National Library of Canada | Bibliothèque nationale du Canada | CANADIAN THESES ON MICROFICHE | *THÈSES CANADIENNES SUR MICROFICHE*

NAME OF AUTHOR/*NOM DE L'AUTEUR* Gerry W Wheeler

TITLE OF THESIS/*TITRE DE LA THÈSE* Some Grassland and Shrubland Communities in the Parklands of Central Alberta

UNIVERSITY/*UNIVERSITÉ* The University of Alberta

DEGREE FOR WHICH THESIS WAS PRESENTED/ *GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* M. Sc

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1976

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* Dr. A. W. Bailey

DATED/*DATÉ* 22/Oct/76 SIGNED/*SIGNÉ* [signature]

PERMANENT ADDRESS/*RÉSIDENCE FIXE* 1710 Bowness Rd. NW.
Calgary, Alberta
Canada

THE UNIVERSITY OF ALBERTA

SOME GRASSLAND AND SHRUBLAND COMMUNITIES IN THE PARKLANDS OF CENTRAL ALBERTA

by

©

Gerry W. Wheeler

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PLANT SCIENCE

EDMONTON, ALBERTA

FALL, 1976

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled SOME GRASSLAND AND SHRUBLAND COMMUNITIES IN THE CENTRAL PARKLANDS OF ALBERTA submitted by Gerry W. Wheeler in partial fulfilment of the requirements for the degree of Master of Science.

Arthur W. Bailey
Supervisor

Donald J. Pluth

....

Date. October 27, 1976

ABSTRACT

A survey of the grassland and shrubland communities on relatively undisturbed sites in the area surrounding the University of Alberta Ranch at Kinsella, Alberta resulted in five plant communities being described. The five plant communities described were a Symphoricarpos, a Symphoricarpos/Festuca, a Festuca-Stipa, a Stipa-Festuca and a Stipa-Agropyron community. The Festuca-Stipa community, the major grassland community in the study area, was subdivided into a grassland phase and a shrub phase based on the presence and cover of Elaeagnus commutata. The literature review indicated that the Festuca-Stipa community may be a recent development resulting from changes brought about by settlement of the prairies. The Stipa-Agropyron community was unusual because of its lack of Festuca scabrella on a site where F. scabrella was expected to be one of the dominant grasses. The presence of the Stipa-Agropyron community was attributed to heavy grazing on the area in the past.

A more detailed survey of 14 stands of Symphoricarpos occidentalis was conducted. the data gathered were analysed using two methods. One was to compare the soils of groups of plots in the S. occidentalis stand with the soils of plots in adjacent grasslands. The second method of analysis was to use a cluster-ordination to gather the plots into groups with similar vegetation. The

cluster-ordination was found to be the most useful method of analysis because it revealed two types of grassland and a bias that was present when the stands were selected for study. The presence of *S. occidentalis* was overemphasized in the selection of stands for study resulting in some grassland stands with scattered *S. occidentalis* plants present being included with the shrub stands.

Of the soil properties studied only moisture, horizon depths and, possibly, potassium levels were correlated with the distribution of stands of *S. occidentalis*. An apparent increase of soil potassium under the *S. occidentalis* stands may have been due to increased release of potassium by leaf fall in the shrub stands relative to the grassland. The presence of a deep enough soil with adequate moisture was apparently one of the major factors affecting the distribution of *S. occidentalis*.

It was also concluded that there may be potential for continued invasion of the grassland by *S. occidentalis*.

ACKNOWLEDGEMENTS

The help of Mr. Lorne Westbrook, who before his accidental death in 1970 gave me permission to use section 28, township 47, range 11, west of the 4th meridian as one of my study areas is gratefully acknowledged. After the death of Mr. Westbrook this land was purchased by the Alberta Department of Agriculture for use by The University of Alberta in range management studies.

I would like to acknowledge the help of Dr. A.W. Bailey who provided guidance and assistance throughout this study.

The financial assiatance of the National Research Council, through a research grant to Dr. Bailey, is gratefully acknowledged.

Finally I would also like to acknowledge my fellow graduate students for their helpful discussion and suggestions, and especially Brian Pinchbeck for the use of some of his computer programs. Also Shannon Campbell, Sandra Campbell and John Seaborn for their assiatance in proof-reading.

Table of Contents

Table of Contents, Continued

List of Tables

List of Figures

INTRODUCTION

During the summers of 1970 and 1971, non-forested plant communities were studied on the University of Alberta Ranch, Kinsella, Alberta. This research was conducted to provide background ecological information on the non-forested plant communities for use in range management studies. The research was conducted in two parts. During the summer of 1970, a reconnaissance ecological survey of the non-forested plant communities was carried out. During the summer of 1971, a more detailed study was made of some of the ecological factors affecting the distribution of *Symphoricarpos occidentalis*[1]

The objective of the reconnaissance synecology study was to determine what plant communities were present in the grasslands and shrublands of the study area.

The objective of the *S. occidentalis* study was to relate selected environmental factors to the distribution of *S. occidentalis* in order to see which factors appeared to have the greatest effect on its distribution.

S. occidentalis, because of its long rhizomes, is one of the few plants capable of invading the grassland and shading it out (Pelton, 1953). This is an important consideration in range management studies since

[1] Nomenclature for vascular plants follows Moss, 1959.

S. occidentalis is an unpalatable shrub (E.W. Tisdale quoted in Pelton, 1953) that provides little forage for cattle as they will not eat this shrub unless forced to do so by starvation. Thus *S. occidentalis* is undesirable on rangeland because it can invade the grassland and replace valuable forage grasses resulting in a lower carrying capacity.

DESCRIPTION OF THE STUDY AREA

Geography, Soils and Geology

The Kinsella Ranch lies within the parkland zone of Alberta. It is located immediately north of the town of Kinsella, Alberta, in township 47, range 11, west of the 4th meridian. The parkland vegetation has groves of *Populus tremuloides* alternating with patches of fescue grassland. General descriptions of the parkland vegetation can be found in Bird and Bird (1967), and Moss (1955).

The plots used in the reconnaissance synecology study were located in the NW 1/4 of section 33, township 46, range 11, west of the 4th meridian; in the SE 1/4 of section 29, township 46, range 11, west of the 4th meridian and in section 28, township 47, range 11, west of the 4th meridian. The *Symphoricarpos occidentalis* study was carried out in section 28, township 47, range 11, west of the 4th meridian (Figure 1).

The ranch lies on an area of hummocky ground moraine called the Viking Moraine. The moraine is dotted with sloughs ranging in size from a few acres to Lac Deroches (0.5 x 1.3 km) and Carrier Lake (0.5 x 2 km). Carrier Lake is the large lake on the east side of the photograph in Figure 1. Both Carrier Lake and Lac Deroches lie in what appears to be a minor glacial outwash channel running through the ranch from north to south and joining a larger

FIGURE 1. AERIAL PHOTOGRAPH OF ONE OF THE STUDY AREAS, SECTION 28, TOWNSHIP 47, RANGE 11, WEST OF THE 4th MERIDIAN (SCALE APPROXIMATELY 1:10 500).

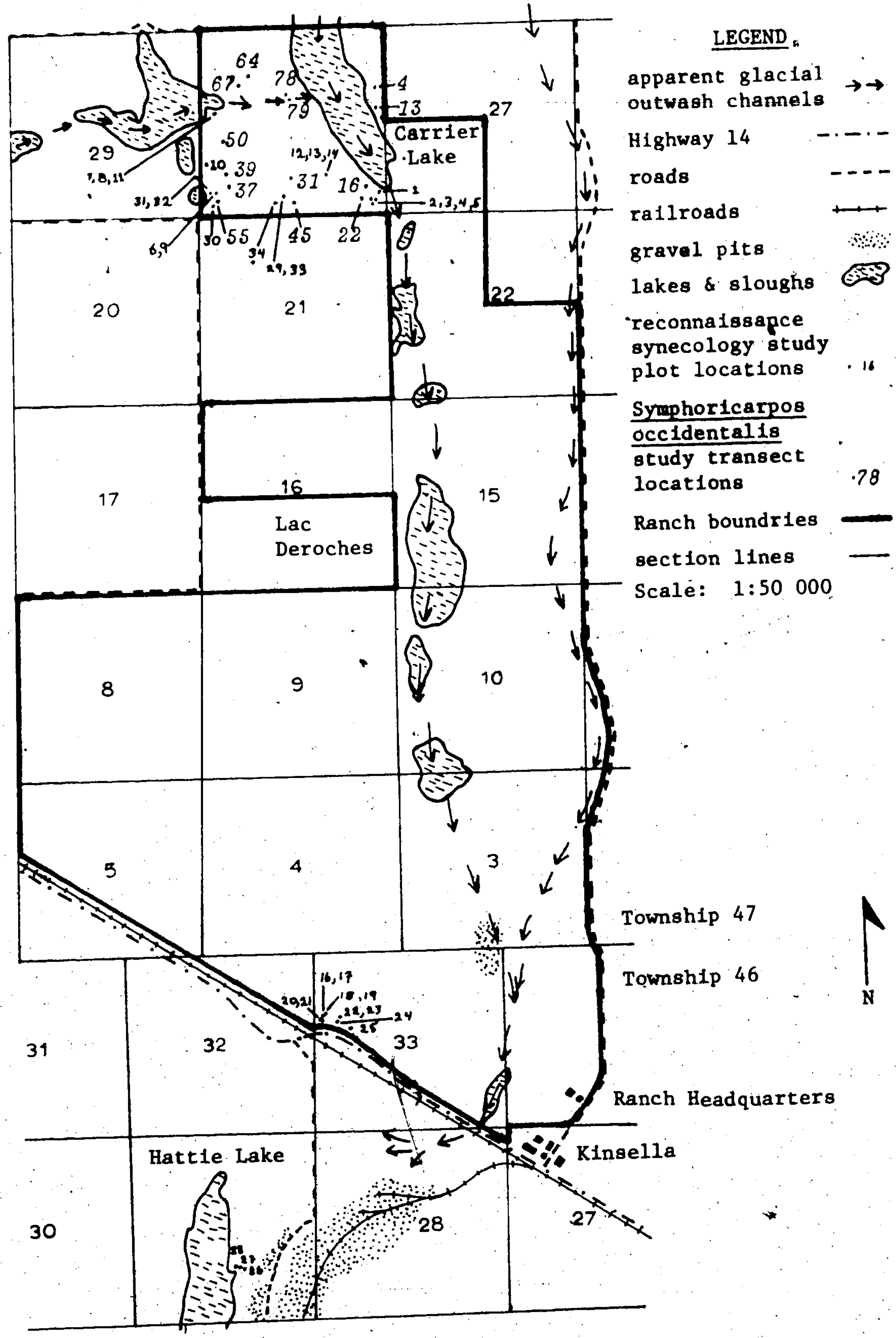
channel about 1.5 km north of the town. The larger channel runs from the area of Camp Lake 14 km north of Kinsella along the eastern edge of the ranch, passing west of the town and crossing Highway 14 0.5 km west of Kinsella. The channel then spreads into the deltaic area centered on the gravel pit east of Hattie Lake (Figure 2).

The soils of the Viking Moraine were mapped as zonally normal shallow black soils developed on unsorted, transported glacial material by Wyatt et al., (1944). Using the System of Soil Classification for Canada (Canada Department of Agriculture, 1974), the grassland soils were classified as orthic and eluviated black and dark brown chernozems. Wyatt et al. (1944) noted the bedrock of the study area was the Pale Beds formation. This formation consisted of sandstones interbedded with greenish shales and some thin coal seams. The Pale Beds formation was of brackish water origin which accounts for the saline nature of many of the sloughs and lakes in the area.

Climate

The climate of the area is continental with cool summers, cold winters and a summer high precipitation pattern (Longley, 1967). For the period from 1966-1974 the average temperature for June, July and August was 15-16°C while the average during December, January and February varied from -11 to -19°C (Environment Canada, 1966-1974).

FIGURE 2. SKETCH MAP OF THE UNIVERSITY OF ALBERTA RANCH, KINSELLA SHOWING THE MAJOR GEOGRAPHICAL FEATURES AND PLOT LOCATIONS.



During this period 67% of the annual precipitation fell during the growing season from May to September and 50% of the yearly total fell in June, July and August. The long term precipitation averages for Ranfurly, 48 km north-northeast, and Viking, 19 km east-northeast, both show similar precipitation distribution patterns with 67% of the precipitation falling during May to September and 50% during June, July and August. The average annual precipitation for Kinsella from 1966-1974 was 433 mm. The long term averages for Ranfurly and Viking were 440 mm and 396 mm, respectively. Snowfall from September to May accounted for 27% of the annual precipitation at Kinsella.

The Kinsella Ranch lies within the dry subhumid zone of Alberta with an average potential evapotranspiration of 510-560 mm of water and an average actual evapotranspiration of 355-405 mm of water (Wonders, 1969).

LITERATURE REVIEW

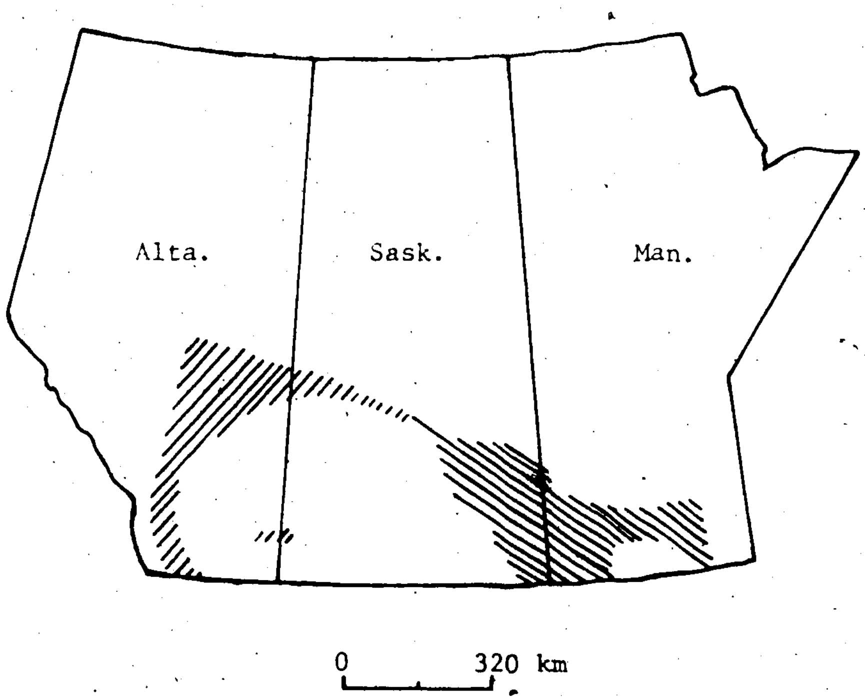
Moss (1955) stated that recognition of the fescue grassland as a distinct entity on the Canadian plains came late considering the extensiveness of the region covered and the conspicuous clumps formed by the dominant grass. John Macoun (1882) made no mention of *Festuca scabrella* for the grasslands of the parkland region. Instead he identified *Stipa spartea*, which he called Northern Buffalo Grass, as the dominant grass in the region. Moss (1932) listed *Festuca scabrella* as one of the leading species of the parkland prairie along with *Koeleria cristata*, *Stipa comata*, *Agropyron tenerum* (=*trachycaulum*), *A. riparium*, *A. daystachyum*, *Helictotrichon hookeri* but made no mention of *Stipa spartea*. Moss (1932) referred to the fescue grassland as the northern prairie. Clarke *et al*. (1942) gave *Festuca scabrella* as the dominant grass of the submontane mixed prairie which they classed as the *Festuca*-*Danthonia* association. The distribution given was similar to that of the parkland region. The *Festuca*-*Danthonia* association was considered to be the climax grassland for most of the black soil zone by Moss (1944).

