The average length of freeze-free season as an index to woody ornamental plant hardiness
by James Lee Murphy

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Horticulture
Montana State University

Abstract:
This study was undertaken to determine the identity of woody ornamental plants currently grown in Montana. Recommendations for plant adaptability and hardiness zones were based upon this information, Communities selected for' this survey included the long freeze-free cities of Billings, Columbus, Miles City, Glendive, Sidney, Glasgow, Great Falls, and Kalispell. Short freeze-free season towns observed were Red Lodge, Lambert, Lindsay, Richey, Scobey, Opheim, Lewistown, Augusta, and Whitefish, Comparisons of the two types of communities revealed that the use of a length of freeze-free season map as a plant hardiness region map was not feasible.

Local floras were established from surveys of all woody plants growing in various blocks of residential areas previously selected in an unbiased fashion from city maps. Resultant data leading to local hardiness designations was used as a basis upon which to suggest changes in the USDA Plant Hardiness Zone Map.

Distribution of species was useful in challenging specific hardiness numbers for several species encountered,

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Date March 1, 1971

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Approved:

Head, Major Department

Chairman, Examining Committee

Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

March, 1971

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ABSTRACT

This study was undertaken to determine the identity of woody ornamental plants currently grown in Montana. Recommendations for plant adaptability and hardiness zones were based upon this information.

Communities selected for this survey included the long freeze-free cities of Billings, Columbus, Miles City, Glendive, Sidney, Glasgow, Great Falls, and Kalispell. Short freeze-free season towns observed were Red Lodge, Lambert, Lindsay, Richey, Scobey, Opheim, Lewistown, Augusta, and Whitefish. Comparisons of the two types of communities revealed that the use of a length of freeze-free season map as a plant hardiness region map was not feasible.

Local floras were established from surveys of all woody plants growing in various blocks of residential areas previously selected in an unbiased fashion from city maps. Resultant data leading to local hardiness designations was used as a basis upon which to suggest changes in the USDA Plant Hardiness Zone Map.

Distribution of species was useful in challenging specific hardiness numbers for several species encountered.

INTRODUCTION AND LITERATURE REVIEW

Winter injury and death of woody ornamental plants has plagued and puzzled home owners, nurserymen and researchers for a long time. Among the proposed explanations of freezing injury to plants is the intracellular ice crystal theory as stated by Levitt (21), Wieser (31), Kenefick (17), Howell and Weiser (16), and Chandler (7). Intercellular ice formation is apparently non-lethal to plants. As ice forms water is drawn from the protoplasts. When a point is reached at which no additional water is available from the cells, ice crystals form within the cells causing their death. Howell and Weiser (16) stated that membrane puncture by ice crystals may be a means of cellular destruction by ice.

Weiser (32) proposed an alternate theory for winter plant mortality through excessive loss of intracellular water. The withdrawal of protoplasmic water by intercellular ice may cause death through several avenues as outlined by Howell and Weiser (16), proteins may be denatured by increased concentration of cytological chemicals as water loss increases, water removal may bring proteins closer together thus allowing for linkage and resultant denatured protein, and some proteins may require a water shell for activity.

Levitt (21), Free (13), Corman (9), and Chandler (7) suggested that the rate of temperature drop is of critical importance in killing of hardy tissues. Gradual temperature decline promotes acclimation; rapid decline results in injury or death. Corman (9) believed that rapid

temperature decline causes sun-scald in woody plants. During the day, the sun warms bark on the southwest side of plant stems to a temperature considerably above air temperature. After sunset the temperature drop of heated tissue is rapid enough to cause injury. Weiser (37) noted that at extremely rapid (experimental) rates of temperature drop the intracellular water does not crystallize but solidifies without crystals through a process called vitrification. Even non-hardy cells can survive vitrification. Weiser (32) concurred with Chandler (7) regarding the inverse relationship between the normal rate of temperature drop and acquired hardiness. Levitt (21) was of the opinion that rapid thawing might also cause injury to plants.

A number of factors affect the ability of cells to develop hardiness. Accumulation of sugars and a decrease in starch tend to increase acclimation according to Levitt (21) and Lapin (20). Weiser (32) expressed the possibility that cellular structures may be disassembled or translocated factors promoting hardiness may form. Levitt (21), Lapin (20) and Kenefick (18) pointed out that membranes may become more permeable and protoplasm more resistant to desiccation, thus allowing free movement of water out of the cells to form intercellular ice and avoid ice crystal formation within cells. Rehder (30) suggested that in general, plants in dry condition can withstand cold because of cellular resistance to desiccation damage. Levitt (21) and Lapin (20) indicated that older plants tend to fare better during winter than

younger ones due to reduced water content. Flint, Boyce, and Beattie (12) were of the opinion that herbaceous species are killed by a single freezing temperature while woody species with more tissues frost kill over a range of temperatures specific for the various tissues. Young woody plants may be affected by cold much as herbaceous species are.

Differentials in growth rhythms related to time of hardening exist between species and among populations of a species. Exotics that could withstand the minimal temperatures of an area are too slow in hardening or too fast in dehardening to survive in that area according to Weiser (32), Flint (11), Lapin (20), and Clark (8). Weiser (32) believed that the initial stimulus to hardening is short days followed by a secondary stage of chilling and a tertiary stage of prolonged cold temperatures. Hardening can be partially inhibited by application of artificial light or periods of warm temperatures.

Many external environmental factors may affect the ability of plants to harden. Wyman (35) cited soil chemistry and physical condition, rainfall, and temperature, especially minimum, as the most influential factors affecting plant hardiness in North America. Soils are often modified by addition of mulch and fertilizer, by leaching, and by removal or burial of topsoil during construction. Rainfall is adequate in most areas of the United States for most ornamentals and is supplemented by irrigation. It has been upon climate, and more specifically temperature, that judgements as to probable hardiness of plant species for given areas have been based.

Montanans have little information available to them regarding the woody plants of potential hardiness in specific areas of the state. Tests currently underway at the Montana Agricultural Experiment Station and its branches may yield useful information in this regard. However, these tests will require years of evaluation, and the number of species potentially desirable for testing may be limited. . .

At present, inquiries regarding plant hardiness must be answered using adaptability information obtained in tests at Bozeman, or based upon staff members' knowledge of plant species found in the locality in question or in analogous sites.

