windbreak was located along Highway 18. The arrangement of species in this belt appeared ideal and provided the effectiveness needed. No shrub row was planted in this belt. This also was one of the better belts surveyed.

Walburg Township. NW ¼ of Sec. 28, Twp. 138 N., Range 53 W — Planted 1942.

The original care of the belt was not known. The understory at the time of this study consisted of bromegrass, Kentucky bluegrass, leafy spurge, green ash and Russian olive. Survival and growth data are shown in Table 14.

Table 14. Survival and Growth Data for shelterbelt surveyed in Walburg Township, Cass County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Boxelder	1	10	4	78.0	5.6	26.4	2.9	1.7^{s-m}	0.3^{2-m}	2.2
Cottonwood	2	10	8	63.0	13.6	62.2	3.0	0	0	1.7
American Elm	3	10	6	88.0	6.1	30.2	3.2	1.3^{s-h}	1.7^{s-h}	1.3
Green Ash	4	12	6	93.0	6.2	32.9	2.9	1.3^{s-h}	0.4^{s-h}	1.7
Russian olive	5	14	4	56.0	5.4	16.1	3.1	0	0.3^{s}	1.4

Overall this shelterbelt had good vigor and survival. Boxelder had the greatest growth in diameter for the last 10 years. Somewhat wider than normal spacing between rows was utilized. This may have had some effect on the vigor and survival. Cottonwood produced very large trees in the low area towards the north end of the belt, greatly enhancing the quality of the belt. Green ash and American elm had the best survival and Russian olive had the poorest. This five row belt was very effective considering its width. This was one of the best belts sampled in this study.

Barnes County

All the shelterbelts were present for each year of shelterbelt planting in Barnes County. This county had 176.75 miles and 2,373,53 acres planted to trees for the years 1935-1942. Data on planting date, location, climate, soil type, orientation, row length and number of rows of each shelterbelt surveyed in Barnes County is presented in Table 15.

Table 15. Planting Date, Location, Climatic Data, Soil Type, Orientation, Row Length and Number of Rows of Each Shelterbelt Surveyed.

Barnes County

Year	Location	Rainfall in Inches	Mean Temp. (F)	Soil Type & Terrain	Orien-tation	Length (Miles)	Number of Rows
1935	Dazey Township E ½, Sec. 30, Twp. 143 N., R 60W	16.56	40.6	Loam & Clay Loam Slightly Rolling Low at West End	E-W	0.4	13
1936	Meadowlake Township SE ¼, Sec. 15, Twp. 138 N., R 61W	7.07	42.2	Loam & Clay Loam Slightly Rolling	N-S	0.5	20
1937	Ashtabula Township S ½, Sec. 8, Twp. 142 N., R 58W	20.85	40.1	Loam & Clay Loam South-Level North-Rolling	N-S	0.3	13
1938	Pierce Township NW ¼, Sec. 36, Twp. 143 N., R 60W	13.34	42.2	Loam & Clay Loam Gently Rolling	N-S	0.2	13
1939	Raritan Township NE ¼, Sec. 34, Twp. 137 N., R 56W	12.71	42.2	Loam & Clay Loam Slightly Rolling	E-W	0.3	9
1940	Noltimier Township N ½, Sec. 34, Twp. 141 N., R 57W	18.75	41.4	Loam & Clay Loam Rolling	N-S	0.2	10
1941	Greenland Township NE ¼, Sec. 32, Twp. 137 N., R 61W	23.04	42.7	Loam & Clay Loam Slightly Rolling	E-W	0.5	10
1942	Springcreek Township NW ¼, Sec. 35, Twp. 137 N., R 60W	24.07	41.4	Loam & Clay Loam	E-W	0.5	9

Barnes County had a belt planted each year of the period 1935 through 1942. The annual rainfall was the least in 1936 with 1942 receiving the most. The annual mean temperatures during the eight year period did not show great variation. The soil type was quite uniform ranging from loam to clay loam. The topography was slightly rolling to rolling. Three of the eight belts were planted in an east-west direction, with the remainder in a north-south direction. The length of the belts varied from two- to five-tenths of a mile. This county contained the widest belts, all over nine rows wide with three 13 rows and one 20 rows.

Dazey Township. E ½ of Sec. 30, Twp. 143 N., Range 60W — Planted 1935.

The original care consisted of hoeing and cultivation for 3 to 4 years. The understory consisted of Kentucky bluegrass, bromegrass and green ash. Table 16 presents the data collected on survival and growth.

