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Study of shelterbelts in eastern Montana

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The University of Montana

A STUDY OF SHELTERBELTS

IN EASTERN MONTANA

by

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CHAPTER I

INTRODUCTION

Protective plantings of trees in Montana are almost as old as the State's admission to the Union in 1889. As early as 1895 there were tree plantings on ranches in the valleys of the Sun, Milk, Tongue, Yellowstone and other rivers. Nearly all of these plantings were farmstead windbreaks made to protect the ranch headquarters from the bitter northwest winds of the winter and the hot searing west and southwest winds of the summer. As is still true today, few were shelterbelts to protect field crops.1/ Most of the planting stock for these early windbreaks was obtained from the cottonwood flats on the river bottoms. Later, as means of transportation were improved, the farmers and ranchers purchased considerable planting stock from private nurseries chiefly in North Dakota, South Dakota, Minnesota and Montana.

THE PROBLEM

Since 1916, when the Field Station of the Bureau of Plant Industry at Mandan, North Dakota first set out some experimental plantings in this state, the bulk of the trees have been planted in connection with the Federal cooperative agencies--Clarke-McNary, Bureau of Plant Industry

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1/ The term shelterbelt as used in this report is applied both to the comparatively few row plantings made to protect field crops, and to protective windbreak plantings around the farm buildings, garden, feedlots, corrals, etc.

and the Soil Conservation Service. Through the assistance of these agencies over 10 million trees have been planted in Montana for windbreak, shelterbelt, soil conservation and wildlife purposes.

Unfortunately, the first step, that of planting, was not followed through in too many cases. No survival and preformance records have been kept. Many of the successful plantings are not known and the failures are not understood. Instructions regarding planting methods and subsequent care differed with the different agencies, and were in some cases contradictory. This emphasizes the need for more and better information on what, when, where, and how to plant.

ORGANIZATION OF THE STUDY

In the spring of 1947 a cooperative study was set up between the Montana Forest and Conservation Experiment Station of the School of Forestry at Missoula and the Montana Agricultrual Experiment Station at Bozeman to appraise conditions now existing in eastern Montana shelterbelts.

The survey was made during the summer of 1947 with cooperation from the Montana Extension Service, the Soil Conservation Service and the Field Station of the Bureau of Plant Industry at Mandan, North Dakota. Approximately 6400 miles were traveled and 220 shelterbelts in the eastern counties of Montana were studied in detail. Figure 1 shows the general route traveled and the number of belts studied in each county. Side trips were made from the county seats so that plantings as far as 50 miles from the main highway were inspected.

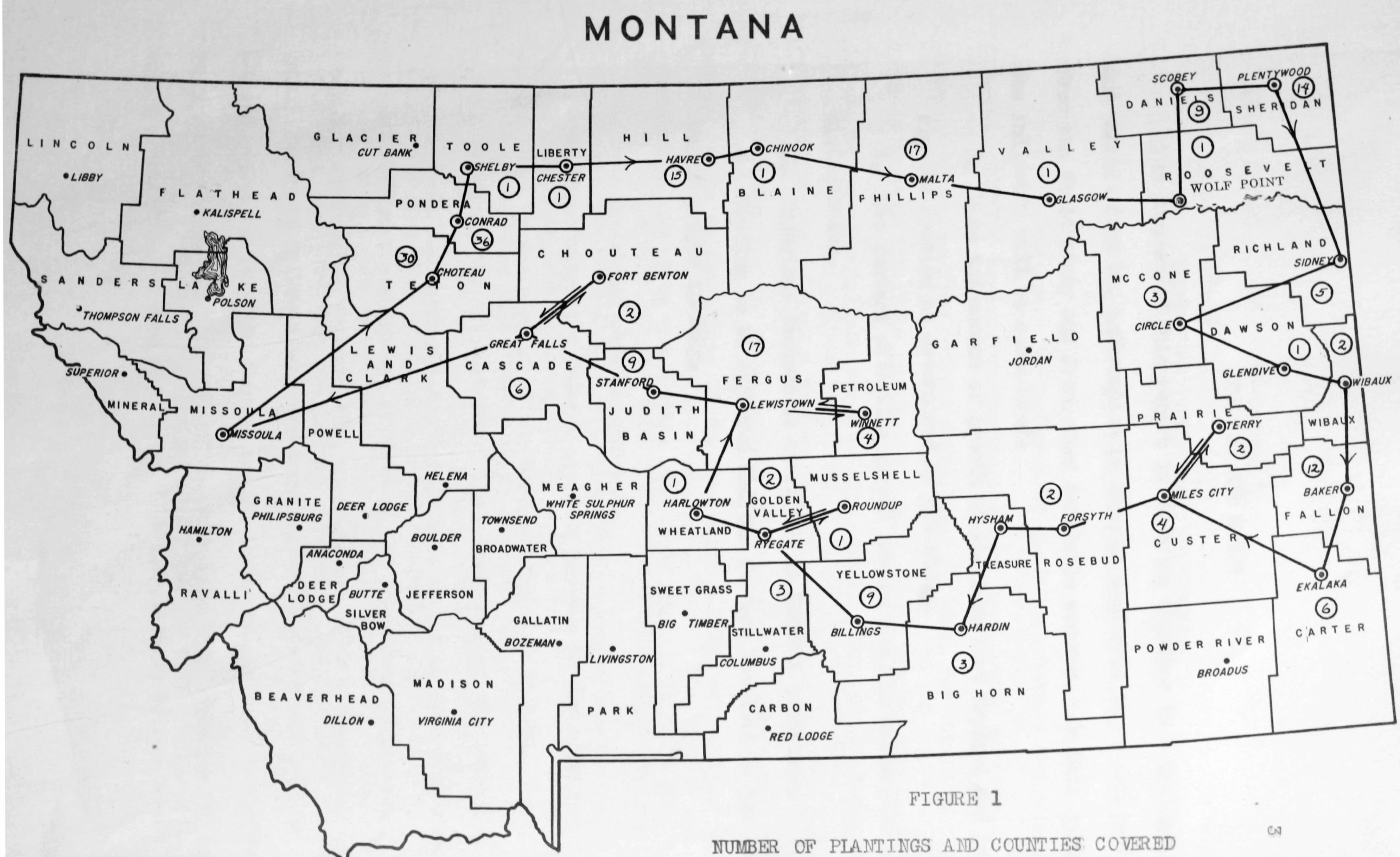

FIGURE 1

NUMBER OF PLANTINGS AND COUNTIES COVERED IN THE 1947 SHELTERBELT STUDY

PURPOSE AND SCOPE

The purpose of this report is to bring together in a systematic and useable form the information on Montana shelterbelts as obtained from the field study and from other available sources. In this paper the following will be considered:

1. Rate and amount of growth of the important dryland and irrigated species as determined by the study.

2. The factors affecting growth and survival in eastern Montana shelterbelts.

3. Injurious factors in operation in Montana plantings.

4. Spacing to be employed and the factors involved in the problem of proper spacing.

CHAPTER II

HISTORY OF SHELTERBELTS IN MONTANA

COOPERATING FEDERAL AGENCIES

For 27 years after Montana entered the Union, farmers and ranchers obtained stock for protective plantings solely from native cottonwood flats, mountain forests or from private nurseries. In 1916, the Bureau of Plant Industry through its field station at Mandan, North Dakota, started a program of experimental plantings in this state. Each year planting stock was furnished free of charge to five farmers or ranchers in each of the prairie counties for the establishment of experimental windbreaks. The persons chosen as recipients of the free stock had to meet certain requirements as set up by the Bureau. The Field Station is still carrying on this investigational planting program.

The first extensive federal planting program in the state was brought about by the passage of the Clarke-McNary Act in 1924. Among other provisions, the act authorized the cooperation of the Federal Government with the various state governments to set up tree nurseries (commonly called Clarke-McNary nurseries) for the growth of planting stock for windbreaks, shelterbelts, woodlots and other protective plantings. The trees produced in these cooperative nurseries are sold at reduced prices to bonafide farmers and ranchers and are used for protective purposes only. In 1927, the State of Montana took advantage of the act by establishing a tree nursery at Missoula operated by the School of

Forestry of Montana State University.

Planting stock from this nursery is distributed through the Montana Agriculture Extension Service. To obtain trees for windbreak purposes, the farmer must apply to his county agent stating the number and species of trees desired. The agent forwards the application for trees to the Extension Horticulturist at Bozeman 1/, who consolidates the orders received from the entire state and then forwards them to the Nurseryman at Missoula.2/ If there is no county agent present in the county, the farmer can make application directly to the Extension Horticulturist. The trees are packed and shipped directly to the farmer or rancher concerned in time for spring planting.

In 1935 another government planting program was set up in Montana by the Soil Conservation Service. All trees planted in cooperation with this service are planted on farms, ranches and demonstration areas in soil conservation districts only. Ordinarily, planting stock is not furnished to landowners outside of the districts.

The number of trees furnished by the Soil Conservation Service varies with the district. In some, 50 per cent of the planting stock required for farmstead windbreaks is furnished by the government agency and the owner purchases the rest. In other districts, the farmer furnishes all of the stock and Service gives only the technical super-

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1/ Mr. E. R. Isaac is the present Extention Horticulturist.

2/ Mr. O. M. Patten is the present Nurseryman.

vision required. However, all of the stock required for field plantings (that is, true shelterbelts) and for the demonstration areas is purchased by the government agency. The planting stock set out in cooperation with this agency generally comes from its nurseries at Mandan or Lincoln, Nebraska or from the Clarke-McNary nursery at Missoula

TREES PLANTED

Together, these three agencies have cooperated with the farmers and ranchers in setting out over 10 million trees in this state (Table 1). In addition, large numbers of private plantings have been made by the farmers and ranchers. It is impossible to estimate the number of such plantings.

The largest numbers of plantings have been made in Cascade, Teton, Pondera and the northeast counties of the state. Distribution of trees planted in cooperation with the Clarke-McNary Act since 1933 is shown in Figure 2. This Figure also shows fairly well the relative distribution of all plantings in the state, as trees from other sources were in general planted in the same locality and in the same proportion as the Clarke-McNary trees.

Table 22 in the appendix tabulates the number of trees shipped to the counties in the state by the Missoula nursery.

TABLE 1

NUMBER OF TREES PLANTED IN MONTANA BY GOVERNMENT AGENCIES SINCE 1916

Agency	Number of trees planted
Bureau of Plant Industry	2,166,760 1/
Soil Conservation Service	1,181,341 2/
Clarke-McNary	6,939,114 3/
Total	10,287,215

1/ Since 1916; from personal correspondence with Mr. Ernest J. George, Superintendent of the Mandan Field Station of the Bureau of Plant Industry at Mandan, North Dakota.

2/ Since 1936; from personal correspondence with Mr. Ross Williams, Regional Forester of the Soil Conservation Service at Lincoln, Nebraska.

3/ Since 1927; from records of the nursery at Missoula, Montana.

No. 1050 — County Outline Map (100 to pad)
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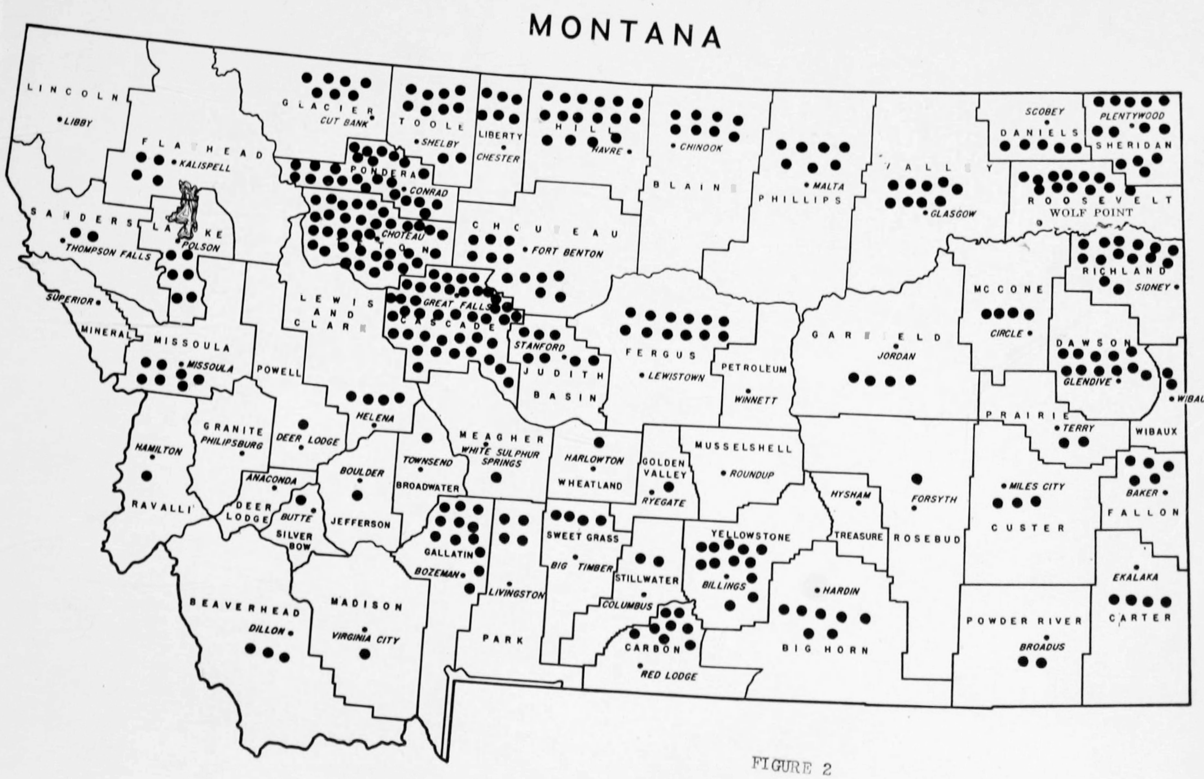

FIGURE 2

SHIPMENT OF TREES BY COUNTIES
FROM THE MISSOULA NURSERY, SINCE 1933
(Each dot represents 10,000 trees)

CHAPTER III

VALUE OF SHELTERBELTS

PHYSICAL BENEFITS

Reduction of Wind Velocity

Most of the benefits of tree windbreaks stem from their ability to reduce wind velocity. Measurements in Minnesota and North Dakota have shown reductions of up to 33 per cent on the leeward side at 200 feet from the planting (Cheyney, 1931; Scholz, 1935). Walker (1946) at the Forest Nursery Station at Indian Head, Saskatchewan, reports that a single row of white spruce 25 feet high reduced the velocity of wind by 80 per cent at 50 feet and by 25 per cent at 250 feet from the belt.

Area Protected

The distance protected by the trees is dependent upon the height of the belt. This distance is expressed in "heights" rather than in feet. For example, to say that a reduction in velocity of the wind is noticed 10 heights from the belt means that the effect extenes a distance of 10 times the average height of the trees in the belt. Bates (1936) observed measurable decreases in wind velocity to a distance of 20 heights. He also found that the value of the belt increases as the velocity of the wind.

The protected area also varies with the length of the belt. As the length increases, the area of protection is increased by the square of the increase in length. To illustrate, a belt 3 rods high and 6 rods long will decrease wind velocity over an area of 9 square rods; if the length of the belt is doubled the area is increased by 4 times, (that is the square of 2) to 36 square rods. This relationship is shown in Table 2.

Reduction of Moisture Loss Due to Evaporation

Reduction in wind velocity decreases the rate of evaporation from the soil and from the crops. In Canada, workers have observed a 40 per cent reduction in evaporation 2 heights from a planting and a 10 per cent reduction 10 heights away (Walker, 1946). The protection afforded by a windbreak by means of reduction in wind velocity and resultant evaporation are most important when rains are fairly frequent yet not so abundant that crops have enough moisture for their optimum development. If drought conditions prevail for a long time the entire supply of surface moisture will be lost regardless of the protection given by a windbreak (Bates, 1936). In other words, windbreaks will produce the most striking results under moderate conditions but will not necessarily insure good crops.

Effects on Soil and Air Temperatures

Although extensive naturally forested areas will cool the air within them and this cool air sometimes spills out into the surrounding country, windbreaks rarely have this effect. They are not extensive enough to cause an actual reduction of temperature outside the belt. In fact, they may have the opposite effect. Observation made when a hot, dry wind

TABLE 2

AREA PROTECTED BY A SHELTERBELT THREE RODS (49.5 FEET) HIGH
(From Bates, 1936)

Length of Belt (rods)	Area Protected (Sq. rods)
6	9
12	36
72	1,296 (8.1 A.)

was blowing over a belt of ash showed that both at 5 feet and 40 feet above the ground the air was warmer by 1° on the leeward side than on the windward side. On clear days and at 2 or 3 heights from the belt the temperatures will be approximately 2° higher than elsewhere (Bates, 1930).

Soil temperatures are also slightly increased by a windbreak. The temperature at 1 and 2 feet below the surface may be slightly over 2°C. higher in the open than within the belt (Cheyney, 1931). At 2 heights from the belt the temperature 20 inches below the surface is about 1°C. higher than the temperature in areas outside of the zone of the shelterbelt influence (Bates, 1911).

The effect of the increased air and soil temperatures on crops is dependent upon the moisture supply available. In Minnesota, for example, corn yields have been increased by an average of 9.22 bushels per acre up to 10 heights away from the belt. Maximum gains of 18 bushels per acre over the yield outside the zone of influence of the belt were recorded at the points where the temperature increase was the most and the evaporation the least. These increases were ascribed to the higher temperatures (Bates, 1911). In a dry year, however, quite the opposite effect might be noted.

Moderation of Sensible Temperatures

While shelterbelts do not moderate the actual temperature to an appreciable amount, they do moderate the "sensible temperatures", that is the temperature that is felt rather than the actual temperature of the air. The difference between these two temperatures may be great and is increased by wind. When a wind blows on a cold day, a p erson feels much colder than he does at the same temperature on a calm day. Winds increase radiation and conduction of heat from the body surface so that any decrease in velocity will bring about a sensation of warmth. Sensible temperatures are quite important to both farmers and their livestock.

Reduction of wind velocity and moderation of sensible temperatures cause a substantial saving in the fuel bill of the owner. Studies conducted in the shelterbelt zone of the Prairie States by the United States Forest Service have shown 40 per cent savings on fuel bills which amounted to 15 to 20 dollars a year (Bates, 1945).

INCREASED REAL ESTATE VALUES

Actual real estate values of a farm or ranch are increased by a well-planned and vigorous windbreak. Mr. Robert Davidson, a farmer near Farmington, has placed a value of $5,000 on his belt, pictured in Figure 3. Other farmers throughout eastern Montana have estimated that their real estate values have increased from 2 to 5 thousand dollars because of their protective plantings. One farmer in the Judith Basin was so enthusiastic about his planting that he threatened a "Winchester p arty" if anyone tried to take his trees.

ESTHETIC BENEFITS

The monetary value of the increased crop yield or increase in real estate value is not the only benefit derived from the trees. Beyond any doubt, living conditions are improved on the bleak plains. Mrs. E. C. Mitchell, a farm wife near Dutton has stated that prior to

FIGURE 3

AN IRRIGATED BELT VALUED BY ITS OWNER AT $6,000 the planting of windbreak on their dryland farm, she was unable to grow any flowers or vegetables because the wind "whipped the plants apart". Since the establishment of their fine windbreak, she is now able to grow columbine, calendulas, delphiniums, roses and many others besides a fine vegetable garden. Other Montana farmers have had similar experiences.

Though he sometimes seems to have a rough and horny exterior, the Montana farmer has a deep appreciation of natural beauty. On a hot August evening the green of his shelterbelt is a pleasant welcome after a day in the dry brown fields. In the winter the green warmth of the evergreens gives his farmstead a "homey look" that makes life seem more worthwhile.

Windbreaks have increased the numbers of birdlife near a farmstead. Over 25 different species of birds have been identified in farmstead plantings.1/ In addition to songbirds, game birds such as sharptail grouse, sage hens, and pheasants use windbreaks and shelterbelts for nesting sites.

The net results of a vigorous, well-planned shelterbelt add up to decreased wind velocity resulting in increased crop yields, better living conditions and higher real estate values.

1/ A list of birds identified in eastern Montana windbreaks is presented in Table 23 of Appendix.

CHAPTER IV

METHOD OF CONDUCTING THE STUDY

CHOICE OF BELTS

Areas studied were chosen on the basis of extent of settlement, number of plantings in the area, diversity of soil types present and availability of water for irrigation purposes. Large areas with few inhabitants and few plantings were studied sketchily or not at all. In those areas where there were many plantings, good, bad or indifferent, the study was more intensive. Generally, belts studied were a mile to 10 miles apart. Frequently, however, neighboring belts were studied if they depicted contradicting situations, such as good cultivation compared to lack of care.

Windbreaks studied in detail were chosen to represent the range of conditions that may be encountered by the shelterbelt planter. They were chosen to represent a certain factor or combination of factors. Items that entered into the selection of the planting were soil type, age, condition of trees, condition of the belt in general, species make-up, site, grazing, fire, lack of care and the like. For example, windbreak "A" may have been chosen because it was growing on a sandy soil and showed evidence of grazing. Windbreak "B", on the other hand, may have been on a clay soil and a rolling site and was composed of a species about which more information was desired. In this manner a considerable amount of data concerning many factors were gathered.

INFORMATION OBTAINED

Each belt was studied with reference to several categories or types of information which were, in turn, broken down into more detailed classes. Following, in outline form, are the types of information obtained about each belt studied in detail:

1. Owner and location of belt
   a. Name and address of owner or tenant
   b. Location of planting by county, section, township and range
2. Statistics of the planting
   a. Type of planting
   b. Length, width and number of rows in the belt
3. Site factors
   a. Soils
      1) depth, texture and pH of surface soil
      2) texture and salt accumulation in subsoil
      3) presence, nature and depth of hardpan
   b. Water
      1) depth to water table
      2) irrigated or dryland
   c. Topographical features
      1) topography, slope, exposure and situation of the planting site
   d. Nutrients
      1) relative abundance of nitrogen and phosphorus

4. History of the belt

   a. Planting date and source of stock

   b. Duration of cultivation and equipment used

   c. Attitude of farmer toward the planting

   d. Any other pertinent data

5. Species data

   a. Spacing; in-row and between the rows

   b. Growth and mortality

      1) age of each row

      2) average height growth and crown width of each row

      3) survival per cent and cause of mortality

      4) cause of damage

   c. Vigor and species rating

All of the information regarding each belt was recorded on a specially prepared field form. Figures 4 and 5 reproduce the field sheet and the key used in conjunction with it.

Soils analyses were made in the field with the Purdue Soil Testing Kit. With high pH conditions this kit will give slightly erroneous results if the soils are analyzed directly. Therefore, plant tissue tests were made with this kit to determine the relative abundance of nitrogen and phosphorus. The pH was determined directly from soil samples. All analyses were made in accordance with the instructions issued with the soil testing kit. (See Appendix for detailed instructions for soil analysis.) From time to time, soil samples were sent to the soils laboratory at the Agricultural Experiment Station at

FIGURE 4

FIELD SHEET USED IN THE SHELTERBELT STUDY

MONTANA SHELTERBELT EXAMINATION RECORD Sheet No.________

County________________________________ Date__________

Cooperator__________________ Owner Tenant Recorder__________

Address______________________ S____ T____ R____

Type________ Length________ Width________ No. Rows________

Surface soil depth____ Texture____ Salts____ PH________

Subsoil texture______ Hardpan______ Depth__________

Watertable________ Irrigated______ Dryland____ Site______

Topography______ Slope____ Exposure____ Situation______

Shelterbelt success________________ Reasons______

W E S

____

Attitude of Cooperator______________________

____

Shelterbelt history Planted 19____ Replanted 19______

____

Ground surface________ Cultivation equip.________

____

Fenced______________ Grazing______________

Remarks: ___________________________________

____

____

Species by rows

1. ____________
2. ____________
3. ____________
4. ____________
5. ____________
6. ____________
7. ____________
8. ____________
9. ____________
10. ____________

SPECIES DATA

Species					
Spacing in row					
Spacing between rows					
Age					
Height					
Crown width					
Survival %					
Cause of mortality					
Cause of damage					
General vigor					
Species rating					

(SAMPLE)

FIGURE 5

KEY USED IN CONJUNCTION WITH THE FIELD SHEET IN THE SHELTERBELT STUDY

MONTANA SHELTERBELT EXAMINATION RECORD CODE

1. Type (of planting)
   1) Farmstead
   2) Field crop
   3) Wildlife
   4) Woodlot
   5) Other (specify)

2. Width--in feet from outside row to inside row

3. Surface soil depth--inches

4. Surface soil texture
   1) Sandy
   2) Sandy loam
   3) Loamy
   4) Clay loam
   5) Clay

5. Subsoil Texture
   1) Gravelly
   2) Sandy
   3) Loamy
   4) Clay
   5) Very heavy

6. Hardpan--depth to in feet
   1) Clay
   2) Lime

7. Watertable--depth to in feet

8. Topography
   1) Level
   2) Sloping
   3) Rolling

9. Exposure--N, S, E, W, etc.

10. Situation
    1) Upland
    2) Lowland
    3) Base of slope
    4) Slope

11. Site--F1, F2, F3, B1, B2

12. Shelterbelt success (in relationship to purpose)
    1) Good
    2) Fair
    3) Poor
    4) Failure

13. Reasons--success or failure
    Consider location, species selection, number of rows, care, snow catching ability, etc.

14. Ground surface
    1) Clean
    2) Light weeds
    3) Heavy weeds
    4) Soddy

15. Vigor (General thrift and vigor of species)
    1) Good
    2) Fair
    3) Poor

16. Species Rating (Effectiveness in belt)
    1) Good
    2) Fair
    3) Poor

17. Causes of mortality
    1) Insects
    2) Fungi
    3) Mechanical
    4) Drouth
    5) Planting methods
    6) Vegetative competition
    7) Other (specify)

18. Cause of Damage
    1) Winter injury
    2) Cultivation
    3) Snow damage
    4) Rodents
    5) Chlorosis
    6) Other abnormal growth characteristics
    7) Other (specify)

19. Grazing
    1) Heavy
    2) Light
    3) None

Bozeman for a check upon the results obtained in the field.

The history of the belt in as much detail as possible was obtained from the farmer. Much of this information was quite intangible and could only be obtained by discreet questioning.

EQUIPMENT USED

The equipment used was as follows:

1. Purdue Soil Testing Kit with color charts
2. Distilled water
3. Shovel
4. Percent abney
5. 100-foot steel tape
6. Metal rule
7. Increment borer
8. Supply of field forms
9. Datum holders
10. List of shipments made by the nursery at Missoula

CHAPTER V

PHYSICAL AND CLIMATIC CHARACTERISTICS OF THE AREA STUDIED

PHYSICAL CHARACTERISTICS

Topography

All of the counties included in the study lie east of the Continental Divide which is a natural dividing line of Montana, dividing the state into two parts of unequal size. The western part is characterized by rough mountains and narrow valleys, while the eastern section is largely the Great Plains type of country, characterized by open flat or rolling plains broken occasionally by wide river valleys and by small groups of mountains. A map showing the general topographical features of eastern Montana is shown in Figure 6.