Several hardiness maps have proven useful to Montanans in estimating plant adaptability for given areas. In the Atlas of American Agriculture 1936, the U. S. was divided into 28 growth regions based on homogeneous native species. A revision extended the zonation to 32 regions.

Rehder (30) of the Arnold Arboretum used mean minimum winter temperatures in producing a zone map of most of the United States and southern Canada (Fig. 1d). Species were rated according to the coldest zone in which they were expected to survive with Zone I the coldest and Zone VII the mildest. Ratings were based on trials at the Arnold Arboretum of Harvard University which is located in Zone V. Recommendations for species not tested were deduced from performances under similar European conditions. A later revision by Rehder was followed by a revision to 10 zones by Wyman (34). A 1967 Hardiness Zones of the

United States and Canada by the Arnold Arboretum was revised from Rehder's older work using more recent weather data (Fig. 1c).

The United States Department of Agriculture released a hardiness zone map in 1960 (27) (Fig. 1b). It is more detailed than the Arnold Arboretum Map (14) but unfortunately its zone numbers were not equated with those of the Arnold Arboretum. Thus species assigned zone numbers in the Manual of Cultivated Trees and Shrubs by Rehder (30) are not delineated by zones of the same number on the Plant Hardiness Zone Map. A comparison of zones from the two sources as adapted from Horticulture Magazine (23) is shown in the table below.

Table 1. Comparison of Plant Hardiness Zones. Temperatures indicated are mean minimums in which plants of that zone can survive.

°F	USDA Zone	Rehder Zone	°F
-50°	1	I	-50°
-40°	2a	II	
	b		
	3a		-35°
-30°	b		
	4a	III	
-20°	b		-20°
	5a		
-10°	b	IV	-10°
	6a	V	- 5°
0°	b		
	7a	VI	5°
10°	b	VII	10°
	8a		
20°	b	VIII	20°
	9a		
30°	b	IX	30°
	10a		
40°	b	X	40°

Although the USDA Map (27) is more complex than those based on Rehder's work, by its own admission it must be considered general in nature and not specific enough for local conditions. It states that "in determining if a certain plant will survive in a given zone, it is necessary to consider factors other than the minimum temperature range of each zone. For example, temperatures of adjacent zones tend to become increasingly similar near their boundaries. Moreover there are innumerable island climates that may be considered milder or colder than the zone average. These islands are especially frequent in hilly or mountainous areas. Mountainous areas on this map are not shown to be as cold as might be expected. The reason for this is that most weather stations from which records were obtained are located in valleys where temperatures tend to be milder and where plants are most likely to be cultivated. Other plant growth factors must also be considered. Frost occurrence, seasonal rainfall distribution, humidity, soil characteristics and duration and intensity of sunlight may bear little relationship to mean winter temperature. The combined effects of all factors determine the plant adaptability. They would be difficult to depict geographically. Frost dates, length of growing season, and minimum winter temperatures are among the least readily controlled of the major factors that govern the geographic adaptability of plants" (27).

A 1967 California study attempted to establish plant climate zones by observed reactions of many native, field crop, and ornamental plants

to the total environment. Kimball and Gilbert (19) considered plants as indicators of climate and their distribution, native and exotic, a response to climate. The three or more regional plant climates within major plant climates were composed of zones and subzones based mostly on temperature.

Canada commissioned an ambitious hardiness study based on low winter temperature, frost free period, summer and winter rainfall, summer high temperatures, snow depth, and wind velocity, Oullet (24), Oullet and Sherk (25, 26). One hundred seventy-four species and cultivars were planted at 108 stations for hardiness observation. Estimates of suitability indices for 640 stations were made. Ten probability of survival zones were then drawn.

The scope of the above investigation seemed impossibly large for a single researcher to attempt in a thesis study for Montana. For the purpose of the present study many environmental influences were considered for examination.

Soils characteristics differ so greatly from one home to the next that a study based on soil chemistry and condition would not be practical. Irrigation negates the effect of seasonal rainfall deficiencies. Subsurface drainage may not be variable enough between Montana cities to base a hardiness study on. Buildings greatly affect air drainage. The effects of sunlight vary within an individual lawn since all exposures are utilized. Inherent vigor of individual plants, and the effects of

animal and spray damage are too variable to be of much consequence. Information on humidity in various Montana communities is of limited availability. Hoag (15) considered soil temperatures due to variable snow cover a factor limiting hardiness. Again, conditions vary greatly from one lawn to another because of utilization of all exposures, variability of snow covers due to changes in air drainage, and wind blockage by buildings. Urban snow cover is less a factor than on rural sites due to the use of mulches on urban plantings. The probability of chinook winds which can cause winter damage was considered according to the Relative Frequency of Distinct Chinooks in Montana 1923 to 1932 inclusive Map (31) (Fig. 1e). The inseparable and not readily controlled factors of frost dates and length of freeze-free season were chosen as a basis for the present study. Fortunately, a detailed average length of freeze-free season map for the State of Montana, based on 32° F freezes, has been prepared by Caprio (6) (Fig. 1a).

The purposes for conducting the research leading to this dissertation were fourfold.

1. To ascertain the identity of currently cultivated woody ornamental plants as a guide to adapted species and varieties in a selected series of Montana cities and towns, and as an aid in selecting plant materials for further testing.

2. To challenge the accuracy of the Montana section of the USDA Plant Hardiness Zone Map (27).

3. To question the accuracy of zone number designations for species currently grown in Montana.

4. To test the Freeze-Free Season Map (6) as a more accurate guide for local conditions. The Freeze-Free Season Map (6) might then be used as an alternate for or a complement to the USDA Plant Hardiness Zone Map (27).