The first reference to the fescue grassland as it is presently conceived was by Moss and Campbell (1947). They made a sharp distinction between the virgin fescue grassland and that disturbed by grazing or mowing. In the virgin fescue grassland, *Festuca scabrella* was the sole dominant with only small amounts of other grasses present. In contrast, the modified fescue grassland had increased amounts of Agropyron trachycaulum, A. dasystachyum, A. subsecundum, Stipa spartea var. curtiseta, Koeleria cristata and Danthonia species. Danthonia parryi was found to be the most common species of Danthonia in southwestern Alberta. In central Alberta D. intermedia was the most common species and D. parryi was absent (Moss and Campbell, 1947). Additional support for considering Festuca scabrella as the sole dominant of the fescue grassland was given by Johnson (1961). He found that with complete rest from grazing, Danthonia parryi decreased while Festuca scabrella increased. Coupland (1961) agreed with Moss and Campbell (1947) that there was no need to subdivide the community. The distribution of the fescue grassland in Canada is given in Figure 3.

The fescue grassland was not only recognized late but there has been a definite trend to give Festuca scabrella more importance as one of the leading grasses in the parkland prairie. This trend suggests the possibility that the recognition of the fescue grassland paralleled its recent development.

In making the distinction between the "virgin" fescue grassland as a relict community and the fescue grassland altered by grazing or mowing, Moss and Campbell (1947) make the assumption that there was no disturbance to

FIGURE 3. THE DISTRIBUTION OF THE FESCUE GRASSLAND IN THE PRAIRIE PROVINCES.



- fescue prairie

- stands of the mixed prairie and the fescue prairie alternate

From Coupland, 1961, p. 140.

reduce the dominance of *Festuca scabrella* prior to white settlement of the area. This was probably an invalid assumption. Bird (1961) indicated that prior to the coming of the white man, bison (*Bison bison*[1]) and to a lesser extent elk (*Cervis canadensis*) grazed in the parkland region. There is ample evidence that grazing, even at light rates, reduces the dominance of *Festuca scabrella* (Moss and Campbell, 1947; Johnston, 1961; and Smoliak *et al*., 1974). There is also some evidence that burning may be detrimental to *Festuca scabrella* (Anderson, 1972). Both H.Y. Hinde (1860) and John Macoun (1882) refer to the annual fall burning of the prairie by the Indians.

Stewart (1956) concluded that some non-geographical force was responsible for the formation and maintenance of the grasslands of America because the moist prairies could support true forests and the dry plains could support scattered trees and shrubs. He concluded that fires set mainly by man were responsible for the grasslands in America.

If further research confirms that *F. scabrella* can be removed or greatly reduced by burning and grazing, this would support the hypothesis that the fescue grassland, as presently conceived, is a recent development. This leads one to suspect that the fescue grassland has been allowed to

---

[1] Zoological nomenclature follows Soper, 1964.

develop by the suppression of fires and the prevention of grazing on some areas since the settlement of the area by Europeans.

In a study of the fescue grassland in Saskatchewan, Coupland and Brayshaw (1953) found that Festuca scabrella decreased from dominance in the north to co-dominance with Stipa spartea var. curtiseta in the south. Hird (1957) studied the distribution of the vegetation on various slope aspects in central Saskatchewan and found Festuca scabrella to be the dominant grass on north-facing slopes while on south-facing slopes the dominant grass was Bouteloua gracilis.

Ayyad and Dix (1964) found differences in vegetative composition related to aspect and slope position similar to those found by Hird (1957). Ayyad and Dix found that soil temperature, soil moisture and solar radiation were the most important environmental factors affecting the distribution of the vegetation with respect to slope aspect and position.

In a study conducted on a 65 hectare area of hilly rangeland in the southern fringe of the parkland zone of Alberta, Wroe (1971) identified eight plant communities. These included of a Populus tremuloides-dominated forest community, a Salix-dominated shrub community, a Symphoricarpos occidentalis-dominated shrub community, a Carex-dominated meadow community, and four grassland communities. Of these, only the S. occidentalis-dominated community did not occupy a predictable topographic site. The other seven communities all occupied predictable sites with respect to aspect and slope position.

S. occidentalis is an unpalatable weedy shrub on rangelands that has been reported to be invading the grasslands (Bird, 1930, 1961; and Moss 1932). Moss (1932) agreed with Bird (1930) that the reported invasion of the grassland by S. occidentalis has been aided by the actions of certain mammals. Mammals having the most influence were Richardson's ground squirrels (Citellus richardsonii), pocket gophers (Thomomys talpoides), badgers (Taxidea taxus), foxes (Vulpes sp.), coyotes (Canis latrans) and, before their extermination, the bison. These animals created bare areas which enabled Symphoricarpos occidentalis to become established through a reduction in competition from grasses. The presence of S. occidentalis stands may have aided in the establishment of Populus tremuloides by providing sheltered sites suitable for the establishment of the tree by seed (Bird, 1961).

Pelton (1953) made a detailed study of S. occidentalis in Minnesota. Pelton agreed with Bird (1930) and Moss (1932) that S. occidentalis normally only established itself on locally disturbed areas such as abandoned gopher mounds. The major causes of seedling mortality were found to be attack by soil invertebrates, drought and damping off fungi.

Pelton found *S. occidentalis* in plant communities ranging from open grassland to dense forest. *S. occidentalis* was very common in grassland-forest ecotones. It occurred on a wide range of soils including mature grassland soils, some mature forest soils and immature alluvial soils. *S. occidentalis* had not been reported on alkaline, saline, very acid, or organic soils. Pelton concluded that soil fertility affected the distribution of *S. occidentalis* in Minnesota indirectly through its effect on competing vegetation rather than by direct action on the shrub itself.

METHODS

RECONNAISSANCE SYNECOLOGY STUDY

Choice of Stands

The reconnaissance synecology study was a survey of the non-forested plant communities in the area around the Kinsella Ranch. Non-forested communities not included in this study were the sedge meadows and saline flats associated with the sloughs. Thirty-three stands of vegetation were chosen from aerial photography and ground survey using the following criteria:

(a) They showed no evidence of recent disturbance by grazing, mowing, or the application of herbicides.

(b) Each stand represented a single aspect and slope position.

(c) Each stand was chosen to be as homogeneous as possible.

(d) The stands were chosen to include as many different types of grass- and shrub-dominated communities as there appeared to be present in the area. Within the fescue grassland several different slope aspects and positions were included.

(e) All 33 stands were limited to an area roughly 6 x 12 km.

One stand was chosen to determine the number of 20 x 50 cm plots which had to be clipped in order to obtain an adequate sample for an analysis of annual herbage production. Stand 26 was chosen because it occupied a relatively large area on a level site so that additional studies could be conducted in the same stand with a minimum of interference from the clipping.

Data Collection

A visual estimate of the canopy coverage was made for each species in each stand. Canopy coverage was defined as "the percentage of ground covered when a polygon, drawn around the extremities of the undisturbed canopy of each plant is projected on the ground and all projections on a given area are summed" (Daubenmire, 1959). A single estimate was made for each stand with no attempt to divide the stand into sub-units or replicates. The estimates were made using the following seven class scale:

Cover class	Percent Cover	Midpoint
1	0 - 1	0.5
2	1 - 5	3
3	5 - 25	15
4	25 - 50	32.5
5	50 - 75	62.5
6	75 - 95	85
7	95 - 100	97.5

All calculations were done using the midpoint of the cover class as the value for a given species in any stand.

In Stand 26, a series of fifty 20 x 50 cm plots were randomly located. Vegetation was clipped to ground level and the clippings were stored stored in plastic bags and frozen. Later these were sorted to species in the laboratory. The air dry weight of each species in each plot was recorded.

On July 16, 1970, soil samples for soil moisture determination were collected from the A, B and C horizons of 19 stands A rain shower interfered with the sampling of the remaining stands. Samples were collected with a 2.5 cm. soil probe, placed in soil moisture cans, taken to the laboratory, weighed, oven-dried overnight (18-20 hrs) at 105°C and reweighed. The moisture content was calculated as a percentage of the oven dry weight of the soil.

Early in September 1970, soil pits were dug in 13 stands. Samples from the A and B horizons were sent to the Alberta Soil and Feed Testing Laboratory, Alberta Department of Agriculture, to be analyzed for available nitrogen, potassium, phosphorus, sodium, pH, conductivity, lime, and organic matter using their standard analyses for agricultural soils.

Data analysis

A stand ordination is a method of displaying interstand relationships by placing stands in relation to one another through their positions on a number of axes

(Swan *et al.*, 1969). A two dimensional ordination using the technique of Swan *et al.* (1969) was used to display the interstand relationships of the thirty-three stands used in this study. This method produced a geometrically acceptable ordination with orthogonal axes in n-dimensional space.

The technique used a matrix of dissimilarity values (distance matrix) between stands as a starting point. All possible stand-defined axes (axes which were defined by choosing one stand at each end of the axis and then positioning all other stands on the axis) were compared to determine which one accounted for the largest proportion of the variation in the distance matrix. The axis which accounted for the most variation was used as the first axis of the ordination. The axis positions of all stands were calculated. If more than one axis was to be displayed, the next step was to correct the distance matrix for the variation accounted for by the preceding axis. Correction was done by calculating a residual which gave the distance of each stand perpendicularly from the axis previously extracted. Once this has been done for all stands, the corrected matrix was used to select a new axis.

This procedure can be repeated until all of the variability in the distance matrix has been removed, or can be stopped when the desired criteria have not been met by the latest axis or after any desired number of axes have been extracted. Two axes were used in this study because they displayed enough information to group the stands into plant communities and subsequent axes provided no additional information useful in grouping the stands into plant communities.

A Euclidean distance matrix (Orloci, 1966; Swan et al., 1969) was used in the study. The interstand distances (dissimilarity values) were calculated using the formula

$$D_{ij} = \left[\sum_{m=1}^{N} (X_{mi} - X_{mj})^2 \right]^{1/2}$$

where D_{ij} is the distance between the i^{th} and j^{th} stand,

X represents the attributes upon which the comparison is being made (species cover in this study), and

N is the number of variables (species in this study).

The distances calculated for this study were a relative measure of the differences between pairs of stands so units of measure were not applicable.

All calculations were done using the IBM System 360/67 computer at the University of Alberta using programs EUCLID and SDWORD (Purchase, 1970). All species occurring in less than two stands or for which the identification was in doubt were excluded from the calculations. This was done to reduce the possibility of mis-identified species or species not normally found in a community affecting the results.

The ordination was used to group the stands into communities. An association table was also produced by arranging the communities that were most alike closest to one another. Within each community the stands were arranged so the ones most alike were closest together. Stands most like one of the adjacent communities were placed next to that community. The ordination was used for this purpose because the stands which were most alike fell closest together on the ordination axes, whereas the stands which were not so similar were separated by some distance on one or more of the ordination axes. The distance between the stands on the ordination axes was proportional to the difference between them.

A one-way analysis of variance for treatments with unequal replication and a logarithmic transformation (Pinchbeck, 1972) was used to check for the statistical significance of differences in soil moisture and soil nutrients.

The number of 20 X 50 cm plots required to obtain an adequate sample for determining annual herbage production was estimated using the following formula from Snedecor and Cochrane (1967):

$$N = 4s^2/\pm l^2$$

where N is the number of samples required,

s^2 is an estimate of the population variance, and

±l are the confidence limits of the mean.

This gives a 95% probability of being within the limits set (Snedecor and Cochrane, 1967). The limits chosen for this study were ±10% of the mean following Milner and Hughes, (1968).

SYMPHORICARPOS OCCIDENTALIS STUDY

Choice of Stands

Within the study area many of the stands of S. occidentalis were identified on large scale aerial photography (1:4800) and by ground survey. The stands chosen had to border on grassland for part of their circumference so a transect could be run from the shrub stand into the grassland. The stands selected were stratified into two groups based upon the density of the shrub canopy of each stand. Forty-two of the stands had an open canopy of S. occidentalis and the remaining 27 had a closed canopy of S. occidentalis. Study sites were randomly chosen from each of the two groups of stands.

Data Collection

Vegetation data were collected on the basis of a three meter wide transect running from the approximate geographical center of the shrub stand to the edge and for an equal distance into the grassland. The only exception was where there was an abrupt change in topography. In such a case, the transect was not extended beyond the break in topography.

The direction of each transect was chosen randomly except where the choice was limited by the availability of adjacent grassland. The directions were chosen by generating a random order of the four compass quadrants (NE, SE, SW, NW) for each transect. Within each quadrant, a degree from 1-90 was randomly chosen. Using the randomly generated order of the compass quadrants, the first potential transect that is, the first one going from the shrub stand into grassland was chosen as the transect for that stand.

Each transect was divided into a series of 2.5 x 3 meter plots to restrict the randomization of the microplots. The number of microplots was set at 50 or the closest multiple of the number of plots in the transect to 50. This was done to give similar sampling intensities in every stand and to obtain a reasonable number of samples in both the shrub and grassland portions of each transect. The microplots were 20 x 50 cm and the canopy coverage was estimated using the method of Daubenmire (1959) as previously described.

Because of the difficulty of positive identification of species of <u>Carex</u> from vegetative specimens, the only distinction made was to distinguish between tall <u>Carex</u> and short *Carex*. Tall *Carex* was defined as having leaves longer than 1.5-2 dm while short *Carex* was defined as having leaves shorter than this. All species of *Agropyron* were lumped together because of the difficulty in identifying species in the vegetative state.

In early September the vegetation in two 20 x 50 cm microplots were clipped so the total standing crop could be determined. The material was sorted to separate shrub standing crop from the grass and forb standing crop. The material was not sorted into dead and live material so no direct estimate of the annual production could be made.

Soil samples, for soil moisture determination, were taken July 17 and 18, 1971 before the canopy coverage data were collected. To avoid disturbance of the vegetation in the plots, the samples for soil moisture analysis were taken adjacent to each plot. These samples were collected using the same method as in the reconnaissance synecology study. Soil samples, for analysis by the Alberta Soil and Feed Testing Laboratory, were collected from pits dug beside randomly chosen transects. These soil samples were collected in July 1971 before the vegetation sampling was done. Measurement of the other soil properties and samples collected for particle size distribution analysis were taken from soil pits dug in the center of each plot after the vegetation sampling was completed. The particle size distribution analysis was done using the hydrometer method of Bouyoucos (1962). The horizon depths measured were the depth of the Ah, the depth to the top of the B horizon and the depth to lime. The depth to the top of the B horizon included the zone of accumulation of organic matter, the Ah horizon, and any eluviated layers below it down to the top of the B horizon where illuviation of clay particles was the predominant soil forming process. The depth to lime was the depth to where lime, as calcium carbonate, had been accumulating in the solum and indicates the depth of the solum. The soils were classified using the System of Soil Classification for Canada (Canada Department of Agriculture, 1974).

Data Analysis

The data were analyzed using two methods. The first method used was to divide each transect into a section with *Symphoricarpos occidentalis* and a section without *S. occidentalis*. A one-way analysis of variance for treatments with unequal numbers of replicates (Pinchbeck, 1972) was used to compare some environmental and vegetational factors among the groups of plots. ANOVA2, a one-way analysis of variance program with correction for missing data (Smillie, 1967), was used to compare the soil nutrient data.