Geologically, glacial drift deposited by the Keewatin ice sheet during the Wisconsin glaciation covers the northern one third of eastern Montana. The generally gentle sweep of the drift is broken in places by steeply rolling morainic hills. With the exception of the small mountainous areas, the rest of eastern Montana is underlain by thick beds of sedimentary deposits, mainly sandstones and shales. Here, too, the topography varies from undulating prairie to rough, rolling hills. The mountainous areas are composed of both sedimentary and igneous rocks.

Badlands, that is, areas of very rough topography and generally with little vegetation, characterize most of the bluffs bordering the river valleys.

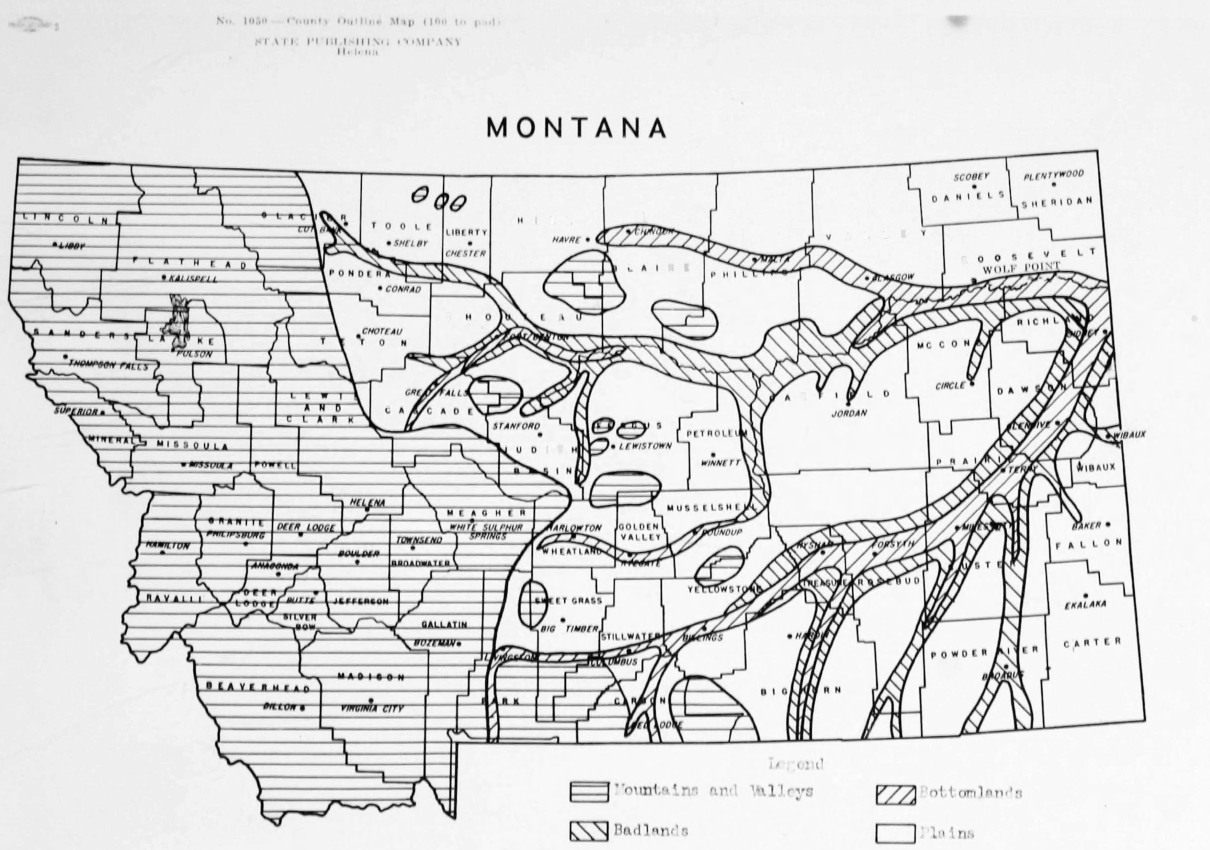

FIGURE 6

GENERAL TOPOGRAPHY MAP OF MONTANA

Altitude

Most of the plains area is of relatively low altitude -- less than 4,000 feet. The lowest point is at Ft. Union on the Montana-North Dakota line where the altitude is 1,100 feet above mean sea level.

Drainage

All of eastern Montana has been classified as being in the upper Missouri River Basin and, except for local areas of impeded drainage, is well drained. Principal rivers are the Milk River draining the northern portion of the plains, the Missouri draining the central and the Yellowstone flowing northeastward and draining the south portion.

CLIMATIC FACTORS

Precipitation

Without doubt, the most decisive climatic factor in eastern Montana is precipitation. Critical moisture supplies affect the growth of shelterbelt trees as well as agricultural crops.

A climatic summary of selected stations in eastern Montana has been prepared in Table 3. From this it can be seen that the annual precipitation varies from 10.53 inches at Chester in Liberty County to 15.71 inches at Wibaux. At only three stations listed in the table, Great Falls, Vida and Wibaux, is the annual precipitation more than 15 inches.

CLIMATIC SUMMARY OF SELECTED STATIONS THAT ARE TYPICAL OF THE PLAINS AREA OF EASTERN MONTANA

(From 1941 Yearbook of Agriculture, Climate and Man)

County	Station	Average Temperature January	Average Temperature July	Temperature Extremes Maximum	Temperature Extremes Minimum	Killing Frost Average Dates Last in Spring	Killing Frost Average Dates First in Fall	Growing Season	Average Precipitation Annual	Average Precipitation Growing Season	Percent in Growing Season 1/
		°F.	°F.	°F.	°F.			Days	In.	In.	%
Blaine	Chinook	14.0	69.9	110	-51	May 13	Sept. 19	129	13.22	10.11	76.5
Carter	Ekalaka	19.0	71.2	108	-43	19	23	127	13.17	10.42	79.2
Cascade	Great Falls	23.0	69.0	107	-49	9	25	139	15.21	10.90	71.7
Custer	Miles City	14.5	75.0	111	-49	Apr. 30	Oct. 5	158	13.16	9.85	74.8
Daniels	Scobey	—	—	—	—	May 24	Sept. 22	121	11.45	8.94	78.1
Dawson	Glendive	14.1	73.2	117	-50	13	24	134	14.03	10.68	76.0
Fallon	Baker	—	—	111	-52	9	25	139	14.21	10.22	71.9
Fergus	Valentine	10.2	70.0	110	-50	17	19	125	10.90	8.41	77.2
	Winifred	10.1	69.1	108	-48	15	23	131	11.64	7.88	67.7
Garfield	Jordan	14.0	72.4	112	-50	19	21	125	11.62	8.43	72.5
Glacier	Cut Bank	16.0	65.1	102	-47	23	15	117	11.24	8.99	79.2
Golden Valley	Ryegate	—	—	—	—	—	—	—	14.32	11.56	78.0
Hill	Havre	12.0	68.3	108	-57	11	22	134	13.07	9.60	73.5
Jud. Basin	Stanford	23.5	65.5	102	-44	23	28	128	14.57	10.58	72.7
Liberty	Chester	9.8	66.7	104	-55	25	7	105	10.53	8.37	79.4
McCone	Vida	—	—	—	—	13	26	135	15.05	9.85	65.4
Musselshell	Roundup	24.0	71.2	107	-52	9	27	141	12.26	8.50	69.3
Petroleum	Flatwillow	21.1	70.2	107	-48	18	25	130	11.88	8.90	75.0
Phillips	Malta	11.0	70.4	109	-56	14	24	133	13.47	10.54	78.4
Pondera	Conrad	17.1	66.8	103	-45	21	19	121	11.63	8.91	77.2
Prairie	Mildred	14.3	70.9	112	-50	14	25	134	12.03	9.72	80.7
Richland	Sidney	9.2	68.8	110	-47	18	21	126	14.98	11.73	78.6
Roosevelt	Poplar	7.1	71.2	110	-63	16	18	125	12.67	9.91	78.3
Rosebud	Forsyth	14.0	71.4	111	-46	16	27	134	12.86	9.24	71.8
Sheridan	Outlook	5.8	66.5	115	-55	23	21	121	12.45	10.28	82.5
Stillwater	Busteed	23.8	69.0	108	-45	22	21	122	14.51	10.15	69.9
Teton	Choteau	20.2	65.3	106	-50	26	15	112	11.79	9.35	79.3
Toole	Shelby	—	—	—	—	27	14	110	11.50	8.12	70.5
Valley	Glasgow	9.0	70.7	113	-58	19	19	123	13.21	9.92	75.0
Wheatland	Harlowton	19.5	66.8	102	-54	June 2	6	96	11.74	8.52	72.5
Wibaux	Wibaux	15.7	68.0	110	-55	May 25	13	111	15.71	12.44	79.1
Yellowstone	Billings No.2	23.2	71.2	112	-49	15	25	133	13.41	9.17	68.3

1/ Precipitation during growing season divided by annual precipitation.

Annual precipitation in Montana is characterised by its cyclic nature. Dry years often occur in series as in the years 1918, 1919 and 1920; or 1928, 1929, 1930 and 1931. Wet years often occur in series likewise as in the years 1912, 1913, 1914, 1915 and 1916 at Miles City or 1923, 1924, and 1925 at Havre (Seitz, 1937). Since the annual precipitation is normally barely sufficient to sustain tree growth so that the protective plantings are always growing under submarginal conditions, these cyclic low precipitation periods are quite serious and greatly retard the growth of the trees even to the point of failure.

Annual and seasonal precipitation zones are shown in Figures 7 and 8. Table 3 also shows the seasonal precipitation for selected points in the state. Normally, 65.5 per cent to 82.5 per cent of the annual precipitation occurs during the growing season, April through September — a typical Great Plains type of distribution. This distribution is presented for four typical points in eastern Montana in graphic form in Figure 9. The fact that most of the precipitation occurs during the growing season is probably the reason that shelterbelts are able to grow under such submarginal conditions as are present in eastern Montana.

Temperature

Average length of growing season, average date of last killing frost in the spring, summer and winter temperatures and the extremes are the most important phases of temperature affecting the growth of trees.

The growing season is the number of days between the average date of the last killing frost in spring and the first killing frost in autumn.

No. 1050—County Outline Map (100 to pad)
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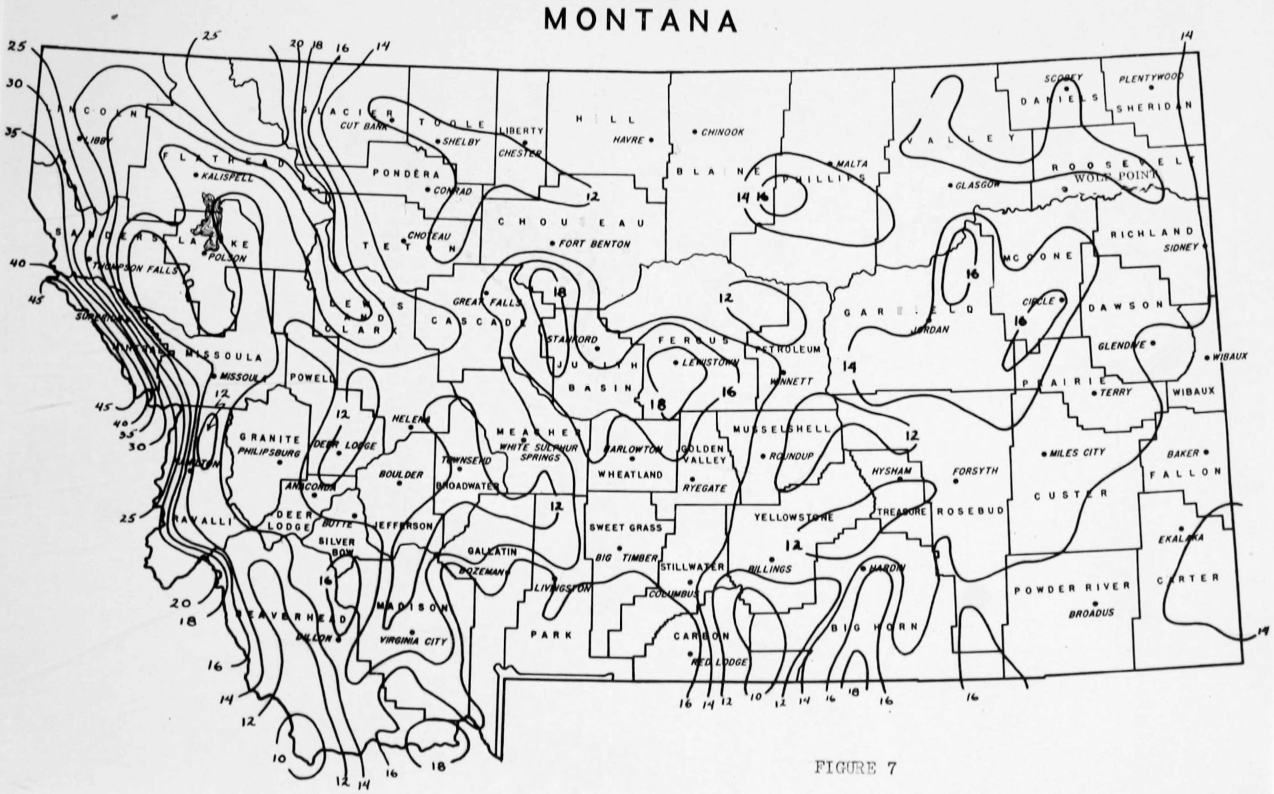

FIGURE 7

AVERAGE ANNUAL PRECIPITATION (Inches)
(From 1941 Yearbook of Agriculture, Climate and Man)

STATE PUBLISHING COMPANY
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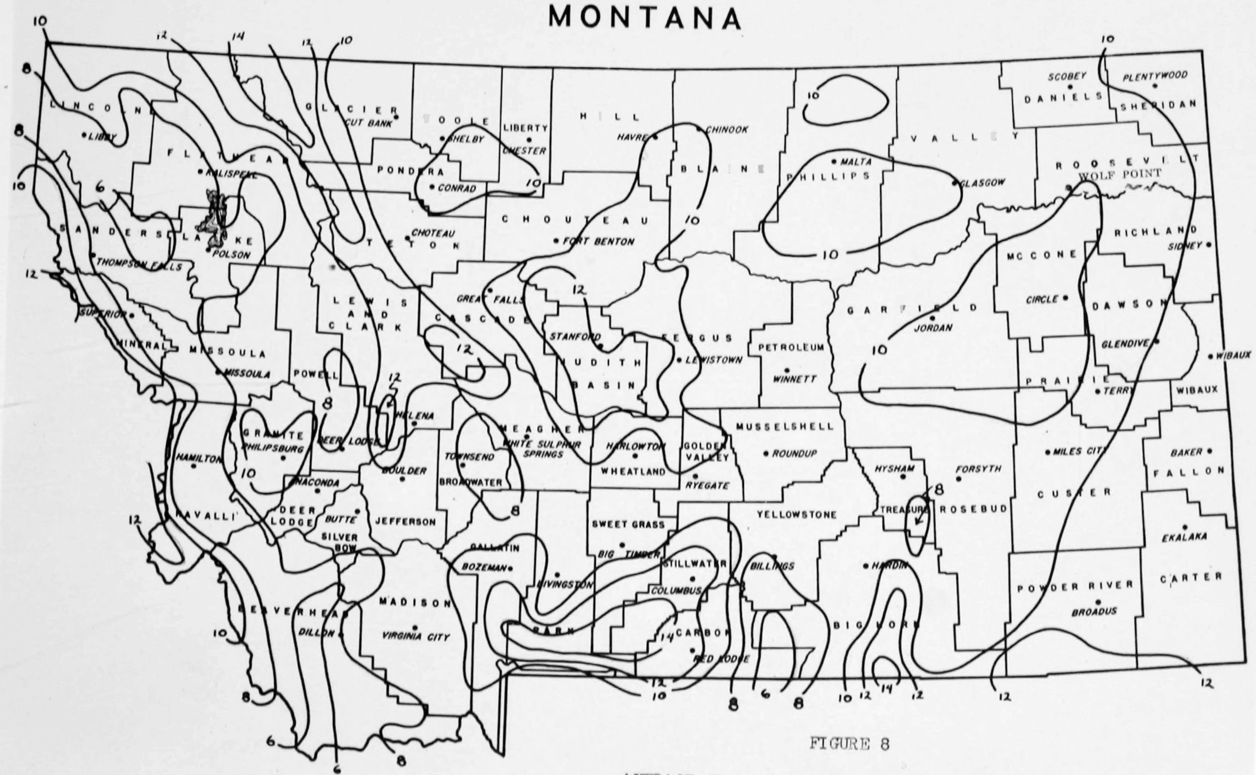

FIGURE 8

AVERAGE GROWING SEASON PRECIPITATION IN INCHES
APRIL TO SEPTEMBER, INCLUSIVE
(From 1941 Yearbook of Agriculture, Climate and Man)

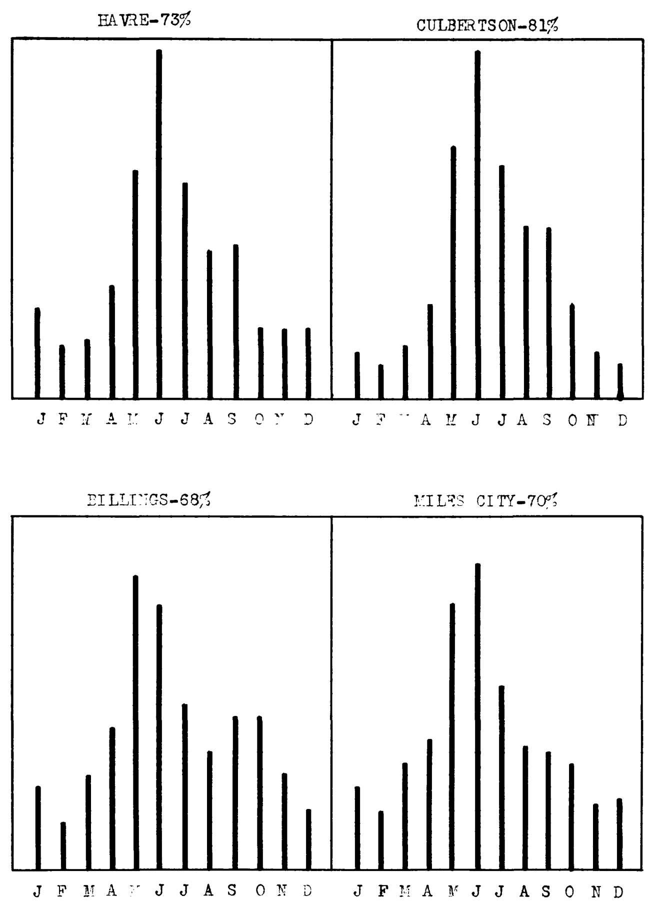

FIGURE 9

AVERAGE PRECIPITATION IN INCHES FOR FOUR TYPICAL STATIONS
IN EASTERN MONTANA WITH THE PER CENT THAT FALLS FROM
APRIL THROUGH SEPTEMBER
(From Reitz, 1937)

Frost data has been summarized in Figure 10, which shows the average length of the frost-free period for all parts of the state. The major portion of the eastern section of the state has a frost-free period of from 120-140 days with a few isolated mountain areas having less than 100 days.

Late killing frosts are important to tree growth as well as to crop growth and especially to those trees that characteristically leaf out early in the spring. Killing frost usually refers to temperatures 32°F. or lower. At times temperatures slightly below 32°F. may be recorded without frost damage while at other times temperatures slightly above may be harmful to certain plants. Therefore, the use of this temperature has only limited specific use but it does indicate the relative earliness or lateness of the growing season. A map has been prepared showing the zones with approximately the same average date of the last killing frost (Figure 11).

Table 3 shows the average temperatures for January and July. The highest average July temperature is at Glendive with 73.2°F. and the lowest average January temperature is 7.1°F. at Poplar. Over the eastern section of the state, however, the lower Yellowstone and the lower Missouri River areas average a few degrees higher than the rest of the section. The average January and July temperature lines have been plotted on a map of Montana as shown in Figure 12.

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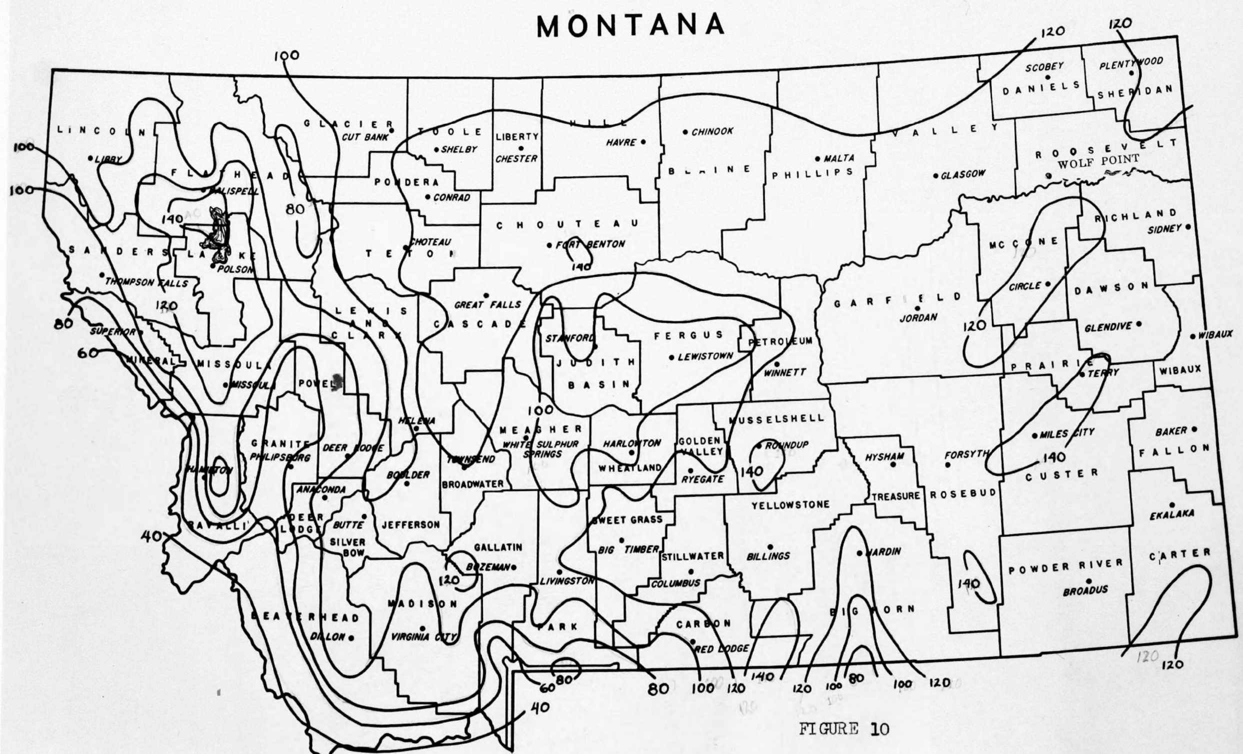

FIGURE 10

AVERAGE NUMBER OF DAYS WITHOUT KILLING FROST
(From 1941 Yearbook of Agriculture, Climate and Man)

No. 1050 — County Outline Map (100 to pad)
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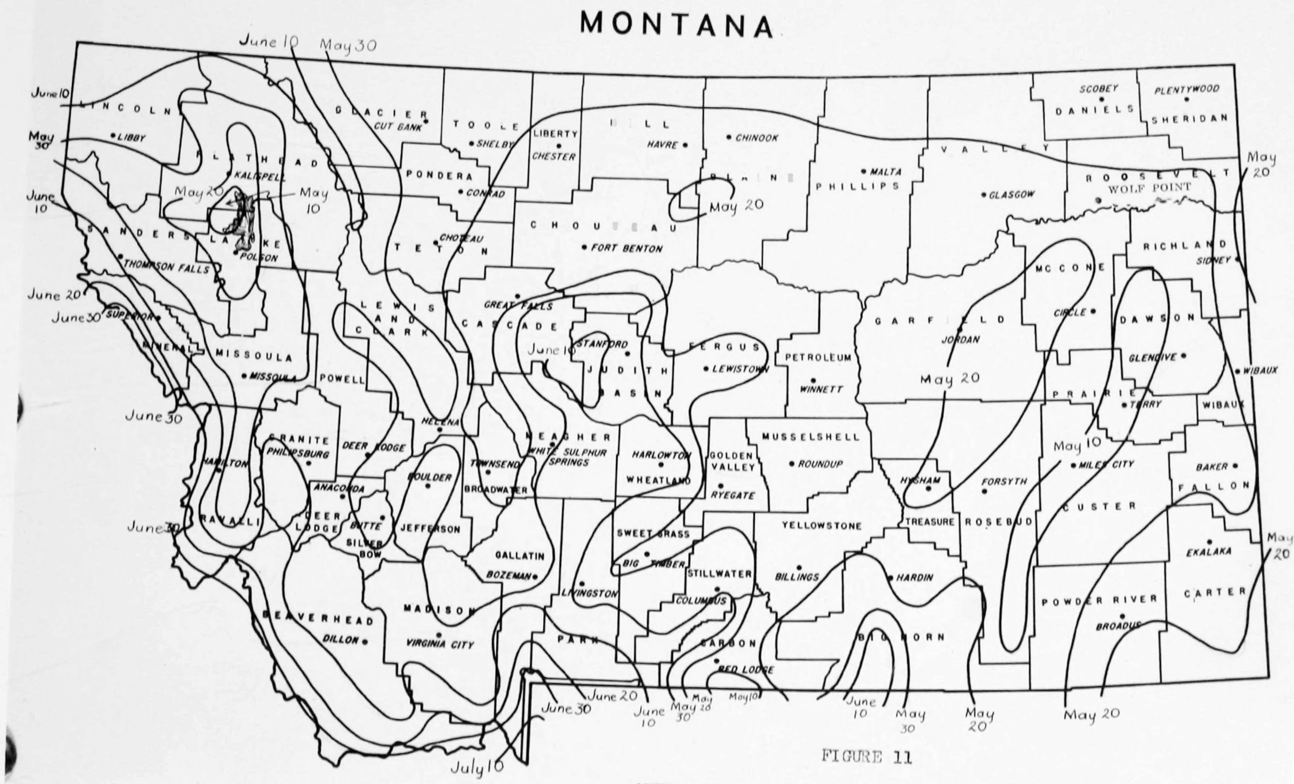

FIGURE 11

AVERAGE DATE OF LAST KILLING FROST IN SPRING
(From 1941 Yearbook of Agriculture, Climate and Man)

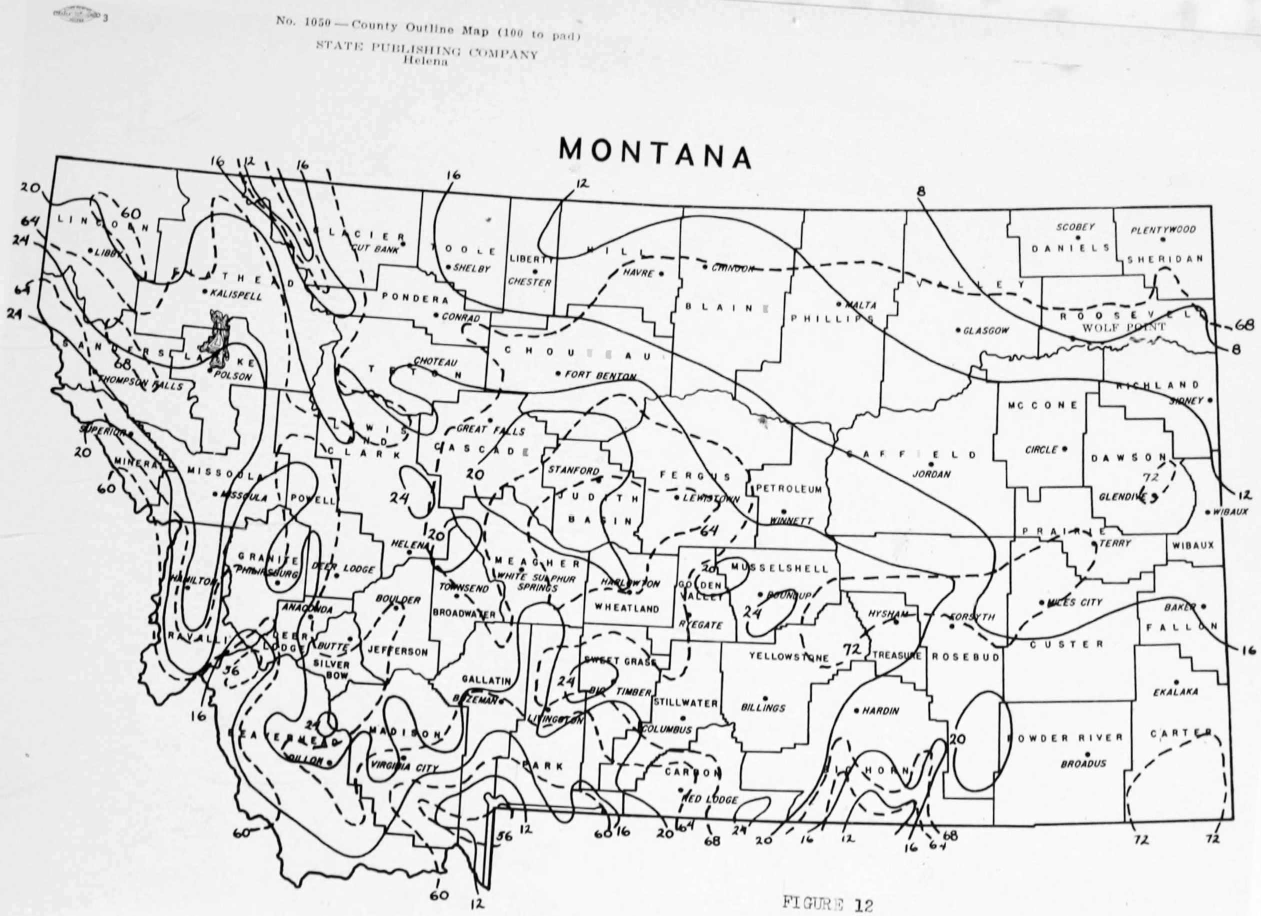

FIGURE 12

AVERAGE JANUARY AND JULY TEMPERATURE
(From 1941 Yearbook of Agriculture, Climate and Man)

Soils

The soils of eastern Montana have developed under cool-temperate, semi-arid conditions and have been classified as belonging to the Chestnut and Brown zonal soil groups and to the azonal lithosols and alluvium.