Table 16. Survival and growth data for shelterbelt surveyed in Dazey Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	8	3	85.0						
Siberian Elm	2	8	6	33.0	7.6	32.0	3.6	1.8[s]	0.8[s-m]	2.4
American Elm	3	8	6	62.0	6.7	31.3	3.0	2.0[s-m]	1.6[s]	2.3
Green Ash	4	8	6	44.0	4.8	25.7	2.5	1.4[s-m]	1.0[s]	
Green Ash	5	8	6	49.0	4.6	30.0	2.5	1.7[s-m]	2.0[s]	1.2
Hackberry	6	8	6	36.0	2.8	17.0	1.6	1.3[s-m]	3.0[s]	0.5
Siberian Elm	7	8	6	45.0	4.5	27.6	2.4	0.4[s]	1.5[s]	
Cottonwood	8	8	6	12.0	18.9	48.0	3.5	0	1.5[s]	2.7
Cottonwood	9	8	6	10.0	10.3	42.0	2.0	0	2.0[s]	
Cottonwood	10	8	6	12.0	11.0	47.0	2.0	0	0	
Siberian Elm	11	8	6	40.0	5.5	27.7	3.3	1.0[s]	1.1[s-m]	
Green Ash	12	8	6	47.0	3.1	20.0	1.7	2.4[s-h]	0.4[s]	
Siberian Elm	13	8	6	75.0	5.5	28.0	2.8	1.8[s]	1.1[s]	1.5

Overall species condition was good but survival was only poor to fair. Green ash was only moderately vigorous and did not have good survival. The hackberry survival and vigor may have been due to competition. The reduced vigor in the ash in Row 12 may have been due to its placement between two rows of Siberian elm. A low wet area at the west end has caused a reduction in vigor of the trees, many of which died.

In this belt the Siberian elm had been used toward the outside edges and had good survival, vigor and diameter growth rate for the last 10 years. This placement seems less effective and may cause too much competition for other slower growing species. Spray damage was noted in Siberian elm.

The common caragana shrub row had good survival and vigor. Three rows of cottonwood were used, none of which had good survival but did have good vigor and diameter growth rate.

Meadowlake Township. SE ¼ of Sec. 15, Twp. 138 N., Range 61W — Planted 1936.

The original care consisted of hoeing in rows for 2 to 3 years and cultivating between rows for a period of 4 to 5 years. The understory at the time of the study consisted of Kentucky bluegrass, bromegrass, green ash, Siberian elm and common caragana.

Overall condition of this shelterbelt was fair to good for most species. The shrub rows had good vigor but only fair survival, resulting in quite large gaps. However the double row of shrubs helped to eliminate some of this problem. This was the widest belt surveyed. The spacing between the rows was quite narrow. The close spacing has provided a thick crown cover, but may have decreased vigor. The placement of this belt has been effective in preventing erosion by wind and water.

Cottonwood had the greatest diameter growth rate for the last 10 years. The green ash and American elm had good survival and vigor and were somewhat better in quality on the east side of the shelterbelt. Table 17 presents the data collected on survival and growth.

Table 17. Survival and growth data for shelterbelt surveyed in Meadowlake Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	6	4	31.0						
Common Caragana	2	6	4	31.0						
Green Ash	3	8	7	40.0	5.6	35.8	2.5	0.3^{s}	0.8^{s-m}	
Green Ash	4	8	6	74.0	4.6	25.8	2.1	2.5^{s-m}	0.6^{s-m}	
Green Ash	5	8	6	77.0	4.0	26.1	2.1	1.0^{s-m}	0.5^{s-h}	1.5
Green Ash	6	8	6	63.0	3.6	22.4	1.9	1.9^{s-m}	0.6^{s-m}	1.5
American Elm	7	8	6	59.0	5.8	28.7	2.9	1.9^{s-m}	1.8^{s-h}	2.3
American Elm	8	8	6	59.0	5.7	28.1	2.7	1.3^{s-m}	1.3^{s-m}	1.2
Siberian Elm	9	8	6	65.0	6.0	28.1	3.0	1.8^{s}	1.3^{s-m}	1.2
Cottonwood	10	8	8	33.0	11.6	50.8	2.7	0	0	
Cottonwood	11	8	8	23.0	11.4	50.3	3.0	0	1.0^{s}	2.6
Cottonwood	12	8	8	38.0	9.2	36.5	1.8	0	1.4^{s}	
American Elm	13	8	7	72.0	5.8	28.8	2.8	2.3^{s-h}	1.0^{s}	
American Elm	14	8	7	78.0	5.7	28.6	2.7	1.1^{s-m}	1.7^{s-m}	1.4
American Elm	15	8	7	89.0	5.9	26.9	3.3	2.9^{s-h}	1.0^{s}	
Green Ash	16	6	6	84.0	4.3	27.5	2.1	1.1^{s-h}	1.0^{s-m}	
Green Ash	17	6	6	82.0	4.2	25.8	2.3	1.1^{s-h}	1.0^{s-h}	1.2
Green Ash	18	6	6	85.0	6.1	26.5	3.7	1.3^{s-h}	1.0^{s-h}	
Common Caragana	19	6	4	23.0						
Common Caragana	20	6	4	27.0						

Ashtabula Township. S ½ of Sec. 8, Twp. 142 N., Range 58 W — Planted 1937.