Figure 1 Montana Climatological Information

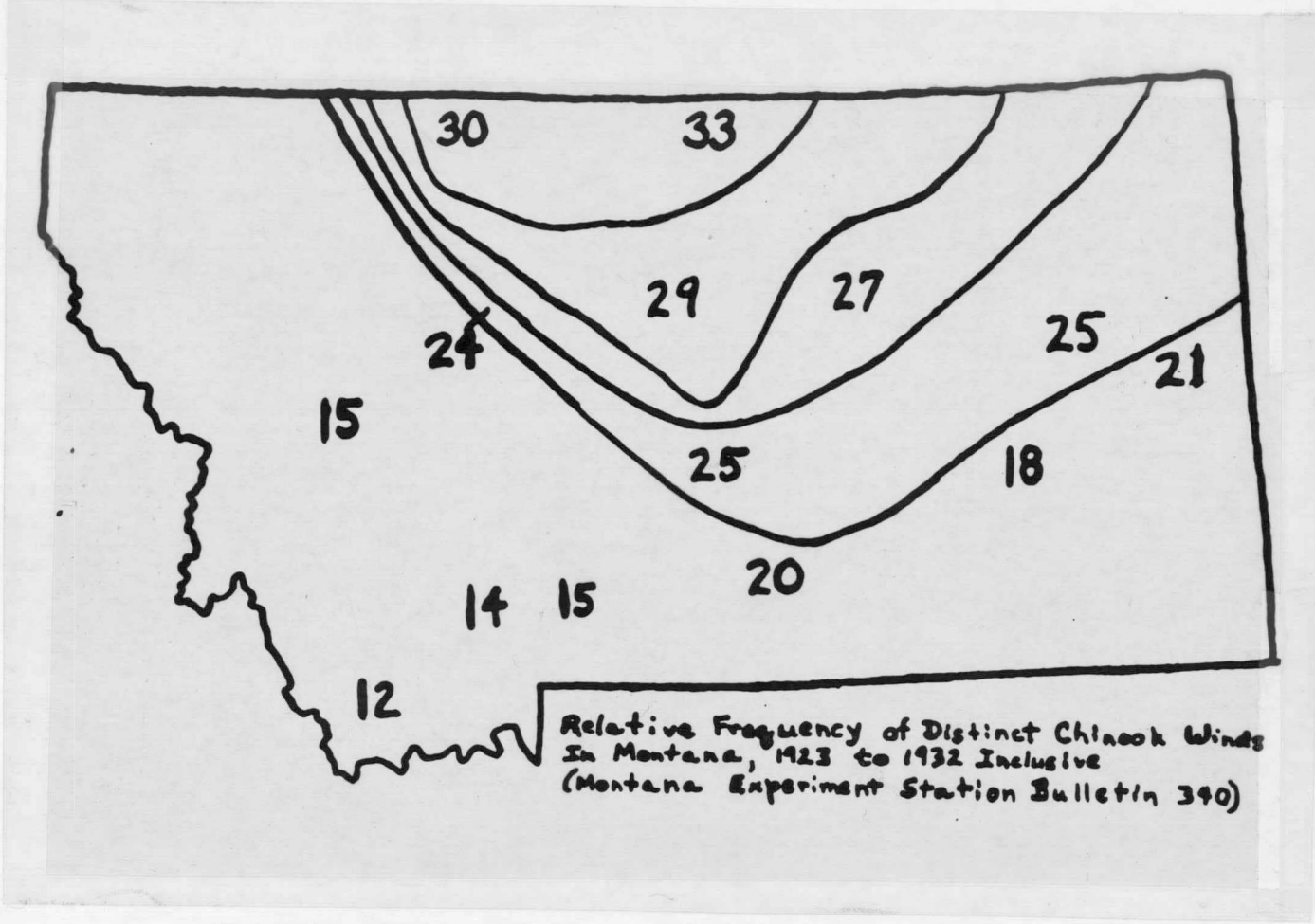
Figure 1a (Colored Photo) Montana Average Length of Freeze-Free Season.

Figure 1b (Transparency) USDA Plant Hardiness Zone Map.

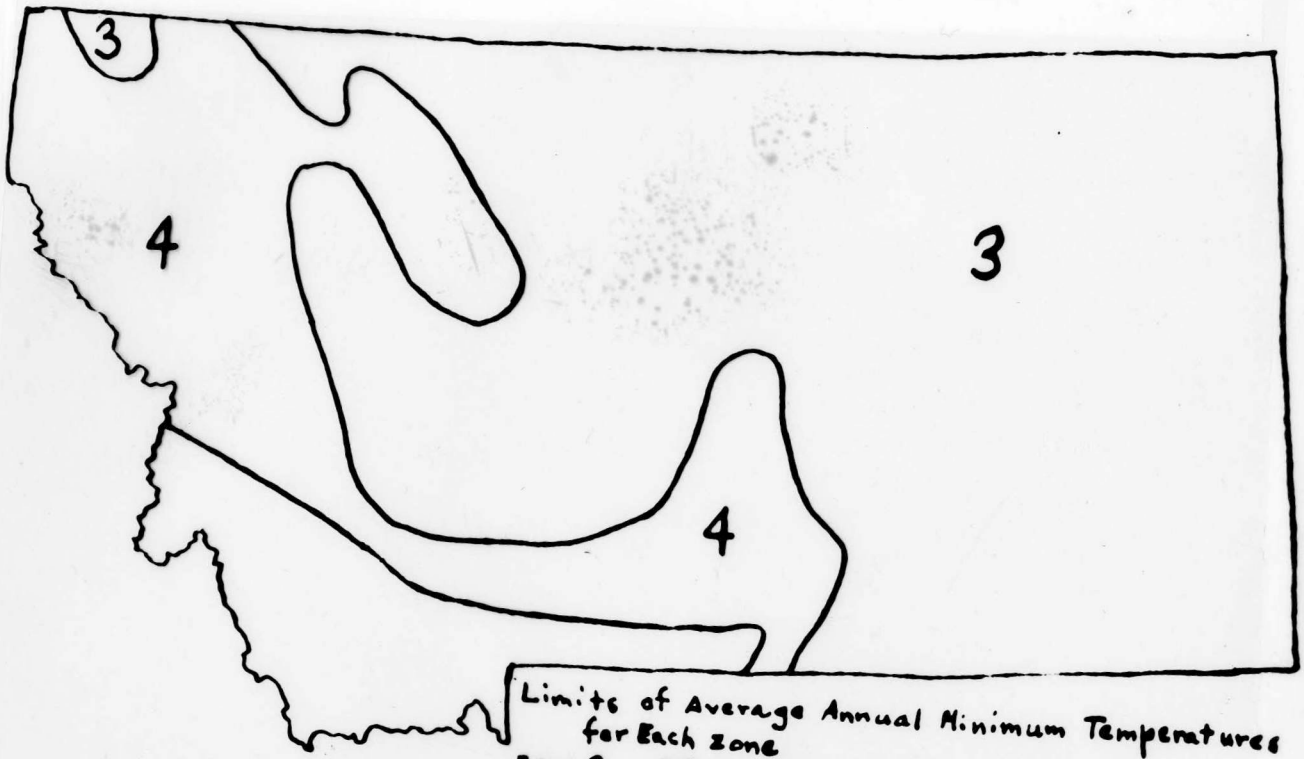
Figure 1c (Transparency) Hardiness Zones of the United States and Canada (Arnold Arboretum).