A map (Figure 13) has been prepared showing the general distribution of the great soil groups in Montana. The soil group boundaries were taken from the map "Soil Associations of the United States" published in *Soil and Men*, Yearbook of Agriculture for 1938. In addition, the approximate southern boundary of the Keewatin ice sheet which spread over northern Montana during the late Wisconsin glaciation is also shown.

Chestnut Soils. The Chestnut soils are characterized by the Williams, Scobey, Morton, and Bainville and other similar and associated soils and support a native stand of mixed short and tall grasses. The Williams and Scobey soils have developed largely over calcareous glacial till while the Morton and Bainville soils are over sandstones and shales. The top soils of these types are from 4 to 24 inches deep and are dark grayish brown in color. In general, the lime zone is well developed and varies in depth. The sub-soil may be grayish yellow or almost white as a result of the high lime concentrations.

Brown Soils. The Brown soils are characterized by the Joplin and other associated soils. They occupy the western part of the northern Great Plains and have developed under more arid conditions than have the Chestnut soils. Over much of the Brown soils, the moisture supply is too low for successful dryland farming except in the more favorable years.

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MONTANA

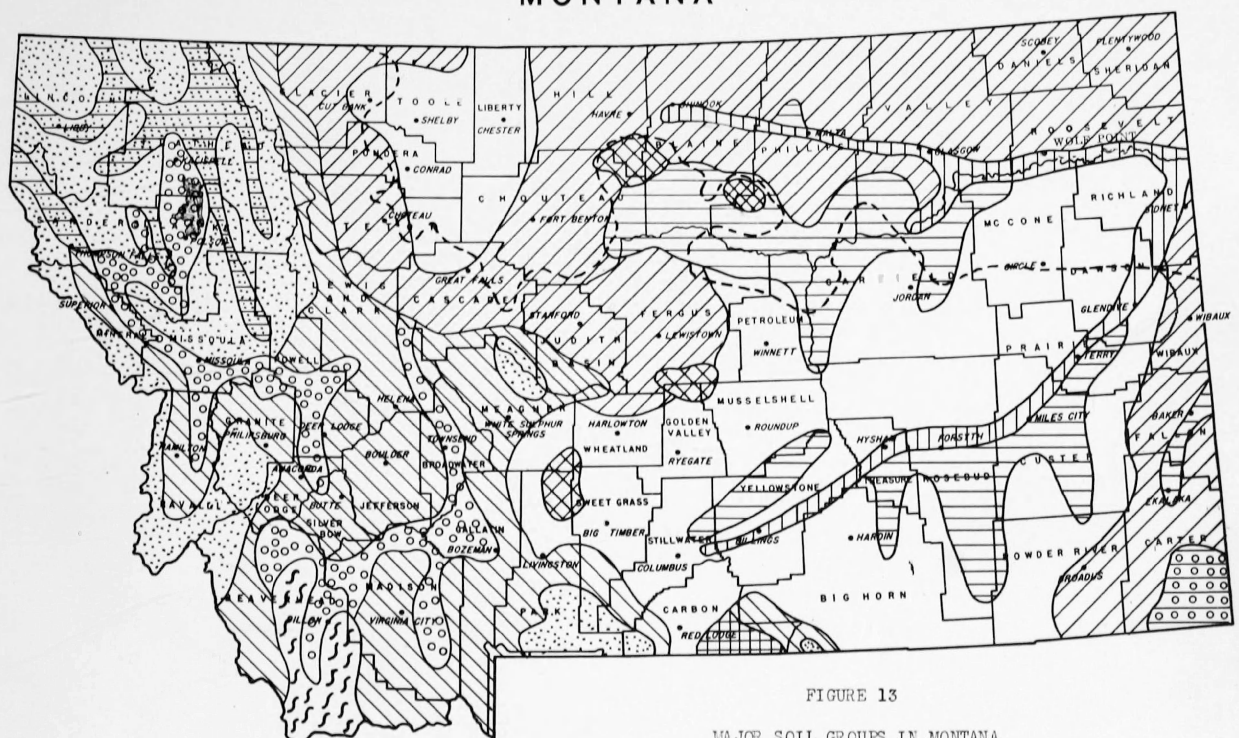

FIGURE 13

MAJOR SOIL GROUPS IN MONTANA
(From 1938 Yearbook of Agriculture, Soils and Men)

FIGURE 13a

LEGEND TO MAP
MAJOR SOIL GROUPS IN MONTANA

Chestnut (Williams-Morton-Bainville)

Brown (Joplin)

Lithosols (Rough broken land)

Alluvial soils

Lithosol (Undifferentiated, rough stony land and shallow podzols--forested)

Lithosols (Underwood-Baab)

Gray-Brown Podzolic Soils (Helmer-Santa-Benewah)

Chestnut (Myrum-Bingham-Avon)

Lithosols (McCarmon-Deschutes)

Gray-Brown Podzolic Soils (Everett-Alderwood)

Lithosols (Pierre)

Sierozem (Navajo-Chipeta)

Native vegetation on these soils is primarily composed of the short grasses with some areas of bunch grass and shrubs. The Joplin type soils have developed from shales and sandstones in the south and from glacial drift in the north part of the state. Surface soils are from 7 to 10 inches deep, grayish brown or gray and often loose or mulchlike. Subsoil is highly calcareous and is grayish brown or brown.

Within both the Chestnut and Brown soils are associated soils of lesser importance that vary in depth, structure and color. These are generally in the badlands or along the foothills of the mountains.

Alkali Spots and Hardpans. Locally within both the Chestnut and Brown soil groups are found "alkali spots" and "hard pans". Alkali spots are areas of high soluble salt concentration that develop when drainage is impeded and vigorous leaching is not a feature of the weathering processes. Such areas are characterized by bare spots known as "blow-out spots" or "slick spots". Only vegetation able to withstand high concentrations of salt are able to grow in these areas.

A hard pan is a dense, relatively impervious layer present in the "B" horizon of the soil profile. It may be of clay or lime-cemented gravel.

Protective plantings have been made in localities underlain with hardpan but rarely on "slick spot" sites.

Lithosols. The lithosols are a group of various intrazonal and azonal soils that vary greatly in character, depth of top soil, soil material and relief. In general, they are shallow soils on mountain foothills or rough hilly terrain. Large areas of badlands along the middle Missouri and Yellowstone Rivers are covered by these soils. Native vegetation is mostly sagebrush, juniper and bunchgrass. Parent material is highly varied ranging from igneous to sedimentary rocks and the outwash from them. The topsoils are mostly shallow and in places is lacking entirely because of rapid natural erosion. Where present, their color varies from grayish brown to dark rust brown. The subsoils of these lithosols are generally light gray, limy and often cemented.

Alluvium. Covering the bottomlands of the Yellowstone and the Missouri are extensive alluvial soils of which the Havre, Billings, and Laurel soils series are typical. These are mostly light-colored, rich in lime, low in organic content and extremely variable as to depth. Natural vegetation is scattered brush and grasses in the drier situations and cottonwoods, willows, sedges and grasses in the more moist areas. Concentrations of salts are high especially in the poorly drained areas where they form the "alkali flats".1/

Texture. Texture of the soils is highly variable. Of 228 soil samples taken from windbreaks planted in the eastern section of the state 4.4 per cent were sands, 24.5 per cent sandy loams, 28.5 per cent loams, 26.3 per cent clay loams and 15.8 per cent clays. (Table 4).

The pH of the topsoil varies from below 6.0 to over 7.2. Samples taken from native sodded areas and tested with the glass electrode method at the soils laboratory in Bozeman have yielded pH values as low as 5.15.

1/ Soil descriptions were taken from the 1938 Yearbook of Agriculture "Soils and Man" published by the United States Department of Agriculture.

TABLE 4

TEXTURE AND pH OF SOILS IN EASTERN MONTANA SHELTERBELTS

Textural Class	Samples	
	Number	Per cent
Sandy	10	4.4
Sandy loam	56	24.5
Loam	65	28.5
Clay loam	61	26.8
Clay	36	15.8
Total	228	100.0
pH Class		
Below 6.0	8	3.7
6.0 to 6.6	24	11.2
6.6 to 7.0	58	27.1
over 7.0	124	58.0
Total	214	100.0

Of the soils tested 42 per cent were neutral, 7.0, or below. Table 4 summarizes the pH relationships of the soils in windbreaks in the eastern portion of Montana.

CHAPTER VI

GROWTH IN MONTANA SHELTERBELTS

SPECIES ENCOUNTERED

Dryland Plantings

Twenty six species of trees and shrubs were recorded in the 270 dryland windbreaks and 15 in the 44 irrigated belts studied. These have been recorded in Tables 5 and 6 in the order of frequency of occurrence in the belts studied.

There were 7 species present (caragana, green ash, box elder, Russian olive, Chinese elm, cottonwood and American elm) in more than one fifth of the dryland belts. Of these, three, caragana, Russian olive and Chinese elm, are not native to this state. Caragana was the first and green ash the second most frequently found tree in the dryland belts. Box elder and Russian olive were encountered in almost the same number of belts. Cottonwood was planted in almost one fourth of the dryland plantings and American elm in one fifth.1/ The evergreens, Black Hills and Colorado blue spruces, juniper and ponderosa pine, have not been planted extensively in the older plantings; they were found in only 15, 5 and 5 per cent of the belts studied, respectively. However, the present

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1/ Though cottonwood was found in almost one fourth of the dryland belts, it is not considered an important dryland species in this paper because of its poor survival after about 10 years after planting. This will be further referred to in another part of this paper.

TABLE 5

OCCURRENCE OF TREE SPECIES IN 176 DRYLAND WINDBREAKS IN EASTERN MONTANA

Common Name	Scientific Name	Windbreaks in Which Found Number	Per cent
Caragana	Caragana arborescens Lam.	145	82.3
Green Ash	Fraxinus pennsylvanica lanceolata (Borkh.) Sarg.	131	74.4
Box Elder	Acer negundo L.	95	54.0
Russian Olive	Eleagnus angustifolia L.	90	51.1
Chinese Elm	Ulmus pumila L., U. parvifolia Jacq.	69	39.2
Cottonwood	Populus deltoides Marsh P. Sargentii Dode.	42	23.8
American Elm	Ulmus americana L.	36	20.4
Northwest Poplar	Populus sp. L.	32	18.2
Spruce, (Colorado Blue and Black Hills	Picea pungens Engelm. P. glauca albertiana (S.Br.) Sarg.	27	15.3
Chokecherry	Prunus melanocarpa (A. Nels.) Sarg.	22	12.5
Willow(Golden, Laurel-leaf and White)	Salix alba vitellina (L.) Stokes, S. pentandra L. and S. alba L.	16	9.1
Hackberry	Celtis occidentalis L.	12	6.8
Ponderosa pine	Pinus ponderosa Laws.	9	5.1
Juniper	Juniperus scopulorum Sarg.	9	5.1
Plum	Prunus americana Marsh.	6	3.4
Current and Gooseberry	Ribes aureum Pursh. and Ribes sp.L.	6	3.4
Lilac	Syringa vulgaris L.	5	2.8
Maple	Acer sp. L.	4	2.3
Jack Pine	Pinus banksiana Lamb	3	1.7
Scotch Pine	Pinus sylvestris L.	2	1.1
Buffalo Berry	Shepherdia argenta Nutt.	2	1.1
Honeysuckle	Lonicera tatarica L.	2	1.1
Honey Locust	Gleditsia triacanthos L.	1	.6
Aspen	Populus tremuloides Michx.	1	.6
Douglas Fir	Pseudotsuga taxifolia (Poir.) Britt.	1	.6

TABLE 6

OCCURRENCE OF VARIOUS SPECIES IN 44 IRRIGATED WINDBREAKS
IN EASTERN MONTANA

Common Name	Scientific Name	Windbreaks in Which Found	
		Number	Per cent
Willow (Golden, Laurelleaf and White)	Salix alba vitallina (L.) Stokes. S. pentandra L. and S. alba L.	31	70.5
Green Ash	Fraxinus pennsylvanica lanceolata (Borkh.) Sarg.	18	40.9
Caragana	Caragana arborescens Lam.	17	38.6
Cottonwood	Populus deltoides Marsh., P. sargentii Dode.	16	36.3
Northwest Poplar	Populus sp. L.	14	31.8
Box Elder	Acer negundo L.	12	27.3
Russian Olive	Eleagnus angustifolia L.	12	27.3
Spruce (Black Hills and Colorado Blue)	Picea glauca albertiana (S. Br.) Sarg. P. pungens Engelm.	6	13.6
Chinese Elm	Ulmus pumila L., U. parvifolia Jacq.	6	13.6
Silver Poplar	Populus alba L.	2	4.5
Maple	Acer sp. L.	1	2.3
Chokecherry	Prunus melanocarpa (A. Nels.) Sarg.	1	2.3
American Elm	Ulmus americana L.	1	2.3
Ponderosa Pine	Pinus ponderosa Laws.	1	2.3
Douglas Fir	Pseudotsuga taxifolia (Poir.) Britt.	1	2.3

trend is to include at least one row of evergreens in the windbreak.

Irrigated Plantings

Seven species, willow, green ash, caragana, cottonwood, northwest poplar, box elder and Russian olive were found to be planted in more than one fifth of the irrigated plantings. Of these, only three, green ash, cottonwood and box elder are native to Montana. The willows are by far the most popular species planted in the irrigated areas, being found in 70.6 per cent of the belt studied. The willows most commonly encountered were golden and laurelleaf in the older plantings and white willow in the newer. This latter species is being recommended by the Mandan Field Station in its experimental plantings on irrigated sites. Surprisingly, cottonwood and northwest poplar, -- fourth and fifth in the order of occurrence were found in a minority of the plantings, 36 and 32 per cent of the belts, respectively. Practically all of the more recently planted belts on irrigated sites have included either of these two species as an important constituent of the planting. Box elder and Russian olive were found in an equal number of belts -- 27.3 per cent of the irrigated belts studied contained these two species. Though typically a dryland species, caragana was found in almost 39 per cent of the irrigated windbreaks.

Generally, in the past, the evergreens have not been planted extensively in these areas; but the more recent plantings in those sections of the state where irrigation has been brought to the benches and uplands now have at least one row of Colorado blue or Black Hills spruce.

Besides the species listed in the tables, many others were found, such as black walnut, apple, white oak, linden, horse chestnut and other mesophytic species. However, these were not a regular component of any belts, but were more or less ornamental species planted at the whim of the owner. As such, they were not classified as shelterbelt species.

GROWTH OF THE TREES

When a farmer plants a belt he wants to know how much and how fast the trees will grow. He wants to know how far the zone of protection will extend and how soon his home and his stock will be protected from the winds. Growth of the trees and the factors affecting growth are of prime importance to him. Therefore, much of the study dealt with the controlling factors affecting the rate and amount of growth of the various species.

Growth in Dryland Belts

An overall picture of growth is shown in Figures 14 through 25. These show the average height growth and average crown spread of the six most important dryland species encountered in the study. The growth curves represent the average growth of shelterbelt trees in eastern Montana under all conditions.

Each point on the scattergraph represents the average height of a row of trees in a particular belt of the species concerned. It was found that tree growth varied widely within a belt as well as between belts. These variations were found according to change in soil conditions,

FIGURE 14

AVERAGE HEIGHT GROWTH OF CARAGANA
IN DRYLAND BELTS IN EASTERN MONTANA

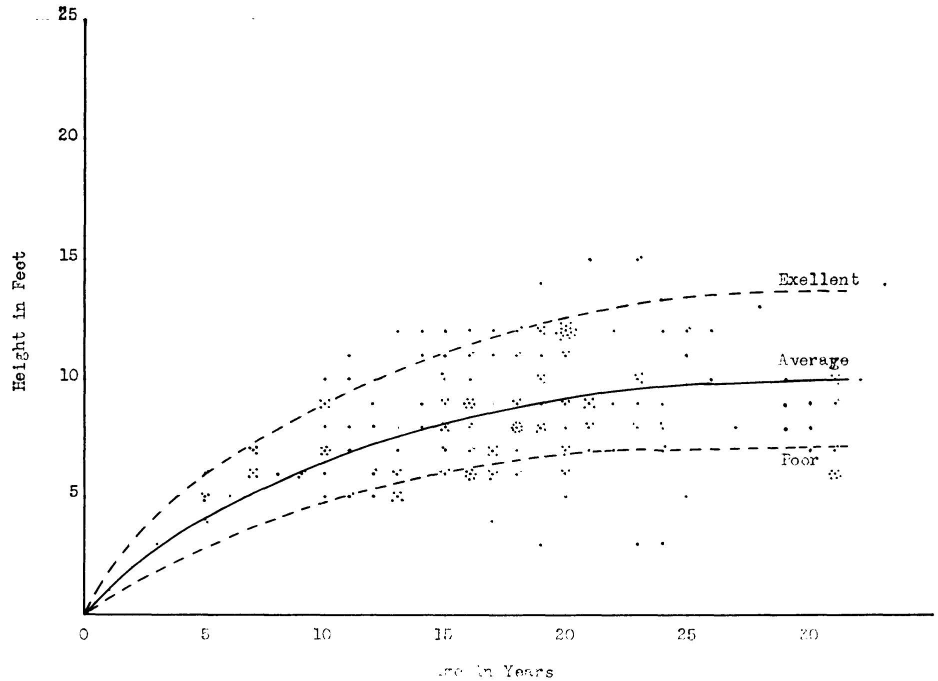

FIGURE 15

AVERAGE HEIGHT GROWTH OF RUSSIAN OLIVE
IN DRYLAND BELTS IN EASTERN MONTANA

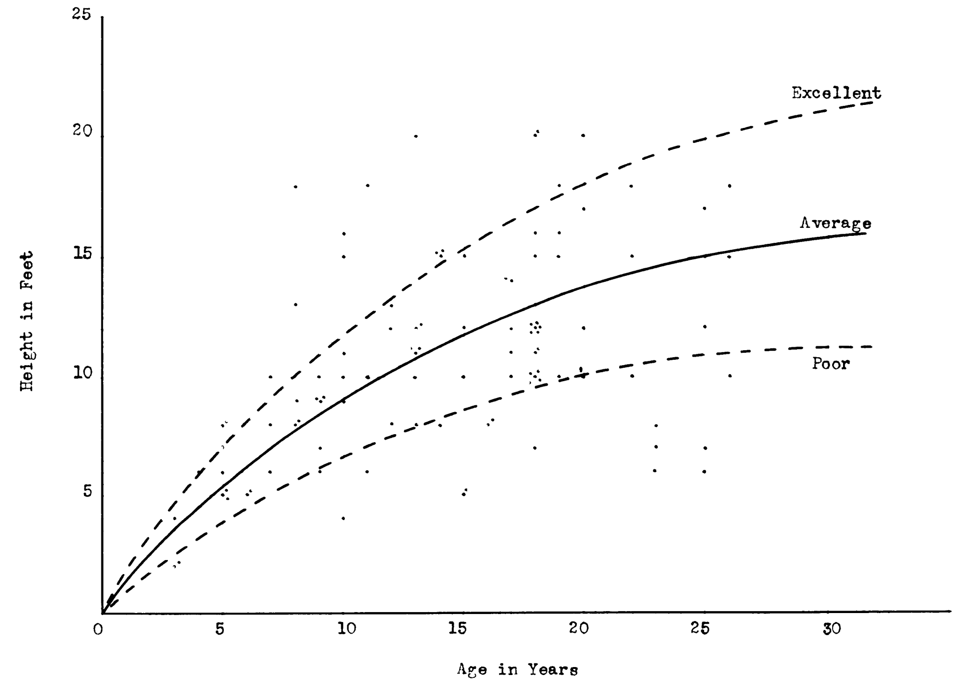

FIGURE 16

AVERAGE HEIGHT GROWTH OF BOX ELDER
IN DRYLAND BELTS IN EASTERN MONTANA

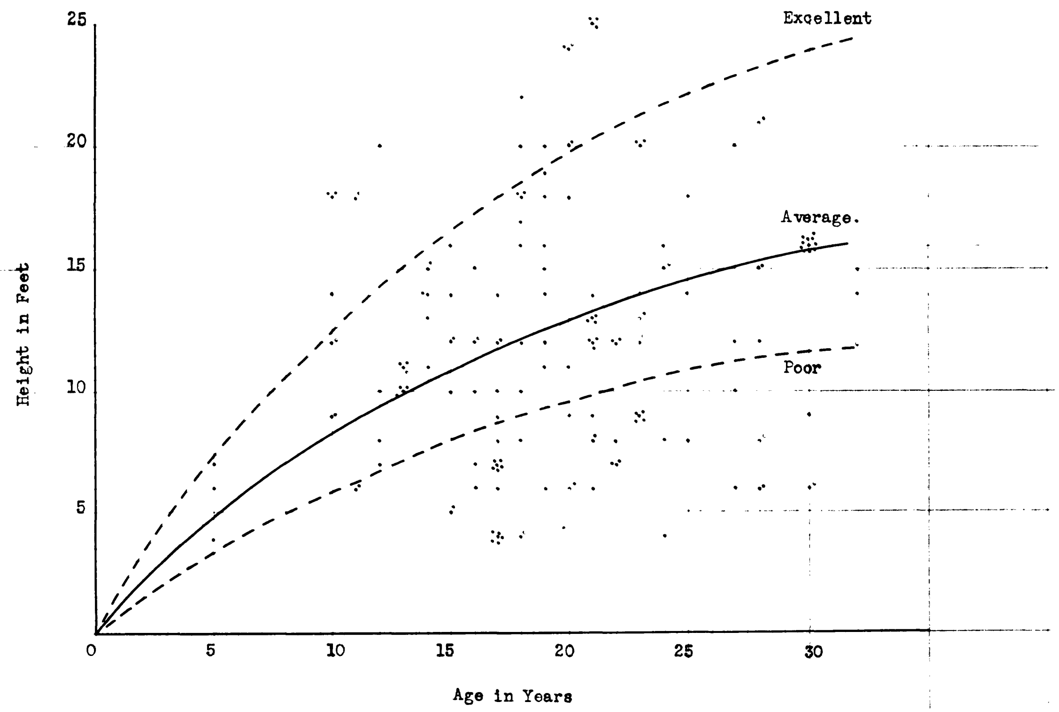

FIGURE 17

AVERAGE HEIGHT GROWTH OF GREEN ASH
IN DRYLAND BELTS IN EASTERN MONTANA

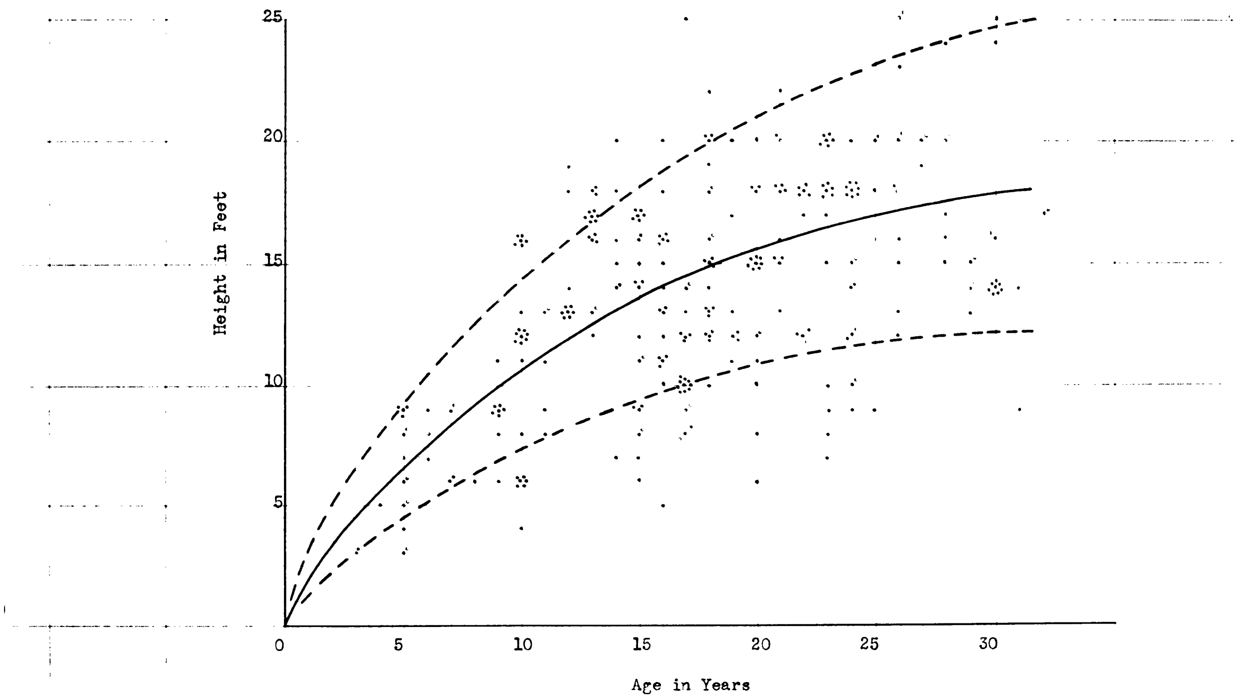

FIGURE 18

AVERAGE HEIGHT GROWTH OF CHINE[illegible]
IN DRYLAND BELTS IN EAST[illegible]