The original care for this shelterbelt was not known. The understory consisted of Kentucky Bluegrass, bromegrass, buckbrush, leafy spurge and green ash. Data collected on survival and growth are presented in Table 18.

Table 18. Survival and growth data for shelterbelt surveyed in Ashtabula Township, Barnes County.

Species	Row No.	Between Rows	Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	8	3	51.0						
Green Ash	2	8	6	70.0	6.4	30.5	3.1	1.5^{s-m}	1.0^{s-h}	1.9
Green Ash	3	8	6	74.0	5.3	28.5	2.2	2.0^{s-h}	1.0^{s-h}	
American Elm	4	8	6	36.0	7.5	29.8	3.6	0.8^{s-h}	1.2^{s-m}	3.1
Cottonwood	5	10	8	1.0	(only three trees exist)					
American Elm	6	8	6	45.0	6.4	29.1	3.0	2.1^{s-m}	0.3^{s}	
Cottonwood	7	10	8	0.0	(no existing trees)					
Siberian Elm	8	8	6	51.0	4.8	24.5	2.1	0.5^{s}	0.6^{s}	1.5
Cottonwood	9	10	8	0.0	(no existing trees)					
American Elm	10	8	6	41.0	5.4	28.0	2.6	1.8^{s}	2.0^{s-m}	
Green Ash	11	8	6	64.0	5.3	28.2	2.6	1.0^{s-m}	1.0^{m-h}	
Green Ash	12	8	6	61.0	5.6	27.0	2.9	1.6^{m-h}	1.0^{m-h}	
Common Caragana	13	8	3	48.0						

Overall condition of this belt was good. The cottonwoods had very poor survival. This might have been due partially to the high land, especially at the north end. In this area trees of all species were less vigorous. Disease and insect damage was somewhat more prevalent in this belt.

The American elm planted adjacent to the cottonwood rows had the best vigor and diameter growth in the last 10 years. Lack of competition probably contributed to these good growth responses. The planting arrangement eliminated the possibility of a large opening in the center of the belt. The green ash rows showed the best survival of all species.

Pierce Township. NW ¼ of Sec. 36, Twp. 143 N., Range 60 W — Planted 1938.

The original care of this shelterbelt was cultivation by the farmer for a period of 4 to 5 years. Understory consisted of bromegrass, leafy spurge, goldenrod, green ash and common caragana.

Overall condition of this belt was fair to good. Two low areas in the belt showed some growth improvement. Vigor in the shrub row was good with fair survival. In the American elm row (#6) six hackberry trees were intermixed; this was the poorer of the two rows of American elm. Green ash survival was good even though it was placed between the two American elm rows. Cottonwood and Eastern red cedar had the poorest survival of all species. Siberian elm had the best vigor and American elm had the greatest diameter growth for the last 10 years. Several rows had gaps due to their low survival. One advantage of this wide belt was that these gap conditions were offset and the barrier remained solid by adjacent, more complete rows. Arrangement of species in the belt was good. Data collected on survival and growth are shown in Table 19.

Table 19. Survival and growth data for shelterbelt surveyed in Pierce Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	8	3	44.0						
Eastern Red cedar	2	8	6	11.0	6.0	16.0	3.0	0	0	1.7
American Elm	3	8	6	87.0	6.0	27.5	2.8	1.4^{s-m}	1.4^{s}	2.2
Green Ash	4	8	6	93.0	4.4	27.0	2.3	2.2^{s-m}	0.1^{s}	
Green Ash	5	8	6	93.0	5.0	30.0	2.3	2.0^{s-h}	0.6^{s}	1.7
American Elm	6	8	6	27.0	4.5	28.0	2.5	1.5^{s-h}	0	
Siberian Elm	7	8	6	62.0	7.3	24.3	3.2	2.4^{s}	1.6^{s}	1.7
Cottonwood	8	8	6	18.0	11.3	51.0	2.0	0	0	
Cottonwood	9	8	6	24.0	10.0	45.5	2.0	0	0	1.2
Cottonwood	10	8	6	29.0	12.5	65.5	3.0	0	0	
Siberian Elm	11	8	6	66.0	7.3	36.6	2.6	1.2^{s}	0.8^{s}	
Green Ash	12	8	6	93.0	6.4	30.0	3.1	2.0^{s-h}	0.2^{s}	
Russian olive	13	8	4	31.0	5.6	15.2	2.7	0	0.3^{s-m}	1.7

Raritan Township. NE ¼ of Sec. 34, Twp. 137 N., Range 56 W — Planted 1939.