Figure 1d (Transparency) Map of Climatic Zones (Rehder).

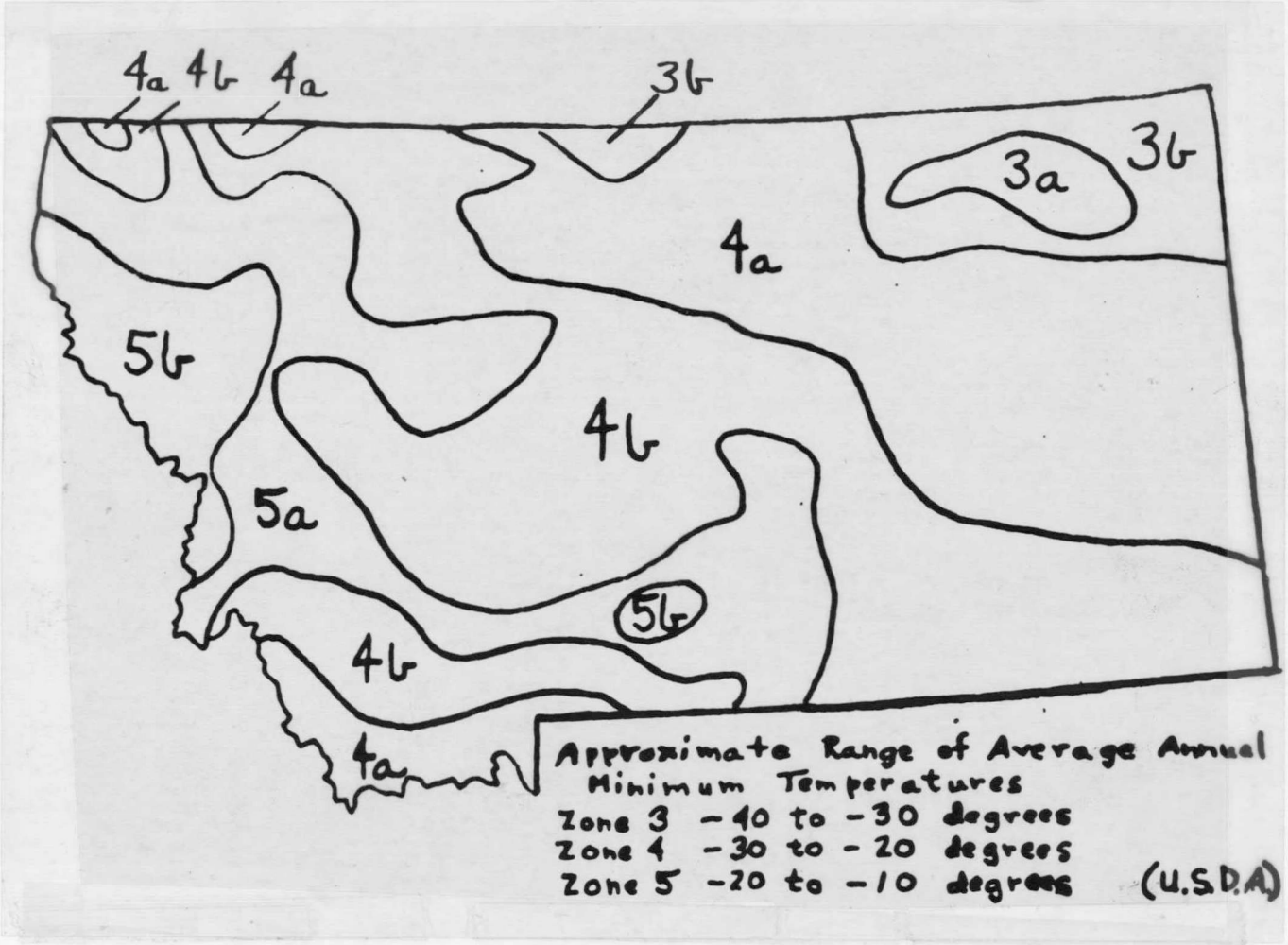
Figure 1e (Transparency) Relative Frequency of Distinct Chinooks in Montana 1923 to 1932 Inclusive. (Reitz).