The second method of analysis employed was devised by Pinchbeck (1972) and utilized a clustering technique in conjunction with ordination of the clusters to classify plots into groups. Once the groups of plots were defined, a one-way analysis of variance for treatments with unequal numbers of replicates was used to compare some of the environmental and vegetational factors among the groups. In order to use this technique, it was necessary to obtain a single cover value for each species in each plot. Four randomly chosen microplots were averaged to give a single set of cover data for each plot. Exceptions to this procedure were two transects where there were only three microplots per plot. Species richness (number of species per plot) in these two transects was compared to the species richness of the plots in the other twelve transects using a one-way analysis of variance. The difference was not significant at the $p<0.1$ level. The analysis of the 14 transects was based on the use of three microplots in two transects and four microplots in twelve transects.

A clustering program based on Carmichael's TAXMAP map cluster analysis program (Carmichael and Sneath, 1969) was used for cluster analysis of the data. This program was modified by Pinchbeck (1972) to accept a distance matrix as the input and to compute a matrix of intercluster distances suitable for ordination. The input used was a Euclidean distance matrix as described in the methods for the reconnaissance synecology study. The clustering technique used the frequency distribution of the inter-operational taxonomic unit (OTU's = plots in this study) proximities to determine discontinuity constants used to delimit clusters of OTU's (Carmichael and Sneath, 1969).

The four criteria used to delimit clusters of OTU's were average linkage, single linkage, a ratio criterion, and the not-in-a-cluster criterion (Carmichael *et al*., 1968). The average linkage was the average of the links (Euclidean distances in this study) between the plot being tested for cluster membership and all of the plots already included in the cluster. A large increase in the average distance indicated the plot being tested for cluster membership was not a member of the cluster. The single linkage was the distance between the plot being tested for cluster membership and the closest member of the cluster to it. A large increase in the single linkage distance indicated the plot being tested should not be included as a member of the cluster. The ratio criterion was the ratio of the maximum distance between the plot being tested for cluster membership and the cluster member furthest from it, and the maximum distance between any two plots already in the cluster. Too low a ratio indicated that the plot being tested for cluster membership was laterally separated from an elongated cluster and was not a member of the cluster, even though the average linkage and the single linkage criteria may not have separated the plot from the cluster. The effect of the not-in-a-cluster criterion was to make the clusters mutually exclusive. That is, once a plot was included in one cluster it could not be considered for inclusion in another cluster (Carmichael *et al*., 1968).

The discontinuity constants used are empirical values which depend upon the data used and the level of resolution desired. At a high level of resolution many small clusters would be produced. At a low level of resolution a few large clusters would be produced. The discontinuity constants used in this study were the ones that Pinchbeck (1972) found most useful for his data.

The clusters of plots produced were ordinated using the technique of Swan et al. (1969). The Euclidean distance matrix was made up of cluster center to cluster center distances. The ordination of the clusters was used to separate the plots into plant communities. A one-way analysis of variance for treatments with unequal numbers of replicates (Pinchbeck, 1972) was used to compare selected environmental factors among the plant communities.

RESULTS

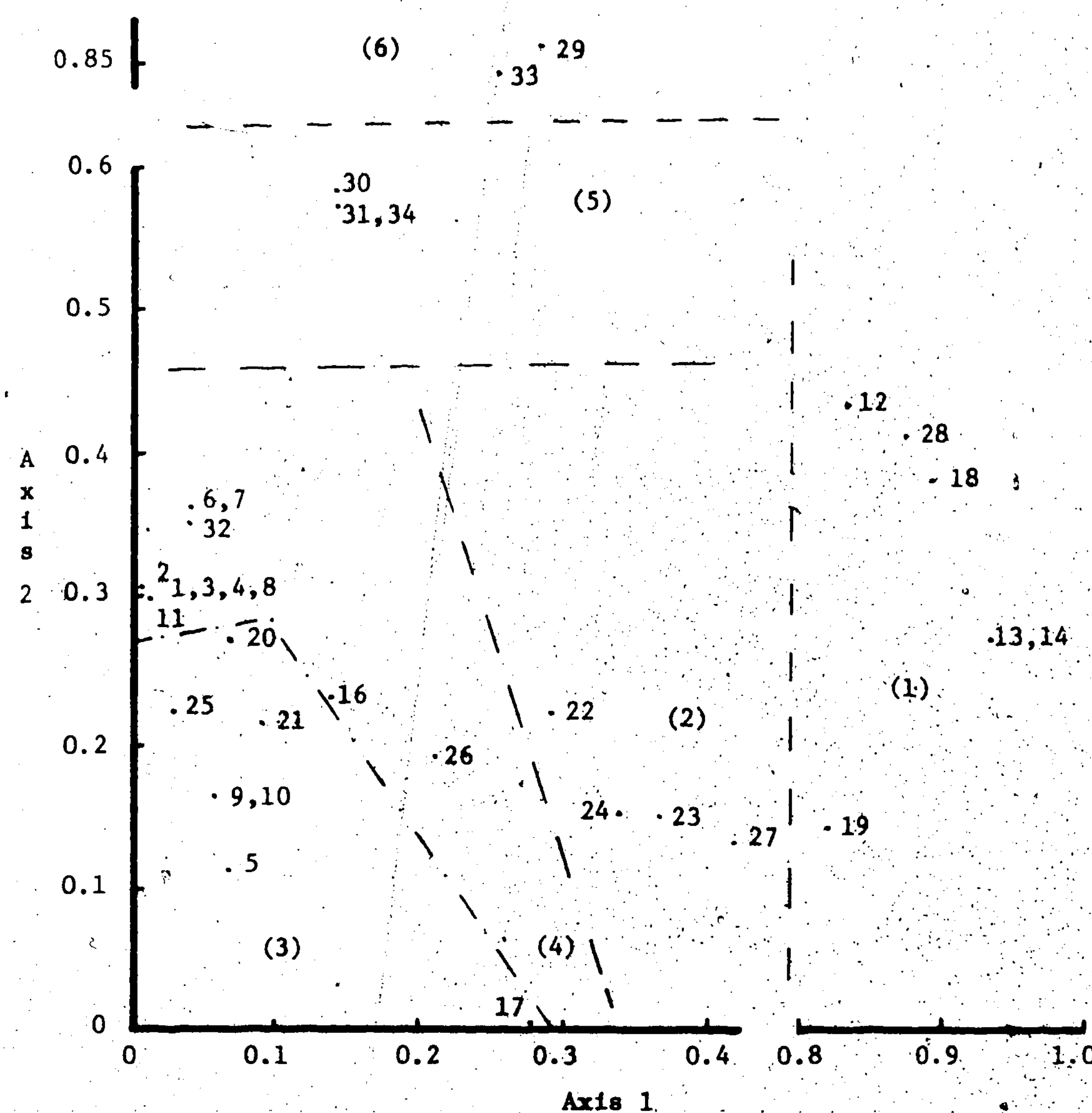
RECONNAISSANCE SYNECOLOGY STUDY

Vegetation

The two dimensional ordination developed to illustrate relationships among the thirty-three stands is given in Figure 4. The two axes accounted for approximately 75% of the variation in the distance matrix and illustrates how the stands were grouped into five plant communities. Table 1 lists the mean canopy cover and frequency of selected species in each of the five plant communities. A complete listing of all species in each stand has been given in Appendix 1.

The *Symphoricarpos occidentalis* (*Symphoricarpos*) community was the most distinctive and easily defined community because of the dominance of *S. occidentalis* in every stand. Stands 12, 13, 14, 18, 19 and 28 were included in this community. Stands of the *Symphoricarpos* community were characterized by a closed shrub canopy composed mainly of *S. occidentalis*. Often, *Rosa acicularis*, *R. woodsii*, *Rubus strigosus*, *Ribes oxyacanthoides* and *Elaeagnus commutata* had a low cover in the shrub layer. The understory, consisting of scattered grasses and forbs, was sparse in these stands. Common grasses in the understory were *Festuca scabrella* and *Agrostis scabra*, while the more common forbs were *Hackelia americana*, *Senecio eremophilous*, *Vicia americana* and *Galium boreale*. Stands of the

FIGURE 4. A TWO DIMENSIONAL ORDINATION OF THE 33 STANDS OF VEGETATION INCLUDED IN THE RECONNAISSANCE SYNECOLOGY STUDY, 1970.



Plant community separation lines. — — — — — —
Plant community phase separation line. — · — · — ·
The numbers in parentheses indicate the following plant communities.

(1) *Symphoricarpos* community,
(2) *Symphoricarpos*/*Festuca* community,
(3) *Festuca-Stipa* community, shrub phase,
(4) *Festuca-Stipa* community, grassland phase,
(5) *Stipa-Festuca* community,
(6) *Stipa-Agropyron* community.

TABLE 1. MEAN CANOPY COVER (%) AND FREQUENCY (%) OF SELECTED SPECIES IN FIVE PLANT COMMUNITIES, 1970.

Species	Plant Community					
	Symphoricarpos	Symphoricarpos/ Festuca	Festuca-Stipa Shrub Phase	Festuca-Stipa Grassland Phase	Stipa-Festuca	Stipa-Agropyron
	n=6	n=4	n=7	n=11	n=3	n=2
Rosa (acicularis + woodsii)	4/67[1]					
Symphoricarpos occidentalis	95/100	68/100		P/9[1]		
Elaeagnus commutata	34/83	4/50	62/100	P/27	P/33	
Galium boreale	P/50	4/25	1/57	5/73		
Achillea millefolium		2/100	2/100	1/91		P/50
Festuca scabrella	6/33	98/100	94/100	94/100	32/100	
Rosa arkansana		1/100	7/100	5/91	2/100	P/50
Stipa spartea var. curtiseta		44/100	75/100	74/100	98/100	91/100
Artemisia frigida		P/25	3/71	1/82	3/100	3/100
Anemone patens		P/25	1/57	1/64	1/67	8/100
Commandra pallida			1/43	P/36	1/67	P/50
Agropyron smithii[2]			P/14			61/100
Koeleria cristata				P/9	6/100	3/100
Bouteloua gracilis					15/100	26/100
Stipa viridula						8/100

[1] Average cover / Percent frequency. P indicates an average cover of less than 1%.

[2] May also include some A. dasystachyum.

Symphoricarpos community were found on all slope positions and aspects with the exception of the upper slope positions on steep south and south-west facing slopes. In spite of the differences among the stands of the *Symphoricarpos* community shown by the ordination (Figure 4), the stands were grouped into a single community because of the dominance of *S. occidentalis* and the sparse herbaceous cover in the understory of every stand.

The second community was less easily separated from the grasslands. The *Symphoricarpos occidentalis*/*Festuca scabrella* (*Symphoricarpos*/*Festuca*) community was easily separated from the *Symphoricarpos* community because of the closed herbaceous layer dominated by *F. scabrella* and the open canopy shrub layer in the *Symphoricarpos*/*Festuca* community. The only other shrub in the shrub layer was *Elaeagnus commutata*. The herbaceous layer of the *Symphoricarpos*/*Festuca* community was very similar to the *Festuca*-*Stipa* community. The major difference between the the *Symphoricarpos*/*Festuca* and the *Festuca*-*Stipa* communities was the presence of significant amounts of *Symphoricarpos occidentalis* in the former. While this dividing line was arbitrary, it was easily set as no extensive areas with scattered *S. occidentalis* plants were found. Areas found either had a dense enough canopy to be included in the *Symphoricarpos*/*Festuca* community, or there was only one or a few scattered plants of *S. occidentalis* in a stand of the *Festuca*-*Stipa* community. Stands 22, 23, 24 and 27 were included in the *Symphoricarpos/Festuca* community. Stands of the *Symphoricarpos/Festuca* community were found on the same range of slope positions and aspects as stands of the *Symphoricarpos* community. This included most slope aspects and positions with the exception of the upper slope position on steep south and south-west facing slopes.

Stands of the *Festuca scabrella-Stipa spartea* var. *curtiseta* (*Festuca-Stipa*) community were also found on the same range of slope positions and aspects as stands of the *Symphoricarpos* and *Symphoricarpos/Festuca* communities. The *Festuca-Stipa* community was separated into a shrub phase and a grassland phase based on the presence and canopy coverage of *Elaeagnus commutata*. Stands with a cover of *E. commutata* greater than 25% were placed in the shrub phase while stands with less than 25% cover of *E. commutata* were placed in the grassland phase. Stands 5, 9, 10, 17, 20, 21 and 25 were included in the shrub phase, while stands 1, 2, 3, 4, 6, 7, 8, 11, 16, 26 and 32 were included in the grassland phase of the *Festuca-Stipa* community. This phase separation was made because of the very different appearance of the shrub phase due to the presence of *Elaeagnus commutata* and the effect *E. commutata* has on grazing cattle. *E. commutata* acts as a barrier to grazing cattle allowing some of the grassland around the base of each shrub to remain ungrazed (Bailey, 1970).

Festuca scabrella was the dominant species and *Stipa* spartea var. curtiseta was the main sub-dominant species in stands of the Festuca-Stipa community. Other species present included Rosa arkansana, Thermopsis rhombifolia, Achillea millefolium, Agropyron spp. (including A. dasystachyum, A. smithii, A. trachycaulum and A. subsecundum) and Campanula rotundifolia. Scattered plants of Symphoricarpos occidentalis were occasionally found.

Stand 17 in the shrub phase and stands 16 and 26 in the grassland phase were unusual because of the low coverage of Stipa spartea var. curtiseta (Appendix 1). Festuca scabrella was the most important grass species in these three stands. The overall similarity of these three stands to other stands in the community, except for the low Stipa spartea var. curtiseta cover and the small areas involved, meant that these three stands fit most closely into the Festuca-Stipa community. Stands 6, 7 and 32 were transitional between the Festuca-Stipa and the Stipa-Festuca communities. The three stands were included in the Festuca-Stipa community because they had a low cover of mixed prairie species common to the Stipa-Festuca community.

As one moved upslope from stands of the Festuca-Stipa community on certain south-facing slopes, stands of the Stipa spartea var. curtiseta-Festuca scabrella (Stipa-Festuca) community were encountered. A shift in dominance from Festuca scabrella to Stipa spartea var. curtiseta was used to separate the Stipa-Festuca community from the

Festuca-Stipa community. In addition to the dominance of Stipa spartea var. curtiseta, stands of the Stipa-Festuca community had a higher canopy coverage of several species normally associated with the mixed prairie of the brown soil zone of south-eastern Alberta. These species included Bouteloua gracilis, Koeleria cristata, Gaura coccinea and Artemisia frigida. Within the study area, stands of the Stipa-Festuca community were restricted to upper slope positions on south and south-west facing slopes on some of the higher hills. They were the drier more exposed sites not occupied by any of the other plant communities in the study area. The stands included in this community were stands 30, 31 and 34.

The Stipa spartea var. curtiseta-Agropyron (Stipa-Agropyron) community was found as small 25 to 100 m^2 stands. Only stands 29 and 33 were found in this study. The most important feature of the community was the absence of Festuca scabrella. Stipa spartea var. curtiseta was the dominant grass with Agropyron smithii apparently being the major subdominant grass. A. dasystachyum, A. subsecundum and A. trachycaulum were also present. Several species commonly associated with the mixed prairie were also found. They included Muhlenbergia cuspidata, Koeleria cristata, Bouteloua gracilis and Stipa viridula. In the study area, stands of the Stipa-Agropyron community were located on steep southerly facing slopes in the middle and upper slope positions.