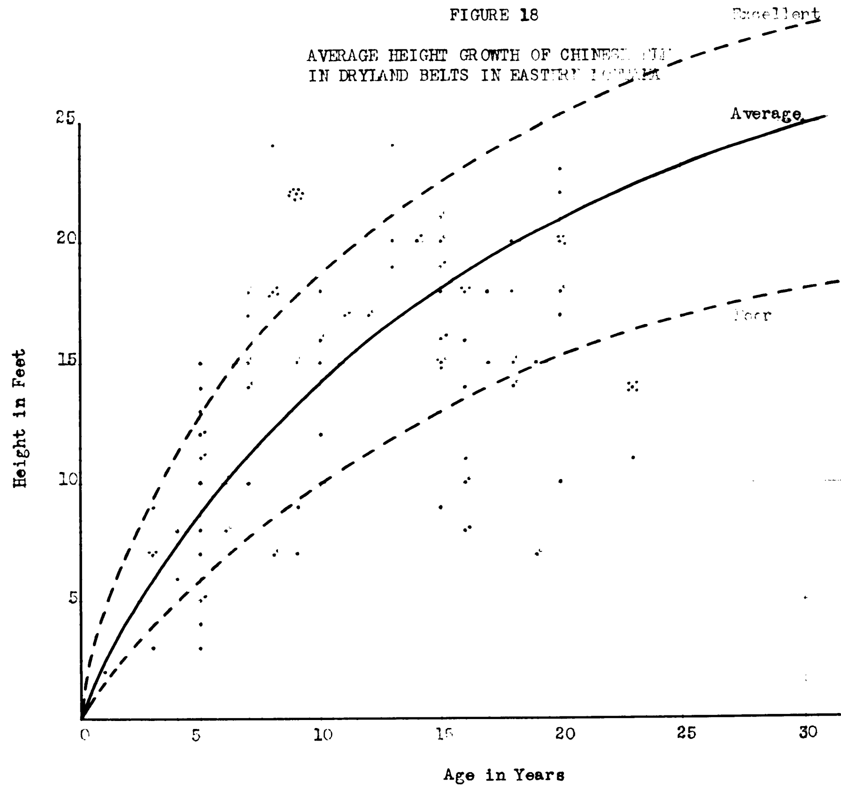

FIGURE 19

AVERAGE HEIGHT GROWTH OF AMERICAN ELM
IN DRYLAND BELTS IN EASTERN MONTANA

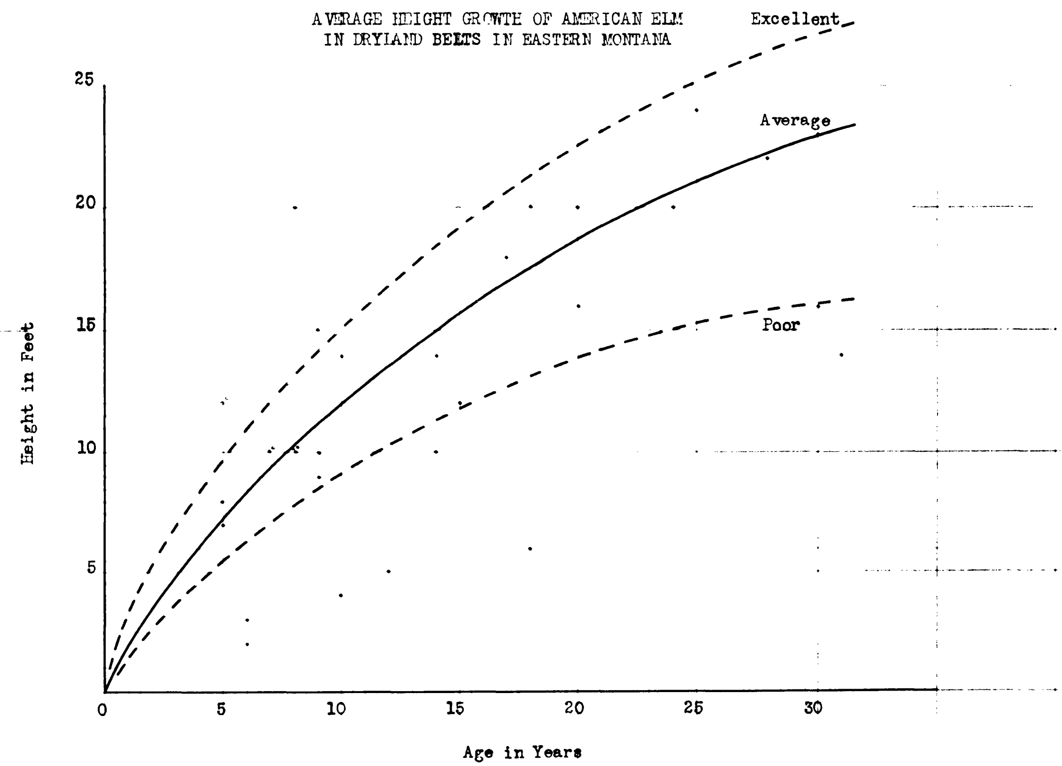

FIGURE 20

AVERAGE CROWN SPREAD OF CARAGANA
IN DRYLAND BELTS IN EASTERN MONTANA

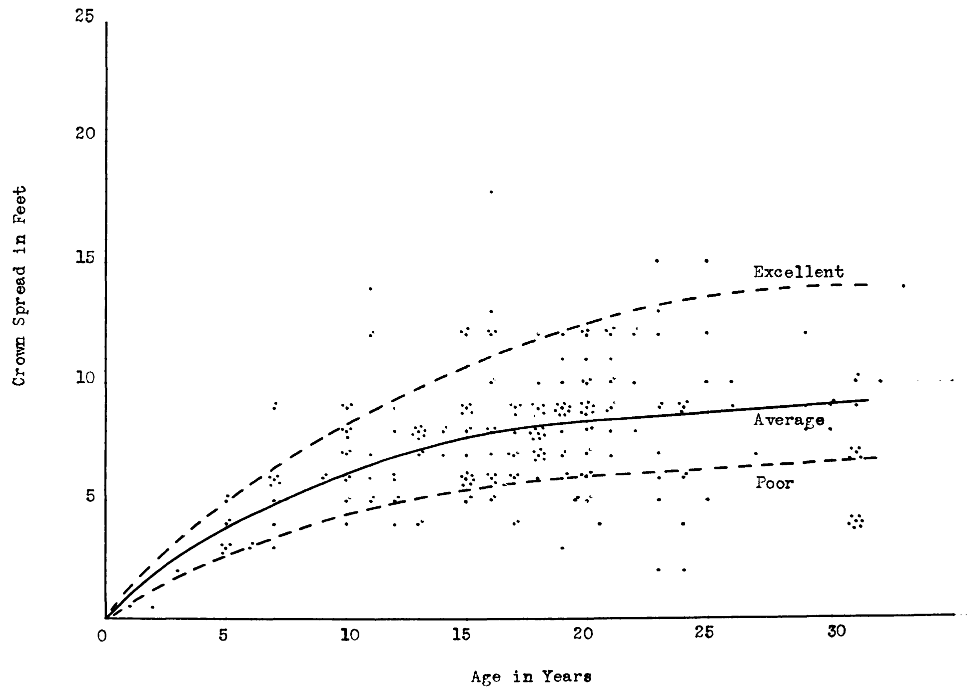

FIGURE 21

AVERAGE CROWN SPREAD OF RUSSIAN OLIVE
IN DRYLAND BELTS IN EASTERN MONTANA

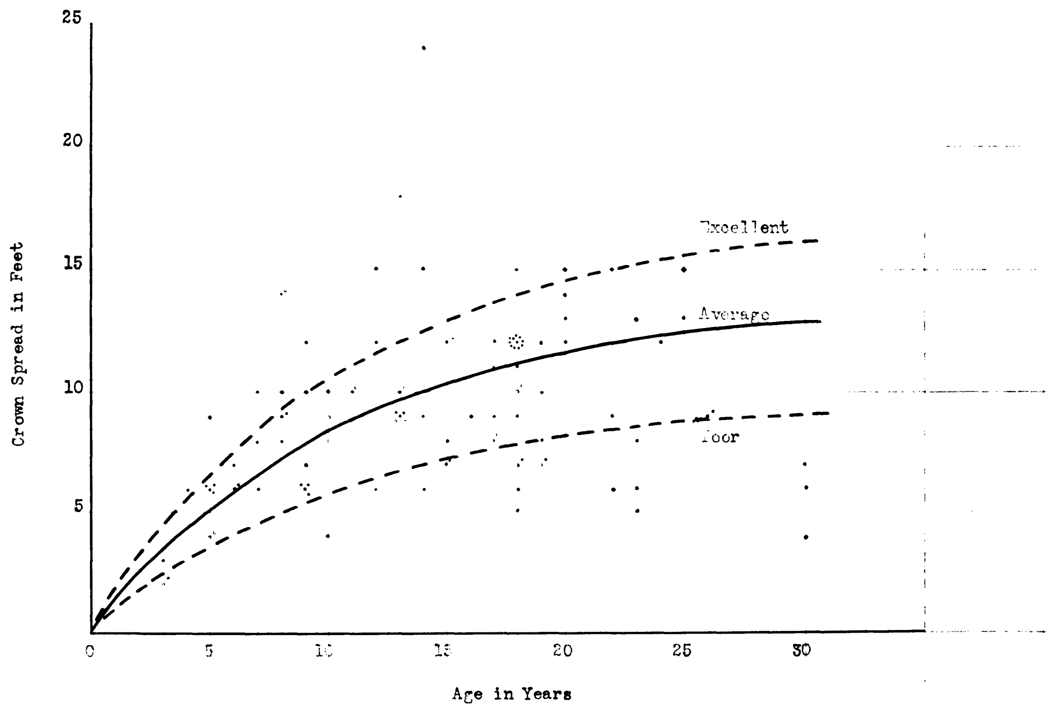

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FIGURE 22

AVERAGE CROWN SPREAD OF BOX ELDER
IN DRYLAND BELTS IN EASTERN MONTANA

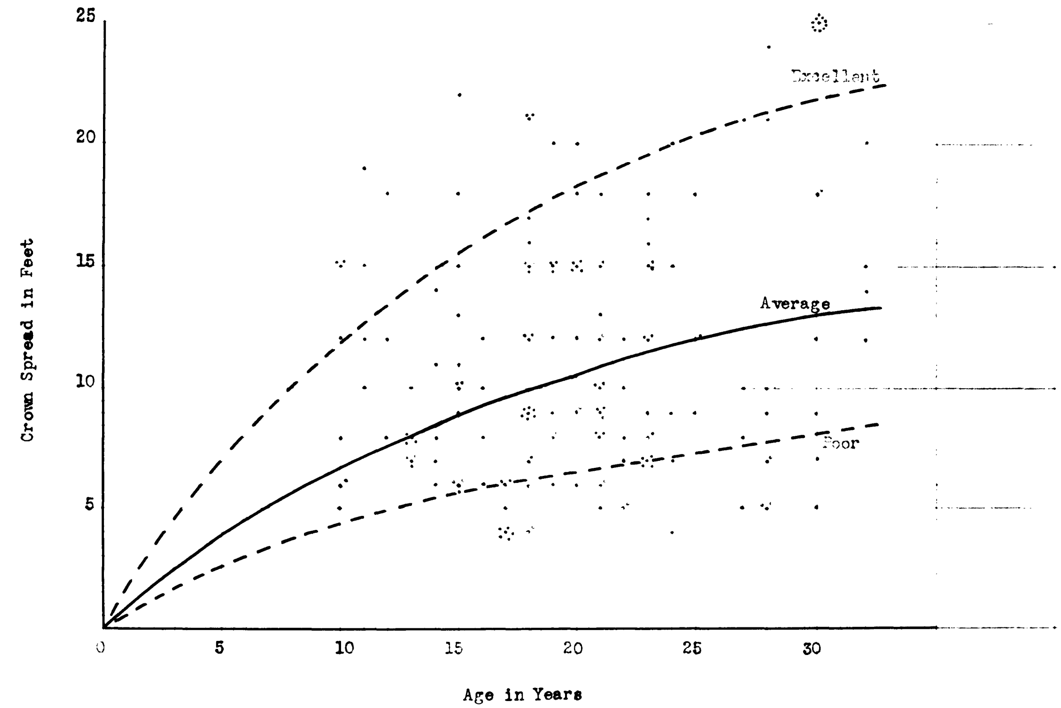


FIGURE 23

AVERAGE CROWN SPREAD OF GREEN ASH
IN DRYLAND BELTS IN EASTERN MONTANA

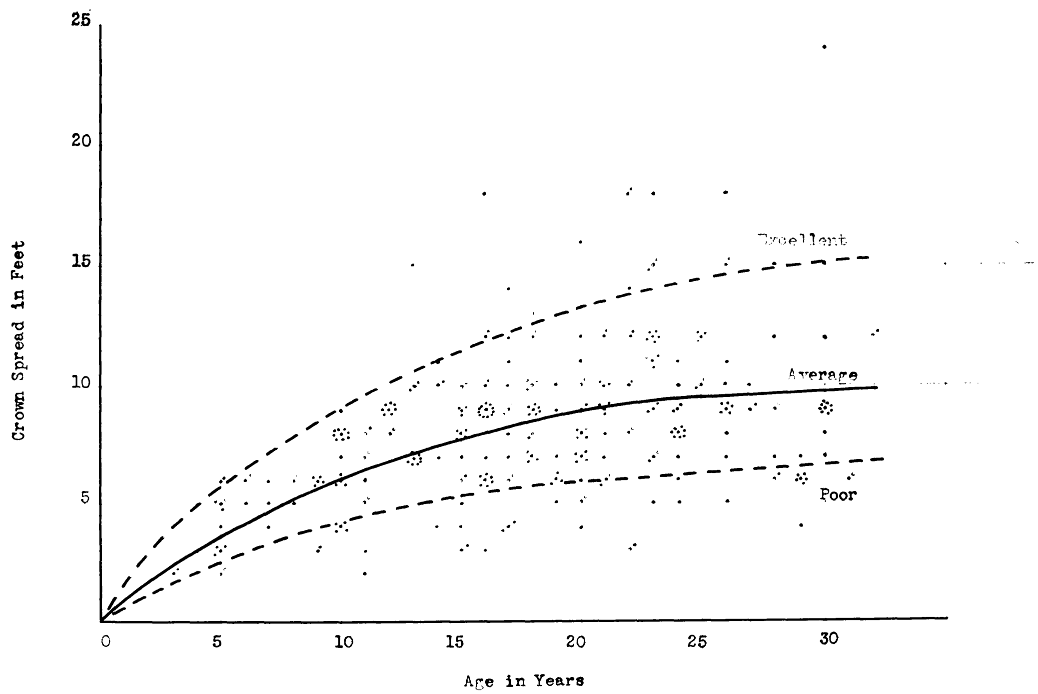


FIGURE 24

AVERAGE CROWN SPREAD OF CHINESE ELM
IN DRYLAND BELTS IN EASTERN MONTANA

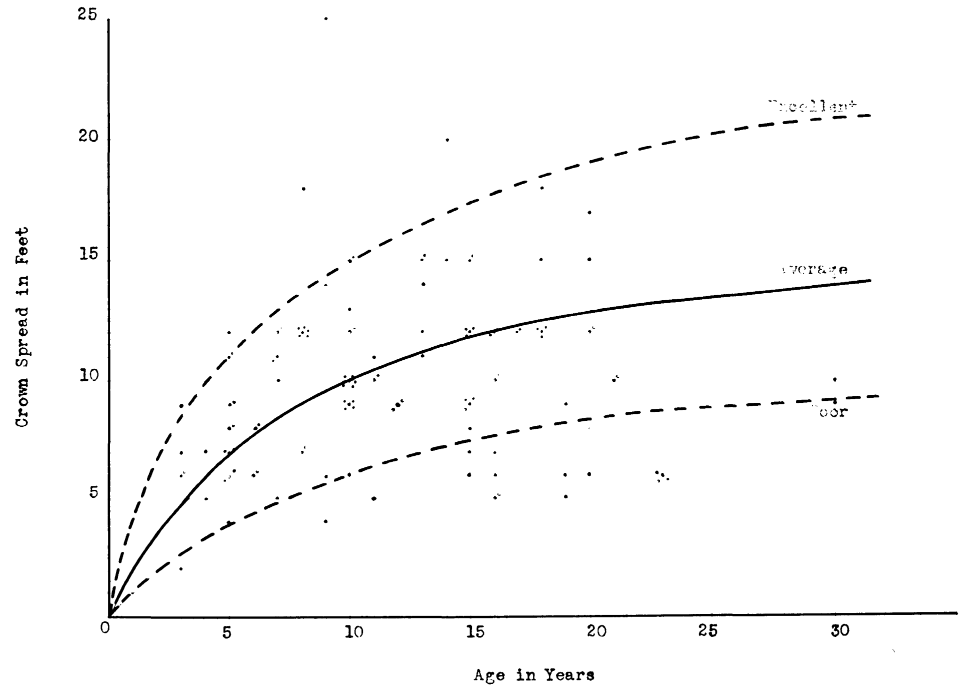
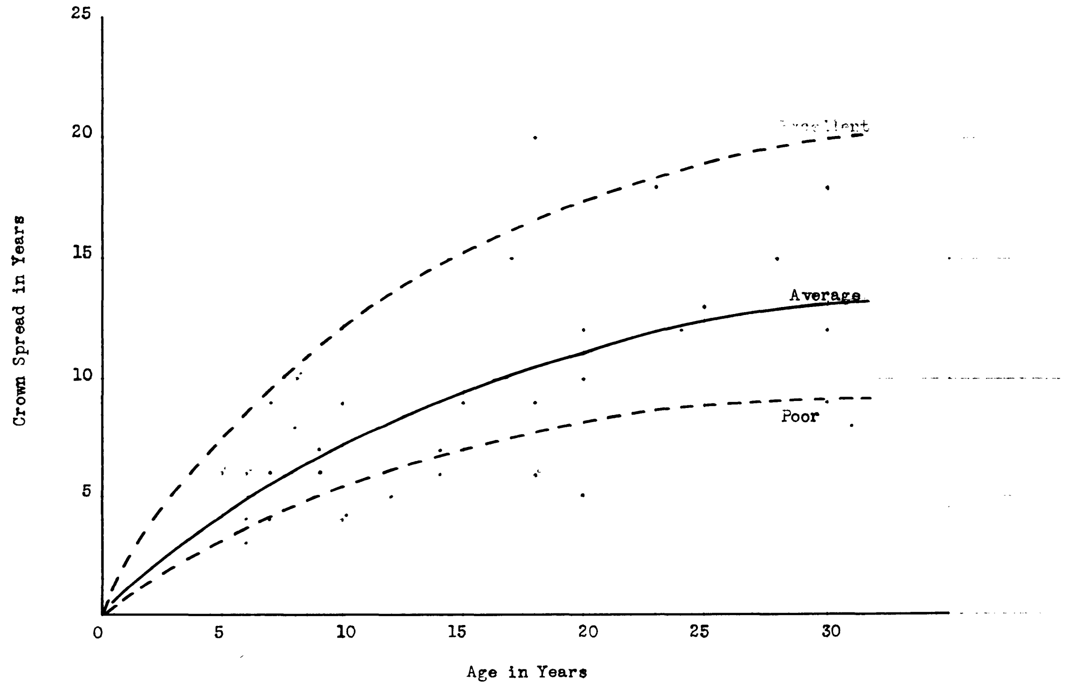


FIGURE 25

AVERAGE CROWN SPREAD OF AMERICAN ELM
IN DRYLAND BELTS IN EASTERN MONTANA



slope, and aspect. Therefore, for the purpose of presentation in this study, a single row in a single direction was regarded as a unit and only the average row height was recorded. Accordingly, each point in the height and crown growth graphs represents the average height and average crown spread of an individual row.

The solid line in the scattergraphs shows the average growth of the species. The position of this line was adjusted so that the variates were divided equally above and below the line.

The dashed lines labeled "excellent" and "poor" were arbitrarily drawn to include most of the variates and represents the range of growth that can be expected from trees planted on dryland sites in eastern Montana. The utility and purpose of these lines will be discussed more fully later in the paper.

The average growth in height and crown spread as determined from the scattergraphs of the 6 species is presented in summary form in Figures 26 and 27. As can be seen from Figure 26, all 6 of the species make most of their growth in the first 15 to 20 years. After that growth slows down and in the case of caragana almost levels off completely. Chinese elm is the fastest grower, growing almost up to 21 feet in 20 years for an average growth of a little over 1 foot per year. In the same time caragana will reach a little over 9 feet, growing at an average rate of .45 feet per year. Green ash, the backbone of many dryland plantings, has an average height growth of 16 feet in 20 years, for an average annual growth rate of .8 feet. Growth figures of box elder and Russian olive are quite similar varying less than a foot from each other through-

FIGURE 26

AVERAGE HEIGHT GROWTH OF SIX IMPORTANT TREES
OF DRYLAND SHELTERBELTS IN EASTERN MONTANA

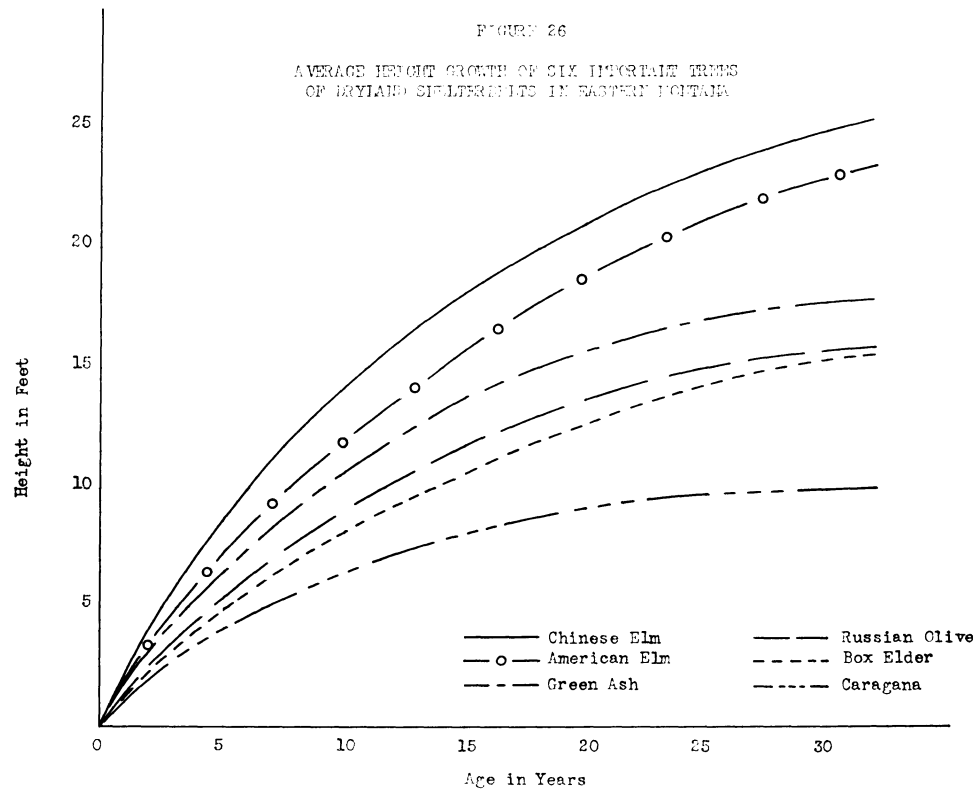
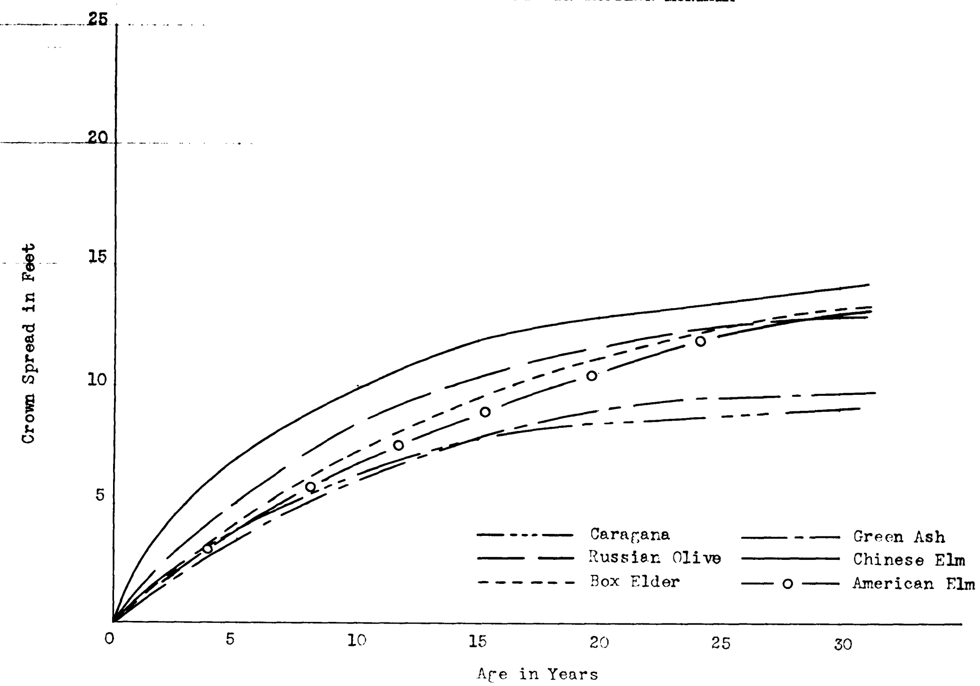


FIGURE 27

AVERAGE CROWN SPREAD OF SIX IMPORTANT DRYLAND TREES
OF DRYLAND SHELTERBELTS IN EASTERN MONTANA



out their lifetimes. American elm is quite comparable to Chinese elm in both rate and amount of height growth.