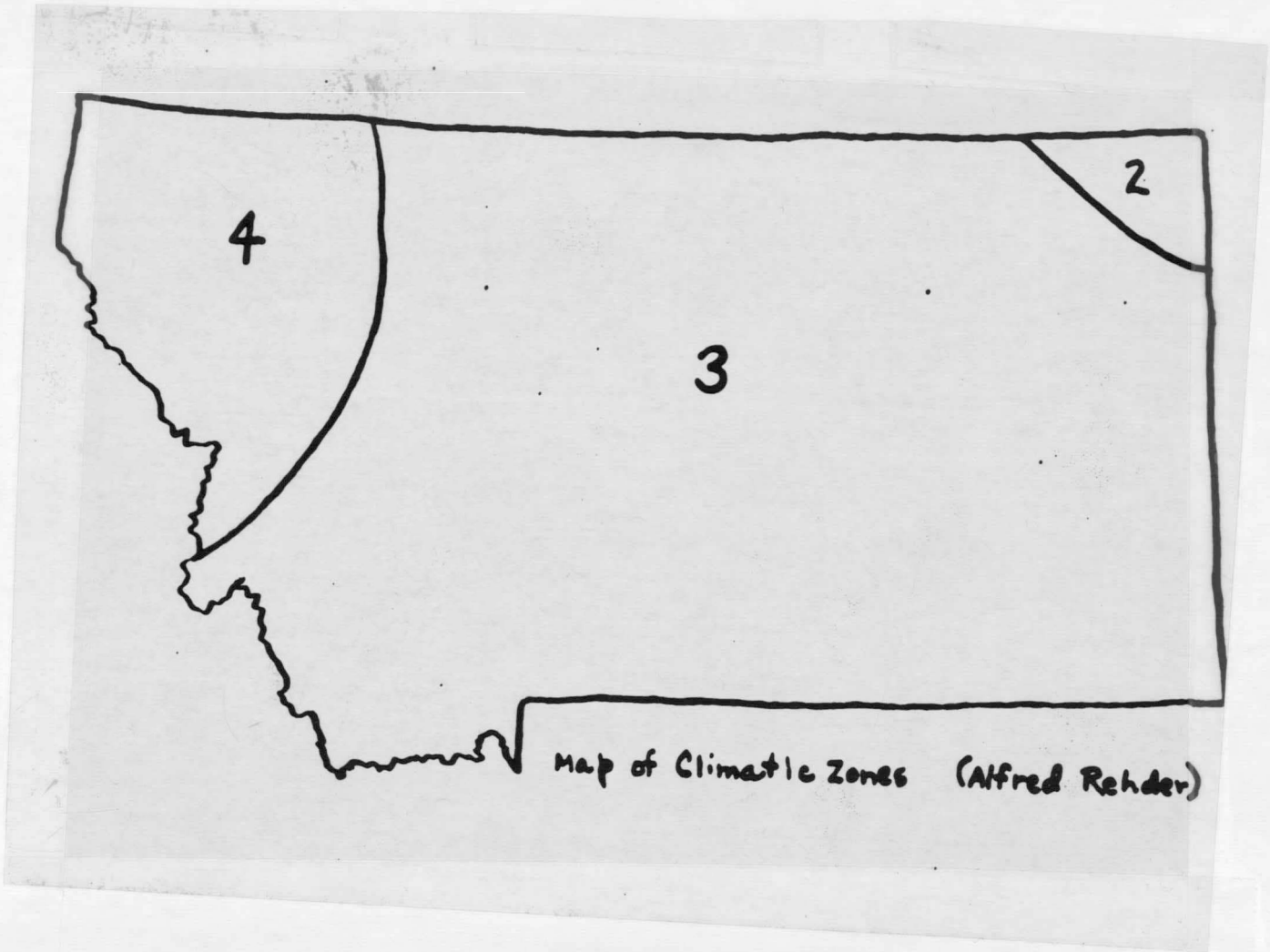


Relative Frequency of Distinct Chinook Winds
In Montana, 1923 to 1932 Inclusive
(Montana Experiment Station Bulletin 340)

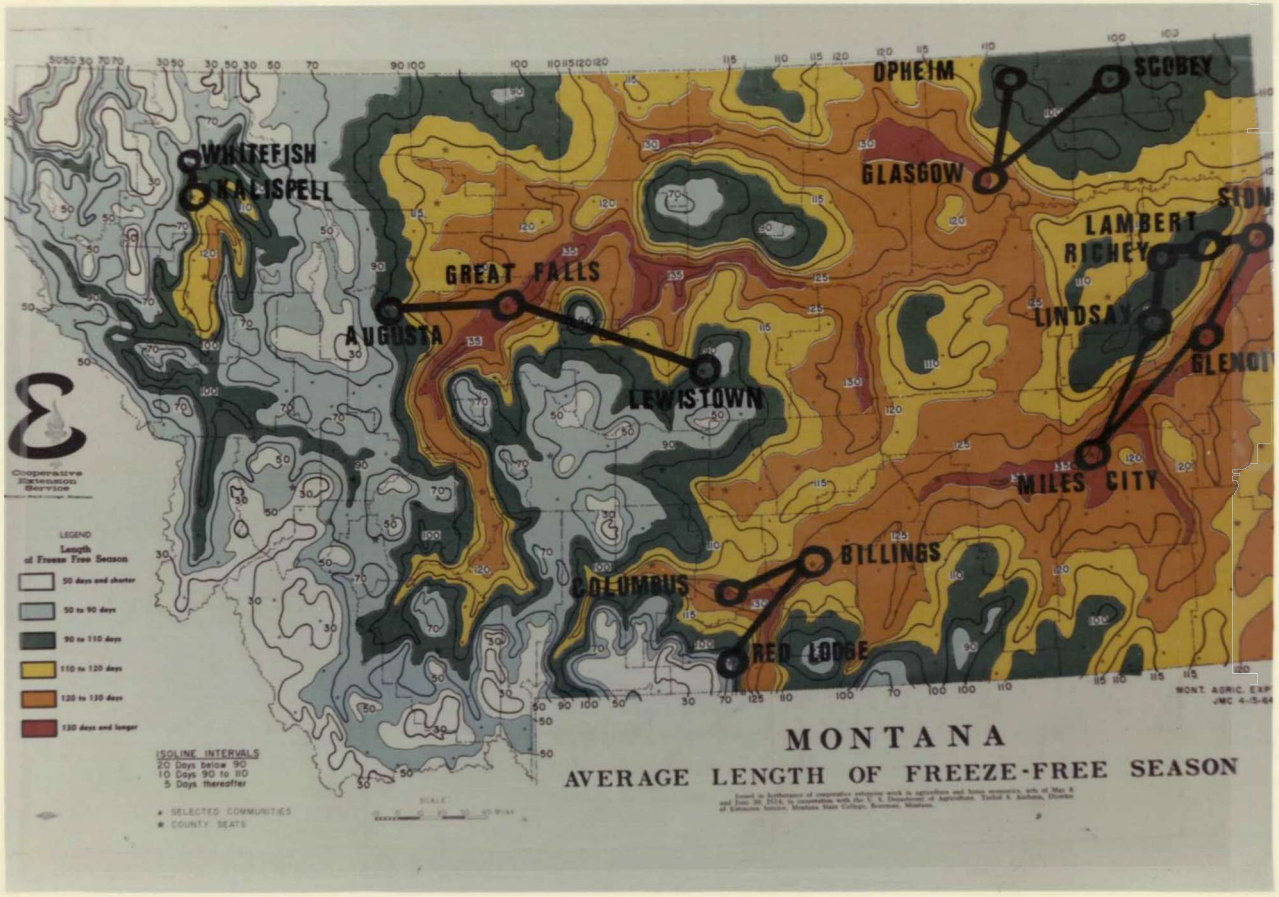


Limits of Average Annual Minimum Temperatures
for Each zone
Zone 3 -35 to -20 degrees
Zone 4 -20 to -10 degrees (Arnold Arboretum 1967)