Soils

Soil had been collected in nineteen of the thirty-three stands in July when a rain shower interrupted sampling. The nineteen stands included three of the five communities (Table 2).

A trend towards lower soil moisture with increasing shrub cover was observed. Statistically significant differences in soil moisture were present in the B and C horizons. In the B horizon, the soil of the *Symphoricarpos* community was drier than the soil in both phases of the *Festuca*-*Stipa* community. In the C horizon, the soil of the *Symphoricarpos* community was drier than the soil of both phases of the *Festuca*-*Stipa* community. The C horizon soil of the *Symphoricarpos*/*Festuca* community was drier than that of the *Festuca*-*Stipa* community.

Other soil properties studied in the three communities included nitrogen, phosphorus, potassium, pH, and conductivity in the A and B horizons (Table 3). No statistically significant differences were found. The only trend apparent was an increase in the level of potassium in the Ah horizon with increasing shrub cover.

Herbage Production

Vegetation from a series of fifty plots was clipped and weighed in stand 26 to determine the number of plots

TABLE 2. SOIL MOISTURE (%) IN THE A, B AND C HORIZONS OF THREE PLANT COMMUNITIES, 1970.

	Plant Community				
			Festuca-Stipa		
Horizon	Symphoricarpos	Symphoricarpos/ Festuca	Shrub Phase	Grassland Phase	F.-Value
	n=3	n=4	n=6	n=6	
A	26.9	28.7	25.8	32.6	1.13
B	16.9 b[1]	18.5 ab	19.1 a	22.6 a	4.56*[2]
C	10.6 c	12.8 bc	16.0 ab	18.0 a	7.70**

[1] Means in the same row followed by the same letter were not significantly different using the New Multiple Range Test for $P < 0.05$.

[2] * $P < 0.05$; ** $P < 0.01$.

TABLE 3. LEVELS OF SELECTED SOIL PROPERTIES IN FOUR PLANT COMMUNITIES, 1970.

Soil Property	By Horizon	Plant Community			
		Symphoricarpos	Symphoricarpos/ Festuca	Festuca-Stipa Shrub Phase	Festuca-Stipa Grassland Phase
		n=3	n=4	n=4	n=2
N[1]	Ah	4.8	1.0	6.7	6.5
	B	4.8	0.8	1.5	1.5
P[1]	Ah	12	6	5	9
	B	9	9	10	5
K[1]	Ah	952	397	306	489
	B	855	674	494	226
pH	Ah	6.2	6.3	6.4	6.2
	B	6.7	6.5	6.8	6.4
Cond[2]	Ah	0.13	0.18	0.12	0.15
	B	0.13	0.12	0.1	0.1

1 Nutrients in kg/ha.

2 Conductivity in mmho/cm.

needed to obtain a sample mean with a 95% probability of being within ±10% of the population mean. The probability of a sample mean being within ±10% of the population mean was calculated for various sample sizes and has been listed in Table 4. The table starts with five plots and was increased by five plot increments until all fifty plots were included. The 95% probability level was reached after 35 plots had been included. This corresponded to the estimate of 35 plots required that was calculated using the formula $n = 4s^2/l^2$ from Snedecor and Cochrane (1967).

The mean weight per plot and the estimated number of plots needed for a 95% probability of the sample mean being within ±10% of the population mean was listed for selected species and groups of species in Table 5.

The total annual production on this site during the summer of 1970 was 2045 kg/ha.

<u>SYMPHORICARPOS</u> <u>OCCIDENTALIS</u> <u>STUDY</u>

The fourteen stands studied were randomly selected from these available and are described in Table 6.

The first method of analysis used was to divide each transect into a shrub portion and a grassland portion as indicated in Table 6. This resulted in four groups of plots for which selected soil and vegetation properties were compared. The first group, the closed-canopy-shrub group,

TABLE 4. PROBABILITY OF A SAMPLE MEAN BEING WITHIN ±10% OF THE POPULATION MEAN FOR FROM 5 TO 50 PLOTS SAMPLED IN STAND 26, 1970.

Number of Plots	Yield g/plot	Standard Deviation	Standard Error	±t	Probability
5	34.0	5.0	2.24	1.53	0.6 - 0.8
10	24.2	4.6	1.46	1.66	0.8 - 0.9
15	23.0	5.9	1.52	1.51	0.8 - 0.9
20	23.0	6.5	1.44	1.60	0.8 - 0.9
25	22.2	6.2	1.23	1.80	0.9 - 0.95
30	21.3	6.0	1.09	1.95	0.9 - 0.95
35	21.0	5.9	1.00	2.11	0.95 - 0.975
40	21.2	6.1	0.97	2.18	0.95 - 0.975
45	20.5	6.1	0.91	2.24	0.95 - 0.975
50	20.5	5.9	0.84	2.45	0.975 - 0.99

TABLE 5. ANNUAL PRODUCTION (kg/ha) AND ESTIMATED NUMBER OF 20 x 50 cm PLOTS REQUIRED FOR A 95% PROBABILITY OF THE SAMPLE MEAN BEING WITHIN ±10% OF THE POPULATION MEAN FOR SELECTED SPECIES AND GROUPS OF SPECIES, 1970.

Species	Frequency	Annual Production kg/ha	Estimated Number of Plots
Agropyron spp.	31	46	172
Carex spp.	50	74	20
Festuca scabrella	50	1747	46
Total graminoids		1874	49
Total forbs		127	2620
Rosa arkansana	17	44	200
Total annual production		2045	35

TABLE 6. THE SHRUB STANDS CHOSEN FOR STUDY, WITH THE NUMBER OF PLOTS AND THE COMPASS BEARING OF EACH STAND, 1971.

Open canopy *Symphoricarpos occidentalis* stands.

Stand Number	Number of Plots	Shrub Plots	Grassland Plots	Compass Bearing[1]
4	8	1-4	5-8	67
13	8	1-4	5-8	48
22	12	1-6	7-12	5
39	6	1-3	4-6	202
50	6	1-3	4-6	138
64	10	1-5	6-10	166
67	8	1-4	5-8	329

Closed canopy *Symphoricarpos occidentalis* stands.

Stand Number	Number of Plots	Shrub Plots	Grassland Plots	Compass Bearing[1]
16	12	1-6	7-12	273
31	12	1-6	7-12	3
37	12	1-6	7-12	22
45	8	1-4	5-8	179
55	12	1-6	7-12	220
78	20	1-13	14-20	350
79	16	1-8	9-1	166

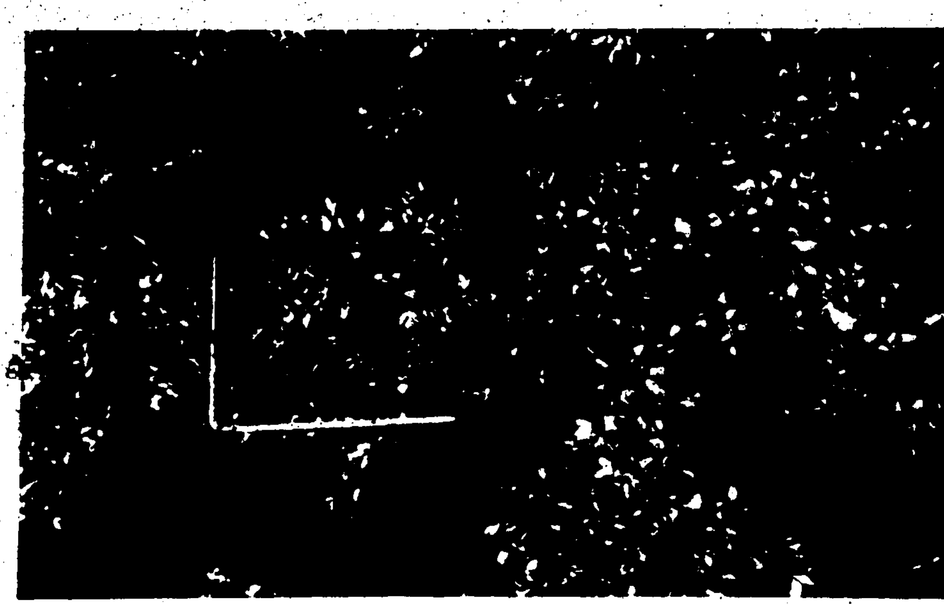
[1] Compass bearing in degrees, along the transect from plot 1 near the centre of the shrub stand to the last plot in the grassland.

consisted of the 52 plots in the shrub portions of the closed-canopy-*Symphoricarpos occidentalis* transects (Figure 5). This group included some plots with an open canopy of *S. occidentalis* as the edge of the stands often had a narrow fringe of *S. occidentalis* with an open canopy. Also within these stands there were small patches with an open canopy of *S. occidentalis*. The second group, the open-canopy-shrub group, included the 29 plots of the shrub portions of the transects in the open-canopied-*S. occidentalis* stands (Figure 5). The grassland portion of these seven transects made up the 29 plots of the third group, the open-shrub-grassland. The 40 grassland plots of the 7 transects in the closed canopy *S. occidentalis* stands made up the closed-shrub-grassland plots, the fourth group of plots.

The plots chosen for soil texture analysis have been listed in Appendix 3. The texture of the Ah horizon was loam in most cases with an occasional silt loam, sandy loam and sandy clay loam. In the B horizon, the texture was more variable with clay loams and sandy clay loams predominating, but with a few loams and sandy loams. The C horizon was also mainly clay loams and sandy clay loams with a sandy loam and a sand in one transect. There was little difference in soil texture among these four groups of plots (Table 7). There were no statistically significant textural differences. The soils were classified into the Dark Brown and Black Great Groups of the Chernozemic Order. The majority of the soils were Eluviated Dark Brown and

FIGURE 5. REPRESENTATIVE PHOTOGRAPHS OF (A) A STAND HAVING A CLOSED CANOPY OF SYMPHORICARPOS OCCIDENTALIS AND (B) A STAND HAVING AN OPEN CANOPY OF S. OCCIDENTALIS. THE PLOT FRAME IN EACH PHOTOGRAPH IS 20 x 50 cm.

(A)



(B)

TABLE 7. SOIL PARTICLE SIZE DISTRIBUTION IN THE A, B AND C HORIZONS OF THE CLOSED-CANOPY-SHRUB, THE OPEN-CANOPY-SHRUB, THE OPEN-SHRUB-GRASSLAND AND THE CLOSED-SHRUB-GRASSLAND GROUPS OF PLOTS, 1971.

Horizon	Particle Size	Closed Canopy Shrub	Open Canopy Shrub	Closed Shrub Grassland	Open Shrub Grassland
		n=7	n=7	n=7	n=7
A	Sand	46[1]	45	46	45
	Silt	39	40	36	42
	Clay	15	16	18	14
B_bB BBBB	Sand	43	47	47	46
	Silt	30	24	26	23
	Clay	27	28	27	31
C	Sand	52	44	47	50
	Silt	24	26	25	21
	Clay	24	29	28	29

[1] Percentage of sand, silt and clay in the soil.

Eluviated Black Chernozems. A few Orthic Dark Brown and Orthic Black Chernozems were also found (Appendix 8).

The depth of the Ah horizon, the depth to lime, and soil moisture in the A, B and C horizons all showed statistically significant differences among the four groups of plots (Table 8). The closed-canopy-shrub plots had the deepest sola with the open-canopy-shrub plots having sola thicknesses intermediate between the closed-canopy-shrub plots and the grassland plots. There was little difference in solum thickness between the two groups of grassland plots. Soil moisture was significantly higher in the closed-canopy-shrub plots than in the other three groups of plots. The two grassland groups and the open-canopy-shrub plots had similar soil moisture averages in all three horizons.

Soil pH, conductivity, nitrogen, potassium and phosphorus in the A and B horizons showed no statistically significant differences among the four groups of plots (Table 9). The only trend apparent was with potassium in both the A and B horizons. The shrub sections of the transects had higher average levels of potassium than the grassland portions of the transects.

The group means for standing crop, total cover and species richness, are presented in Table 10. A trend towards decreasing herbage standing crop with increasing shrub standing crop was apparent. However, it was

TABLE 8. HORIZON DEPTH (cm) AND SOIL MOISTURE (%) IN THE CLOSED-CANOPY-SHRUB, THE OPEN-CANOPY-SHRUB, THE OPEN-SHRUB-GRASSLAND AND THE CLOSED-SHRUB-GRASSLAND GROUPS OF PLOTS, 1971.

Soil Property by Horizon	Closed Canopy Shrub	Open Canopy Shrub	Closed Shrub Grassland	Open Shrub Grassland	F-Value
	n=52	n=29	n=40	n=29	
Depth of Ah Horizon	11a[1]	10ab	8b	8b	4.20**[2]
Depth to B Horizon[3]	20a	20a	15b	15b	5.57**
Depth to Lime[3]	67a	57ab	47b	49b	6.33**
Moisture in the Ah[4]	23a	16b	16b	18b	12.00**
Moisture in the B[4]	15a	12b	11b	12b	12.14**
Moisture in the C[4]	15a	10b	11b	9b	30.10**

1 Means, which are geometric, in the same row followed by the same letter were not significantly different using the New Multiple Range Test for $P < 0.05$.

2 ** $P < 0.01$.

3 See text page 24 for an explanation of these statistics.

4 Soil moisture as a percentage of the oven dry weight of the soil.

TABLE 9. LEVELS OF SELECTED SOIL PROPERTIES IN THE CLOSED-CANOPY-SHRUB, THE OPEN-CANOPY-SHRUB, THE OPEN-SHRUB-GRASSLAND AND THE CLOSED-SHRUB-GRASSLAND GROUPS OF PLOTS, 1971.

Soil Property by Horizon		Closed Canopy Shrub	Open Canopy Shrub	Closed Shrub Grassland	Open Shrub Grassland
		n=6	n=6	n=6	n=6
N[1]	Ah	2.0	1.0	0.8	0.5
	B	1.0	0.7	0.7	1.0
P[1]	Ah	23	14	11	12
	B	60	25	26	26
K[1]	Ah	494	450	256	219
	B	1235	1251	806	907
pH	Ah	5.8	6.1	6.0	5.7
	B	6.0	6.5	6.4	6.4
Cond.[2]	Ah	0.38	0.41	0.42	0.35
	B	0.30	0.38	0.32	0.45

1 Nutrients in kg/ha.

2 Conductivity in mmho/cm.

TABLE 10. STANDING CROP (kg/ha), TOTAL COVER (%) AND SPECIES RICHNESS IN THE CLOSED-CANOPY-SHRUB, THE OPEN-CANOPY-SHRUB, THE OPEN-SHRUB-GRASSLAND AND THE CLOSED-SHRUB-GRASSLAND GROUPS OF PLOTS, 1971.

	Closed Canopy Shrub	Open Canopy Shrub	Closed Shrub Grassland	Open Shrub Grassland	F-Value
	n=52	n=29	n=40	n=29	
Herbage[1] Standing Crop	680b[2]	3310a	3800a	4090a	36.87**[3]
Shrub Standing Crop	3850a	410b	20c	80c	115.25**
Total Standing Crop	7140a	4140b	3830b	4270b	26.16**
Total Cover	209	222	222	222	0.83
Species Richness[4]	11b	13a	13a	15a	6.49**

1 Herbage consisted of all non-woody plants including grasses, grall-like plants and forbs.

2 Means, which are geometric, in the same row followed by the same letter were not significantly different using the New Multiple Range Test for $P < 0.05$.