The original care consisted of hoeing by W.P.A. workers for 2 years and cultivation by the farmer for 4 years. Understory consisted of bromegrass, Kentucky bluegrass, wild grape, thistles, green ash, honeysuckle and American elm. Survival and growth data are presented in Table 20.

Table 20. Survival and growth data for shelterbelt surveyed in Raritan Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Honeysuckle	1	10	6	Now removed						
Eastern Red cedar	2	10	6	72.0	5.1	18.4	2.5	0	0	2.0
Colorado Spruce	3	10	6	75.0	6.6	25.3	2.8	0	0	2.2
Green Ash	4	10	6	89.0	7.0	30.5	3.3	1.7^{s-m}	0.2^{s}	
Green Ash	5	10	6	75.0	6.6	31.0	3.2	1.8^{s-h}	0.2^{s}	1.9
American Elm	6	10	6	90.0	6.8	30.3	3.3	2.3^{s-h}	0.7^{s-m}	1.5
Cottonwood	7	10	8	51.0	12.7	49.2	3.0	0	0	1.0
Cottonwood	8	10	8	52.0						
Siberian Elm	9	10	6	49.0	6.9	28.3	2.5	0.5^{s}	1.0^{s}	2.0

This shelterbelt was good overall. American elm, Eastern red cedar and Colorado spruce had especially good survival rate. Green ash and American elm had the best vigor and Colorado spruce had the greatest diameter growth for the last 10 years. The good survival and vigor may be due in part to the good initial care. The shrub row (honeysuckle) was removed by the owner about 1959.

Noltimier Township, N ½ of Sec. 34, Twp. 141 N., Range 57 W — Planted 1940.

The original care for the belt was not known. The understory consisted of Kentucky bluegrass, bromegrass, buckbrush, leafy spurge and sage. Table 21 presents the survival and growth data.

Table 21. Survival and growth data for shelterbelt surveyed in Noltimier Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	10	2	80.0						
Boxelder	2	10	6	24.0	8.3	22.5	3.5	1.5^{s-m}	0	1.9
Siberian Elm	3	10	6	62.0	5.2	27.4	2.6	1.4^{s}	0.8^{s}	
Siberian Elm	4	10	6	54.0	7.0	28.8	3.2	1.4^{s}	0.8^{s}	1.7
American Elm	5	10	6	39.0	6.2	27.5	2.6	2.0^{s-m}	1.3^{s}	2.4
Green Ash	6	10	6	56.0	5.2	26.5	2.0	0.1^{s}	0.7^{s-h}	
Green Ash	7	10	6	63.0	5.5	27.0	2.4	2.1^{s-m}	0.6^{s}	1.6
Ponderosa Pine	8	10	6	7.0	9.0	27.0	4.0	0	0	2.9
Eastern Red cedar	9	10	6	32.0	3.8	11.0	2.0	0	0	2.3
Russian olive	10	10	4	59.0	4.4	17.0	2.5	0	0	2.7

Overall condition was poor due mainly to the grazing of cattle. The south end of the belt was lower in elevation than the north end and had much better quality trees. The best survival was noted on green ash, Siberian elm and Russian olive. Ponderosa pine had poor survival but vigor was good with a 2.9 inch diameter growth in the last 10 years. Height growth of the pine is exceeded only by Siberian and American elm.

Greenland Township. NE ¼ of Sec. 32, Twp. 137 N., Range 61 W — Planted 1941.

The original care of the shelterbelt consisted of hoeing for 3 to 4 years. The understory consisted of Kentucky bluegrass, bromegrass, buckbrush, green ash and common caragana. Data collected on survival and growth are shown in Table 22.

Green ash reproduction was found in most shelterbelts.

Table 22. Survival and growth data for shelterbelt surveyed in Greenland Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	9	3	85.0						
Eastern Red cedar	2	9	7	30.0	4.0	15.6	1.4	0	2.0[s]	2.2
Green Ash	3	10	7	92.0	6.1	31.1	3.0	1.3[s-m]	0.9[s]	1.6
Green Ash	4	10	7	90.0	5.1	30.2	2.5	0.8[s]	0.3[s-m]	
Green Ash	5	10	7	87.0	4.8	28.1	2.3	1.1[s-m]	0.4[s]	
American Elm	6	12	8	78.0	6.3	31.9	3.0	1.1[s]	0.5[s]	2.7
Siberian Elm	7	10	8	70.0	6.6	32.3	3.1	1.6[s-m]	0.1[s-m]	2.0
Cottonwood	8	10	8	7.0	19.5	66.0	4.0	0	3.0[s]	2.7
Boxelder	9	10	6	58.0	4.9	20.0	2.6	1.9[s-m]	0.1[s]	2.5
Russian olive	10	10	5	86.0	4.4	15.0	2.3	0	0	
Common Caragana	11	10	3	87.0						