Almost the same comparisons are true as regards crown spread. The fastest spread occurs in the first 10 to 15 years with a definite reduction in rate of spread occurring thereafter. (Figure 27). Chinese elm is again the fastest grower and widest spreader, with a crown spread of over 13 feet in 25 years. Green ash has a relatively small crown, 9.5 feet, as compared to the other trees at 25 years. Russian olive and box elder are almost identical in crown spread except for the variation at 10 and 15 years of age.

Growth in Irrigated Belts

Growth and crown spread curves (Figures 28 and 29) have been prepared for the irrigated species. The picture here is quite different. As might be expected, growth of most species is faster and better than in the dryland belts. However, caragana seems to be adversely affected by the abundance of water. For the first 10 years the growth rate is quite similar to that on dryland sites (see Figure 26 page 60) but then a decided leveling off takes place so that the average height in 20 years is only 7 feet. The fastest growing species is northwest poplar growing to an average height of 55 feet in 20 years or 2.75 feet per year. Cottonwood is not far behind with a little over 48 feet in 20 years. While the willows and box elder have a faster initial growth than green ash, the three grow to about the same height in 20 years, 23 to 25 feet. Thereafter, box elder falls considerably below green ash and the willows.

FIGURE 28

AVERAGE HEIGHT GROWTH OF SEVEN IMPORTANT TREES
OF IRRIGATED SHELTERBELTS IN EASTERN MONTANA

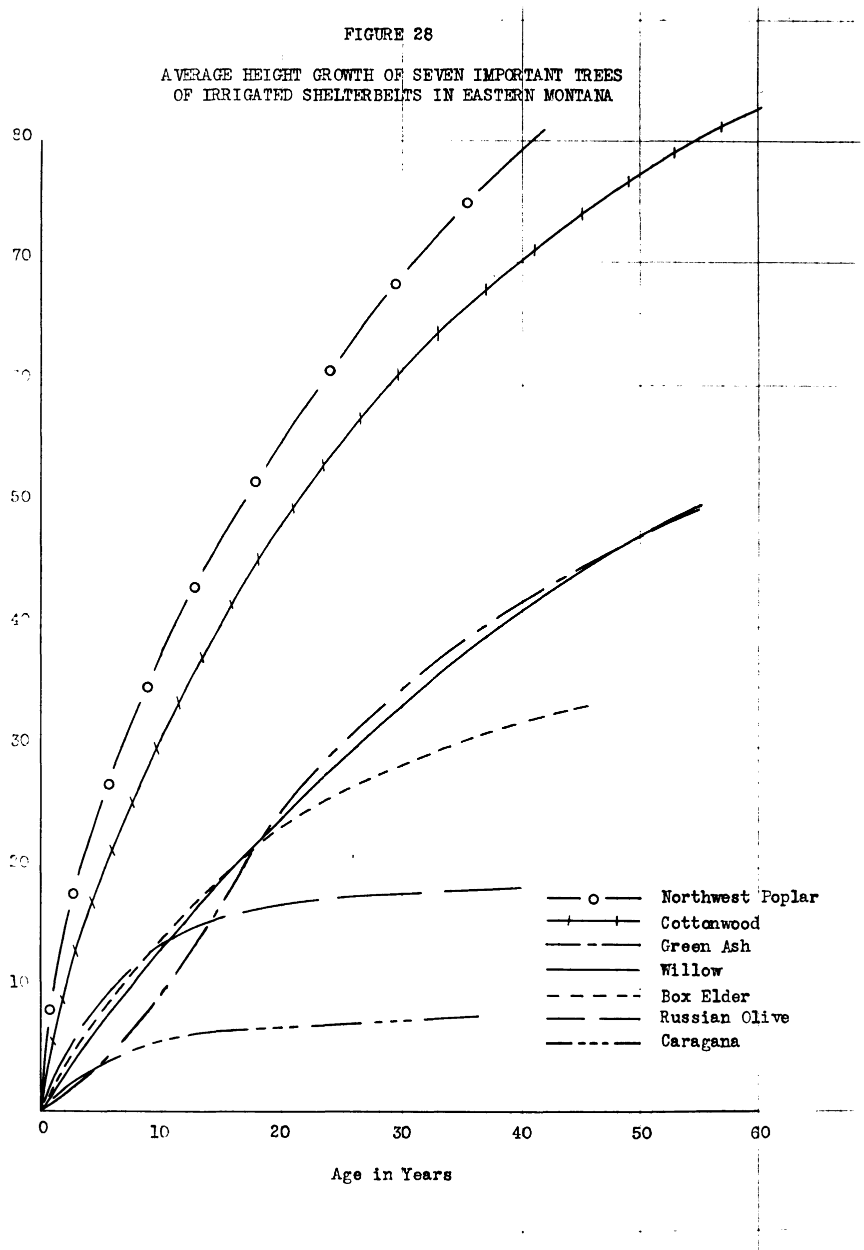
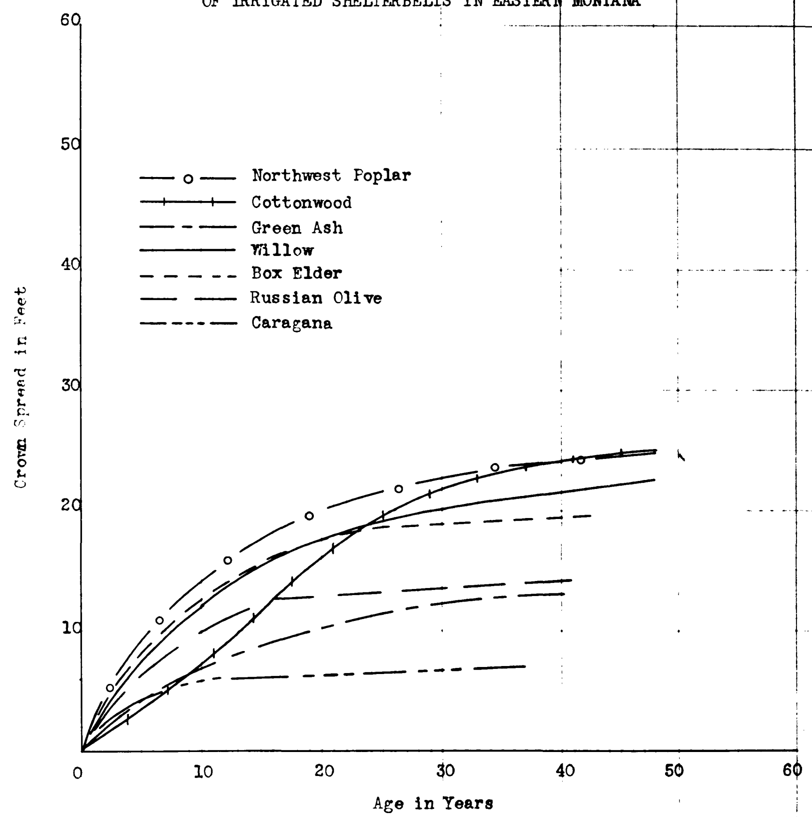


FIGURE 29

AVERAGE CROWN SPREAD OF SEVEN IMPORTANT TREES
OF IRRIGATED SHELTERBELTS IN EASTERN MONTANA



Russian olive has practically reached its limit in height growth at 20 years almost leveling off at 17 to 18 feet.

Crown spread of caragana, as well as height growth, is reduced by irrigation. This species soon reaches its maximum spread and by 10 years has leveled off almost completely. Russian olive, box elder and green ash, also important in dryland belts, start leveling off in about 20 years but at a higher level than on dryland sites. Cottonwood and northwest poplar have the fastest and widest crown spread. Although they have smaller crowns than poplar and cottonwood, the willows are more dense, especially near the ground surface. Therefore, they serve well as the outside or buffer row in windbreak plantings on irrigated sites.

Range of Growth Most Frequently Encountered

While these average growth curves are convenient to express height growth and crown spread, they may not show the complete picture, especially to the farmer. To him "average growth" is likely to mean the range in growth most frequently encountered and he will express it as "from 6 to 10 feet" or "from 12 to 16 feet" and so on as the case may be. He is not expressing the average growth but the range of height growth most frequently encountered.

To illustrate the point, consider the scattergraph on height growth of caragana as seen in Figure 14. The average growth at 20 years is 9.2 feet while the total range of height growth is from 5 to 12 feet. The most frequently observed height growth at that age is apt to be from 6.8 to 12.5 feet as shown by the dashed lines.

As can be seen from the charts showing the growth of the other species, there is also wide variation in height growth and crown spread in the other important dryland species. Tables 9 and 10 summarize the range of the most frequently encountered height growth and crown spread for the six important dryland species.

Variation in Growth

Many factors affect growth and cause the wide variation shown in the height growth and crown spread curves. This variation is due to the difficult growing conditions in the plains and to interactions of many factors which tip the survival balance one way or the other. Tables 7 and 8 summarize the range and variation in growth of the important shelterbelt trees studied in this survey. Other workers have encountered the same situation in their work with plains shelterbelts and have reported variations of as much as 100 per cent or more in 4-year old demonstration plantings in Montana. (Wilson and Cobb, 1923).

As shown in the tables, each of the 6 species has a wide range in both height growth and crown spread. In the majority of the cases the range of growth was greater than 50 per cent of the average. In 7 instances for height growth and 6 for crown spread, the variation was greater than 100 per cent of the average. Caragana seems to be the most consistent in height growth. The greatest variation found for this species was 74 per cent of the average height growth at 20 years. Box elder and Russian olive are both highly variable, each having variations over 100 per cent of the average growth. The high variation in height growth of

TABLE 7

RANGE OF GROWTH AND VARIATION IN PER CENT OF AVERAGE HEIGHT GROWTH FOR SIX IMPORTANT TREES IN MONTANA SHELTERBELTS

Years after Planting	Caragana	Russian Olive	Box Elder	Green Ash	Chinese Elm	American Elm
5 Years						
Range of Growth 1/ in feet	4- 6	5- 8	6- 7	3- 9	3-15	7-12
Variation in per cent of average growth 2/	40	49	15	92	131	51
10 Years						
Range of growth in feet	5-10	4-16	9-13	4-16	12-18	6-14
Variation in per cent of average growth	65	111	30	109	39	111
15 Years						
Range of Growth in feet	6-12	5-15	5-16	6-17	9-21	— 3/
Variation in per cent of average growth	71	106	104	87	70	—
20 Years						
Range of Growth in feet	5-12	10-20	6-24	6-20	10-23	16-20
Variation in per cent of average growth	74	68	111	99	69	22
25 Years						
Range of Growth in feet	5-12	6-17	8-18	9-20	—	— 3/
Variation in per cent of average growth	70	88	77	67	—	—

1/ Represents minimum and maximum height growth found at that specific age.

2/ Obtained by dividing the difference between minimum and maximum height growth by the average height growth of the rows recorded of that specific age.

3/ Only one row of trees of that age was recorded; therefore, there is no range or variation in height growth.

TABLE 8

RANGE OF CROWN SPREAD AND VARIATION IN PER CENT OF AVERAGE CROWN SPREAD FOR THE IMPORTANT TREES IN MONTANA SHELTERBELTS

Years after Planting	Caragana	Russian Olive	Box Elder	Green Ash	Chinese Elm	American Elm
5 Years						
Range of Crown Spread 1/ in feet	3- 5	4- 9	—	2- 6	4-12	— 3/
Variation in per cent of average 2/ crown spread	53	85	—	103	101	—
10 Years						
Range of Crown Spread in feet	4- 9	4-10	5-15	4- 9	6-15	4- 9
Variation in per cent of average crown spread	71	75	97	74	87	88
15 Years						
Range of Crown Spread in feet	5-12	7-12	6-22	3-10	6-15	— 3/
Variation in per cent of average crown spread	89	54	147	97	87	—
20 Years						
Range of Crown Spread in feet	5-15	12-15	6-20	4-16	6-17	5-12
Variation in per cent of average crown spread	114	22	100	146	94	78
25 Years						
Range of Crown Spread in feet	5-15	13-15	9-18	10-12	—	— 3/
Variation in per cent of average crown spread	95	14	69	18	—	—

1/ Represents minimum and maximum crown spread found at that specific age.

2/ Obtained by dividing the difference between minimum and maximum crown spreads by the average crown spread of the rows recorded of that specific age.

3/ Only one row of trees of that age was recorded; therefore, there is no range or variation in crown spread.

TABLE 9

RANGE OF HEIGHT GROWTH MOST FREQUENTLY ENCOUNTERED
IN THE DRYLAND SHELTERBELTS OF EASTERN MONTANA

Species	Age in Years					
	5	10	15	20	25	30
Caragana	3 - 5	5 - 8	6 -10	7 -11.5	7 -12.5	7 -13
Russian Olive	4 - 7	7 -12	9.5-15	10.5-17.5	11.5-19	--
Box Elder	4 - 6.5	5.5-11.5	8 -16.5	9.5-20	10.5-22.5	11.5-24
Green Ash	4.5-8	8 -12.5	10 -16	11 -18.5	12 -20	12.5-21.5
Chinese Elm	5.5-13	10 -18.5	13 -22.5	15.5-25.5	17 -27.5	--
American Elm	5 -10	9 -15.5	12 -19.5	14.5-22.5	16 -25.5	18 -27.5

TABLE 10

RANGE OF CROWN SPREAD MOST FREQUENTLY ENCOUNTERED
IN THE DRYLAND SHELTERBELTS OF EASTERN MONTANA

Species	Age in Years					
	5	10	15	20	25	30
Caragana	3 -5	4.5- 8.5	5.5-10.5	6 -12	6 -12.5	6 -12.5
Russian Olive	3.5-6.5	6 -10.5	8 -13	9 -14.5	9.5-15.5	--
Box Elder	2.5-5.5	4.5-10	5.5-13.5	6.5-16	7.5-18	8 -19
Green Ash	2.5-5	4.5- 8.5	5.5-11	6 -12	6.5-12.5	6.5-13
Chinese Elm	4 -9.5	6.5-13	8 -15.5	8.5-17	8.5-17.5	--
American Elm	3 -6.5	5.5-10	7 -13	8 -15	9 -16.5	9 -17

these two species is due in large amount to winter kill occurring during the dormant season. This is especially true of box elder. Normally, green ash is quite consistent with respect to growth, but the relatively high amount of variation in growth shown in the table is due to the die-back resulting from a severe late frost last spring. The data on American elm are insufficient to draw any valid conclusions.

Russian olive had the least variation in crown spread while box elder had the most — 147 per cent of the average crown spread at 20 years. All of the other species had relatively large ranges of crown spread. This would seem to indicate that the factors causing variation in growth have a greater effect upon the average crown spread than they do upon average height growth.

CHAPTER VII

FACTORS INFLUENCING GROWTH IN MONTANA SHELTERBELTS

AGE

Rate of growth varies with age. As can be seen in Figures 26 and 28 on page 63 the fastest rate of growth for important trees in both dry-land and irrigated belts is in the first 10 to 20 years. Thereafter, the rate of growth slows down to a point where there may be no further height growth. There may be, in fact, a negative height growth as the tops of the trees become stag-horned and the height of live trunk decreases. This will continue until the tree dies of old age or is blown down.

However, few belts examined had reached this condition. In the Yellowstone River valley some cottonwood and silver poplar plantings over 50 years old had reached this age. The trees were ragged in appearance, with many large, dead branches in the crowns. Some windfall had already occurred. This is typical of old cottonwood trees, whether found naturally or in shelterbelt plantings.

In the dryland belts no plantings were observed that had reached the stage of senility described above. However, the data obtained from dryland plantings do show a definite slowing down in rate of growth after 20 years. Caragana slows down in growth about 5 years sooner than the other species.

CRITICAL MOISTURE CONDITIONS

Importance of Water

Available moisture is the most important limiting factor affecting growth, vigor and survival of trees in Montana windbreaks. In their book "Ecology", Weaver and Clements (1938), have summarized the importance of water to all plants in general as follows:

> "Water is important to plants in many ways. It is a component of protoplasm and with carbon dioxide is essential in building plant foods. It usually constitutes 70 to 90 per cent of the weight of herbaceous plants. All substances that enter plant cells must do so in solution. Water is the great solvent. It serves as a medium of transport of nutrients and foods from place to place since their transport can take place for the most part only in solution. It keeps the cells turgid or stretched, a condition essential for their normal functioning. It also serves to prevent excessive heating of the plant, acting as a buffer in absorbing the heat generated by the multitudinous chemical reactions taking place in the plant. A shortage of water early in the life of the plant results in retarded growth, while later in its development it may induce premature ripening and seed of low viability. The greatest dangers which the plant has to meet are insufficient absorption and excessive transpiration."

Precipitation

Available moisture in the eastern section of the state is dependent almost entirely upon the annual precipitation. The ground water table is usually below the zone of root penetration and has been reported as deep as 50 to 100 feet. Therefore, the dependence of trees upon precipitation for moisture is absolute.

It has been estimated that, under natural conditions, at least

15 inches is the minimum annual precipitation required to maintain forest conditions in Montana (Toumey and Korstian, pg. 52 1937). As can be seen from the precipitation map and table on pages 28 and 26 the total annual precipitation throughout most of the plains section is less than this amount. Most of the region has from 12 to 14 inches and only in a few areas does the annual precipitation exceed 15 inches. This means that the trees in the plains windbreaks are growing under continual submarginal moisture conditions and emphasizes the fact that moisture conservation measures are necessary for the successful establishment of the plantings.

As a result of the typical Great Plains pattern of distribution, 70 to 80 per cent of the total annual precipitation falls during the growing season, that is through the months of April to September. Where the moisture balance is so critical as in the plains, it is this summer rainfall that favors growth sufficiently to allow trees and agricultural crops to be grown without irrigation. Shortage during this time of even 1 inch is apt to deplete the supply of subsoil moisture to a point where water is no longer available to the trees. (Scholz, 1935).

A species that is adapted to drought conditions, such as caragana, will reduce its demand for moisture by losing its leaves unseasonably, but for the most part, the trees will suffer more or less severly through the loss of its moisture supply during the growing season. Continued reduction of this summer moisture as brought about by the cyclic nature of Montana climate will most surely cause the death of a high percentage of the trees in the plantings. It is for this reason that the drought during the thirties caused the death of so many trees in the belts in eastern Montana and particularly in those belts where species unsuited for arid conditions were planted.

Snow

While snow ordinarily furnishes a minor part of the annual precipitation over the area as a whole, it contributes much to the soil moisture of a shelterbelt. The extent that water conditions within a belt will be increased by drifted snow was demonstrated by a planting near Antelope, Montana. During the winter of 1946-1947 snow had piled in the belt to a depth of 12 to 15 feet. As a result of the large amount of moisture obtained upon thawing, water trickled from the belt as from a spring until the middle of June and the ground was too moist for cultivation equipment to enter until after the 4th of July. The increased water content in the soils resulting from the melting snow caused vigorous growth of all species with Russian olive making as much as four feet of new growth last summer.

Measurements have shown that the water content of snow drifted in belts is as much as 2.4 to 4.29 inches per foot of snow. (George, 1943; Graves, [illegible]). The extent to which snow melt replenishes the soil moisture in shelterbelts was determined by George (1943) who found that in a belt at the beginning of the growing season there was 1.15 inches more stored water in the upper 6 feet of soil than there was outside the planting.

CULTIVATION

Effect Upon Growth

Cultivation is the only practical means available to the farmer or rancher for conserving moisture in protective plantings. The study showed that it was the most important factor affecting the trees and that height growth is from 4 to 48 per cent better in well cultivated windbreaks than in uncultivated ones.

Comparative growth tables have been prepared for the six major dryland species and are shown in Figures 30 through 35.

Reference to the charts shows that Russian olive is the most responsive to good cultivation and American elm the least. Height growth of Russian olive after 20 years is 15.5 feet in cultivated belts as compared to 10.5 feet in uncultivated plantings — a 47.6 per cent better growth. At the same time, growth of American elm is only .6 foot more with cultivation as compared with no cultivation. This is an increase of only 3.6 per cent. The actual increased growth, in feet, of caragana in well tilled belts is quite low, but when put on a comparative basis of percent of increase in growth the difference is quite substantial. Box elder and Chinese elm show substantially better growth in the dryland belts where thorough cultivation is practiced than where the floor of the belt is allowed to become overrun with weeds.

The per cent of increase in growth in well tilled plantings has been computed for the various species and is recorded in table 11.