4a 4b 4a
3b
3a
3b
4a
5b
4b
5a
5b
4b
4a
Approximate Range of Average Annual Minimum Temperatures
Zone 3 -40 to -30 degrees
Zone 4 -30 to -20 degrees
Zone 5 -20 to -10 degrees
(U.S.D.A)



Map of Climatic Zones (Alfred Rehder)


OPHEIM
SCOBEY
WHITEFISH
KALISPELL
GLASGOW
LAMBERT
RICHEY
GREAT FALLS
AUGUSTA
LINDSAY
LEWISTOWN
MILES CITY
BILLINGS
COLUMBUS
RED LODGE
Cooperative Extension Service
LEGEND
Length of Freeze Free Season
50 days and shorter
50 to 90 days
90 to 110 days
110 to 120 days
120 to 130 days
130 days and longer
ISOLINE INTERVALS
20 Days below 90
10 Days 90 to 110
5 Days thereafter
SELECTED COMMUNITIES
COUNTY SEATS
SCALE
MONTANA
AVERAGE LENGTH OF FREEZE-FREE SEASON

EXPERIMENTAL PROCEDURES

The Montana Average Length of Freeze-Free Season Map (6) is divided into six colored zones. Freeze-free seasons of 50 days and shorter are depicted as white areas, 50 to 90 days blue, 90 to 110 days green, 110 to 120 days yellow, 120 to 130 days orange, and 130 days and longer red (Fig. 1a).

Five areas distinguished by length of freeze-free season were selected as study sites. One or more communities in each long season area were researched and nearby relatively short season communities were surveyed for comparison.

Area 1 was concerned primarily with Billings (120-130 frost-free days). Nearby Columbus (130 days +) was also observed. Red Lodge (50-90 days) was the nearest short season community and was chosen for comparison.

Area 2 included the long season cities of Miles City, Glendive and Sidney (all 130 days +). The small 90-110 day communities of Lambert, Lindsay and Richey were surveyed as short season comparisons.

Glasgow (130 days +) and Scobey and Opheim (90-110 days) were selected as Area 3.

The central Montana cities of Great Falls (130 days +) and Lewistown and Augusta (90-110 days) were selected as Area 4.

Although, relatively brief in freeze-free season, Kalispell (110-120 days) was chosen to represent western Montana and was designated

Area 5. With the exception of Polson, all other sizable communities west of the continental divide having growing seasons shorter than 110 days. Whitefish, with 50 to 90 consecutive freeze-free days, was selected as the short season city to compare to Kalispell.

City maps were procured from the major communities under study, although none were available from the small communities of Opheim, Lambert, Lindsay, Richey and Augusta. With help from city officials, the commmercial and industrial sections were identified on the maps. Beginning in the residential areas every third block in either direction was marked on the map. In the larger cities of Billings and Great Falls every sixth residential block was marked. These blocks were chosen in an unbiased fashion before visiting the site. In Lambert and Lindsay all buildings were visited. In Richey and Augusta the residential area containing the most houses was surveyed until a typical flora was established by visiting about three blocks in each community.

Once the blocks to be studied were established, the author, during the summer of 1968, recorded all woody plants present in them. Volunteer specimens of such species as Populus alba and Fraxinus pennsylvanica were not considered as being planted purposely and so were not recorded. The multitude of roses, hardy everywhere in Montana, were also not considered. Counting the number of plants in hedges proved impractical so an estimate of the hedge footage was recorded. For the purposes of this paper the term 'hedge' was used to indicate a row of

closely planted trees or shrubs, a wall or fence of vines, an expanse of ground cover plants, and all situations where difficulty was encountered in distinguishing individual plants.

To aid in species identification, 311 pressed specimens were collected and filed in the Montana State University Herbarium. Primary sources consulted for specimen identification were Rehder (29, 30), Wyman (33, 34, 35, 36), Booth (4), Booth and Wright (5), Hoag (15), Bailey (2, 3), and Anderson and Weir (1). A Checklist of Woody Ornamental Plants of California by Mathias and McClintock (22) was chosen as the standard upon which to base scientific names.

An attempt was made to record the mean age of plants grown in a sample block because it was believed that newly planted specimens could not be considered as having demonstrated hardiness. Such age values were approximations. Some new homes had been built and landscaped in old residential areas while in other cases new plants were added to older lawns. This age approximation was made by observation of plant size and apparent age of buildings. Although probably not necessary here, for future publication the age could be determined by checking dates when building permits were issued.

The data was arranged for each city by the block surveyed; alphabetically listing the Zone I species, then Zone II species, etc. Species were further categorized as broadleaf trees, coniferous trees, broadleaf shrubs, coniferous shrubs, and vines and ground covers. Totals for individual specimens of each species observed were then determined.

Hedge footage was converted to individual plants to simplify the statistical treatment. To convert footage to individuals the recommendations of Wyman (34) were used. The suggested spacing of 18 inches for most species, 3 feet for evergreens, 5 feet for large trees, and 5 feet for vines, produced the number of individual plants per hedge from the footage estimated. Tabulated results were recorded as individual plant counts for each species; hedge footage for each species was listed as a separate count. Hedge conversion values were recorded and the individual counts and conversion individuals were added and recorded as Individuals plus Hedge Conversion. The figures of the Individuals plus Hedge Conversion were used in the final summation of plants for each zone number in each category.

Percent of the total plant population per species, percent of the total plant population in each zone and a mean zone number for the total plant population for each community was also determined.

RESULTS AND DISCUSSION

While conducting this survey a number of difficulties in plant identification were encountered. Varieties and forms are difficult to identify so varietal names were given only on positive identifications. Habit or color adjectives were often added to species names, for example, tall blue forms of Rocky Mountain juniper might be listed as Juniperus scopulorum upright blue. Hybrids can be confused with species. For example, Ulmus x rubra often looks much like Ulmus americana. Some species easily hybridize and offspring show gradations of form between species. The Betulae are quite interfertile. Betula pendula 'Gracilis' is unique, but other birches were all called Betula papyrifera in this thesis with the realization that others may be present in the population. The Salix also cross freely and many specimens were referred to as Salix sp. The various Prunus sp. and Ribes sp. are difficult to identify. Rapid field differentiation between Cornus stolonifera and Cornus alba 'Sibirica' and between the many Philadelphus sp. is impossible. The author encountered difficulty in differentiating between Pinus cembra and Pinus nigra austriaca. Counts on these two species may be inaccurate. Finally, immature and clipped specimens of some conifers were difficult to identify. Since all spruces grown in Montana are Zone II species, unidentified specimens were included in statistical data. Junipers vary in zonation, so unidentified specimens were listed but not included in the data.