3 ** $P < 0.01$.

4 Species richness was the number of species per plot.

statistically significant only to the extent of separating the closed-canopy-shrub plots from the remainder. Total cover was approximately the same in all four groups of plots with the closed-canopy-shrub plots having a somewhat lower total cover than the others. Species richness was lower in the closed-canopy-shrub plots than in the grassland and the open-canopy-shrub plots.

The transects used in this study were set up to determine if there was a gradient of soil properties from the *Symphoricarpos occidentalis* stands into the adjacent grasslands. Gradients were not apparent along the transects (Appendix 3). However, differences between the grassland and shrubland segments of each transect were found (Tables 7, 8, 9 and 10). The analyses of variance for Tables 7, 8, 9 and 10 were originally done twice, once with all plots included and once with the two plots at the edge of the shrub stand removed. One plot from the grassland segment and one plot from the shrubland segment of each transect were removed (Table 6). The analyses with the two ecotonal plots removed were done to determine the effect of their removal on the analyses. There was little difference apparent among the environmental variables between the two groups of analyses of variance. The only significant difference between the two sets of analyses was in the shrub standing crop, where the mean shrub standing crop in the closed shrub canopy plots increased from 3850 kg/ha to 5180 kg/ha when the ecotonal plots were excluded from the analysis. As the only significant difference between the two groups of analyses of variance was related to the characteristic used to separate the portions of the transect, that is, the presence of S. occidentalis, only the results of the analyses with all plots present were given. The analyses with all plots present were used so the results would be comparable to the second method of analysis.

The second and more effective method of analysis was to use the cluster-ordination technique of Pinchbeck (1972) to group the plots into clusters that contained similar vegetation. The two dimensional cluster-ordination of the 150 plots (Figure 6) was used to group the vegetation into four groups of plots. Each of the groups of plots, delimited by means of the cluster-ordination, corresponded to one of the plant communities described in the reconnaissance synecology study and will be referred to by the name of the community to which it corresponded. However, individual plots were not equivalent to stands of a community because of the small size of each plot.

The first and most obvious separation made was to separate cluster numbers 1, 14, 18, 19 and all of the single plot clusters falling within the radius of cluster 1 (Figure 6). A listing of all of the plots in each cluster has been given in Appendix 5. The group of 36 plots resulting from the above separation corresponded to the Symphoricarpos community.

FIGURE 6. A TWO DIMENSIONAL ORDINATION OF ALL PLOTS OF THE SYMPHORICARPOS OCCIDENTALIS STUDY, 1971 (n=150, SEE APPENDIX 5, FOR A LIST OF THE PLOTS INCLUDED IN EACH CLUSTER).

24-numbers in italics indicate single plot clusters.

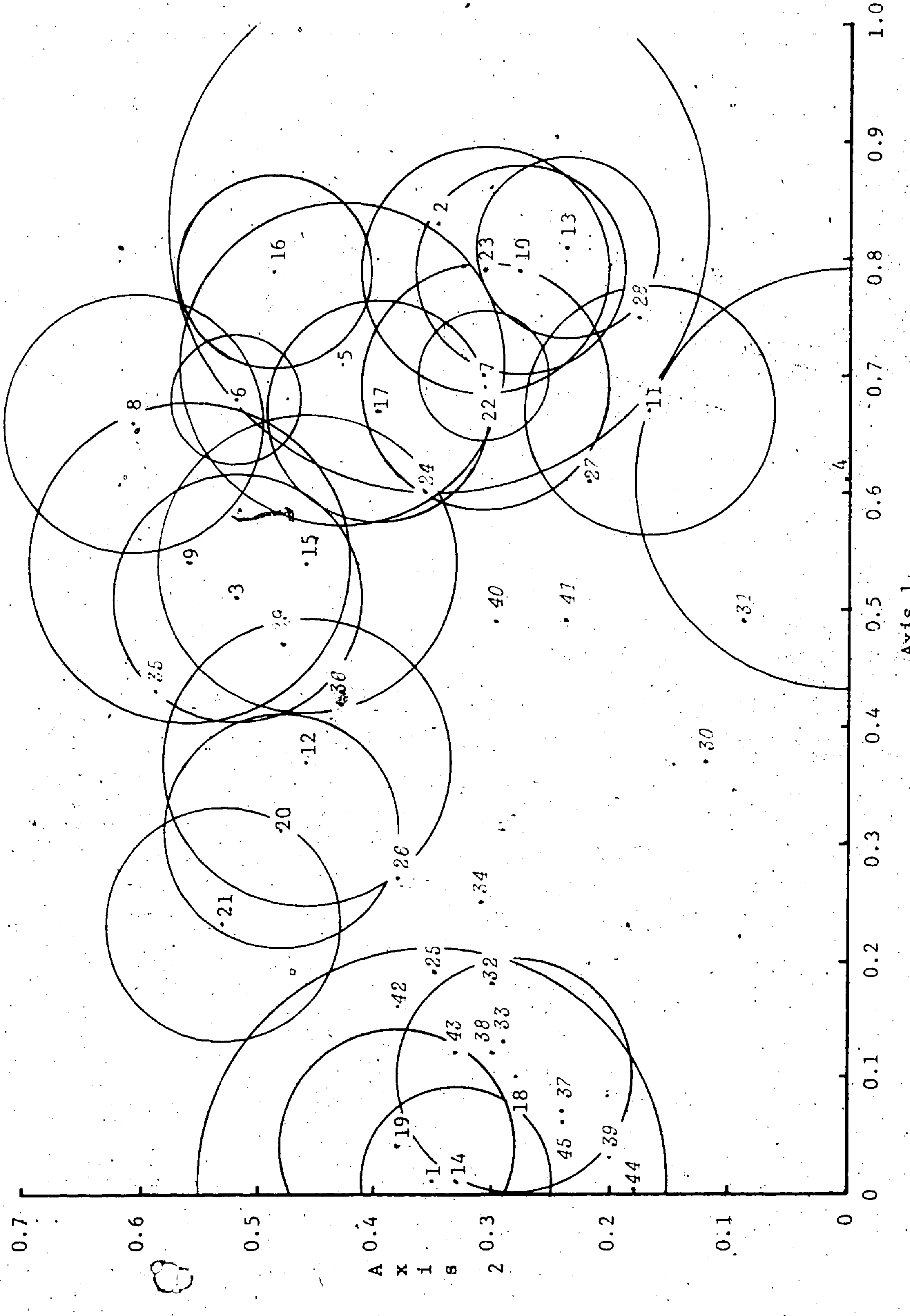
The Symphoricarpos group of plots included clusters 1, 14, 18, 19, *25*, *32*, *33*, *37*, *38*, *39*, *42*, *43*, *44* and *45*.

The Symphoricarpos/Festuca group of plots included clusters 3, 12, 20, 21, *26*, *29*, *34* and *36*.

The Festuca-Stipa groups of plots included clusters 2, 5, 6, 7, 8, 9, 10, 13, 15, 16, 17, 22, 23, *24*, *27*, *28*, *40* and *41*.

The Stipa-Festuca group of plots included clusters 4, 11, *30* and *31*.

FIGURE 6.

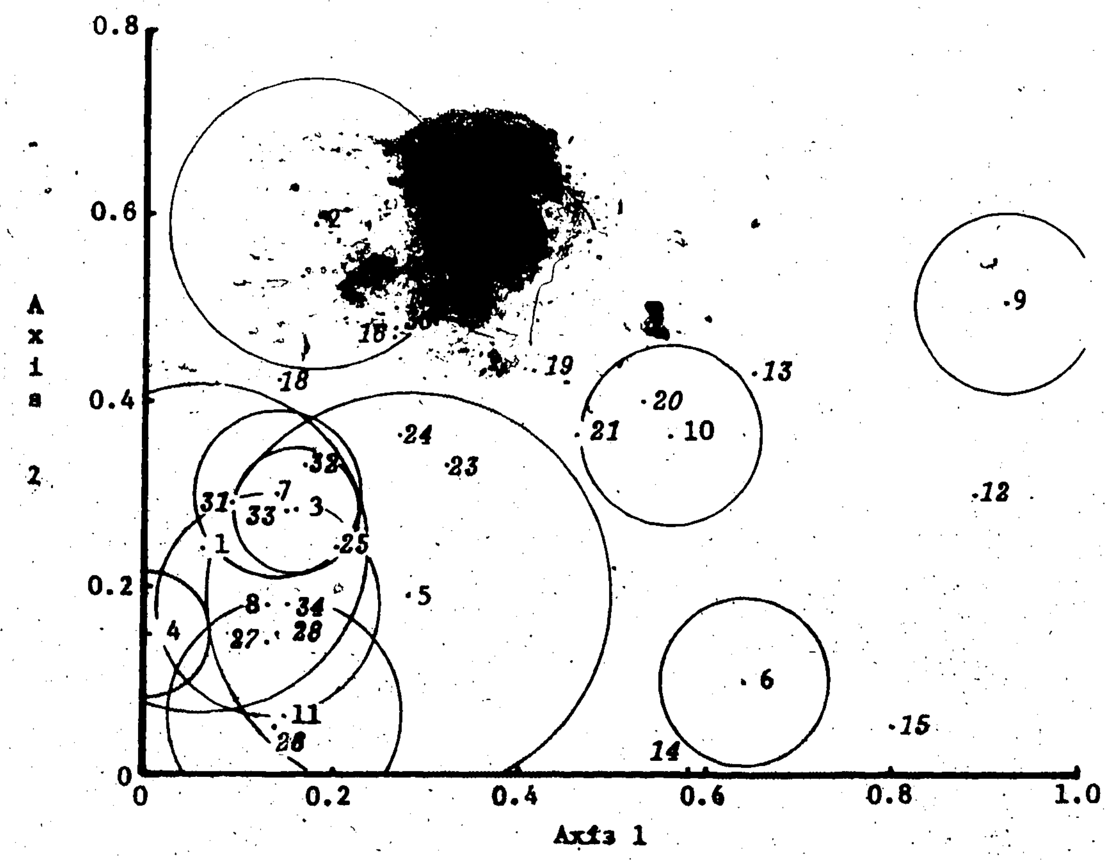


The second group of plots corresponded to the _Symphoricarpos/Festuca_ community. It included the plots in clusters 3, 12, 20, 21 and the single plot clusters 26, 29, 34 and 36 (Figure 6). Eighteen plots were included in the _Symphoricarpos/Festuca_ group.

The group of plots corresponding to the _Festuca-Stipa_ community included 78 plots in clusters 2, 5, 6, 7, 8, 9, 10, 13, 15, 16, 17, 22, 23, 24, 27, 28, 40 and 41 (Figure 6).

The plots corresponding to the _Festuca-Stipa_ community were cluster-ordinated separately (Figure 7). This was done to determine whether or not any obvious sub-groups were present. A sub-division of this large group of plots was desirable so as to reduce the disparity in numbers of plots among the four groups of plots. With the exception of a small number of plots in outlying clusters, there were no obvious separations to be made using this cluster ordination (Figure 7). However, this analysis was used to help separate the _Festuca-Stipa_ group of plots into two equal sized sub-groups. Sub-group I consisted of those plots more like the _Symphoricarpos/Festuca_ community while sub-group II consisted of those plots more like the _Stipa-Festuca_ community. It is important to remember that, while these two groups were separated on the basis of similarity to other plant communities, they were much more similar to each other than either was to any other group of plots. The

FIGURE 7. A TWO DIMENSIONAL ORDINATION OF CLUSTERS OF THE <u>FESTUCA-STIPA</u> PLOTS OF THE <u>SYMPHORICARPOS OCCIDENTALIS</u> STUDY, 1971 (n=79, SEE APPENDIX 6, FOR A LIST OF THE PLOTS INCLUDED IN EACH CLUSTER).



12 -numbers in italics indicate single plot clusters.

The number of plots included in this cluster-ordination does not equal the number of plots in the <u>Festuca-Stipa</u> groups of plots because this analysis was done before the final groupings of the plots were arrived at.

phase separation of the _Festuca_-_Stipa_ community in the reconnaissance synecology study was not used to subdivide this group of plots because there were too few plots with a high enough cover of _Elaeagnus_ _commutata_ to make a worthwile subdivision (Appendix 3).

The plots corresponding to the _Stipa_-_Festuca_ community was the fourth group of plots delimited. Included here were 18 plots in clusters 4, 11, 30 and 31 (Figure 6). These plots were not as clearly separated from the _Festuca_-_Stipa_ plots as were the _Stipa_-_Festuca_ stands included in the reconnaissance synecology study. A lower total standing crop, along with differences in the environmental variables measured, indicated this distinction was a valid and useful one.

The mean cover and percent frequency of selected species in the _Symphoricarpos_, the _Symphoricarpos_/_Festuca_, the _Festuca_-_Stipa_ and the _Stipa_-_Festuca_ groups of plots were listed in Table 11. A complete listing of all species has been included in Appendix 2.

The cluster-ordination of the _Symphoricarpos_ _occidentalis_ study plots brought out two features that were obscured by the separation of the transects into grassland and shrubland sections. The first was the presence of two grassland types instead of the one grassland type suggested by the analysis based on the transect divisions. The second feature brought out by the cluster-ordination was the over-

TABLE 11. MEAN COVER (%) AND FREQUENCY (%) OF SELECTED SPECIES IN FOUR PLANT COMMUNITIES, 1971.

Species	Plant Community				
	Symphoricarpos	Symphoricarpos/Festuca	Festuca-Stipa I	Festuca-Stipa II	Stipa-Festuca
	n=36	n=18	n=39	n=39	n=18
Epilobium angustifolium	2/11[1]				
Prunus virginiana	P/8	P/6[1]			
Calamagrostis inexpansa	8/47	5/11			
Rubus strigosus	5/64	2/22	P/3		
Ribes oxyacanthoides	3/8	P/6	1/3		
Galium boreale	5/53	14/61	22/67	4/31	
Fragaria virginiana	3/19	5/50	1.21	1/15	
Symphoricarpos occidentalis	93/100	54/100	8/36	1/18	7/33
Elaeagnus commutata	14/56	1/17	1/26	2/30	1/17
Festuca scabrella	6/36	78/100	89/100	93/100	15/56
Stipa spartea var. curtiseta	P/11	7/76	35/100	81/100	81/100
Helictotrichon hookerii	P/6		1/51	2/72	7/61
Artemisia frigida	P/3		P/13	P/13	3/89
Hedysarum alpinum			P/5	P/5	
Geum triflorum		P/17	3/44	4/51	P/6
Thermopsis rhombifolia		P/17	3/67	1/41	2/28
Rosa arkansana		P/22	1/36	3/69	P/17
Commandra pallida		1/22	2/62	1/67	4/83
Koeleria cristata			P/5	P/5	1/44
Bouteloua gracilis				P/3	6/67

1 Average cover / Percent cover. P indicates an average cover of less than 1%.

emphasis placed on *Symphoricarpos occidentalis* when the stands were being selected. The presence of *S. occidentalis* was weighted too heavily for inclusion of stands in the open canopy *S. occidentalis* group of stands. For example, all of transect 67 was included in the *Stipa*-*Festuca* community by the cluster-ordination technique. As subsequent results will show, this segregation was supported by differences in the environmental variables between the *Stipa*-*Festuca* plots and the other three groups of plots.