Overall vigor and survival of the belt were good. This belt had wider than normal spacing, between and in the rows. This spacing may be one reason for the good vigor and survival. Russian olive survival was excellent. The west half of the Russian olive row was planted to common caragana which had good vigor and survival. Cottonwood survival was poor but vigor and diameter growth rate was excellent. The survival of the green ash was excellent and good survival was noted with the remainder of the deciduous species. The last 300 feet of the common caragana shrub row on the north side was planted to plum. Only a few of the plums remained, probably due to a low wet area where they were planted.

The three very excellent rows of green ash adjacent to each other had developed a very dense and uniform barrier. This improved the effectiveness of the belt.

Springcreek Township. NW ¼ of Sec. 35, Twp. 137 N., Range 60 W — Planted 1942.

The original care for this belt was hoeing and cultivation for 5 to 6 years. Understory at the time this study was made consisted of Kentucky bluegrass, bromegrass, thistle, buckbrush, sage, goldenrod, anemone, common caragana and green ash.

Overall condition of this shelterbelt was fair. Vigor varied with the row but generally was fair to good. Ponderosa pine had very poor survival but excellent vigor. The best survival was green ash but vigor was generally poor for this species. Large, low, wet areas at the west end caused huge gaps in this belt. Spray damage may have caused dieback in the Siberian elm. Table 23 presents the data collected on survival and growth.

Table 23. Survival and growth data for shelterbelt surveyed in Springcreek Township, Barnes County.

Species	Row No.	Spacing (feet) Between Rows	Spacing (feet) Within Rows	% Survival	DBH	Height (feet)	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Common Caragana	1	10	3	30.0						
Eastern Red cedar	2	10	6	28.0	4.6	15.8	2.5	0	3.3^{s}	2.2
Ponderosa Pine	3	10	6	5.0	8.5	30.0	4.0	0	4.0^{s}	2.7
Green Ash	4	10	6	59.0	5.3	26.1	2.5	2.2^{s-m}	0.8^{s}	2.2
Green Ash	5	10	6	58.0	4.6	26.3	2.3	0.8^{s-m}	1.0^{m}	
American Elm	6	12	6	44.0	5.5	26.2	3.0	2.4^{s-h}	0.7^{s-h}	1.6
Siberian Elm	7	12	6	38.0	7.4	26.7	3.5	1.1^{s-m}	0.3^{s}	1.3
Cottonwood	8	12	8	29.0	14.7	31.8	3.2	0	0	2.6
Boxelder	9	12	4	31.0	6.3	19.4	2.9	1.9^{s-m}	0	2.3

Combined Data for All Species

The 20 shelterbelts surveyed in this study usually contained six or more species of trees and shrubs. The following table (Table 24) presents data for all species. Data for honeysuckle, chokecherry and American plum were not recorded because of extremely poor stands. The combined data collected for each species were growth class, per cent survival, DBH, height, vigor, insect rating, disease rating and diameter growth the last 10 years.

Tall, Fast-Growing Deciduous Trees

The tall, fast-growing deciduous trees, such as cottonwood and Siberian elm, were present in almost every belt. The white willow was used as individual rows at times, but seemed generally used as a fill-in for lowland areas. This growth class was used to provide the maximum height in the shortest possible time.

Table 24. Combined Data for All Species in 20 Shelterbelts.

Growth Class	Species-Types	% Survival	DBH	Height	Vigor	Insect Rating	Disease Rating	Diameter Growth Last 10 Years
Tall, fast growing deciduous	Cottonwood	30.3	12.6	52.2	2.8	0.9^{s-m}	0.45^{s-m}	2.7
	Siberian Elm	53.5	6.7	30.4	3.0	1.1^{s-h}	0.9^{s-h}	1.9
	White Willow	35.1	7.8	30.6	2.86	0	0.6	2.3
Tall, medium to slow growing deciduous	Green Ash	75.8	5.3	28.6	2.7	1.4^{s-h}	0.6^{s-h}	1.8
	American Elm	64.8	5.5	26.9	2.6	1.5^{s-h}	1.3^{s-h}	1.9
	Common Hackberry**	50.5	3.5	17.5	2.0	1.9^{s-m}	1.5^{s}	0.95
	Bur Oak*	88.0	4.2	18.2	2.5	0.6^{m}	1.7^{s-m}	1.5
Short, fast growing deciduous	Boxelder	46.3	5.9	23.1	1.9	1.6^{s-m}	0.2^{s-m}	2.3
	Russian olive	45.5	5.9	17.9	2.9	0	0.1^{s-m}	1.9
Conifers	Eastern Red Cedar	39.6	4.8	16.3	2.41	0	1.5^{s-m}	2.0
	Ponderosa Pine	23.5	7.5	26.4	3.2	0	2.4^{s-m}	2.5
	Colorado Spruce**	66.0	6.6	24.3	2.7	0	0.18^{s-m}	2.8
Deciduous shrubs	Common Caragana	52.3						
	Common Lilac							