FIGURE 30

AVERAGE HEIGHT GROWTH OF CARAGANA IN CULTIVATED AND UNCULTIVATED DRYLAND BELTS OF EASTERN MONTANA

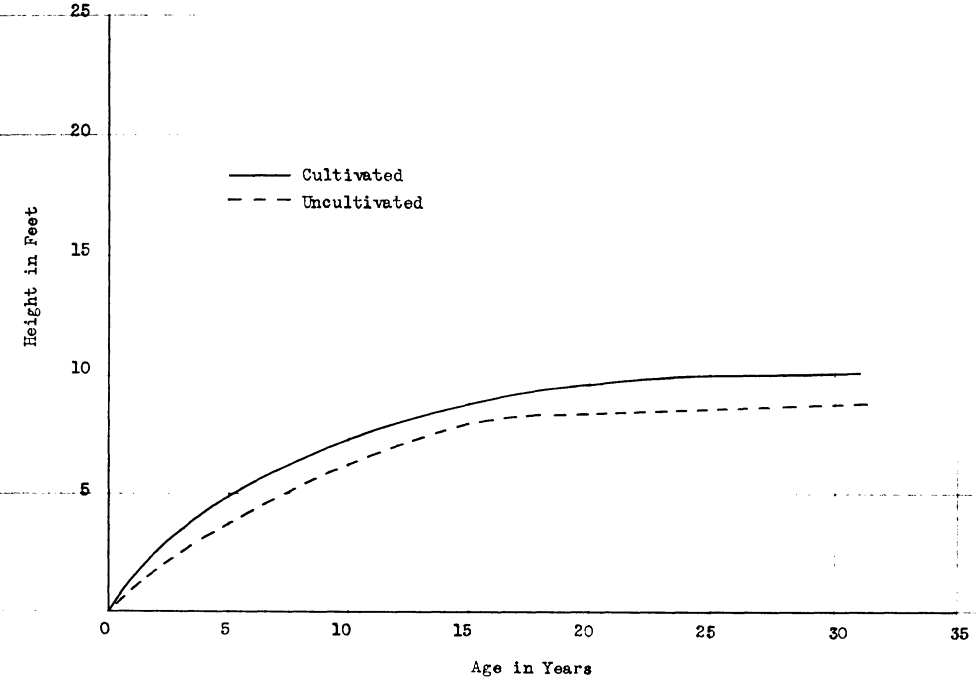


FIGURE 31

AVERAGE HEIGHT GROWTH OF BOX ELDER IN CULTIVATED AND UNCULTIVATED DRYLAND BELTS OF EASTERN MONTANA

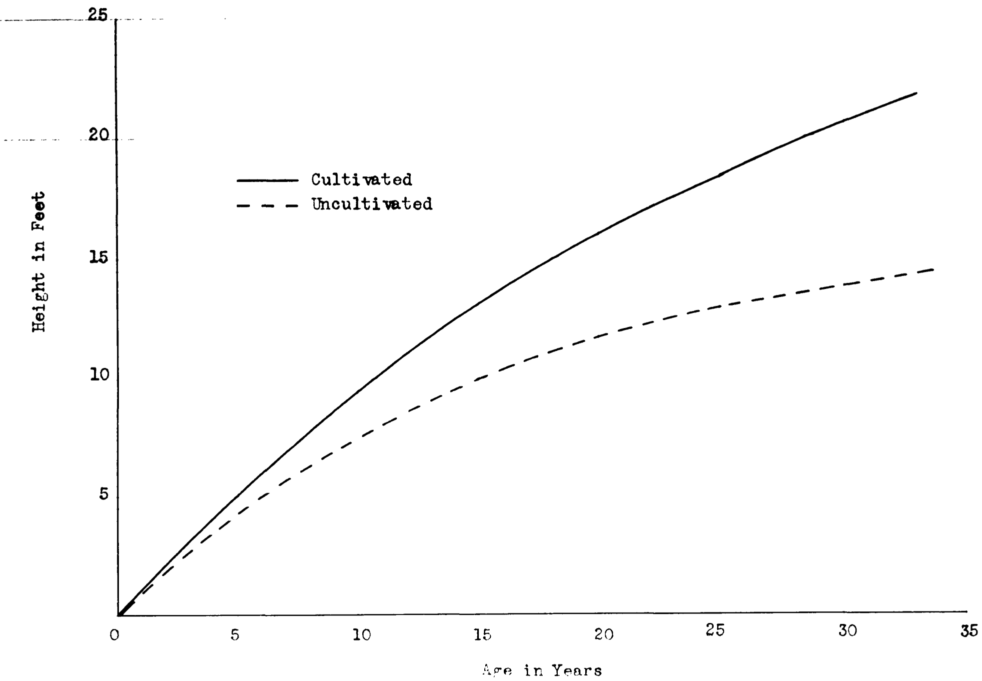


FIGURE 32

AVERAGE HEIGHT GROWTH OF RUSSIAN OLIVE IN CULTIVATED AND UNCULTIVATED DRYLAND BELTS OF EASTERN MONTANA

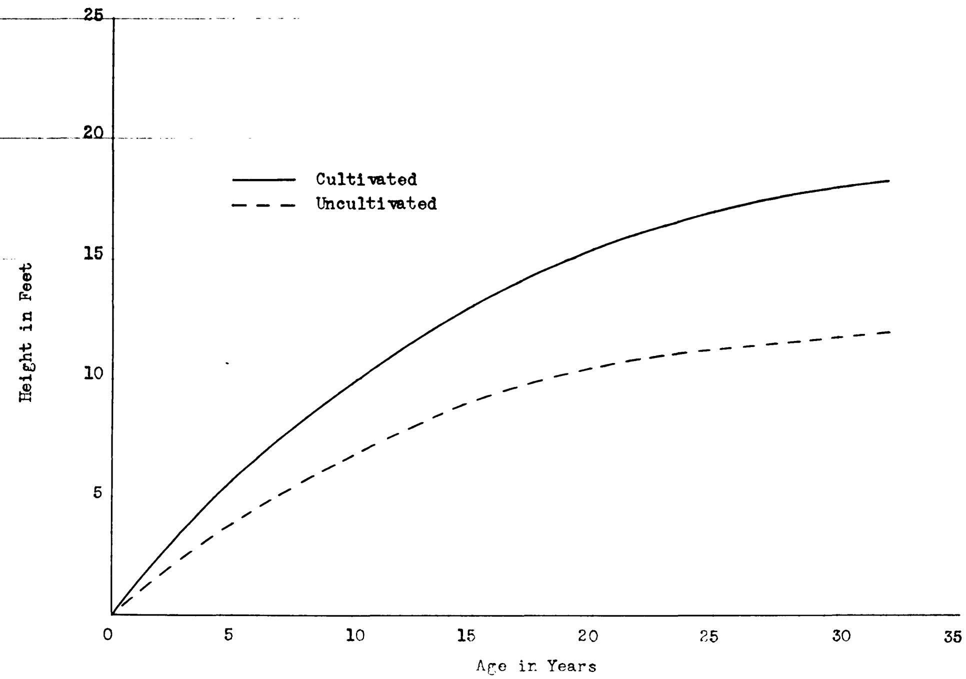


FIGURE 33

AVERAGE HEIGHT GROWTH OF GREEN ASH IN CULTIVATED AND UNCULTIVATED DRYLAND BELTS OF EASTERN MONTANA

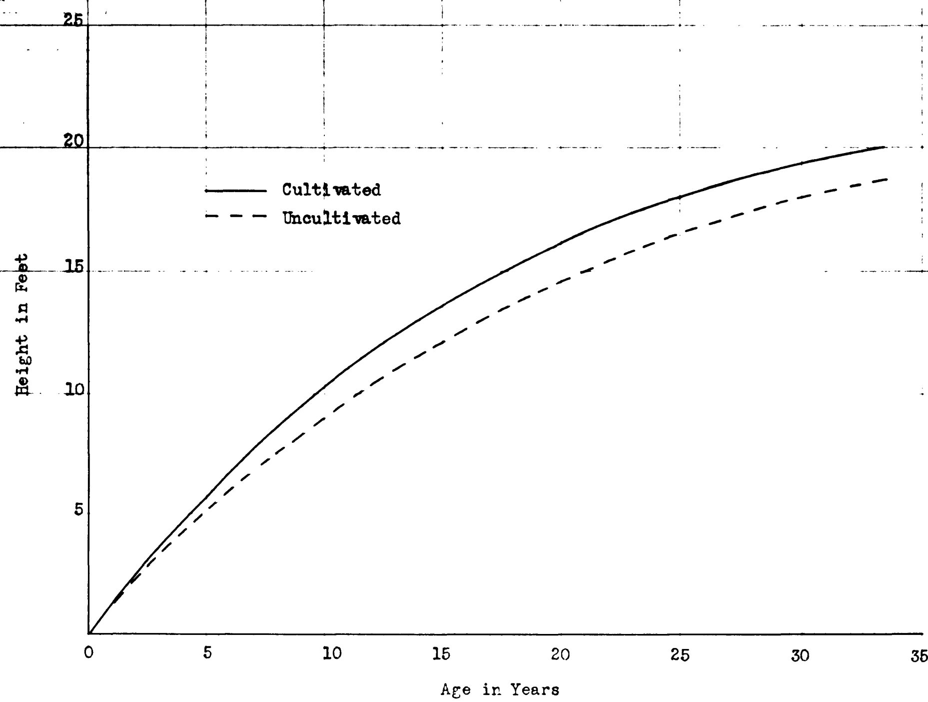


FIGURE 34

AVERAGE HEIGHT GROWTH OF CHINESE ELM IN CULTIVATED AND UNCULTIVATED DRYLAND BELTS OF EASTERN MONTANA

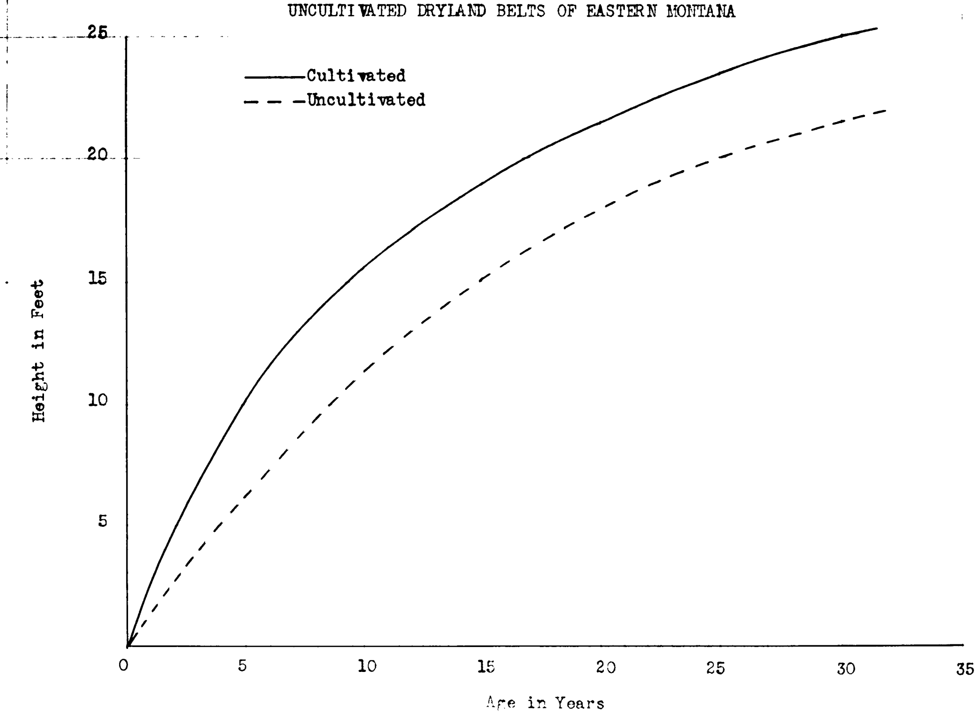


FIGURE 35

AVERAGE HEIGHT GROWTH OF AMERICAN ELM IN CULTIVATED AND
UNCULTIVATED DRYLAND BELTS OF EASTERN MONTANA

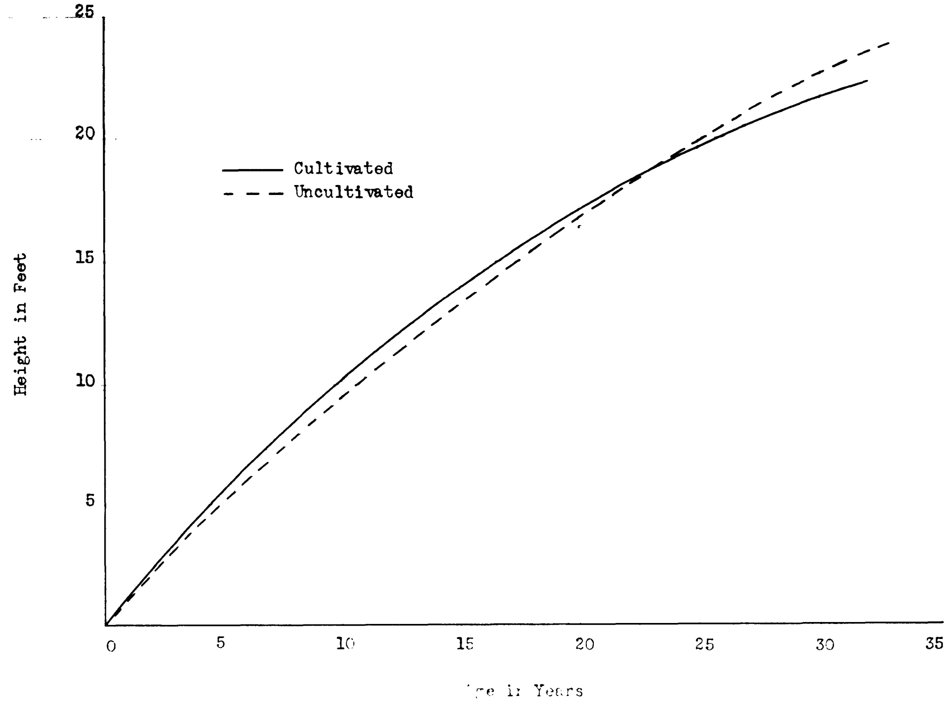


TABLE 11

EFFECT OF CULTIVATION UPON HEIGHT GROWTH OF THE
SIX IMPORTANT DRYLAND SPECIES IN EASTERN MONTANA
(Expressed in Per Cent of Increase in Average Growth)

Species	Years after Planting				
	5	10	15	20	25
Caragana	33.4	20.0	9.4	11.5	16.3
Box Elder	22.4	26.7	32.0	37.0	42.3
Green Ash	0.5	11.4	11.5	10.2	9.0
Chinese Elm	66.4	40.4	26.7	19.4	17.5
Russian Olive	53.8	48.1	45.5	47.6	51.1
American Elm	11.5	7.3	6.4	3.6	-1.5 1/

1/ Height growth was slightly better in uncultivated belts. Difference was too small to be significant.

Effect Upon Survival

Cultivation increases the survival of trees in shelterbelts as well as growth. Table 12 shows the survival of six dryland species under four conditions of cultivation, "clean", "light weeds", "heavy weeds" and "sod". Under "clean" cultivation no weeds were present between the rows but some weeds may have been present in the rows and between the trees where the cultivator could not reach them. Classed as "light weeds" were light stands of annual weeds and grasses as a result of no cultivation for the current year up to the time of inspection of the belt. Dense stands of annual and perennial grasses and weeds as a result of no cultivation for approximately five years were classed as "heavy weeds". Lack of cultivation for approximately 10 years or stands of native or introduced perennial grasses and weeds were classed as "sod". Belts in which the owner had planted crested wheat grass or sweet clover were also included in this category.

Cultivation had the least effect upon the survival of caragana and the most upon American elm and Russian olive. In the case of American elm this is quite opposite the effect of cultivation upon height growth. Whereas, little increase in growth was noticed by cultivation, survival of this species is definitely increased as a result of tillage. The small increase in survival in the case of caragana can probably be attributed to the noted drought resistant characteristics of this species. There is an apparent discrepancy in the case of green ash under the caption light weeds. The cause of the low survival in this case is not understood at the present time.

TABLE 12

EFFECT OF CULTIVATION UPON THE SURVIVAL OF SIX IMPORTANT DRYLAND SPECIES IN EASTERN MONTANA SHELTERBELTS

Species	Per cent of Survival			
	Clean	Light Weeds 1/	Heavy Weeds 2/	Sod 3/
Caragana	86.3	85.4	65.5	80.5
Russian Olive	88.3	85.0	62.3	53.3
Box Elder	75.7	76.4	54.7	57.3
Green Ash	65.6	66.6	78.5	70.4
Chinese Elm	84.4	77.7	47.3	63.8
American Elm	83.3	92.1	57.9	46.4

1/ Light growth of annual weeds present as a result of no cultivation during the summer of 1947.

2/ Dense stand of annual and perennial weeds as a result of no cultivation for approximately 5 years.

3/ Native or introduced perennial grasses and weeds as a result of no cultivation for 10 years. Belts in which crested wheat grass and sweetclover were planted were included in this category.

Workers in other parts of the nation have also shown that cultivation is vital to the growth and survival of shelterbelt plantings. Increases in growth of 10 to 50 per cent have been reported in Minnesota (Records, 1913, Cheyney, 1931). These findings are quite comparable to those of our study. Data published by George (1943) shows that green ash is quite responsive to cultivation — more so than has been indicated by this study. He showed that height growth, survival, crown spread and freedom from winter injury are all increased by clean cultivation.

Competition from Weeds

Growth and survival are better in cultivated plantings because of the more favorable moisture conditions brought about by the removal of competing weeds and grasses. The competition for moisture between roots of trees and weeds is quite intense. Approximately 97 per cent of the roots of the common shelterbelt trees are in the upper four feet of the soil while the roots of grasses and weeds have been shown to go down 3.3 to 5.0 feet. (Ten Eyck, 1900; Finnell 1929; Yeager, 1935). This means that the bulk of the tree and weed roots are in the same soil zone and are competing directly with each other for the available moisture present. Good cultivation will remove this competition and so will save up to 20 per cent of the precipitation for use by the trees. (Finnell 1929; Hysell, 1938). Protection of moisture from utilization by weeds has been estimated to allow the moisture to exist in the subsoil for periods of 3 to 5 months without material loss (Finnell, 1929) and is available for use by the trees during the dry months when precipitation is scant.

Certain grasses and weeds apparently compete more intensely with the trees than do others. Several farmers had sown crested wheat grass or sweet clover in their plantings. In all such cases, the trees were in poor vigor, had shown poor growth and were drying out. When present in light stands the annual species such as foxtail barley, cheat grass and the mustards apparently have less effect upon the trees. But even these, if present in dense stands, will cause a material decrease in height growth and survival as was brought out by table 12, page 85 where the effects of cultivation upon survival were shown.

Continuous Cultivation is Necessary

The continued growth, vigor and survival of trees in eastern Montana is dependent upon clean cultivation throughout the entire life of the shelterbelt. This is true because with the critical shortage of available moisture, there is little likelihood that the tree crowns will interlace and shade the ground sufficiently to exclude native and introduced grasses and weeds, thereby creating a forest condition and eliminating the need for further cultivation. Even in well established and vigorous belts, trees are not able to exclude other vegetation from the floor of the belt. Several abandoned belts that had been well cultivated at one time were examined in the course of the field survey. Without exception, the trees were dying out from lack of sufficient moisture. A belt north of Lohman in Blaine County demonstrates the dependence of trees upon continuous cultivation quite well. The owner had thoroughly cultivated his trees for some years and had even hauled barrels of water by horse and wagon for more than 5 years so that the trees were well established and growing vigorously. But after his wife died, the old fellow left and cultivation was stopped. Now all the trees are drying out and the rate of mortality is increasing.

In a few exceptionally favorable sites in the dryland areas, a forest condition in the shelterbelt may be possible. These sites are generally those with sandy loam soils and are located in the bottom of a draw, at the base of a slope so that additional moisture is obtained through runoff, or where the water table is sufficiently close to the surface of the ground. Such sites are relatively few in eastern Montana, and even under these conditions a forest condition is not assured, and continuous cultivation is the safest procedure.

Cultivation in Irrigated Belts

In irrigated plantings the conditions are entirely different from those in dryland belts. Since the object is to conserve moisture by the elimination of competing weeds and grasses there is no point to practicing continuous cultivation where there is sufficient water available to the trees even in the face of severe competition. Cultivation should be practiced for the first 4 or 5 years until the trees have become well established. Thereafter, weeds and grasses cannot compete successfully with the trees.

Light Cultivations are the Best

Shallow cultivations by disk or harrow are more beneficial than deep ones. As long as weeds have been eliminated the desired objective has been achieved and with the minimum of water loss due to evaporation from the disturbed soil surface. Deep cultivations stir the soil unnecessarily and increase the loss of water through evaporation. In addition, shallow growing tree roots are apt to be injured by blades set too deep.

Since high survival and maximum growth in height and crown spread are essential for effective windbreak, and the study has shown that these have been attained best in those belts that have been clean cultivated, it appears that the cost of labor and equipment involved is more than justified.

SOILS

The study showed no consistent relationship between soil texture and height growth. The differences in growth on varying soil textures were in most cases not significant. The effects of texture upon height growth are presented for 10 and 20 year old trees in table 13.

The greatest difference in growth in the 10-year old trees is in the case of green ash where growth on clay soils was 2.9 feet higher than on the sandy soils. Russian olive showed the least difference in growth with only one half foot difference in favor of the sandy soils. At 20 years of age American elm showed the most difference in height growth on the different soil types with 3.7 feet higher growth on the heavy soils. Box elder showed the least effect — only .3 foot better on the heavy soils.

TABLE 13

EFFECT OF SOIL TEXTURE UPON HEIGHT GROWTH OF TEN AND TWENTY YEAR OLD TREES IN EASTERN MONTANA SHELTERBELTS

Species	Ten Year Old Trees			Twenty Year Old Trees		
	Sandy	Loamy	Clayey	Sandy	Loamy	Clayey
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
Caragana	6.3	7.0	7.5	8.0	9.0	8.9
Russian Olive	9.5	9.8	9.0	14.8	14.8	12.7
Box Elder	7.2	7.1	7.8	12.5	12.5	12.8
Green Ash	8.6	9.4	11.5	14.5	14.8	17
Chinese Elm	15	14	13	21.0	19.5	19
American Elm	11	12.2	12.4	15.7	18.1	19.4

The differences in growth as shown in the table are neither consistent enough nor sufficiently large to draw any valid conclusions regarding the effect of soil texture upon growth of trees in dryland windbreaks in eastern Montana.

These results are contrary to the statements made by other workers in the field who have shown that the wilting coefficient (percentage of moisture in a soil when plants permanently wilt) is a property of the soil and decreases with increase in particle size. Analyses have shown that the wilting coefficient of fine sand is 4 per cent, of silt loam, 10.5 per cent and clay 19 per cent (Lutz and Chandler, 1946). Others have shown that sandy soils are better sites for planting trees in areas where moisture is deficient (Wilson and George, 1929; Stoeckeler and Bates, 1939 and Lutz and Chandler, 1946).

TOPOGRAPHY

In addition to the amount and type of precipitation, slope and nature of the soil surface influence the water content of the soil and through it the growth of shelterbelt trees. In general, rainfall lost by runoff increases with the angle of slope and the water absorbed correspondingly decreased. Even on the relatively flat plains over much of Montana, the water lost by runoff varies from 15 per cent in light showers to 50 per cent in heavy "cloudburst" rains (Weaver and Clements, 1938). Slopes as little as 5 to 6 per cent are sufficient to cause a noticeable difference in growth between trees on the knolls and those in the swales where runoff has accumulated.

The effect of topography upon the growth of trees in a 20-year old planting near Vida is shown in Figure 36. Note the decreased height growth and general sparseness of the trees growing on top of the knoll. The average height of the three species in the belt are tabulated in table 14 to show the difference between growth on the knoll and in the swale. In this case, the slope was only 5 per cent but was sufficient to cause runoff into the swale resulting in more favorable growing conditions for the trees.

The height growth of green ash was 27 feet higher in the swale than on top of the knoll. Growth of box elder was 26 feet higher. Laurel willow was unable to survive at all on the knoll but had a height growth of 12 feet with a survival of 10 per cent in the swale. Windbreaks planted at the base of a slope also benefit from the accumulation of water runoff.

Similar examples were found by Scholz (1935) in North Dakota who found cottonwood growing as much as 25 feet higher in the swales than on the knolls.

If possible, plantings should be so planned as to take advantage of all topographical features that cause accumulation of moisture and so better the growing conditions.

The soil surface may often show irregularities which retard runoff allowing more time for the rainfall to soak into the soil. The increase in soil moisture through this means is not great but is always beneficial. However, no observations concerning soil surface were made in the study so no conclusions regarding the effects of soil

FIGURE 36

EFFECT OF TOPOGRAPHY ON HEIGHT GROWTH

(Slope is 5 per cent)

TABLE 14

HEIGHT GROWTH OF TREES IN FEET IN A ROLLING BELT

	Laurel Willow	Green Ash	Box Elder
In the swale	12	34	34
On the knoll	0 1/	7	8

1/ Laurel willow was unable to survive on top of the knoll.

irregularities upon growth shelterbelt trees in Montana can be made.

NUTRIENTS

Nutrients are important to tree growth and vigor but in this study the effects of any possible deficiencies were not noticeable because of the overshadowing importance of moisture.

The relative abundance of available nitrogen and phosphorus was determined by making tissue tests with the Purdue Soil Testing Kit. Results of the analyses are summarized in table 15.

As shown in the table, 88.5 per cent of the samples tested had low to very low available nitrogen and 78.3 per cent had high to very high amounts of available phosphorus. This is contrary to what was expected at the beginning of the study.

However, within the range of nutrient conditions obtained, no consistent relationship between tree growth and the abundance of available nitrogen and phosphorus was determined. Belts planted on soils where the analysis showed a lack of either nitrogen or phosphorus or both had as good growth as those belts on soils in which these elements were abundant.

Studies carried out at the Central States Forest Experiment Station have also shown no definite correlation between mineral nutrients and the growth of trees because moisture was such an important factor. (Auten, 1940).

TABLE 15

ABUNDANCE OF AVAILABLE NITROGEN AND PHOSPHORUS
IN THE SHELTERBELTS OF EASTERN MONTANA

Relative Amount	Number of Samples	Per cent of Total Number
Nitrogen — 192 Samples		
Very High	9	4.7
High	13	6.8
Medium	22	11.5
Low to very low	148	77.0
Phosphorus — 191 Samples		
Very High	93	48.7
High	47	24.6
Medium	43	22.5
Low to very low	8	4.2

CHAPTER VIII

DETRIMENTAL FACTORS IN MONTANA SHELTERBELTS

USE OF SPECIES NOT ADAPTED TO THE CLIMATE

In order to determine the extent of mortality of the trees planted in the plains of eastern Montana, the average survival of each row of trees was recorded. Table 16 summarizes the survival data on nine species planted in the dryland windbreaks. The age of the trees varied from 5 to 15 years.

As may be seen from the table, 70 per cent of all the trees of these nine species were still living when the study was made. Cottonwood showed the poorest adaptability to the dryland sites with 73 trees dying out of every 100 planted. Poor survival was likewise shown by the willows and northwest poplar with two out of every three dying. Caragana showed the highest survival, 84 per cent, demonstrating its ability to withstand the climatic extremes of the area studied. American elm and green ash were almost equal in survival but the information on the former is based upon considerably fewer trees than in the case of green ash. Russian olive and Chinese elm are also quite comparable in their ability to withstand the rigorous growing conditions with 72 and 74 per cent survival respectively. Box elder has a relatively high mortality figure with 4 out of 10 trees planted dying.

From this study of 1262 rows of trees, it is evident that cottonwood, willow and northwest poplar are poorly suited to the growing condi-

TABLE 16

PER CENT OF SURVIVAL OF TREES IN DRYLAND
SHELTERBELTS IN EASTERN MONTANA

Species	Rows Examined	Survival
	Number	Per cent
Caragana	264	84.4
American Elm	39	79.2
Green Ash	338	78.1
Chinese Elm	148	73.9
Russian Olive	124	71.6
Box Elder	193	62.3
Northwest Poplar	60	34.0
Willow 1/	27	32.2
Cottonwood	79	27.3
Total	1262	70.0

1/ Includes laurelleaf, golden and white willows.

tions present in the dryland plantings in the plains area of Montana. Caragana, green ash, Chinese elm, American elm and Russian olive are quite well suited to withstand the climatic extremes. It is interesting to note that of the five species with better than 70 per cent survial, three of them are exotic species.

Although American elm, green ash and box elder are native to this state, they are not native to the sites in which most of the dryland shelterbelts are planted. The natural habitat for these species is either along the drainage bottoms or in depressions where additional moisture is obtained by seepage. When planted in sites less favorable than the natural one, these native species will be aided in survival by cultivation which removes the competing vegetation and thus conserves moisture.

SNOW

Drifted snow in shelterbelts may not be an unmixed blessing. Deep drifts are often too heavy for the tree branches to bear, resulting in severe breakage. During the winter of 1946-47 peculiar conditions existed that caused more than the usual amount of snow damage. After a heavy snowfall, a warm spell partially melts the snow on the branches. Subsequently, freezing temperatures froze the partially melted snow into crusts of ice that encased the branches in a vise-like grip. Additional snowfall, instead of sliding off the branches, stuck to the ice-crust and the increased weight caused as much as 100 per cent damage to the trees.

In a planting near Antelope in Sheridan County, Russian olive, 15 foot tall, was stripped of all branches and the main stems were broken to [illegible] foot stubs. Chinese elm and green ash suffered almost as severe damage. However, when examined, all of the trees were putting out vigorous root sprouts with growth as much as 4 to 5 feet during the summer, and there is some hope for the survival of the planting as a whole. No caragana was present in this windbreak, but in others it had also been heavily damaged by winter snows.

Though snow damage was reported by many of the farmers interviewed, no mortality that could be actually attributed directly to the snow was encountered. However, the wounds caused by the breakage served as focal points for insect attack. Green ash, in particular, suffered heavily in this manner, with wood borers concentrating at those points where branches had broken off near the bole of the tree.

WINTERKILL AND DIEBACK

Considerable winter die-back of Chinese elm and box elder was encountered during the study. Green ash, Russian olive and cottonwood also suffered but to a lesser extent. Ordinarily, winterkill and dieback are caused by factors other than low temperatures during the dormant season as all of these species are cold hardy plants and have the ability to develop cold resistance within their tissues.

In the case of Chinese elm, chinooks or mild periods of any duration may be an important cause of winterkill and dieback. Warm air temperatures induce a relatively high rate of transpiration which the tree is unable to sustain because of the slow rate of water absorption from the frozen soil. The result of this unbalanced condition is a gradual desiccation of the branches and tips which may be severe enough to cause the death of some of the branches or even of the entire tree.

Considerable damage may occur if the trees enter the winter in a dry condition, and if the soils are relatively dry at the time it freezes. Box elder, in particular, is damaged by these conditions. However, in general, the broadleaves are less apt to suffer damage if they should receive little or no water after the middle of August until after they have dropped their leaves. Apparently a dry period at the end of the summer acts as a hardening agent rendering the trees less susceptable to winter injury. After that time and before the ground is frozen, a good soaking rain or irrigation is beneficial and will do much towards decreasing winter dieback.

Box elder and Chinese elm have fallen into some disrepute because of their susceptibility to winterkill and dieback. Many plantings containing these two species are nothing more than a brushy mass of half dead and half live trees. While such plantings are quite effective as windbreaks, they are very unthrifty and untidy looking and are looked upon with disfavor by many Montana farmers.

LATE SPRING FROSTS

Though freezing temperatures ordinarily do no harm during the winter months, late spring frosts can be particularly damaging to shelterbelt trees if growth is already well advanced. On the night of May 28, 1947, a particularly severe frost in which temperatures dropped to 18°F. occurred throughout most of the eastern counties of Montana.

Species damaged by the frost were caragana, cottonwood, northwest poplar, green ash and spruce. Spruce was the only evergreen damaged by the frost. All of the current season's needles were killed and in many cases the older ones also. Only those buds which had not yet opened at the time of the frost were unharmed. Later in the season, all needles except those developed subsequent to the frost dropped off, leaving a relatively small area of photosynthetic tissue on the trees. There is some question as to whether sufficient food could be manufactured by those new leaves to permit the trees to survive the winter. Of the broadleaf species, green ash was the hardest hit, with as much as 100 per cent damage to the leaves. Figure 37 shows a planting of green ash 23 days after the frost. Notice the extent to which the trees had leafed out and that all the leaves on each green ash tree were killed by the frost.

New growth of the injured trees after the frost originated from dormant buds in the trunk, branches and root crown, and was promoted by watering soon after the frost. In those belts where rain occurred or irrigation was applied immediately after the frost, recovery was faster and better than where additional moisture had not been supplied. Recovery was poorest and slowest in dryland belts that had not been cultivated. Figure 38 shows a 15-year old planting of green ash in an uncultivated

FIGURE 37

GREEN ASH 23 DAYS AFTER THE FROST OF MAY, 28, 1947

FIGURE 30

GREEN ASH IN AN UNCULTIVATED BELT 48 DAYS AFTER THE

FROST OF MAY 20, 1947

dryland belt near Havre as it looked 43 days after the frost. The ground is covered with a dense stand of mustard and foxtail barley grass. Recovery is very poor with at least 5 to 6 years of growth killed back. Death of the limbs was ascertained by checking the cambial layer — which was brown and withered.