Soil texture showed no differences among the four groups of plots delimited from the cluster-ordination (Table 12). A trend towards deeper soils with increasing *S. occidentalis* cover was apparent (Table 13). The *Symphoricarpos* and *Symphoricarpos*/*Festuca* groups of plots had the deepest soil profiles. However, *S. occidentalis* was present in one-third of the *Stipa*-*Festuca* plots, the group of plots with the shallowest soil profiles.

The *Stipa*-*Festuca* plots also had the least soil moisture in all three horizons. In the A and C horizons, it was significantly lower than the soil moisture content of the other three groups of plots. The *Symphoricarpos* plots had the highest soil moisture in all three horizons followed by the *Symphoricarpos*/*Festuca* plots. Soils of both *S. occidentalis*-dominated groups of plots had a higher moisture content than the soil of the *Festuca*-*Stipa* plots.

The herbage standing crop showed a slight but non-

TABLE 12. SOIL PARTICLE SIZE DISTRIBUTION IN THE A, B AND C HORIZONS OF FOUR PLANT COMMUNITIES, 1971.

		Plant Community				
Horizon	Particle Size	Symphoricarpos	Symphoricarpos/ Festuca	Festuca-Stipa I	Festuca-Stipa II	Stipa-Festuca
		n=8	n=2	n=6	n=9	n=3
A	Sand	44[1]	41	48	40	50
	Silt	38	42	30	44	38
	Clay	15	16	17	14	13
B	Sand	40	40	47	46	51
	Silt	27	29	22	25	21
	Clay	25	28	29	28	28
C	Sand	49	37	54	46	47
	Silt	20	30	20	23	23
	Clay	22	31	24	29	29

1 Geometric means for the percentage of sand, silt and clay in the soil.

TABLE 13. HORIZON DEPTH (cm) AND SOIL MOISTURE (%) IN FOUR PLANT COMMUNITIES, 1971.

Soil Property by Horizon	Plant Community: Symphoricarpos	Symphoricarpos/ Festuca	Festuca-Stipa I	Festuca-Stipa II	Stipa-Festuca	F-Value
	n=36	n=18	n=39	n=39	n=18	
Depth of Ah Horizon	10a[1]	12a	9a	8a	8a	2.32
Depth to B Horizon[2]	20ab	23a	17b	16b	12c	7.06**[3]
Depth to Lime[2]	64a	66a	56a	53a	34b	8.69**
Moisture in the Ah[4]	24a	21ab	17c	19bc	12d	20.34**
Moisture in the B[4]	15a	14a	11b	12b	10b	10.69**
Moisture in the C[4]	16a	14a	10b	10b	8c	25.37**

1 Means, which are geometric, in the same row followed by the same letter were not significantly different using the New Multiple Range Test for $P < 0.05$.

2 See text page 24 for an explanation of these statistics.

3 ** $P < 0.01$.

4 Soil moisture as a percentage of the oven dry weight of the soil.

significant decrease in the *Symphoricarpos/Festuca* plots as compared to the *Festuca-Stipa* plots (Table 14). The *Stipa-Festuca* plots had the next lowest standing crop and the only significant difference was found in the *Symphoricarpos* plots which had the lowest herbage standing crop. The shrub standing crop was highest in the *Symphoricarpos* plots, second highest in the *Symphoricarpos/Festuca* plots and lowest in the grassland plots. Total standing crop was highest in the *Symphoricarpos* plots and lowest in the *Stipa-Festuca* plots.

The total cover and species richness were lowest in the *Symphoricarpos* and *Stipa-Festuca* groups of plots and highest in the *Festuca-Stipa* plots (Table 14).

TABLE 14. STANDING CROP (kg/ha), TOTAL COVER (%) AND SPECIES RICHNESS IN FOUR PLANT COMMUNITIES, 1971.

	Plant Community					
	Symphoricarpos	Symphoricarpos/ Festuca	Festuca-Stipa I	Festuca-Stipa II	Stipa-Festuca	F-Value
	n=36	n=18	n=39	n=39	n=18	
Herbage[1] Standing Crop	290b[2]	3390a	3830a	4140a	2830a	83.40**[3]
Shrub Standing Crop	7100a	1510b	110c	90c	40c	130.98**
Total Standing Crop	8080a	5660b	4260c	4330c	2910d	33.96**
Total Cover	191b	223a	228a	240a	179b	7.41**
Species Richness[4]	9c	13ab	14a	14a	11bc	12.49**

1 Herbage consisted of all non-woody plants including grasses, grass-like plants and forbs.

2 Means, which are geometric, in the same row followed by the same letter were not significantly different using the New Multiple Range Test for $P < 0.05$.

3 ** $P < 0.01$.

4 Species richness was the number of species per plot.

DISCUSSION

Wroe's study was the first to report a *Symphoricarpos* community within the fescue grassland of central Alberta. Earlier reports, Moss (1932), Moss and Campbell (1947), and Coupland and Brayshaw (1953) only noted the presence of *S. occidentalis* stands in the grassland and did not discuss them in any detail. Wroe (1971) gave the *Symphoricarpos* community a broader definition than was done in this study. Wroe included stands with an open canopy of *Symphoricarpos occidentalis* and a closed herbaceous canopy dominated by *Festuca scabrella* in his *Symphoricarpos* community. In this survey such stands were separated out as a separate community called the *Symphoricarpos*/*Festuca* community.

The *Symphoricarpos* community investigated was probably a successional community leading to the aspen forest. Moss (1932), Pelton (1953) and Bird (1961) all agree that stands of *Symphoricarpos occidentalis* tend to be invaded by trees and thus may form a successional community to the aspen forest in the parkland zone of Alberta. Since these authors did not discuss the *S. occidentalis* stands in any detail, it was not possible to determine whether the *Symphoricarpos*/*Festuca* community would be invaded directly by aspen or whether development of a closed canopy of *S. occidentalis* would be needed. It is quite likely that both the *Symphoricarpos* and the *Symphoricarpos*/*Festuca* communities may be directly successional to aspen forest with the *Symphoricarpos*/*Festuca* community also being successional to the *Symphoricarpos* community.

The major grassland community in the study area was the *Festuca*-*Stipa* community, which corresponded to the *Festuca*-*Stipa* community of Wroe (1971). This plant community formed the majority of the *Festuca scabrella* association of Moss and Campbell (1947), and Coupland and Brayshaw (1953). The separation of this community into a shrub phase and a grassland phase, based on the presence and cover of *Elaeagnus commutata*, represents a departure from earlier writers who simply noted that *E. commutata* was present in the fescue grassland (Moss, 1932; Moss and Campbell, 1947; and Coupland and Brayshaw, 1953).

Three stands of the *Festuca*-*Stipa* community studied during the reconnaissance synecology study were separated from the other stands of this community on the basis of low cover of *Stipa spartea* var. *curtiseta*. These three stands were most like the "virgin" fescue grassland of Moss and Campbell (1947) while the remainder of the stands studied were somewhat more like the modified fescue grassland described by Moss and Campbell. Stand 26, one of the three stands was located beside the C. N. R. gravel pit south of Kinsella. The area the plot was located on, the SE1/4 of section 29, township 46, range 11, west of the 4th meridian, was purchased by the C. N. R. in 1927 and has apparently not been grazed since that time. The latest possible grazing was prior to the late ninteen fifties when the C.N.R. was crushing gravel on this quarter section.[1] The other two stands with a low cover of <u>Stipa spartea</u> var. <u>curtiseta</u> were numbers 16 and 17. They were located adjacent to each other in the southwest corner of the NE 1/4 of section 33, township 46, range 11, west of the 4th meridian. This field had not been grazed since 1966[2]. Even prior to 1966, this area was probably only lightly grazed because the nearest permanent water supply was more than 1.5 km distant. This was a large slough north of the highway just west of the town of Kinsella (Figure 2, page 6). The small sloughs closer to stands 16 and 17 would have often been dry during part of the summer, leaving the cattle a long walk through hilly terrain to the location of the two stands. Thus there was unlikely to have been much grazing pressure in this area. What little grazing pressure there was, was likely restricted to the hilltops and south-facing slopes. Wroe (1971) stated that cattle preferred to graze hilltops and south-facing slopes rather than on the east-northeast facing slopes such as stands 16 and 17 were located on. The most probable reason for the low cover of <u>Stipa spartea</u> var. <u>curtiseta</u> on the three sites was the absence of grazing.

---

[1] Personal communication Mr. R. Morris, Canadian National Railways, 1976.
[2] Personal communication A.W. Bailey, 1976.

Moss and Campbell (1947) and Johnston (1961) referred to the increase in cover of Festuca scabrella in ungrazed areas to the extent of almost excluding other species of plants.

The Stipa-Festuca community of this study and that of Wroe (1971) were similar to the transition zone between the fescue prairie and the mixed prairie described by Coupland and Brayshaw (1953). Although vegetationally equivalent to Wroe's Stipa-Festuca community, stands of the Stipa-Festuca community found in this study occupied different topographic positions than the stands of this community located by Wroe (1971). In this study the stands were found on upper slope positions on south- and west-facing slopes in areas where Wroe found stands of a Stipa-Artemisia community. Wroe found the stands of the Stipa-Festuca community on somewhat lower slope positions below stands of the Stipa-Artemisia community.

The most likely reason for the absence of any community comparable to Wroe's Stipa-Artemisia community was the fact that the stands included in this study were located in areas showing no recent disturbance from grazing. Wroe attributed the species composition of the Stipa-Artemisia community to past grazing and noted that Artemisia frigida had a much lower cover in ungrazed areas than it had in grazed areas. Additional support for the contention that little or no grazing was the reason for the lack of a community similar to Wroe's Stipa-Artemisia community comes from Bailey (1968). In a study of the plant communities on the University of Alberta Ranch, Bailey found a plant community which he named the *Stipa*-*Bouteloua* community. It was similar to the *Stipa*-*Artemisia* community of Wroe (1971). This community was found in grazed fields on the middle and upper slope positions on southerly facing slopes and on some steep east-facing slopes as well.

The *Stipa*-*Agropyron* community, represented here by two small stands, has not been previously described for this area. This community was more like the *Stipa*-*Agropyron* faciation of the mixed prairie as described by Coupland (1961) than the *Agropyron*-*Stipa* association of the Peace River prairie as described by Moss (1955). The *Stipa*-*Agropyron* community was considered different from the *Stipa*-*Artemisia* community described by Wroe (1972) because of the low cover of *Artemisia frigida* and the lack of *Festuca scabrella*. The absence of *F. scabrella* from stands of this community was unusual because it was one of the dominant species in the surrounding grassland.

The lack of *F. scabrella* from stands of the *Stipa*-*Agropyron* community was thought to be due to an interaction between past grazing and edaphic or microclimatic factors. The two stands of this community were both located on section 28, township 47, range 11, west of the 4th meridian. This section had been heavily grazed from about 1916 to the mid 1940's after which it was mowed for hay in alternate years until 1969[1]. The presence of F. scabrella in the grasslands around stands 29 and 33 indicates some edaphic or microclimatic factors had apparently prevented the establishment of F. scabrella in these stands of the Stipa-Agropyron community.

The soil property which seemed to be most related to the distribution of the Symphoricarpos occidentalis stands was soil moisture. This agrees with Ayyad and Dix (1964) who found soil moisture, along with soil temperature, to be the most important factors controlling the distribution of grassland vegetation in Saskatchewan. They did not include S. occidentalis in their study. Pelton (1953) indicated soil moisture may be important in affecting the distribution of S. occidentalis when he stated that in the moister part of its geographical range S. occidentalis was found on the drier soils while in the drier parts of its range it was found on the moister soils.

The relationship between S. occidentalis stands and soil moisture presented a problem since S. occidentalis was associated with soils having lower soil moisture than grassland soils in 1970. In 1971 the reverse was true. S. occidentalis was in general associated with soils having higher soil moisture than the grassland soils.

The probable reason for this difference may be seen

[1] Personal communication Miss Helen Westbrook, July 1976.

in a comparison of the daily soil moisture balance, calculated using the method of Thornthwaite and Mather (1957), for the month and a half prior to sampling for soil moisture determination for both years (Appendix 7). The water balance calculations for June of both years showed a slight decrease in soil moisture storage. During the first half of July 1970 the calculated soil moisture storage continued to decrease. However, during the first half of July 1971 the calculated soil moisture storage increased indicating an excess of precipitation over the amount of water the plants could have been expected to use. Thus it is possible that the _Symphoricarpos_ stands tended to occupy soils where more soil moisture was available. This was indicated by the presence of the _Symphoricarpos_ stands on soils with greater soil moisture during a time when soil moisture was apparently being recharged. In order to explain the soil moisture situation in 1970 one has to assume that, during periods when the vegetation was apparently depleting soil moisture, the _Symphoricarpos_ stands used more water than did the grassland.

There is some evidence that the _Symphoricarpos_ stands could be expected to use more soil moisture than the grasslands since they form a taller canopy than the grasslands. Stanhill (1965) showed that in an alfalfa crop the energy available for transpiration increased with crop height. Rutter (1970) stated that the amount of air turbulence caused by vegetation, when there was a wind blowing, was related to plant height in such a way that increasing plant height would cause increasing air turbulence. Air turbulence may cause increased evapotranspiration by continually bringing drier air in contact with the vegetation. Rutter (1968) in a review of the literature on evapotranspiration rates, noted that the ratio of evapotranspiration of grassland to forest apparently fell between 0.8 and 1.0 when the water supply was not limiting and that the greatest difference in evapotranspiration between grasslands and forests was when the soil moisture deficit was severe. Thus it seems that the Symphoricarpos stands have tended to develop on soils with a somewhat better soil moisture regime than the grasslands.

/ The apparent lack of differences of the major soil nutrients between the Symphoricarpos-stand soils and the grassland soils supports the contention of Pelton (1953) that soil fertility had no direct effect on the distribution of S. occidentalis. Although the trend to higher levels of potassium in soils under the Symphoricarpos stands was not statistically significant, it was present in the data for both years.

Scheffler (1976) found soil potassium levels were related to slope position, with the highest levels being found in the lower slope positions and lowest levels in the upper slope positions. Aspect was apparently not related to potassium levels in her study. Scheffler attributed the distribution of potassium to one of two possible reasons: downslope leaching by water movement, or to increased potassium release by leaf fall in the plant communities on the lower slope positions.

If the difference in potassium levels found between the *Symphoricarpos* stand soils and the grassland soils was real, then the probable reason for higher levels in the *Symphoricarpos* stand soils was increased deposition by leaf fall. Potassium is easily leached from the soil (Buckman and Brady, 1969) and the *Symphoricarpos* stands tended to be found on areas where soil leaching was greater than the average for the grassland soils as shown by the greater depth to lime in soils under *Symphoricarpos* stands than under the grassland stands. Direct measurement of potassium release by leaf fall is needed to confirm or reject the hypothesis that the *Symphoricarpos* community released more potassium than the *Festuca*-*Stipa* community. The south- and west-facing upper slopes were probably the only slope positions too dry for *Symphoricarpos* stands. This appears to be the case in the central aspen parkland used in this study and at the southern fringe of the parkland studied by Wroe (1972). The large amount of overlap between the amount of soil moisture found in *Symphoricarpos* stand soils and fescue grassland soils indicated that there may still be a great deal of potential for continued invasion of the fescue grassland by *Symphoricarpos occidentalis*. This overlap also suggested that some factor other than soil moisture was at least partly responsible for the present distribution of *S. occidentalis*.

The most likely factor would have been the actions of small mammal's creating bare areas to facilitate shrub establishment.