* One row only
** Two rows only

Cottonwood — *Populus deltoides*

Percentage-wise, cottonwood had the poorest survival rate of any of the deciduous species (30.3%). Where cottonwood was present it generally had good vigor or was completely dead. The initial purpose of this species was not for its longevity but for rapid establishment and growth. In some belts it almost completely died out. Cottonwood usually had the greatest growth over the past 10 years. Cottonwood is quite disease-free.

Siberian Elm — *Ulmus pumila*

Siberian elm showed rapid establishment and height growth and was much better suited for the dryer upland sites than cottonwood. It seemed longer-lived than cottonwood but showed decadence, as many broken and dead limbs were evident in many of the crowns. The Siberian elm survival percentage was much better than cottonwood, but usually slightly less than that of the green ash or American elm. The Siberian elm is susceptible to 2,4-D sprays; this was evident in a number of belts. Some disease and insect problems were noted in Siberian elm, such as blackleaf spot *Gnomonia ulmea,* mites, leaf chewing and rolling insects. These conditions were generally not heavy infestations and did not affect the vigor in most cases. This species played a very important role in the effectiveness of windbreaks of the early belts. The diameter growth rate was somewhat less than the cottonwood, but usually was better than the green ash.

White Willow — *Salix alba*

The white willow (35.1%) is similar to cottonwood (30.3%) for survival. DBH and height are considerably less for white willow as compared to cottonwood. White willow forms a dense and uniform barrier, and is quite disease-free. The willow was used quite often as a fill-in for low areas and could have been used more frequently for continuous rows. The willow had good vigor but relatively poor survival in most sites where it had been used.

Tall, Medium to Slow-Growing Deciduous Trees

The tall, medium to slow-growing deciduous trees are a very important group which were planted not only for height but for their extended life to maintain an effective barrier. The greatest number of rows were of this class of trees in almost all shelterbelts. The American elm and green ash were most widely used. Common hackberry and bur oak were present in a few belts.

American Elm — *Ulmus americana*

The growth and vigor of the American elm was good on most sites, but varied substantially from belt to belt and also from row to row. The DBH would vary from 2 inches to 10 inches, while the height would be from 15 to 40 feet. Diameter growth rates for the last 10 years varied from 0.5 to 3.4 inches.

American elm and green ash had the greatest survival rates for all species and were the best of the species surveyed. Some disease was again noted but not usually serious enough to affect growth. Insects most commonly present were leaf gall and chewing types, but infestations generally were not heavy. The American elm, a very important species in shelterbelt plantings, now must be replaced by other species because of the threat of Dutch elm disease. Elm does not perform as well as ash on the dryer sites.

Green Ash — *Fraxinus pennsylvanica*

Green ash, like American elm, usually had good vigor but varied from tree to tree as did the elm. The DBH, height and survival percentages of the green ash were comparable to those of the American elm. Ash performance, however, was slightly better on most sites. Green ash was superior and may have been used exclusively on the more difficult sites and produced a denser crown and lower branching habit than the American elm.

The most common disease, anthracnose, was present in every belt but was not serious. Other problems present were mites and chewing insects. The green ash was probably the most important species in the shelterbelts because of its good survival and was effective adjacent to the evergreen rows.

Common Hackberry — *Celtis occidentalis*

Hackberry was sampled in two belts. The soil type in one belt was a deep loam and the hackberry was placed adjacent to the conifer row. The other belt was planted on sandy loam with slightly rolling land and the hackberry was located towards the center of the belt between Siberian elm and green ash. The hackberry was very weak in this belt, apparently because it was being suppressed by the ash and elm.

The DBH, height and survival per cent were much less in the suppressed belt. The DBH ranged from 1 inch to 6 inches, height from 8 to 25 feet and diameter growth in the last 10 years from 0.5 inches to 1.4 inches.

Hackberry belts could have been used more often, but only in heavier soils when wider belts were desired to obtain variation in species or when placed towards the outside rows of the belt.

Insect problems consisted mainly of gall and mites. Infestations of these were quite heavy on some of the trees. This very possibly affected growth to some degree.