The significance of this late frost is yet to be determined. As shown by the weather records (table 8, page 26) the frost was not unusually late for several stations have reported average last dates of killing frost to be in the last week of May. Since the date was not unusual, it must have been the low temperature that was significant because this was the first time in 20 years that green ash had shown such severe injury as the result of late frosts. (Patten, 1948). The permanent effects of this frost on the survival of trees, and in particular green ash and the spruces, are yet unknown and will be better determined the first summer after the frost.

GRAZING

The farmer can sign no surer death warrant for his tree plantings than by allowing livestock to graze in the belt. Livestock and shelterbelts just don't mix. Growing conditions are difficult enough without the added damages of grazing which in most cases constitute the proverbial last straw.

Sheep

As shown by the study, all three classes of stock, sheep, cattle and horses are equally destructive. In most cases where sheep were involved they were present in the belt only during the winter season when the planting was used as a protected feedlot. Unfortunately, the sheep do not confine their feeding to the hay! Caragana appears to be the most palatable species present in the shelterbelts and accordingly suffers the most damage from actual browsing.

Figure 39 shows a 10year old planting of caragana and Chinese elm which has been used as winter feedlot for sheep for the past four years. Notice the browse line and the broken branches. As a result of the browsing of the succulent side branches, the crowns have not closed in, and as far as stopping the wind is concerned, the belt is little more effective than would be a row of posts. Survival in this 10-year old belt was 50 per cent for the caragana and 65 per cent for the Chinese elm, or 34 per cent below the average for caragana and 7 per cent below the average for Chinese elm. (See table 16, page 98).

Cattle

Many Montana farmers permit cattle in their belts both summer and winter. Such a practice is sure death to dryland plantings. Figures 40 and 41 show range livestock in a 9-row planting of green ash, and Russian olive that is 23 years old located south of Sinnott. In the first figure notice the dieback at the ends of the branches of the Russian olive. This has been caused by the already critical moisture supply being depleted by soil packing and thus preventing replenishment of the soil moisture supply. The second figure shows

FIGURE 30

WINTER SHEEP DAMAGE IN A 10-YEAR OLD BELT OF CARAGANA AND CHINESE ELM

FIGURE 40

CATTLE IN A DRYLAND PLANTING

(Looking east along the south belt)

FIGURE 42

THE RESULT

the result of the soil packing, browsing and rubbing. There is little evidence that at one time nine rows of trees existed in the planting. All that is left of the Russian olive is the snag in the foreground and one bush with foliage next to 4 dead clumps in the background. Five green ash trees are the sole survivors of this part of the belt, and these are characterized by dead branches, sparse foliage, no low-growing branches and poor vigor in general.

Several species are readily browsed by cattle, chief among them are caragana, Chinese elm, box elder, green ash, cottonwood and willow. As is frequently true with other members of the legume family to which it belongs, caragana is very readily browsed by cattle. Year-long presence of cattle in a belt containing this species will result in the extinction of this species in short order. New growth of Chinese elm is also quite palatable to cattle. The succulent shoots of box elder and green ash are readily taken; but the chief damage to these trees, at least when they are 10 feet or more high, is through trampling and rubbing. Low branches are broken off and the crowns are prevented from closing in at the bottom, allowing the wind to sweep through practically unimpeded.

Irrigated belts are also damaged by cattle. Figure 42 shows cattle in a 10-year old planting of northwest poplar near Utica in Judith Basin County. The bottom of the belt is very open as the result of browsing of the reproduction. Normally, poplar will produce enough root sprouts to fill the bottom and maintain a tight windbreak. At one time a row of caragana was also present near the old fence; now there

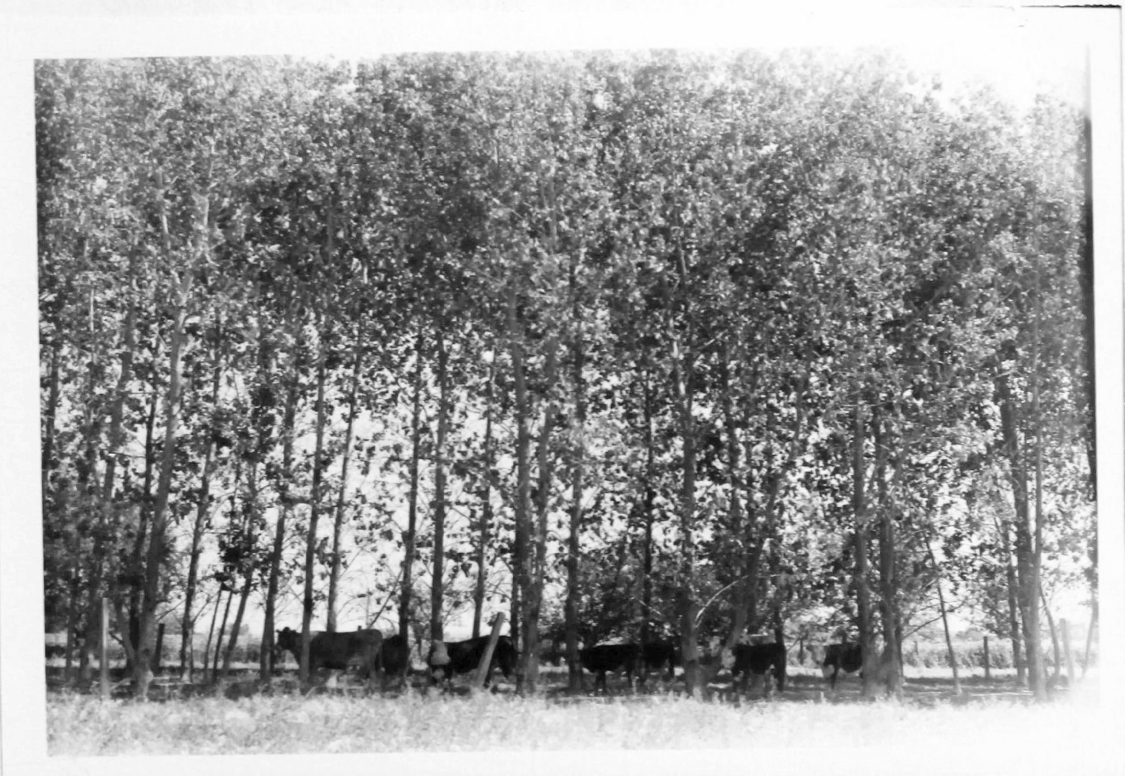


FIGURE 42

BROWSING OF REPRODUCTION HAS OPENED THIS BELT OF NORTHWEST POPLAR is nothing left of the row except some half rotten stubs six to 12 inches high.

Horses

Horses were encountered occasionally in the windbreaks. In most instances only one or two animals were present, usually the children's personal stock. These did not do much damage by browsing except to reproduction. The chief form of damage by horses is through packing of the soil and rubbing of the trees.

Importance of Soil Packing

All classes of stock seriously impair the vigor and reduce the survival of trees by packing the soil. This inhibits penetration of water into the subsoil and decreases aeration. This is important in irrigated belts as well as dryland plantings. One belt observed east of Conrad had been packed by cattle to such an extent that despite frequent irrigations, water was unable to penetrate to any depth resulting in high mortality of green ash and laurelleaf willow -- 40 and 80 per cent respectively. The vigor of the remaining trees was low and the belt was only partially effective as a windbreak.

The detrimental effect of livestock can be briefly summarized into a few statements. They cause damage by (1) browsing of the branches and of the reproduction; (2) rubbing and breaking the low-growing limbs and hence preventing the crowns to close at the bottom; and (3) packing the soil inhibiting moisture penetration and decreasing aeration.

Severity of the damage done depends upon the number of stock, the duration the stock are present and the season the stock are present in the planting.

INSECTS

Locally, insect depredations may be severe enough to cause a reduction in the vigor and growth and even the death of shelterbelt trees. The destructive insects can be divided into 3 classes: 1. the defoliators or leaf eaters, insects that defoliate the trees; 2. the suckers or piercers, insects that pierce the epidermis of the leaves and suck the plant juices, and 3. the borers, those that bore into the trunk or branches of the trees. Grasshoppers and blister beetles are examples of the first class, plant lice or aphids of the second and the green ash borer of the third class. All three classes were encountered during the survey.

Defoliators

The largest amount of insect damage encountered was caused by members of the defoliator class. Heavy infestations of grasshoppers and blister beetles were encountered in local areas scattered throughout eastern Montana. The grasshoppers were the most omnivorous of all the insects observed, attacking all trees in the windbreaks. Though past damage was reported by farmers, no attacks by grasshoppers on evergreens were actually observed during the study. Other defoliators, the blister beetle and the secropia worm showed a little more preference in their attacks. This beetle seemed to be partial to caragana, honeysuckle and the leaves on the lower branches of green ash. Secropia attacked box elder and green ash primarily but when present in epidemic proportions was observed to attack all broadleaf species except caragana.

Suckers

Of the sucker type insects, the wooley elm aphid attacking American elm caused the most damage. This insect causes leaf curling and rosettes on the elm. The poplar stem gall aphid and the poplar twig gall aphid were also frequently found on the cottonwood and less so on northwest poplar. Though causing some damage, these two aphids rarely kill any trees. Another plant louse, the spruce gall aphid, attacks the terminal buds of the spruce trees causing the formation of prominent galls. Black Hills spruce was attacked more severly than was Colorado blue spruce.

Borers

The only borer insects observed during the survey were the green ash and the Chinese elm borers. In almost all cases, infection was accomplished where branches had been broken by wind or snow or had been pruned. These insects tunnel into the trunk and branches weakening them so that high winds will cause excessive breakage. In one belt observed east of Forsyth, Chinese elm with trunk diameters of 6 to 8 inches 2 feet from ground had been so weakened by borer activity that a strong wind had snapped many of the trees 4 or 5 feet from the ground.

Insect damage may be locally severe in occasional years, but is seldom serious enough to cause mortality by itself. But if trees are already in a weak condition, insect depredations may result in more serious consequences than usual. Thus any insect attack last summer upon green ash or spruce has probably resulted in more permanent damage than it would have if the trees had not been weakened by the late frost.

FIRE

Occasionally a planting is damaged by fires that have escaped from burning stubble fields. Some have been damaged by the owners burning Russian thistle, tumbling mustard and other weeds that have piled up on the fence surrounding the planting. All species are fatally injured by fires in the windbreak. Fortunately, however, fires are seldom allowed in a shelterbelt.

FUNGI

The importance of fungi as a detrimental factor in eastern Montana shelterbelts is unknown as no observations were made in this study to determine the damage caused by them. However, it is very probable that damage by fungi may prove to be another important factor in windbreak plantings.

CHAPTER IX

SPACING

PROBLEM OF SPACING

Spacing has been the subject of much controversy. The main point of contention is the desirability of narrow spacing over wide spacing and vice versa. The question is not purely a academic one for it has important practical applications. The spacing employed affects the growth, vigor and survival of the trees and, in a large measure, the duration and amount of cultivation the planting will receive. In addition the amount of planting stock required to establish a belt is directly dependent upon the spacing used.

Definition

The purpose of this section of the paper is to state the findings of the study regarding spacing and to discuss the factors pertinent to the problem.

A definition of wide and narrow spacing has not been agreed upon. Workers in North Dakota and Minnesota consider wide spacing to be that combination of between-row and in-row spacing that allows more than 40 square feet per tree (Scholz, 1935; Hansen and Schmitz, 1930). Other workers believe that less than 30-40 feet per tree is narrow spacing (Harrington and Morgan, 1935; Thompson, 1932). For the sake of consistency in this paper, less than 72 square feet per tree will be considered as narrow spacing.

Review of Literature

Review of the literature shows that there is little agreement between workers as to recommended spacings and the results obtained from the different spacings. Earlier workers almost always advocated narrow spacings of 4 x 4, 4 x 8, 6 x 6, and 8 x 8 feet (Records, 1918; Smith, 1917). During the 1920's the recommended spacings were somewhat wider but still varied from 6 x 6 to 6 x 12 feet (Siecke and Lyman, 1920; Wilson and Cobb, 1923; Phillips, 1928, and Wilson, 1929). Bode (1924) was an early advocate of wide spacing and recommended in-row spacings of 10 to 12 feet and 14 to 16 feet between the rows. Phillips (1928) also recognized the desirability of wider spacing on the drier sites by recommending a 10 x 10 feet spacing. In the thirties more workers advocated wider spacing, especially those in the far west; but there was still widespread disagreement. Prominent among those advocating narrow spacing were Olsen and Stoeckeler (1935), George (1936), Wilson (1937) and Hansen and Schmitz (1938). Supporters of wider spacing were Jensen and Harrington (1930), Cheyney (1931), Thompson (1932) and Watkins and Maxwell (1939).

SPACING COMBINATIONS OBSERVED

As a result of the many recommendations offered there is no uniform spacing policy followed by the various agencies prominent in planting shelterbelts in Montana. The Bureau of Plant Industry and the Soil Conservation Service have, in general, been advocating the narrower spacing while the Extension Service has been advocating wider spacings to facilitate cultivation.

Combinations Found

Thirty-six spacing combinations were observed in dryland windbreaks in eastern Montana (table 17). Almost one-half (49 per cent) of the dryland belts observed had no single spacing combination. There is no one spacing combination preferred but of those encountered four (6 x 9, 6 x 10, 6 x 12 and 6 x 15 feet) were the most commonly used accounting for 22 per cent of the belts studied. The remaining 29 per cent are distributed among 32 other spacing combinations.

The picture is even more confused in the irrigated belts (table 18). Twenty-one spacing combinations were found distributed almost evenly in 57 per cent of the belts examined. The remaining 43 per cent had no single spacing combination and were classed as irregular.

Spacing for the hedge row is just as variable. Twenty-three different combinations were found in the spacing of the hedge row in dryland belts (table 19). Three combinations (3 x 10, 3 x 12, and 3 x 15 feet) accounted for 48 per cent of the hedgerows. The most frequently encountered spacing between shrubs is three feet, 83 per cent of the outer rows were planted with this spacing.

For purposes of comparison the spacing combinations have been subdivided into two groups — those which have less than 72 square

TABLE 17

SPACING COMBINATIONS OBSERVED IN DRYLAND WINDBREAKS IN EASTERN MONTANA

Spacing	Growing Space Per Tree	Windbreaks		Spacing	Growing Space Per Tree	Windbreaks	
	Square Feet	Number	Per cent		Square Feet	Number	Per cent
Narrow Spacing:				Wide Spacing (Cont.)			
3 x 6	18	1	.6	6 x 15	90	10	5.7
4 x 5	20	1	.6	6 x 16	96	3	1.7
3 x 10	30	1	.6	8 x 12	96	3	1.7
4 x 8	32	1	.6	10 x 10	100	2	1.1
6 x 6	36	1	.6	6 x 20	120	1	.6
5 x 9	45	1	.6	8 x 15	120	3	1.7
6 x 8	48	3	1.7	12 x 10	120	1	.6
5 x 10	50	2	1.1	8 x 16	128	2	1.1
6 x 9	54	6	3.4	9 x 16	144	2	1.1
9 x 6	54	1	.6	12 x 12	144	3	1.7
6 x 10	60	8	4.6	10 x 15	150	2	1.1
4 x 15	60	1	.6	10 x 20	200	1	.6
4 x 16	64	1	.6	15 x 15	225	1	.6
Wide Spacing:				12 x 20	240	1	.6
6 x 12	72	15	8.7	14 x 18	252	1	.6
9 x 18	72	1	.6	16 x 16	256	1	.6
4 x 20	80	1	.6	20 x 20	400	1	.6
8 x 10	80	3	1.7	Irregular 1/		85	48.8
9 x 9	81	1	.6				
6 x 14	84	2	1.1	Total		174	100.0

1/ Irregular indicates that more than one spacing combination was used in the windbreak.

TABLE 18

SPACING COMBINATIONS OBSERVED IN IRRIGATED WINDBREAKS IN EASTERN MONTANA

Spacing	Growing Space Per Tree	Windbreaks		Spacing	Growing Space Per Tree	Windbreaks	
	Square Feet	Number	Per cent		Square Feet	Number	Per cent
Narrow Spacing:				Wide Spacing:			
2 x 6	12	1	2.4	6 x 12	72	1	2.4
3 x 6	18	2	4.7	8 x 10	80	1	2.4
3 x 10	30	1	2.4	6 x 14	84	1	2.4
4 x 8	32	1	2.4	6 x 15	90	1	2.4
3 x 12	36	1	2.4	9 x 10	90	1	2.4
6 x 6	36	2	4.7	8 x 12	96	2	4.7
4 x 10	40	1	2.4	10 x 10	100	1	2.4
9 x 5	45	1	2.4	6 x 20	120	1	2.4
6 x 9	54	1	2.4	12 x 12	144	1	2.4
6 x 10	60	1	2.4	15 x 15	225	1	2.4
8 x 8	64	1	2.4	Irregular 1/	—	18	42.7
				Total		42	100.0

1/ Irregular indicates that more than one combination was used in the windbreak.

TABLE 19

SPACING COMBINATIONS FOR HEDGE ROWS IN DRYLAND WINDBREAKS IN EASTERN MONTANA.

Spacing	Growing Space Per Bush	Windbreaks	
	Square Feet	Number	Per cent
Narrow Spacing:			
3 x 3	9	2	1.8
2 x 6	12	1	.9
3 x 4	12	4	3.6
4 x 4	16	1	.9
3 x 6	18	3	2.7
2 x 10	20	2	1.8
2 x 12	24	4	3.6
3 x 8	24	7	6.3
3 x 9	27	6	5.4
2 x 15	30	1	.9
3 x 10	30	15	13.5
3 x 12	36	20	18.1
4 x 10	40	4	3.6
3 x 14	42	3	2.7
3 x 15	45	18	16.2
3 x 16	48	7	6.3
4 x 12	48	1	.9
3 x 18	54	2	1.8
6 x 9	54	1	.9
3 x 20	60	5	4.5
2 x 32	64	1	.9
Wide Spacing:			
6 x 12	72	2	1.8
4 x 20	80	1	.9
Total		111	100.0

feet per tree (narrow spacing) and those which allow more than 72 square feet per tree (wide spacing).

Present Trend

There has been a general trend towards wider spacing in the plantings made in eastern Montana. Typical of this trend are the plantings made on the Otto Jehnke place near Flatwillow. The early planting in 1930 was established with 6 x 6 feet spacing while the later one in 1940 had a 10 x 16 feet combination. Other farmers throughout the state have achieved wider spacing in their belts by removing alternate rows where the spacing was too narrow to accommodate their equipment. In this manner original spacing combinations allowing 6, 8 or 10 feet between rows have been modified so that the rows are now 12, 16 or 20 feet apart. When queried as to their preference in spacing, most farmers advocated not less than 16 feet between the rows so that their field cultivation equipment could be used in the care of the planting. A few considered 12 feet as sufficient while some believed that 20 to 24 feet should be the minimum.

FACTORS INVOLVED

Published data are contradictory as to the relative merits of wide and narrow spacing. In North Dakota old groves that had been closely spaced (4 x 4, 4 x 6, 4 x 10 and 6 x 6 feet) were found to be in better condition than were those that had been more widely spaced (6 x 8, 6 x 10, and 8 x 12 feet) (Scholz, 1935). George (1936) found that close spacing was more favorable to tree growth with wide spacing (6 x 12 feet) being detrimental to box elder. Hansen and Schmitz (1933) found no significant difference in survival in Minnesota between trees planted closely and those planted with wide spacing. On the other hand, Cheyney (1931) found that close spacing resulted in a jungle of stunted trees when the belts were 25 years old. Thompson (1932) in Wyoming reported that plantings did better with 10 x 10 feet spacing than by 6 x 10 feet. In Montana, information published by Jensen and Harrington (1930) show that survival and trunk diameter growth was better with wider spacings.

In deciding upon whether to use narrow or wide spacing, the answers to some clear cut questions must be taken into account. Is there enough moisture available under eastern Montana conditions to maintain closely spaced trees? Is the establishment of forest conditions possible in areas of deficient moisture? What effect does root competition for moisture and nutrients have upon growth vigor and survival of trees? Are widely spaced belts as effective as narrowly spaced belts? What is the relationship between width of belt and snow drifting? What is the effect upon ease of cultivation? What is the effect of immediate situation of the belt, and what does the value of the land have to do with spacing? These are some important questions that should be answered upon deciding which system is the best. This section of the paper is an attempt to give at least a partial answer to these questions.

Will Critical Moisture Conditions in Eastern Montana Support Closely Spaced Trees?

This question cannot be answered definitely with just "yes" or "no". The answer depends upon the site upon which the belt has been planted. Where water is available for irrigation or where moisture conditions are exceptionally favorable, such as those sites located in the bottom of draws, at the base of slopes where runoff water is collected, or in areas of high water table, there is probably enough water to sustain a dense canopy of vegetation.

As the reader probably knows, these good sites are not normally encountered on the plains and moisture conditions are generally not so favorable. Water usually is not available for irrigation nor are most belts planted at the base of slopes or in the bottomlands. Moisture supply is normally a critical factor. The drier the situation, the sparser is the vegetation so that in desert conditions spacing is very wide and the distance between plants is relatively great. Dryland farmers have recognized this principle in planting row crops on dry lands. Corn, alfalfa, wheat and even crested wheat grass are all planted less densely on dryland fields than in irrigated fields to partially insure sufficient moisture for the crops.

In brief, with the exception of irrigated and exceptionally favorable sites, there is probably not enough moisture to support dense stands of vegetation. Should the shelterbelt planter fail to recognize this moisture relationship, he is almost certain to suffer substantial losses during drought years. The answer to this question consequently indicates that in the majority of eastern Montana situations, the wider spacings are necessary.

Possibilities of Developing a Forest Floor in Areas of Critical Moisture Supply?

Forest conditions are those conditions within a shelterbelt where as a result of extreme competition for moisture, nutrients and light, grasses and weeds are unable to flourish within the planting. These conditions are popularly thought to be brought about by the meeting of the trees' crowns and the consequent shading of the ground. With 20 inches or more of precipitation, shelterbelt trees planted 4 x 6 or 4 x 8 feet will interlace approximately 5 years sooner than those with over 6 x 8 feet spacing and so establish forest conditions in 15 to 20 years (Hansen and Schmitz, 1938).

This occurs, however, under conditions much more favorable than in Montana from the standpoint of moisture relations. Examination of the precipitation records (table 3, page 26) shows that the highest average annual precipitation is less than 16 inches — approximately equal to the driest conditions encountered by Hansen and Schmitz.

Of the 176 dryland belts encountered in the study only 6 or 3.4 per cent had developed forest conditions. However, 11 out of 44 or 25 per cent of the irrigated belts had developed a forest floor. The 6 dryland belts were on exceptionally favorable sites and had developed such a condition in from 12 to 30 years. The irrigated belts had developed a forest floor in as little as 5 years after planting. See table 20.

Certain species seem to be more apt to form forest floor conditions than others. In irrigated belts the willows are among the earliest to develop such a condition and under exceptional circumstances will do so in as little as 5 years after planting. In the dryland plantings, caragana, if planted in 2 adjacent rows, will often develop a forest floor between those 2 particular rows only. This condition was observed in several belts in the Teton and Pondera Counties. Accordingly, the spacing between two rows of caragana can be safely reduced to 8 to 10 feet. In the favorable bottomlands, swales, draws and toes of slopes, box elder may develop a forest floor. Of the 6 dryland belts encountered that had developed forest conditions, 3 were located in such sites in Sheridan County and others at widely separated points in the state.

On the basis of the findings of the study and with only 3.4 per cent of the dryland belts encountered having a forest floor, the chances appear to be pretty slim that chronically limited moisture supply in the eastern section of the state will ever permit a cover sufficiently dense to shade the ground so that weeds and grasses will be excluded and a forest floor be obtained. With irrigation, however, forest conditions can be reasonably expected.

TABLE 20

WINDBREAKS WITH FOREST FLOOR CONDITIONS IN EASTERN MONTANA
(Based on 176 Dryland and 44 Irrigated Windbreaks)

Years after Planting	Number of Belts	Per cent of total
Dryland:		
12	1	.57
21	1	.57
22	1	.57
23	1	.57
24	1	.57
30	1	.57
Total	6	3.4
Irrigated:		
5	1	2.3
6	2	4.5
18	1	2.3
19	1	2.3
21	1	2.3
30	2	4.5
33	1	2.3
50	2	4.5
Total	11	25

What Effect Does Intensified Root Competition Resulting From From Narrow Spacing Have Upon the Growth, Vigor and Survival of Trees?

As brought out above, shading is thought to be the important factor in the establishment of forest conditions. However, perhaps it has been over-stressed, and root competition under-emphasized. Investigations in the white pine type have shown that there was no canopy sufficiently dense to inhibit the growth of subordinate layers of vegetation as long as root competition between trees and shrubs for moisture and nutrients was eliminated (Toumey and Keinholz, 1931 as in Toumey and Korstain, 1937). Thus it appears that root competition and not shading is the important factor in the establishment of forest conditions.

Teleologically speaking, the roots of shelterbelt trees "go a long ways" to secure moisture and nutrients. Roots of common broadleaf shelterbelt species growing on dryland sites have been found to extend from the tree for distances varying from 1 to 2.1 times the height of the tree. Roots of the conifers did not spread so far — only .4 to .8 times the height of the tree (Yaeger, 1935). This means that a broadleaf tree, green ash for example, 15 feet high would have roots from 15 to 31.5 feet from the base. The narrower the spacing, the sooner will the roots meet and the more severe will be the competition for moisture and nutrients.

The severity of root competition in narrow spacing reduces the growth and vigor of the trees.

This, in turn, results in higher mortality figures. Studies of 11-year old trees at the Judith Basin Experiment Station in Montana have shown that belts planted with wide spacing had as much as 30 per cent better survival than those belts planted with narrow spacing (Jensen and Harrington, 1930). Results of the study are tabulated briefly in table 21.

In most cases increased mortality is due to the suppression brought about by root competition for moisture and by shading. The suppressed trees are spindly, of poor vigor and are in many cases focal points of insect attack and contribute little to the value of the shelterbelt. In fact, the suppressed trees are of negative value for as long as they are alive, they are competing with the more dominant trees for the critical soil moisture. In this respect, they are nothing more than weeds. It would be better to have used a wide spacing in the beginning giving each tree the benefit of more soil moisture resulting in more vigorous trees from the start.

The effect of root competition between individual species is as yet unknown. However, certain species, commonly called "sappers", are known to be more vigorous competitors for moisture and nutrients than are others. Cottonwood is the most familiar example; Chinese elm is another. Trees planted in rows close to these species are apt to suffer as a result of the intensive competition; therefore, wide spacing is definitely necessary when these two species are used in the shelterbelts.