BIBLIOGRAPHY

Anderson, M.L., 1972. The effect of fire on grasslands in the Alberta aspen parkland. M.Sc. Thesis, Department of Plant Science, The University of Alberta.

Ayyad, M.G.A., and R.L. Dix, 1964. An analysis of a vegetation - microenvironmental complex on prairie slopes in Saskatchewan. Ecological Monographs, 34(4): 421-442.

Bailey, A.W., 1968. Unpublished data.

__________ 1970. Barrier effect of the shrub _Elaeagnus commutata_ on grazing cattle and forage production in central Alberta. Journal of Range Management, 23(4): 248-251.

Bird, R.D., 1930. Biotic communities of the aspen parkland of central Canada. Ecology, 11: 356-442.

__________ 1961. Ecology of the Aspen Parkland of Western Canada in Relation to Land Use. Research Branch, Canada Department of Agriculture, Ottawa, Publication no. 1066.

Bird, C.D. and R.D. Bird, 1967. The Aspen Parkland: in Alberta a Natural History. W.G. Hardy Ed., Published by the Patrons and Sponsors, distributed by M.G. Hurtig Publishers, Edmonton, PP. 135-149.

Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analyses of soils. Agronomy Journal 54: 464-465.

Buckman, H.O. and N.C. Brady, 1969. The nature and properties of soils. Seventh edition. Collier-Macmillan Canada, Ltd., Toronto, Ontario.

Canada Department of Agriculture, 1974. The System of Soil Classification for Canada. Queens Printer, Ottawa.

Carmichael, J.W. and P.H.A. Sneath, 1969. Taxometric maps. Systematic Zoology, 18: 402-415.

Carmichael, J.W., J.A. George and R.S. Julius, 1968. Finding natural clusters. Systematic Zoology, 17: 144-150.

Cla[illegible] S.E., J.A. Campbell and J.B. Campbell, 1942. An Ecological and Grazing Capacity Study of the Native Grass Pastures in Southern Alberta. Canada Department of Agriculture, Technical Bulletin, no. 44.

Coupland, R.T., 1961. A reconsideration of grassland classification in the northern great plains of North America. Journal of Ecology, 49: 135-167.

________ and C. [illegible]shaw, 1953. The fescue grassland in Saskatchewan. Ecology, 34: 386-405.

Daubenmire, R., 1959. A canopy coverage method of vegetation analysis. Northwest Science, 33: 43-64.

Environment Canada, 1966-74. Atmospheric Environment Service. Monthly Record of Meteorlogical Observation in Canada, Ottawa.

Hinde, Henry Youle, 1860. Narrative of the Canadian Red River Exploring Expedition of 1857 and of the Assiniboine and Saskatchewan Exploring Expedition of 1858. M.G. Hurtig, Edmonton, 1971 reprint. Vol. 1, p. 105.

Hird, S., 1957. Variation in Grassland in Relation to Slope Aspect in Central Saskatchewan. M.Sc. Thesis, Department of Plant Ecology, University of Saskatchewan.

Johnston, A., 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Canadian Journal of Plant Science, 41: 615-622.

Longley, R.W., 1967. Climate and weather patterns: in Alberta: a Natural History. W.G. Hardy Ed. Published by the Patrons and Sponsors, distributed by M.G. Hurtig Publishers Edmonton.

Macoun, John, 1882. Manitoba and the Great North-west. World Publishing Co. Guelph, Ontario. p. 246.

Moss, E.H., 1932. The vegetation of Alberta IV: The poplar association and related vegetation of central Alberta. Journal of Ecology, 20: 380-415.

________ 1944. The prairie and associated vegetation of southwestern Alberta. Canadian Journal of Research, 22: Section C, 11-31.

__________ 1955. The vegetation of Alberta. Botanical Review, 21(9): 493-567.

__________ 1959. The Flora of Alberta. University of Toronto Press, Toronto.

__________ and J.A. Campbell, 1947. The fescue grassland of Alberta. Canadian Journal of Research, 25: Section C, 209-227.

Orloci, L., 1966. Geometric models in ecology. I. The theory and application of some ordination methods. Journal of Ecology, 54: 193-215.

Pelton, J., 1953. Studies on the life-history of Symphoricarpos occidentalis Hook, in Minnesota, Ecological Monographs, 23(1): 17-39.

Pinchbeck, B.R., 1972. Ordinational classification and statistical analysis of landscape vegetation. M.Sc. Thesis, Department of Plant Science, The University of Alberta.

Purchase, J.E., 1970. EUCLID and SDWORD. Plant Ecology Laboratory, Department of Botany, The University of Alberta, unpublished computer programs.

Rutter, A.J., 1968. Water consumption by forests. In Water deficits and plant growth. Vol. II Plant water consumption and response. Edited by T.T. Kozlowski, Academic Press, New York and London. pp 23-84.

__________ 1970. Interactions of environment and crop in the water balance of tree crops. In Physiology of tree crops. Proceedings of the second Long Ashton Symposium 1969. Edited by L.C. Luckwill and C.V. Cutting, Academic Press, New York and London. pp 181-192.

Scheffler, E.J., 1976. Aspen forest vegetation in a portion of the east central Alberta parklands. M.Sc. Thesis, Department of Plant Science, The University of Alberta.

Smillie, K.W., 1967. Statpack I. Department of Computing Science, The University of Alberta, Edmonton.

Smoliak, S., A. Johnston, R.A. Wroe and M.G. Turnbull, 1974. Alberta Range Pastures. Alberta Department of Agriculture and the Alberta Department of Lands and Forests, Agdex 134-14.

Snedecor, G.W., and W.G. Cochrane, 1967. Statistical Methods. 6th ed. Iowa State University Press, Ames, Iowa. p. 58.

Soper, J.D., 1964. The Mammals of Alberta. The Hamly Press Ltd., Edmonton.

Stanhill, G., 1965. The concept of potential evapotranspiration in arid zone agriculture. In Arid zone research XXV Methodology of plant eco-physiology. Proceedings of the Montpellier Symposium UNESCO. pp.109-117.

Stewart, O.C., 1956. Fire as the first great force employed by man. In Man's Role in Changing the Face of the Earth. Edited by W.L. Thomas Jr. University of Chicago Press, Chicago, pp. 115-133.

Swan, J.M.A., R.L. Dix and C.F. Wehrhahn, 1969. An ordination technique based on the best possible stand-defined axes and its application to vegetation analysis. Ecology, 50: 206-212.

Thornthwaite, C.W., and J.R. Mather, 1957. Instructions and tables for computing potential evapotranspiration and the water balance. Drexel Institute of Technology, Publications in Climatology, Vol. 10 No. 3 Centerton, New Jersey.

Wonders, W.C., 1969. Atlas of Alberta. The Government of Alberta and the University of Alberta, Edmonton.

Wroe, R.A., 1971. Synecology of a Festuca scabrella Torr. grassland. M.Sc. Thesis, Department of Plant Science, The University of Alberta.

Wyatt, F.A., J.D. Newton, W.E. Bowser, W. Odynsky and J.A. Allan, 1944. Soil Survey of Wainwright and Vermillion Sheets. Department of Extension, University of Alberta, Edmonton.

Appendix 1.

Canopy cover class of plant species in the 33 stands of vegetation included in the reconnaissance synecology study.

A list of the species and the abbreviations used in the following association table.

Hackelia americana	Hac am
Senecio eremophilus	Seo er
Rubus strigosus	Rub st
Rosa spp.[1]	Ros
Symphoricarpos occidentalis	Sys oc
Vicia americana	Vic am
Fragaria virginiana var. *glauca*	Frg gl
Lactuca pulchella	Lac pu
Elaeagnus commutata	Elg co
Erigeron glabellus	Erg gl
Cirsium undulatum	Cim un
Hieracium undulatum	Him un
Populus tremuloides	Pop tr
Agrostis scabra	Ags sc
Hedysarum alpinum var. *americanum*	Hey al
Campanula rotundifolia	Can ro
Galium boreale	Gam bo
Taraxacum officinale	Tar of
Artemisia ludoviciana var. *gnaphalodes*	Art lu
Aster laveis var. *geyri*	Asr la
Gentianella amarella	Gel am
Achillea millefolium	Ach mi
Geum triflorum	Geu tr
Solidago missouriensis	Sog mi
Festuca scabrella	Fes sc
Cerastium arvense	Cem ar
Heuchera richardsonii	Heu ri
Rosa arkansana	Ros ar
Sisyrinchium montanum	Siy mo
Stipa spartea var. *curtiseta*	Sti sp
Astragalus agrestis	Ass ag
Thermopsis rhombifolia	The rh
Aster pansus	Asr pa
Amelanchier alnifolia	Ame al
Artemisia frigida	Art fr
Anemone patens var. *wolfgangiana*	Ane pa
Solidago lepida	Soo le
Gaillardia aristata	Gai ar
Helictotrichon hookeri	Het ho
Allium textile	All te
Erigeron pumilus	Erg pu
Shepherdia canadensis	She ca
Comandra pallida	Com pa
Astragalus flexuosus	Ass fl

[1] Includes *Rosa acicularis* and *R. woodsii*.

Appendix 1. Continued.

<u>Linum lewisii</u>	Lnm le
<u>Chrysopsis villosa</u>	Chy vi
<u>Agropyron smithii</u>[1]	Agn sm
<u>Muhlenbergia cuspidata</u>	Muh cu
<u>Petalostemon purpuraeum</u>	Pem pu
<u>Gaura coccinea</u>	Gar co
<u>Koeleria cristata</u>	Kol cr
<u>Lygodesmia juncea</u>	Lyg ju
<u>Bouteloua gracilis</u>	Bou gr

[1] May also include some <u>Agropyron dasystachyum</u>.

Appendix 1. Continued.

Stand	13	14	12	18	28	19	27	24	23	22	17	5	9
Hac am	2	1	2										
Seo er	1	2	2										
Rub st	1	1	1	3									
Ros		1		3	2	2							
Sys oc	7	7	6	7	7	7	5	4	6	6			
Vic am		1	3		1								
Prg vi		2			1					1			
Bac pu									2	1			
Elg co	5	5	1	3		5		1	3		6	6	5
Erg gl								1			1	1	
Cim un	1			1								1	
Him ca								1					
Pop tr								1	2				1
Ags sc		1		1									3
Hey al					1								
Cam ro							1	1		1	2	2	1
Gam bo		1			1	1	3					1	2
Tar of	1			1			1				1	1	1
Art lu					1		1	3	3	2	2	1	
Asr la								2	1	1	1	1	
Gel [illegible]							2				1	1	1
[illegible]							1	2	2	2	2	1	1
[illegible]							1	1	1			1	1
[illegible]							1	2	1	1	1	1	2
B[illegible]					1	4	7	7	7	7	7	7	7
Ce[illegible] ar										1		1	1
Heu ri							1				1	1	1
Ros ar							1	1	1	1	3	2	1
Siy mo										1			1
Sti sp							3	3	5	6	3	6	6
Ass ag								2		2		1	2
The rh						1					1	1	2
Asr pa							1		1		1	2	1
Ame al												1	
Art fr							1					1	1
Ane pa									1			1	1
Soo le													
Gai ar													1
Het ho													1
All te													
Erg pu													
She ca													
Com pa													
Ass fl													
Lnm le													
Chy vi													
Agn sm													
Muh cu													
Pem pu													
Gar co													
Kol cr													
Lyg ju													
Bou gr													

Appendix 1. Continued.

[illegible]	10	21	25	20	16	26	11	4	2	3	1	8	6
Hac am													
Seo er													
Rub st													
Ros													
Sys oc							1						
Vic am								1					
Frg vi	1												
Lac pu					1								
Elc co	5	5	4	4			1	1			1		
Erg gl	1		1	1									
Cim un					1				1	1			
Him ca			1		1								
Pop tr			1		1		1						
Ags sc													3
Hey al								1	1				
Can rb	1	1			1	1		2	1	1	1		1
Gal bo	2		1			2	3		2	3	1	2	3
Tar of	1		1	1	1			1	1	1			1
Art lu	2				1	2		1	1		1		
Asr la	1	1	1	1	2			1	1	1			1
Gel am	1			1		1		1	1	1	1	1	
Ach mi	2	2	2	1	1	1	1	2	2	1	2	1	1
Geu tr		1	2	1		1		1	1	1	1	1	3
Soo mi	1	2	1	2		[illegible]		2	1	1	2		
Fes sc	7	6	7	6	7	7	7	7	7	7	7	7	6
Cem ar								1		1	1		1
Heu ri									1	1		1	1
Ros ar	1	3	3	1	3	2	1	1	2	3	2	2	
Siy mo								1					1
Sti sp	6	6	6	6	4	3	6	6	6	6	6	6	6
Ass ag		1	2	1	1	1	2	1	2	2		1	
The rh	2	1	1	2	3	1	1	2	2	2	2	2	
Asr pa	1	1			1		1	1		1	2	1	2
Ame al	1							1				1	1
Art fr	1	3		2		1	1	1		1	1	1	1
Ane pa		1		1			1		1	1	1	1	
Soo le					1						1		
Gai ar					1							1	
Het ho	1									1	1		1
All te						1	1					1	1
Erg pu									1		1		1
She ca								1		1		1	1
Com pa	1	1		2							1		1
Ass fl			1										
Lnm le											1	1	
Chy vi		1											
Agn sm				2									
Muh cu												2	3
Pem pu													
Gar co													
Kol cr													
Lyg ju													
Bou gr													

Appendix 1. Continued.

Stand	7	32	34	31	30	33	29
Hac am							
Seo er							
Rub st							
Ros							
Sys oc							
Vic am							
Frg gl	1						
Lac pu							
Elg co			1				
Erg gl							
Cim un							
Him ca							
Pop tr							
Ags sc	2						
Hey al							
Can ro							
Gam bo	1						
Tar of	1						1
Art lu	1	1				1	
Asr la	1	1					
Gel am							1
Ach mi	1						
Geu tr	2						
Soo mi		1	1	1	1		
Fes sc	6	6	4	4	4		
Cem ar							
Heb ri	1						
Ros ar	1	3	1	1	2		1
Siy mo	1						
Sti sp	6	6	7	7	7	7	6
Ass ag	1	2		2	2		2
The rh	2	1	1	1	1		1
Asr pa	1	1	3	2	3	1	
Ame al	1				1		
Art fr	2	1	2	2	2	2	2
Ane pa	1	1	1		1	1	3
Soo le	1						
Gai ar			1	1			
Het ho		1	1	2			
All te	1						
Erg pu							
She ca	1						
Com pa	1	1		1	1		1
Ass fl		1				1	
Lnm le	3			1			
Ghy ve		1	1	1	2		
Agn sm						4	6
Muh cu	3			2	2	3	3
Pem pu			2	2	1		
Gar co			2	2	1		
Kol cr		1	1	2	3	2	2
Lyg ju			1	1	1		1
Bou gr			3	3	3	4	3

Appendix 2.

Average cover (%) and frequency (%) of species in the four plant communities of the *Symphoricarpos* study.