Hackberry grew slower than green ash and warrants planting in shelterbelts only if soil, moisture and placement are considered before planting.

Bur Oak — *Quercus macrocarpa*

Bur oak was present on a rolling upland site in one belt in Ransom County. Vigor of bur oak was fair, with survival rate for the single row excellent. The DBH ranged from 2 to 6 inches, height of 10 to 25 feet and diameter growth rate for the last 10 years of 0.9 to 1.5 inches was comparable to the best row of hackberry.

Bur oak could have been planted to a greater extent. Oak grows very slowly and would be easily suppressed by the faster growing deciduous species; therefore, proper placement is necessary.

Short, Fast-Growing Deciduous Trees

These species were planted to create low barrier density in place of shrubs and to fill in from the taller species and were present in most belts.

Russian olive — *Elaeagnus angustifolia*

Russian olive survival percentage was quite poor on most sites, usually better than cottonwood but about the same as boxelder. Overall vigor was good. Diameter growth in the last 10 years ranged from 1.2 to 2.8 inches, height from 11 to 20 feet and DBH ranging from 3 to 11 inches.

Russian olive had minimal disease problems but did show some dead limbs in the tree crown. Snow build-up had caused some damage, but not too extensive. This species contributed a great deal to the wind barriers because of its low spreading, dense crown and ability to withstand drought and alkaline soils. This species was usually planted adjacent to conifers in many belts and suppressed coniferous growth to some extent.

Boxelder — *Acer negundo*

The boxelder was generally taller and had a similar DBH to Russian olive, although diameter growth rate for boxelder the last 10 years was greater. Survival rate for boxelder was similar to Russian olive but less than green ash. The boxelder had the same growth habit as Russian olive, showing a dense, spreading crown. This was very important in reducing the wind velocity. Boxelder was often planted between the tall-growing species and Russian olive or adjacent to conifers. The more rapid growth of the boxelder suppressed the slow-growing conifer. When planted on the leeward side adjacent to the larger species, boxelder acted more as a shrub row since under these conditions it formed a dense barrier.

Insects present were usually galls and chewing types. At times the disease anthracnose was present. The pests present did appear to affect growth.

Boxelder, like Russian olive, often are broken down by strong winds and snow build-up. Boxelder is not planted widely today, but still has some usefulness in windbreaks.

Deciduous Shrubs

Deciduous shrubs were present in almost all belts with one row on one or both sides or two rows on each side. Their presence was important for the dense, low barrier they provided. The shrubs could reduce the wind going through the belt or uplift the wind over the belt.

Common Caragana — *Caragana arborescens*

Common caragana was used in most of the belts surveyed and produced a very effective barrier. Shrubs were planted 3 to 4 feet apart in all cases. Where survival was good the barrier was very dense, but gaps did occur. The only insects noted were blister beetles. These caused quite severe defoliation in some belts.

Common caragana had good vigor and survival in most belts. Normal growth was 6 to 10 feet high. It is adapted to dry upland and alkaline conditions and should continue to be used.

Common Lilac — *Syringa vulgaris*

The common lilac was present in a few belts and was very well adapted to a wide range of sites. The vigor and condition were good and survival was excellent. It produced a uniform, dense 6 to 8 foot hedge. The suckering ability of lilac was very important to rejuvenate the species and to obtain the maximum effect for which it was intended. No disease was noted. Common lilac was more effective than common caragana because of its density, and had a similar adaptability range.

Tatarian Honeysuckle — *Lonicera tatarica*

Honeysuckle was used as a partial row with lilac in one belt and had been completely removed by the farmer in the other. Honeysuckle was not as effective as common caragana or common lilac because with age the bottoms get leggy and become very sparse.

American Plum — *Prunus americana*
Chokecherry — *Prunus virginiana*

The American plum and chokecherry were present in a number of belts but only incorporated with other shrub rows. These species were usually planted because of the farmer's desire to have a few plants for fruit purposes or for wildlife feeding.

The American plum was much superior to chokecherry for dense, low cover and probably had fewer disease problems. The common lilac and common caragana were better able to withstand snow build-up as compared to the plum or chokecherry. These two species still warrant planting in the Dakotas for shelterbelt purposes but full consideration should be given before using as the snow-catch row.

Conifers

Conifers were present in most belts. Their importance as a long-lived, dense barrier warrants planting in every belt. They can provide greater density with usually fewer rows. Double rows of conifers adjacent to each other should be considered. Conifers are slower in initial height growth and are susceptible to winter burning. Ponderosa pine survival (23.5%) was less than that of all the shelterbelt species. Only cottonwood (30.3%) and white willow (35.1%) had poorer survival than Eastern red cedar (39.6%). Colorado spruce (66%) was comparable to American elm (64.8%).