One must not assume that a species not growing in a certain locale

could not do so. What is planted in a community is often a reflection of what is available from local nurseries or mail order catalogs servicing that community. What survives is a reflection of the community's climate.

Affluence of an area also affects the type of plant materials grown. Low income neighborhoods are often underplanted or planted with either native species or those exotics that tend to multiply easily. The author felt that community size was an indication as to the ability of the local homeowners to care for exotic species. Very small communities tend to be agriculturally oriented. Citizens must spend long hours working during the growing season, and have less time for lawn work than individuals in larger cities. An abundance of plant materials requiring little care was noted in smaller cities. The maturity of many plantings in low population centers was also noted. Small communities reflect the exodus to the cities in that most homes and plantings are over 30 years old and few new residences are being constructed. Many buildings have been abandoned. Only Billings and Great Falls show a regular gradation in age of residential areas from the older center of the city to new suburbs.

Data from the appendix survey tables (pages 81 to 184) was condensed into short summaries appended to discussions regarding the communities studied.

In comparing survey results in the communities involved, the

author attempted to first characterize the climate of each city. Next, hardiness zones of the old Rehder map (30), the later Arnold Arboretum map (14), and the USDA Plant Hardiness Zone Map (27) were compared. A weighted mean for all plants recorded in each local survey was used to compare cities. The author then chose what he felt was a possible hardiness zone designation for each community based on previous work and that of this paper. Finally, unusual species noted in each community were discussed.

AREA 1 - BILLINGS, COLUMBUS AND RED LODGE:

The larger community of Billings is horticulturally complex. A mild climate allows for great variety among woody ornamental plants.

The mean minimum January temperature in Billings was recorded as 12° F. Relative humidity varies from a yearly average of 48% at 5 P.M., M.S.T. to 69% at 5 A.M., M.S.T. (10) Chinook winds have been rare - 20 or less (31) and Billings has enjoyed an average of 120-130 freeze-free days yearly. Rehder considered Billings to be in a Zone III area (USDA 3b, 4a, 4b). The Arnold Arboretum and the USDA designated Billings Zones IV and 5a respectively. The author found all plants recorded averaged a zone number of 3.164, second only to Miles City's 3.198.

Comparing percent total plant population for plants in various zone numbers, the author would concur with the USDA and raise the zone number to 5a for Billings. While only 6% of all plants were ZONE V species, the author felt the tempering effects of the sizeable city's

shelter allowed for a high zone rating. Suburban areas would not enjoy as hardy a plant climate. Certainly the Arnold Arboretum designation of Zone IV (USDA 5b) would be a minimal zone recommendation. In general the plant population of Billings was found to be thrifty with little evidence of winter damage. In suburban areas the hot dry summer climate was found to be more detrimental than the winter climate.

Billings appeared to be a horticulturally aware city, with evidence of professional landscaping. As noted, much variety of materials exists in Billings. The amount of affluence dictated the amount of variety. In the comparatively wealthy Rimrock section of the city unusual and expensive species and varieties abound. The same was not true of the less affluent south side.

Among the more unusual specimens sighted were Platanus occidentalis, Rhamnus davurica, Fraxinus mandshurica, Rhamnus frangula, Quercus borealis, Pyracantha coccinea, Buxus microphylla japonica, Robinia hispida, Liriodendron tulipifera and Phellodendron amurense.

Campsis radicans did well in Billings as a blooming vine. Ginkgo biloba was sighted only in Billings, and the much unexpected Buddleia alternifolia was observed while in blossom.

Tabular results include total plants recorded in each of Rehder's zone classes. The % total of the entire plant population (T.P.P.) for each city was determined. The product of zone number and the % total plant population (Zone # X % T.P.P.) was recorded.

Table 2. Plant population summary and mean zone designation for Billings, Montana.

Plant Zone		Totals	% Total Plant population	Zone # X % T.P.P.
Total Zone I	Plants	18	.095	.001
Total Zone II	Plants	4553	24.077	.482
Total Zone II.5	Plants	528	2.792	.070
Total Zone III	Plants	7192	38.033	1.141
Total Zone III.5	Plants	26	.137	.005
Total Zone IV	Plants	5319	28.128	1.125
Total Zone IV.5	Plants	6	.032	.001
Total Zone V	Plants	1152	6.092	.305
Total Zone V.5	Plants	94	.497	.027
Total Zone VI	Plants	14	.074	.004
Total Zone VII	Plants	8	.042	.003
Total all plants		18,910		
Average zone number for total of all plants identified				3.164

Columbus has a mean minimum January temperature of 8° F and a mean maximum July temperature of 90° F, the highest recorded by Dightman (10). The chinook belt did not extend to Columbus where an average of 15 chinooks were recorded per year (31). An average of 130 or more consecutive freeze-free days can be expected yearly.

Rehder considered the area surrounding Columbus to be of Zone III (equal to USDA 3b, 4a, 4b) in climate. The Arnold Arboretum indicated

Zone IV , while the USDA classified Columbus as a Zone 5a. The author found that an average zone number for all plants recorded in Columbus was a relatively high 3.067. Only Miles City and neighbor city Billings were found to rate higher. Fifty percent of all plants recorded were of Zone III (3b, 4ab) designation. Twenty percent were Zone IV plants (5ab).

Because of the high average zone number and a sizable Zone IV (5ab) plant population the author would choose middle ground and agree with the former consideration by the Arnold Arboretum and the USDA of Zone IV (5a).

Table 3. Plant population summary and mean zone designation for Columbus, Montana.