TABLE 21

SURVIVAL OF 11-YEAR OLD TREES AT THE JUDITH BASIN EXPERIMENT STATION
(From Jensen and Harrington, 1930)

Species	Spacing in feet			
	4 x 4	4 x 8	8 x 8	4 x 12
	Per cent	Per cent	Per cent	Per cent
Box Elder	69.4	76.4	66.6	79.1
Green Ash	91.7	97.9	96.1	100
Poplar	0	8.3	77	54
Buffalo Berry	95.9	95.9	100	87
Willow	0	22.9	76.9	56.1
Average	51.4	60.3	83.3	75.2

It is entirely probable that other species are also as vigorous "sappers" as cottonwood and Chinese elm. Further information is needed upon this subject.

Answering the question then, the increased root competition as a result of narrow spacing results in a decrease in vigor and a consequent increase in mortality as compared to wide spacing. Certain species as cottonwood and Chinese elm are known to need wider spacing than most because of their rooting habits.

<u>What is the Effect of Spacing Upon Cultivation?</u>

As brought out in the chapter on growth, fairly wide spacing and continuous intertillage is the most direct means of moisture conservation available to the farmer. To accomplish this, the spacing recommended must be sufficiently wide to allow the farmer to cultivate with ordinary field cultivation equipment.

The cultivation equipment of most of the farmers contacted was from 10 to 12 feet in width. This means that any row spacing less than 14 to 16 feet could not be cultivated without the use of special equipment. Experience has shown that few Montana farmers have been willing to invest in special cultivation equipment or to modify their present machinery for the cultivation of narrowly spaced trees. As a result, narrow-spaced belts have gone untilled after the first few years.

Arguments are often advanced that accommodation of farmers equipment should not enter into the determination of spacing.

However, practical considerations must be taken into account. Often the farmer will cultivate his windbreak as he is coming in to supper from the fields. If he can draw his disk or harrow through the belt without unhitching his regular field equipment, the cultivation of the windbreak is more apt to be assured.

The writer does not mean to infer that the spacing recommended should be so wide that all types of equipment can be accommodated. Those farmers and ranchers who have crawler type tractors which by means of an offset hookup can pull 2, 3, or 4 cultivators and so cultivate from 30 to 40 feet in one round are in the financial position to either purchase special or to modify their present equipment so that rows 16 feet apart can be cultivated.

Type of cultivation equipment needed and ease of cultivation are dependent upon the spacing between the rows in the shelterbelt. If the spacing is such that standard field equipment can be used, cultivation is made easier, thus tending to assure continuous cultivation throughout the life of the belt.

<u>Relationship Between Snow Drifting and Width of Belt</u>

Distance snow will drift through a belt may have some effect upon the maximum width of rows. George (1943) has shown that snow will drift approximately 100 feet into the belt, with maximum drifting near 30 feet. As emphasized in the discussion on snowfall, the additional moisture derived from melting snow drifts plays an important part in the success of the windbreak. In order that all of the planting will benefit from the snow drifts, the width of the belt should not be much over 100 feet. This means that with a 6-row planting the spacing between rows should not be over 20 feet; a 7-row planting should have a maximum of 16 feet.

Do Narrow and Wide Spaced Shelterbelts Give the Same Degree of Protection?

This is a very practical question, for if 100 trees will give the same amount of protection as 200 there is no reason to incur the additional expense by planting the extra trees. Assuming that all conditions other than the spacing between the rows are equal, and particularly that within-row spacings are fairly close, there is no reason to believe that narrowly spaced trees will give more protection than will widely spaced trees.

What is the Effect of the Value of Land Upon Spacing?

Ordinarily, the value of land will have little effect upon the spacing used in dryland belts. The benefits, financial and otherwise, accruing from a protective planting will outweigh the income that could be derived from the land if it had been cropped. However, in irrigated sections the value of the land is sufficiently high as to limit the amount of land available for shelterbelt purposes. Several such situations were encountered in the irrigated lands along the Yellowstone and Tongue Rivers.

Summary

Briefly summarizing the answers to the questions posed at the beginning of this section, the following points can be stated:

1. There is generally insufficient moisture available in the majority of the planting sites in eastern Montana to maintain a closely spaced planting except in certain favorable sites as those in the bottom of draws, at the base of slope or where the water table is near the surface of the ground.

2. Establishment of forest conditions within windbreaks planted on dryland sites is quite doubtful. Only 3.4 per cent of the dryland belts examined in the study had developed such a condition. However, the chances are quite favorable in irrigated belts as one-fourth of the irrigated belts studied had developed a forest floor. Willows are the most likely species to develop forest conditions in irrigated belts, while caragana and box elder are the ones most likely to in dryland belts.

3. The more severe root competition for soil moisture and nutrients resulting from narrow spacing causes a decrease in vigor and a consequent increase in the mortality of the trees. Cottonwood and Chinese elm are noted for their ability to "sap" the soil and should be planted with a wider spacing.

4. Wide spacing facilitates cultivation with ordinary field equipment. In general, Montana farmers have been unwilling to invest in special machinery or to modify their present equipment to cultivate

belts with narrow spacing.

5. Maximum width of spacing may be dependent upon the distance of snow drift into the belt. Studies have shown that the maximum distance of drift is approximately 100 feet which may limit the width of the belt to a distance near that figure.

6. With all other conditions being equal, narrow and wide spaced belts give the same amount of protection.

7. On dryland farms the value of the land ordinarily has no effect upon the maximum width of the planting. However, this is not true in irrigated sections where land values are much higher. Here the width tends to be reduced by the high values.

The net effect of these considerations is that the wider spacings and continued cultivation are advisable under most eastern Montana dryland conditions.

Conclusions

In view of the considerations discussed in this chapter, the following spacings are recommended for shelterbelt plantings in eastern Montana:

Dryland Belts

1. Hedgerow.

If one hedgerow is used, plant 3 feet within the row and 15 feet from the second row.

If two rows of caragana are used, plant 3 feet within the row and 12 feet between the 2 rows with 15 feet between the second and third rows.

2. Broadleaf species.

Plant 8 to 10 feet apart within the rows and 15 to 20 feet between the rows. In the case of Chinese elm and cottonwood, plant these not less than 10 feet apart in the row and 18 to 20 feet between the rows. (Note: Cottonwood is not recommended for dryland plantings).

4. Evergreens.

These trees should not be planted farther apart than 8 feet within the row and 16 feet between the rows. However, if planted adjacent to Chinese elm, plant 20 feet away. Juniper should be planted closer in the rows, 6 feet being the recommended spacing.

Irrigated Belts

1. Buffer row.

Plant willows 4 feet apart in the row and 10 to 12 feet between the rows.

2. Other rows.

Plant broadleaved species 6 to 8 feet apart in the row and 10 to 12 feet between the rows.

3. Evergreens.

These trees should be planted 6 feet between the trees in the row and 16 feet from the adjacent broadleaf row. If planted next to a row of cottonwood or northwest poplar, plant the evergreen row 20 feet away to eliminate overtopping by the other trees.

If cultivation can be carried out for the first 3 or 4 years, the spacing between the rows can be safely reduced to 6 feet except in the case of an evergreen row adjacent to a broadleaf row.

CHAPTER X

SUMMARY AND CONCLUSIONS

SUMMARY

Planting of shelterbelts is not a recent thing in this state. As long ago as 1895 homesteaders and settlers planted trees for protective purposes in the valleys of the Sun, the Yellowstone, Milk and Tongue Rivers. The stock for these early plantings generally came from the cottonwood flats on the river bottoms. Since 1916, when the Field Station of the Bureau of Plant Industry at Mandan, North Dakota, first set out some experimental plantings in this state, the bulk of the trees have been planted in cooperation with three Federal cooperative agencies — Clarke-McNary, Bureau of Plant Industry, and the Soil Conservation Service. Through the assistance of these agencies, some 10 million trees have been planted in Montana for windbreak, shelterbelt, soil conservation and wildlife purposes.

Unfortunately, in most cases, no survival and performance records have been kept. Many of the successful plantings are not known and the failures are not understood. This emphasizes the need for more and better information concerning Montana conditions.

In the spring of 1947, a cooperative study was set up between the Montana Forest and Conservation Experiment Station at Missoula, and the Montana Agricultural Experiment Station at Bozeman to appraise the conditions as they now exist in eastern Montana shelterbelts.

This paper is a report on the growth conditions affecting the important dryland and irrigated species as determined by the study. It also treats of the spacing in Eastern Montana and the factors that must be taken into consideration in the determination of proper spacing.

All of the counties included in the study lie east of the Continental Divide. The topography of this area is the typical Great Plains type of country, characterized by open flat or rolling plains broken occasionally by wide river valleys and small groups of mountains. The altitude is relatively low -- less than 4,000 feet, with the lowest point being at Ft. Union on the Montana-North Dakota line where the altitude is 1,109 feet above sea level. All of the area is in the upper Missouri River Basin with the important rivers being the Missouri, Milk, Tongue and Yellowstone Rivers.

The climate of eastern Montana is characterized by a fairly long summer season of scanty precipitation and low humidity, with many days of hot, sunny weather, and by cold hard winters with little snowfall and low temperatures. Mean annual precipitation ranges from 10.53 to 15.71 inches with 66 to 83 per cent falling during the growing season, April through September. This fortunate precipitation pattern is probably the reason that trees and agricultural crops can be grown in the plains area without irrigation.

The average growing season varies from 120 to 140 days throughout most of the area with the average dates of the last killing frosts ranging from April 30 to June 2. Average July temperatures are from 64° F. to 72° F., and average January temperatures from 7.1° F. to 24° F. Yearly maximum temperatures average well over 100° F. and yearly minima to well below -40° F.

The soils have been classified as belonging chiefly to the Chestnut and Brown zonal soil groups, and to the azonal alluvium and lithosols. The zonal soils and the lithosols have developed chiefly from sedimentary rocks and glacial till, and the alluvium from the outwash from these and igneous rocks. The texture of these soils is variable, ranging from sandy to clayey. Acidity reaction varies from pH 5.15 to over 7.2.

Two hundred and twenty plantings were studied in detail. Of these, 176 were on dryland and 44 on irrigated sites. Twenty six species were found in the dryland plantings and 15 in the irrigated ones. Caragana was found in 82 per cent of the dryland and willow in 71 per cent of the irrigated belts. Of the 6 important dryland species, three, caragana, Russian olive and Chinese elm are not native to this state and of the 7 important irrigated species, four have been introduced, willow (golden, white and laurelleaf), northwest poplar, caragana and Russian olive.

The fastest rate of growth for the important trees in the dryland and in the irrigated windbreaks is during the first 10 to 20 years. Chinese elm is the fastest growing dryland species with an average annual height growth of a little over 1 foot per year; green ash was next with .8 feet per year and caragana the slowest with .45 feet per year. Chinese elm also has the fastest rate of crown spread, .5 feet annually, and will spread out to 13 feet in 25 years. Green ash has a relatively small crown spread, 9.5 feet in 25 years.

Growth of all species, except caragana, is better on irrigated sites than on the dryland ones. Northwest poplar is the fastest growing tree with an average annual growth of 2.75 feet per year for 20 years. Cottonwood has a slightly lower rate, 48 feet in 20 years. Willow, green ash and box elder have approximately the same height growth after 20 years, but thereafter box elder falls behind. Northwest poplar and cottonwood have the widest average crown spread, 22 and 23 feet respectively, of all the species in the irrigated plantings.

At 20 years of age the range of height growth most frequently encountered for the important dryland species was as follows: caragana, 7 to 11.5; Russian olive, 10.5 to 17.5; box elder, 9.5 to 20; green ash, 11 to 18.5; Chinese elm, 15.5 to 25.5, and American elm, 14.5 to 22.5 feet.

Considerable range of height growth and crown spread was found for all the important species in Montana plantings. Box elder and Russian olive were the most variable with a range of over 100 per cent of the average height growth. Caragana was the least variable with only 74 per cent variation. Russian olive had the least range in crown spread while box elder had the most with a variation of 147 per cent of the average crown spread. In general, all species had a larger amount of variation in crown spread than in height growth which seems to indicate that the factors effecting growth have a greater effect upon average crown spread than upon average height growth.

Moisture is the most important limiting factor affecting growth, vigor and survival of trees in eastern Montana windbreaks. It is dependent entirely upon the annual precipitation. Workers have estimated that, under natural conditions, 15 inches is the minimum annual rainfall required to maintain forest growth in Montana. Since most of the eastern portion of the state has an annual precipitation of only 12 to 14 inches, the shelterbelt trees are growing under continual submarginal moisture conditions. Moisture conservation measures are, therefore, necessary for the successfull establishment of the plantings.

The scanty annual precipitation is augmented in the windbreaks by snow drifting into the planting. The moisture supply in the upper 6 feet of the soil may be increased as much as 1.15 inches by the melting drifts. Topography may also influence the amount of soil moisture present by controlling the amount of runoff. Slopes as little as 5 and 6 per cent are sufficient to cause a large difference in growth. Green ash was found growing as much as 27 feet higher in the swales than on the knolls.

Cultivation is the only practical means available to the farmer or rancher to conserve soil moisture for his plantings. It removes the grasses and weeds which compete seriously with the trees for both moisture and nutrients. In doing this, cultivation will save up to

20 per cent of the precipitation for use by the trees. As a result, growth of trees was found by the study to be as much as 48 per cent better and survival up to 30 per cent higher in the cultivated plantings than in the uncultivated ones. Even long established windbreaks are unable to exclude the growth of competing vegetation. Intertillage, therefore, is necessary throughout the life of the windbreak.

On a few exceptionally favorable sites such as those located in drainage bottoms, at the base of a slope or where the water table is near the surface, continuous cultivation may not be necessary because tree growth may be sufficiently vigorous to exclude the growth of grasses and weeds. This is also true in irrigated plantings and cultivation need only be practiced for 4 to 5 years or until the trees are well established.

Shallow cultivations are preferable to deep cultivations because the latter result in excessive soil moisture loss through evaporation, and may injure tree roots growing near the surface of the soil.

The differences in growth, as determined by the study, on the different soil texture classes were neither large enough nor consistent enough to draw any valid conclusions regarding the effect of soil texture upon tree growth. Green ash, which had the largest growth difference of the 10-year old trees, was only 2.9 feet taller on clay than on sandy soils. Russian olive, on the other hand, had the least growth difference with only one-half foot better growth on the sandy soils. However, other workers have shown that in areas of deficient moisture supply the lighter soils are more favorable for tree growth.

No correlation between relative abundance of mineral nutrients and tree growth was found. This is probably due to the overshadowing importance of the critical moisture supply. Several factors causing damage and mortality to the trees were encountered in the study. These were (1) use of species unsuited to dryland conditions in eastern Montana; (2) heavy winter snows; (3) late spring frosts; (4) grazing by domestic livestock; (5) insect attacks, and (6) fire.

The species showing the best survival in the dryland belts are caragana with 84 per cent, American elm with 79 per cent, green ash with 78 per cent, Chinese elm with 74 per cent and Russian olive with 72 per cent. Box elder had 62 per cent survival while northwest poplar, willow and cottonwood had 34, 23 and 27 per cent survival, respectively. On the basis of these figures, northwest poplar, cottonwood and willow are not suitable species to plant in the dryland areas. Although caragana, Chinese elm and Russian olive are not native to this country, they are capable of withstanding the drought conditions common in eastern Montana.

Considerable snow damage occurred during the winter of 1946-47. As much as 12 feet breakage was suffered by Russian olive, Chinese elm and green ash. Though the snow damage was severe, the effect upon survival apparently was low.

A late spring frost during the night of May 28, 1947, was particularly damaging to green ash and spruce. In the case of green ash, this tree suffered dieback of at least 5 or 6 years' growth in the uncultivated plantings. Recovery was facilitated by cultivation and rain or irrigation immediately after the frost. As yet, however, the permanent effects of this frost are unknown.

Livestock cause damage and mortality by browsing and rubbing the trees and by packing the soil. Some Montana farmers are using their plantings as winter feedlots for sheep and as yearlong holding pens for cattle and horses. Such practices have resulted in the virtual extinction of their belts.

Insect depredations may be severe enough to cause a reduction in growth and vigor of trees in local areas. Grasshoppers, blister beetles and secropia worms have caused the most damage, attacking practically all species in the protective plantings. Aphids or plant lice, attack American elm, Colorado blue spruce and Black Hills spruce primarily, and have caused some damage. Green ash and Chinese elm are the species favored by the wood borers which usually gain entrance through wounds resulting from wind and snow breakage and pruning. The permanent effects of insect attack are largely dependent upon the condition of the trees at the time of the depredations.

Because of their infrequent occurrence, fires are a minor factor in the survival of eastern Montana windbreaks. However, where fires have escaped from burning stubble fields in adjacent plantings, the tree mortality has been 100 per cent.

Proper spacing for plantings in areas of submarginal moisture conditions has been a controversial issue between shelterbelt workers for many years. As a result, many spacing recommendations have been made, and many spacing combinations employed in eastern Montana.

Thirty six spacing combinations were observed in the dryland windbreaks and 21 in the irrigated. Almost 50 per cent of the former and 43 per cent of the latter had no single spacing combination. Hedge-row spacing combinations were just as variable with 23 combinations encountered in the study. These results indicate the present state of confusion regarding spacing in Montana plains shelterbelts.

Available literature concerned with spacing is contradictory as regards the relative merits of wide and narrow spacing. This confusion may be eliminated if some definite factors are taken into account.

Since an annual precipitation of at least 15 inches is required for natural forest growth in Montana and normal precipitation is less than this amount, it is apparent that there is not enough moisture available to support dense stands of tree growth. Consequently, it is unlikely that forest conditions will develop in the dryland plantings except in the most favorable sites.

In irrigated plantings, however, development of forest conditions can be reasonably expected in as early as 10 to 15 years. The willows are among the earliest to develop such conditions, one belt being found with a forest floor as early as 5 years after planting.

The ease of cultivation and the amount received by a planting is dependent upon the spacing between the rows. The study has shown that, in general, since the Montana farmer is not prone to purchase special or to modify his present equipment for the cultivation of his plantings, narrowly spaced trees will not be cultivated after the first few years because regular field equipment cannot be used in the planting. The spacing used, therefore, must be sufficiently wide, at least 15 feet, to accommodate the average cultivation equipment used -- generally 10 to 12 feet.

George has shown that snow will drift approximately 100 feet into a belt and that the maximum drifting occurs at about 80 feet. Accordingly, the maximum spacing in a planting may be limited to 20 feet between rows in a 5-row planting and 15 feet in a 7-row planting so that all the rows will benefit from the additional moisture derived from the melting snows.

There is no reason to believe that narrow spaced belts will provide more protection than wide spaced plantings if the spacings within the rows are the same. This means, that to obtain the same amount of protection, less trees are needed with wide spacing than with narrow spacing, and the original cost of the belt is correspondingly reduced.

In the plains area of Montana the low value of the land ordinarily has no restrictive effect upon the spacing used, but in the irrigated sections, the high land values tend to reduce the width between rows.

The factors discussed all indicated that wide spacing between rows, that is, at least 15 feet, is necessary in the protective plantings over most of eastern Montana.

CONCLUSIONS

1. Growth rate varies by species. Chinese elm is the fastest grower in dryland belts and northwest poplar the fastest in irrigated belts. In all species studied, the fastest growth occurs during the first 10 to 20 years.

2. Height growth and crown spread of all species studied, with the exception of caragana, were increased by irrigation.

3. All the species vary considerably in both height growth and crown spread. Box elder and Russian olive are the most variable with over 100 per cent variation from the average growth. The factors causing variation have a greater effect upon crown spread than upon height growth.

4. Moisture is the most important limiting factor affecting growth, vigor and survival of trees in eastern Montana windbreaks. Cultivation is the only practical means available to the farmer or rancher to conserve soil moisture for his shelterbelt. Thorough tillage will increase growth and survival of trees planted in the plains area of Montana.

5. Intertillage throughout the life of the planting is necessary in most dryland Montana situations.

6. Northwest poplar, willow and cottonwood are not suitable species for planting in dryland windbreaks.

7. Detrimental factors important in the plains windbreaks are drifting snows, late spring frosts, grazing by domestic livestock, insect depredations and fire.

8. At least 15 feet between rows are necessary in protective plantings in most dryland sites of eastern Montana.

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APPENDIX

SOIL TESTING PROCEDURE 1/

Acidity Test

Soils

1. Tear off a strip of waxed paper, crease it lengthwise to make a trough.

2. Place a small pinch of soil in the fold and add, from Acidity Test Solution No. 1, enough of the indicator solution to a little more than saturate the soil.

3. Work the solution back and forth through the soil to insure the completion of the reaction.

4. If the soil gives a yellow color without a trace of green, tear off another strip of the waxed paper and test in the same manner using the Acidity Test Solution No. 2. The Special Indicator is used in a like manner.

5. Interpret in accordance with the Acidity Test Color Charts accompanying the soil testing kit.

1/ From instructions accompanying the Purdue Soil Testing Kit. These are amplified in Purdue University Agriculture Experiment Station Circular 204.

Nitrate Test

Plants

1. With large stemmed plants split open a main stem or a leaf petiole. With smaller plants cut a few thin disks from the main stem or leaf petiole and place in a vial.

2. Apply a few drops of Nitrate Reagent and observe the color produced. A blue color indicates an abundant nitrogen supply. Absence of color coupled with a pale green color of the foliage indicates a deficient nitrogen supply.

Note: This test is not suited for use with legumes and woody plants.

Phosphate Test

Soils

1. Fill the vial to the mark (10 cc.) with Phosphate Reagent No. 1.

2. Add ½ teaspoon level full of soil (¼ teaspoon for soils above pH 7 and all greenhouse soils).

3. Shake vigorously for 1 minute.

4. Filter into a funnel, collecting the entire filtrate and then add 1 or 2 cc. more of the Phosphate Reagent No. 1 to the filtrate.

5. Add an amount of Phosphate Reagent No. 2 equal in size to a pin head (no more).

6. Mix and at once observe the color produced.

7. Compare with the Phosphate Color Chart accompanying the soil testing kit.

8. Add another portion of Phosphate Reagent No. 2 and mix as before. If color darkens, use the higher reading.

Note: This test is not adapted for use with soils that are alkaline (above pH 7.0) and may give too high results on subsoils.

Phosphate Test

Plant Tissue Tests

1. Place 1 teaspoonful of finely cut plant material in a vial.

2. Fill to the mark (10 cc.) with Phosphate Reagent No. 1.

3. Shake vigorously for 1 minute.

4. Add an amount of Phosphate Reagent No. 2 equal in size to a mustard seed.

5. Mix and at once observe the color produced.

6. Compare with the Phosphate Color Chart.

7. Add another amount of Phosphate Reagent No. 2 and mix as before. If the color darkens use the higher reading.

Note: Tests should be made on main stems or leaf petioles from actively growing portions of the plants and should not be used after the plant is mature.

PREPARATION OF THE TEST REAGENTS

Soil Acidity

Indicator No. 1

1. Dissolve 0.04 grams of brom-thymol blue powder in 5 cc. of 95 per cent ethyl alcohol.

2. Add 95 cc. of distilled water and adjust to pH 6.6 (yellowish-green color) by adding, drop by drop, a 0.2 normal solution of sodium hydroxide.

3. The pH range is 5.8 to 7.5.

Indicator No. 2

1. Prepare a solution of brom-cresol green as for Indicator No. 1.

2. Adjust to pH 4.6 (yellowish-green color).

3. The pH range is 3.8 to 5.5

Special Indicator

1. Prepare a solution of chlorophenol red as for Indicator No. 1.

2. Adjust to pH 5.6 (reddish-orange color).

3. The pH range is 4.8 to 6.2.

Nitrate Test

Reagent No. 1

1. Dissolve 1 gram of diphenylamine in 100 cc. of concentrated sulphuric acid.

CAUTION: This solution is very corrosive.

Phosphate Test

Reagent No. 1

1. Dissolve 4 grams of ammonium molybdate in 500 cc. of distilled water.

2. Add, slowly and with constant stirring, a mixture of 63 cc. of concentrated hydrochloric acid and 437 cc. of distilled water.

Note: As this solution may become unsuited for use after standing for a few months, it is desirable to prepare a solution of 5 times this concentration and to dilute as needed.

Reagent No. 2

Dry powdered stannous chloride or stannous oxalate.

TABLE 22

NUMBER OF TREES SHIPPED FROM THE MISSOULA NURSERY,
1933 TO 1947 INCLUSIVE

County Shipped To	Number of Trees	County Shipped To	Number of Trees
Beaverhead	29,980	Meagher	10,000
Big Horn	66,664	Mineral	554
Blaine	76,060	Missoula	70,046
Broadwater	5,983	Musselshell	4,960
Carbon	76,942	Park	43,867
Carter	41,367	Petroleum	4,615
Cascade	405,252	Phillips	71,345
Choteau	123,127	Pondera	235,063
Custer	31,465	Powder River	20,838
Daniels	46,693	Powell	10,611
Dawson	105,343	Prairie	23,007
Deerlodge	4,150	Ravalli	14,079
Fallon	54,220	Richland	141,646
Fergus	115,628	Roosevelt	119,024
Flathead	38,625	Rosebud	41,264
Gallatin	115,156	Sanders	17,795
Garfield	35,902	Sheridan	134,340
Glacier	66,820	Silver Bow	11,575
Golden Valley	10,045	Stillwater	21,638
Granite	2,170	Sweetgrass	44,620
Jefferson	11,600	Teton	353,026
Hill	163,517	Toole	104,107
Judith Basin	65,916	Treasure	2,325
Lake	63,917	Valley	91,155
Lewis and Clark	43,003	Wheatland	9,850
Liberty	58,063	Wibaux	24,067
Lincoln	500	Yellowstone	116,332
McCone	40,736		
Madison	10,780	Total	3,653,361

TABLE 23

BIRDS IDENTIFIED IN EASTERN MONTANA SHELTERBELTS IN THE COURSE OF THE STUDY

Common Name	Scientific Name
Blackbird	Euphagus cyanocephalus
Red winged Blackbird	Agelaius phoeniceus
Eastern Bluebird	Sialia sialis
Yellow Warbler	Dendroica aestiva
Long Billed Curlew	Numenius americanus
Mourning Dove	Zenaidura macroura marginella
Gold Finch	Spinus tristus
Sharp Tailed Grouse	Pedioecetes phasianellus
Night Hawk	Chordeilis minor
Red Tailed Hawk	Buteo borealis
Swainson's Hawk	Buteo swainsoni
Sage Hen	Centrocercus urophasianus
Eastern Kingbird	Tyrannus tyrannus
Western Kingbird	Tyrannus verticalis
Meadowlark	Sturnella neglecta
Lark Bunting	Calamospiza melanocorys
Baltimore Oriole	Icterus galbula 1/
Barn Owl	Tyto alba pratincola
Hungarian Partridge	Perdix perdix perdix
Chinese Pheasant	Phasianus colchicus torquatus
Robin	Turdus migratorius
White-Rumped Shrike	Lanius ludovicianus excubitorides 1/
English Sparrow	Passer domesticus domesticus
Sage Sparrow	Amphispiza nevadensis 1/
Vesper Sparrow	Pooecetes gramineus 1/
Swallow	Hirundo erythrogaster

1/ Identification not definite regarding species.