Eastern Red cedar — *Juniperus virginiana*

Eastern red cedar was very hardy, well adapted to most sites in the Dakotas and was the most commonly used evergreen. In some belts it was incorporated with ponderosa pine and in one case was present in a green ash row. The reason for the latter was not known.

The Eastern red cedar had a DBH from 2.5 to 6 inches, height from 8 to 23 feet and the diameter growth rate for the last 10 years averaged 10 inches. Disease was not a serious problem, although a needle blight was noted.

Ponderosa Pine — *Pinus ponderosa*

Ponderosa pine was encountered in a number of the belts. The survival rate was somewhat less than that of Eastern red cedar. This species was very effective adjacent to juniper or spruce as the next row inward toward the mass of the belt. A DBH of 6 to 10 inches and height of 30 to 40 feet was not uncommon. The diameter growth rate of the past 10 years was superior to juniper and many of the deciduous species. Ponderosa pine warrants more extensive planting.

Pine needle blight was the major disease noted. The vigor of ponderosa pine was good, although slow initial growth was common. Once the species was established the growth was quite rapid. Ponderosa pine was able to withstand dryer upland sites.

Colorado Spruce — *Picea pungens*

Colorado spruce was sampled in only two belts. Read (12) recommended spruce be planted only on the better sites in the Dakotas. Colorado spruce may have a greater adaptability range than previously stated and should be used more extensively. Survival percentage of Colorado spruce was greater (66%) than that of ponderosa pine (23.5%). Height and DBH were about the same for Colorado spruce and ponderosa pine. Increment borings showed a greater diameter growth rate in the last 10 years for Colorado spruce.

Spruce produces a dense, low barrier near the ground which is very effective as a wind barrier. A double row of spruce is very effective in conjunction with or adjacent to juniper or pine.

SUMMARY AND CONCLUSIONS

This study was designed to examine the growth and survival of 20 shelterbelts located throughout Barnes, Ransom and Cass counties of eastern North Dakota. Most belts sampled varied substantially, although a high percentage of the shelterbelts contained green ash, American elm, cottonwood, Siberian elm, boxelder and/or Russian olive, Eastern red cedar and/or ponderosa pine and common caragana.

Each twentieth tree in each row selected for study was sampled and DBH, height, vigor, insect and disease incidence were recorded. Increment borings were obtained to measure diameter growth for the last 10 years, which ranged between 0.3 and 1.8 inches. The greatest growth occurred with cottonwood and Siberian elm, while the least was from hackberry, suppressed green ash, American elm and bur oak. Conifers fell between this range.

Survival percentage was calculated and was compared from one species to the other. Of the deciduous trees, green ash and American elm showed the best survival followed by Siberian elm, boxelder and hackberry, with cottonwood and Russian olive having the lowest survival. Ponderosa pine had the lowest survival of all species planted. Colorado spruce, on the basis of a small sample, had excellent survival.

Location and orientation, design of field windbreaks, species composition, spacing and arrangement were discussed. The shelterbelts of 1935-1942 were designed and established to reduce wind velocity, erosion, crop desiccation and transpiration. Other purposes considered were wildlife food and protection, production of edible fruit, wood products, aesthetic value and employment.

The fast growing deciduous trees (cottonwood, white willow, Siberian elm) are very important in the development of field windbreaks due to their quick establishment and rapid height growth. These should not be planted without the more permanent species, such as green ash or conifers, because of the wide adaptability range and extended life span of the latter.

The tall, slower growing species (American elm, green ash, bur oak, common hackberry) are important for crown density, longevity and as a fill-in between the tall, fast-growing deciduous trees and the short, fast-growing deciduous trees.

The shorter but faster growing deciduous trees (boxelder, Russian olive) should be used when needed to obtain fairly rapid establishment and a solid dense barrier to fill in between shrubs and slower growing tall deciduous trees.

Shrub rows are also needed, possibly on both sides of the windbreaks, to form a low dense barrier to uplift the wind and act as an initial snowtrap. Common lilac and common caragana are superior and should be used in the outside rows.

Factors that may influence the effectiveness of shelterbelts are power lines, livestock damage, planting too close to roadways and intersections, fires, pest problems, snow buildup, wind and drought.

Trees dead or dying should be replaced in the first years after planting to prevent size difference which may cause large permanent gaps.

Shelterbelts of five to seven rows gave sufficient protection in most cases. Depending on its intended purpose, three row and one row belts could be effective. Ten rows of trees make a very effective belt if there is sufficient room and provide the other intended purposes for which shelterbelts were originally planted.

Farmers must be encouraged to plant shelterbelts. Row width of newly established belts should depend upon the situation for which the belt is established.

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