Plant Zone		Total	% Total Plant population	Zone # X % T.P.P.
Total Zone II	Plants	199	13.365	.267
Total Zone II.5	Plants	199	13.365	.334
Total Zone III	Plants	747	50.168	1.505
Total Zone IV	Plants	294	19.745	.790
Total Zone IV.5	Plants	2	.134	.006
Total Zone V	Plants	37	2.485	.124
Total Zone V.5	Plants	11	.739	.041
Total all plants		1489		
Average zone number for total of all plants identified				3.067

Red Lodge, Montana was characterized climatically as an alpine community. The mean minimum January temperature was calculated to be 12° F (10). The frequency of chinook winds was found to be low, as the chinook belt did not extend this far south. Average length of freeze-free season was found to be 50 to 90 days. The 1967 Arnold Arboretum map and Rehder's map included Red Lodge in a Zone III area. Rehder's III includes USDA's (3b, 4ab). The USDA map indicated a Zone 4b designation. Plants recorded in Red Lodge revealed an average zone number of only 2.631, which was found to be eleventh or twelfth of the 15 communities researched. Fifty-seven percent of the plants recorded were Zone II species. Nineteen percent were Zone III and 17 percent Zone IV. All former work pointed toward a ZONE III designation. This study found no justification for a change from III (4b).

The author noted that the climate of Red Lodge was harsh on ornamental plants. Fraxinus pennsylvanica was found to be of marginal hardiness because of winter injury. Red Lodge as a whole appeared underplanted with a limited number of species. Sorbus aucuparia, Syringa vulgaris and Lonicera tatarica were overplanted. Much native material was grown probably as much for necessity as for preference.

Two unusual plants were noted. A mature weeping form of Sorbus aucuparia seemed worthy of propagation. Also a hardy Rhododendron sp. was seen during two consecutive summers. The azalea was not thrifty.

Table 4. Plant population summary and mean zone designation for Red Lodge, Montana.

Plant Zone		Total	% Total Plant population	Zone # X % T.P.P.
Total Zone I	Plants	8	.389	.004
Total Zone II	Plants	1180	57.393	1.148
Total Zone II.5	Plants	65	3.161	.079
Total Zone III	Plants	397	19.309	.579
Total Zone IV	Plants	342	16.634	.665
Total Zone IV.5	Plants	3	.146	.007
Total Zone V	Plants	60	2.918	.146
Total Zone VII	Plants	1	.049	.003
Total all plants		2056		
Average zone number for total of all plants identified				2.631

AREA 2 - MILES CITY, GLENDIVE, SIDNEY, LAMBERT, LINDSAY AND RICHEY:

Miles City had the highest average zone number for all plants recorded in this survey. A fairly low 6° F mean minimum January temperature was recorded. The chinook belt does not include Miles City where 18 or less chinooks were observed yearly (10). Miles City has an average of 130 or more consecutive freeze-free days each year.

Rehder and the Arnold Arboretum have classified Miles City as a Zone III city. Rehder's Zone III includes the USDA 3b, 4a and 4b. The USDA designated Miles City as a Zone 4a. With 28% of all plants grown in this city belonging to the Zone IV (5a) category, that zone would be

a minimal zone designation. Nearly 7% of the plants were Zone V species, indicating that Miles City might be considered marginally Zone V (6a).

Much of the Miles City residential area was older. Thus, those plants that grew there could be considered hardy, but a lack of newer introduction was noted. Ulmus pumila was much overplanted.

Morus alba, Cotinus coggygria and Fraxinus nigra were unusual members of the local flora. A fairly large Prunus armeniaca was also noted.

Table 5. Plant population summary and mean zone designation for Miles City, Montana.

Plant Zone		Total	% Total Plant population	Zone # X % T.P.P.
Total Zone II	Plants	1208	21.618	.432
Total Zone II.5	Plants	69	1.235	.031
Total Zone III	Plants	2374	42.484	1.275
Total Zone IV	Plants	1542	27.595	1.104
Total Zone IV.5	Plants	2	.036	.002
Total Zone V	Plants	375	6.711	.336
Total Zone V.5	Plants	18	.322	.018
Total all plants		5588		
Average zone number for the total of all plants identified				3.198

Mean minimum January temperature in Glendive was found to be 40° F. The Montana chinook belt stopped north of Glendive where an average 21 chinook winds were recorded each year (31). The average annual length

of freeze-free season was noted as the maximal 130 days or longer, Rehder and the 1967 Arnold Arboretum works suggest that Glendive lies in a number III hardiness zone. The USDA map rated Glendive as Zone 4a. In observing the horticultural flora of Glendive, the author found that all plants recorded growing in the community averaged a mean zone classificiation of 3.067. Only Miles City and Billings averaged higher. The USDA designation might have been the more accurate. Thirty-two percent of the species found in Glendive were Zone IV with more than 3% Zone V species as a marginal group. Having used Rehder extensively as the reference for species hardiness numbers, the author noted that the large Zone IV group of plants would be equivalent to a zone 5a, b rating by the USDA. The author felt that a hardiness rating of 5a on the USDA Scale (IV) is a safe minimal designation with the likelihood that a number of Zone V species should also be hardy.

Several unusual plants found in Glendive were worthy of note. The heart leaf Dioscorea batatas vine was seen once, a particularly coarse leaf Ulmus americana might be worthy of propagation, and the only specimens of Viburnum lentago found in this work were seen in Glendive.

For a small community, Glendive possessed a good variety of materials and ornameals rarely seen.

Table 6. Plant population summary and mean zone designation for Glendive, Montana.

Plant Zone		Total	% Total Plant population	Zone # X % T.P.P.
Total Zone II	Plants	1747	31.874	.637
Total Zone II.5	Plants	130	2.372	.059
Total Zone III	Plants	1640	29.922	.898
Total Zone IV	Plants	1754	32.001	1.280
Total Zone IV.5	Plants	5	.091	.005
Total Zone V	Plants	190	3.467	.173
Total Zone V.5	Plants	14	.255	.014
Total Zone VII	Plants	1	.018	.001
Total all plants		5481		
Average zone number for total of all plants identified				3.067

Climatological data for Sidney is rather sparse. Mean minimum January temperature has been found to be 0° F. Sidney can expect an average 25 chinook winds yearly and the maximal 130 consecutive freeze-free days or more.

Rehder and the Arnold Arboretum designated Sidney Zone III for plant hardiness. The USDA said Zone 4a which is equivalent to the Rehder III. The author found that Sidney rated a Zone 3.062 as a weighted mean for all plants noted in that city. Former work may have underestimated the mild climate of the Sidney area. Although 39% of all species noted in Sidney were Zone III species, 19% and 9% were found to be Zone IV and V