Species	Sys	Sys/Fes	Fes-[illegible] I	Fes-[illegible] II	Sti-Fes
Salix spp.	1/14				
Polygonum convolvulus	1/14				
Geum (aleppicum or macrophyllum)	1/14				
Viola spp.	p/3 [1]				
Phleum pratense	p/3				
Epilobium angustifolium	2/11				
Lappula redowskii	1/14				
Smilacina	1/17				
Prunus virginiana	p/8	p/6			
Thalictrum venulosum	p/6	p/6			
Aster hesperius	p/3	p/6			
Calamagrostis inexpansa	8/47	5/11			
Muhlenbergia richardsonis	1/6	1/6			
Carex spp. (tall)	9/31	p/6			
Unidentified forb #4		p/6			
Cirsium foodmanii		p/6			
Bromus inermis		2/6			
Monarda fistulosa var. menthaefolia		[illegible]			
Rubus strigosus	5/64	2[illegible]	p/3		
Poa pratensis	1/19	8[illegible]2	2/15		
Amelanchier alnifolia	p/3	1/[illegible]1	p/3		
Lactuca pulchella	p/3	1/17	p/3		
Ribes oxyacanthoides	3/8	p/6	1/3		
Hierochloe odorata	1/19		p/8		
Poa spp.	1/8	p/11		1/8	
Sonchus spp.[2]	1/3	p/6		p/3	
Botrychium virginianum	p/6	p/3			
Erysimum chieranthoides		p/6	p/3		
Vicia americana	1/22	1/17	p/8	p/15	
Galium boreale	5/53	14/61	22/67	4/31	
Arnica spp.[3]	p/6	p/6	p/3	p/[illegible]	
Agrostis scabra	1/14	1/17	p/13	p/11	
Campanula rotundifolia	p/6	p/17	p/33	p/23	
Lathyrus venosus var. intensus	1/11	1/17	p/3	p/3	
Taraxacum officinale	p/6	p/23	1/44	p/21	
'Solidago missouriensis'	p/3	p/11	1/38	p/21	

---

[1] p indicates an average cover of less than 1%.
[2] Includes *Sonchus arvensis* and *S. uliginosus*.
[3] Possibly *Arnica fulgens*.

Appendix 2. Continued.

Species	Sys	Sys/Fes	Fes-Sti I	Fes-Sti II	Sti-Fes
Sisyrinchium montanum	p/6	p/6	p/8	p/11	
Artemisia ludoviciana var. gnaphalodes	p/11	3/56	1/33	1/31	
Solidago lepida	p/3	p/6	p/10	p/23	
Stellaria longipes	p/8			p/3	
Heuchera richardsonii	p/6		p/5	p/5	
Stipa viridula	1/3	p/11	p/3		3/17
Haplopappus spinulosus			p/5		
Muhlenbergia cuspidata			p/8		
Lathyrus ochroleucus		p/6	p/3	p/5	
Symphoricarpos occidentalis	93/100	45/100	8/36	1/18	7/33
Rosa (acicularis and woodsii)	12/69	1/33	p/15	p/11	p/11
Elaeagnus commutata	14/56	1/17	1/26	2/30	1/17
Festuca scabrella	6/36	78/100	89/100	93/100	15/56
Achillea millefolium	p/17	2/78	1/74	2/74	p/6
Aster laevis var. geyri	1/17	p/11	1/11	[illegible]	p/6
Astragalus agrestis	p/6	1/17	1/31	[illegible]	p/33
Cerastium arvense	p/6	p/33	p/33	[illegible]	p/22
Erigeron canadensis	p/3	p/28	p/36	[illegible]	p/6
Carex spp. (short)	17/72	30/100	36/100	[illegible]	49/100
Agropyron spp.[1]	5/67	[illegible]	14/95	[illegible]	[illegible]/89
Stipa spartea var. curtiseta	p/11	7/67	35/100	81/[illegible]	[illegible]/100
Helictotrichon hookeri	p/6		1/51	2/72	7/61
Artemisia frigida	p/3		p/13	p/13	3/89
Potentilla hippiana	p/3		p/5	p/5	p/6
Hedysarum alpinum var. americanum			p/5	p/5	
Unidentified forb #1			p/5	p/5	
Danthonia intermedia			p/5	p/5	
Antennaria spp.			p/5	p/18	
Erysimum inconspicuum			p/8	p/3	
Gaillardia aristata			p/5	p/3	
Bromus anomalus			p/3	p/5	
Agoseris glauca			p/5	[illegible]/3	
Potentilla spp.			p/3	[illegible]/8	
Geum triflorum		p/17	3/44	4/51	p/6
Astragalus striatus		1/22	1/18	1/33	p/11
Aster pansus		p/11	p/18	2/28	2/29
Commandra pallida		1/22	2/62	1/67	4/83
Rosa arkansana		p/22	1/36	3/69	p/17

[1] Includes *Agropyron dasystachyum*, *A. trachycaulum* and *A. subsecundum*.

Appendix 2. Continued.

Species	Sys	Sys/Fes	Fes-Sti I	Fes-Sti II	Sti-Fes
Anemone spp.[1]		1/22	2/44	4/69	8/78
Thermopsis rhombifolia		p/17	3/67	1.41	2/28
Astragalus flexuosus				p/3	
Unidentified forb #2				1/5	
Hieracium umbellatum				p/3	
Androsace septentrionalis			p/3	p/5	p/17
Calamagrostis montanensis			p/10	p/3	1/17
Koeleria cristata			p/5	p/5	1/44
Potentilla gracilis			1/3		p/11
Spheralcea coccinea			p/3		p/11
Festuca saximontana				p/3	p/6
Stipa comata				p/3	p/17
Chrysopsis villosa				p/8	p/11
Bouteloua gracilis				p/3	6/67
Oxytropis (campestris or serecia)				p/5	p/6
Unidentified forb #3					p/6
Lygodesmia juncea					p/6

[1] Probably mainly *Anemone patens* var. *wolfgangiana* along with some *A. multifida*.

Appendix 3.

Community membership, aspect, slope (%), horizon depth (cm) and soil moisture (%) of each of the plots included in the Symphoricarpos occidentalis study.

Plot #		Community	Slope Aspect	(%)	Horizon Depth (cm) Ah	B	Lime[1]	Soil Moisture (%) A	B	C
4-1	*[2]	Sys[3]		0	6	31	50	17	12	10
4-2		Sys/Fes		0	8	30	49	26	16	11
4-3		Sys/Fes	NE	5	3	24	46			
4-4		Fes-Sti I	NE	5	9	20	52	25	13	10
4-5		Fes-Sti I	NE	5	7	11	46	23	17	9
4-6		Fes-Sti I	NE	5	6	9	32	28	17	18
4-7		Fes-Sti [illegible]	NE	5	7	10	31	27	22	18
4-8	*	Fes-Sti II	NE	5	6	11	40	21	12	11
13-1		Sys	SW	12	15	50	>100	15	9	9
13-2		Fes-Sti I	SW	18	9	49	>90	14	8	11
13-3		Fes-Sti I	SW	15	10	46	>70	16	14	12
13-4		Fes-Sti I	SW	15	7	52	>70	11	14	10
13-5		Fes-Sti II	SW	15	11	21	>70	15	12	9
13-6	*	Fes-Sti I	SW	15	9	16	63	15	12	10
13-7		Fes-Sti II	SW	15	6	13	44	13	10	11
13-8		Fes-Sti II	SW	15	8	18	63	8	10	14
22-1		Sys/Fes	N	9	9	32	72	15	11	11
22-2		Fes-Sti II	N	9	6	23	70	18	12	11
22-3	*	Fes-Sti II	N	9	6	20	64	16	10	10
22-4		Fes-Sti I	N	9	10	19	74	14	10	9
22-5		Fes-Sti I	N	6	8	19	>100	17	9	8
22-6		Fes-Sti I	NE	2	6	19	>90	17	14	10
22-7		Fes-Sti II	NE	11	7	24	44	22	14	10
[illegible]		Fes-Sti II	NE	13	7	20	68	16	14	10
[illegible]		Fes-Sti II	NE	15	9	18	>90	21	10	9
[illegible]	*	Fes-Sti II	NE	17	12	18	48	18	10	9
[illegible]		Fes-Sti II	NE	19	6	20	40	20	12	10

---

[1] Ah indicates the depth of the Ah horizon, B indicates the depth to the top of the B horizon and Lime indicates the depth to where lime, as calcium carbonate was accumulating in the profile.

[2] * indicates a plot chosen for soil texture analysis.

[3] The abbreviations for the plant communities are as follows: Sys = the Symphoricarpos community, Sys/Fes = the Symphoricarpos/Festuca community, Fes-Sti I = the Festuca-Stipa (I) community, Fes-Sti II = the Festuca-Stipa (II) community, and Sti-Fes = the Stipa-Festuca community.

Appendix 3. Continued.

Plot #	Community	Aspect	Slope (%)	Horizon Depth (cm) Ah	B	Lime	Soil Moisture (%) A	B	C
22-12	Fes-Sti II	NE	20	7	18	48	17	9	8
39-1	Fes-Sti I	NNE	3	10	10	22	12	12	8
39-2 *	Sti-Fes	NNE	5	9	13	28	13	11	8
39-3	Fes-Sti II	NNE	8	5	8	26	12	12	8
39-4	Fes-Sti I	NNE	9	6	9	25	12	9	7
39-5 *	Fes-Sti II	NNE	9	6	10	29	14	8	9
39-6	Fes-Sti I	NNE	9	6	9	22	15	12	9
50-1	Fes-Sti I	NE	8	10	12	60	27	9	5
50-2 *	Sys/Fes	NE	8	9	14	55	25	12	9
50-3	Fes-Sti II	NE	8	9	15	59	16	11	9
50-4	Fes-Sti II	NE	8	5	14	59	17	10	9
50-5 *	Fes-Sti I	NE	8	7	18	73	23	11	8
50-6	Fes-Sti II	NE	8	7	26	71	17	8	8
64-1	Sys/Fes	SE	6	10	16	42	22	15	15
64-2	Sys/Fes	SE	6	11	18	61	15	10	13
64-3 *	Sys/Fes	SE	6	12	18	53	17	9	13
64-4	Fes-Sti II	SE	6	20	24	88	23	16	9
64-5	Fes-Sti II	SE	4	13	17	62	21	14	9
64-6	Fes-Sti II	SE	1	14	18	58	24	13	8
64-7 *	Fes-Sti II	SE	4	10	14	54	26	13	8
64-8	Fes-Sti II	SE	4	13	18	80	23	14	8
64-9	Fes-Sti II	SE	4	12	14	89	27	18	8
64-10	Fes-Sti II	SE	4	9	12	85	31	20	8
67-1	Sti-Fes	SW	15	20	20	67	12	11	8
67-2 *	Sti-Fes	SW	15	19	26	50	12	12	7
67-3	Sti-Fes	SW	17	20	20	45	9	9	8
67-4	Sti-Fes	SW	19	16	21	34	12	12	9
67-5	Sti-Fes	SW	20	15	20	37	11	10	8
67-6	Sti-Fes	SW	22	10	14	33	12	9	8
67-7 *	Sti-Fes	SW	24	9	12	31	11	10	6
67-8	Sti-Fes	SW	25	8	12	40	14	10	8
16-1	Sys		0	10	30	>110	33	18	19
16-2	Sys	E	7	15	46	>105	34	27	19
16-3	Sys	E	7	19	19	>130	36	36	17
16-4 *	Sys	E	7	14	19	>130	32	23	13
16-5	Sys	E	4	20	22	>110	30	22	16
16-6	Sys/Fes	E	2	25	25	100	24	19	18
16-7	Fes-Sti I	E	1	20	20	>100	27	15	17
16-8	Fes-Sti I	E	1	5	15	>100	30	12	14
16-9 *	Fes-Sti II	E	1	6	20	77	26	12	13
16-10	Fes-Sti I	E	1	6	44	78	24	12	5
16-11	Fes-Sti I	3	1	6	15	80	20	12	9

Appendix 3. Continued.

Plot #	Community	Slope Aspect	(%)	Horizon Depth (cm) Ah	B	Lime	Soil Moisture (%) A	B	C
16-12	Fes-Sti II	E	1	5	20	80	13	15	15
31-1	Sys/Fes	S	4	20	20	69	20	15	18
31-2	Sys/Fes	S	4	7	25	65	18	16	14
31-3	Sys/Fes	S	2	6	19	50	19	20	18
31-4	Sys	S	1	7	26	55	21	14	14
31-5 *	Sys	N	1	7	18	50	43	19	16
31-6	Sys	N	3	6	26	70	22	14	14
31-7	Sys/Fes	N	3	37	37	97	21	16	14
31-8	Sys/Fes	N	2	23	50	74	22	13	12
31-9	Fes-Sti I		0	10	25	58	21	12	14
31-10 *	Fes-Sti II	S	1	11	31	55	23	12	16
31-11	Fes-Sti II	S	2	13	13	40	23	12	19
31-12	Fes-Sti II	S	4	6	15	50	16	10	12
37-1	Sys	N	2	6	23	100	28	21	14
37-2	Sys		0	9	18	95	30	13	13
37-3 *	Sys	S	2	9	20	92	23	14	14
37-4	Sys	S	2	6	20	68	19	13	12
37-5	Sys/Fes	S	2	6	19	75	24	16	12
37-6	Fes-Sti I	S	2	5	12	56	32	15	14
37-7	Fes-Sti II	S	2	6	18	59	19	15	11
37-8	Fes-Sti II	S	2	5	16	55	17	13	8
37-9 *	Fes-Sti II	S	2	5	10	47	18	14	12
37-10	Fes-Sti II	S	2	9	19	47	14	12	9
37-11	Fes-Sti II	S	1	6	10	34	15	10	10
37-12	Fes-Sti II	S	1	6	10	34	19	11	9
45-1	Sys	S	1	6	20	38	12	16	17
45-2 *	Sys	S	1	14	14	45	27	12	16
45-3	Sys	S	1	14	14	50	29	17	23
45-4	Fes-Sti I	S	1	21	21	46	20	13	9
45-5	Fes-Sti I	S	1	17	17	43	15	15	13
45-6	Fes-Sti I	S	1	10	10	33	15	12	10
45-7 *	Fes-Sti I	S	2	5	5	40	12	10	15
45-8	Sti-Fes	S	4	3	3	25	12	13	12
55-1	Sys	SSW	1	8	8	27	23	18	26
55-2	Sys	SSW	1	10	15	28	22	15	18
55-3 *	Sys	SSW	1	10	15	36	21	13	11
55-4	Sys	SSW	1	8	8	30	22	17	18
55-5	Sys	SSW	2	8	14	33	23	18	18
55-6	Fes-Sti I	SSW	4	11	15	29	14	13	10
55-7	Sti-Fes	SSW	7	7	10	24	13	9	10
55-8	Fes-Sti I	SSW	12	4	6	27	13	10	9
55-9	Fes-Sti II	SSW	16	8	11	28	12	9	11
55-10 *	Fes-Sti II	SSW	19	9	13	27	17	10	13

Appendix 3. Continued.

Plot #	Community	Slope Aspect	(%)	Horizon Depth (cm) Ah	B	Lime	Soil Moisture (%) A	B	C
55-11	Sti-Pes	SSW	20	8	12	31	16	13	13
55-12	Pes-Sti II	SSW	20	7	12	26	27	16	17
78-1	Sys	0		26	35	105	40	24	17
78-2	Sys	0		8	17	105	34	18	17
78-3	Sys	S	13	8	12	88	34	17	18
78-4 *	Sys	S	11	10	15	69	[illegible]	15	13
78-5	Sys	S	11	10	15	62	22	14	12
78-6	Sys	S	11	11	17	64	26	15	15
78-7	Sys/Pes	S	14	12	17	75	24	13	18
78-8	Sys/Pes	S	14	15	20	>100	23	13	18
78-9	Sys/Pes	S	14	14	22	>100	22	13	17
78-10	Sys	S	14	14	21	>100	23	10	13
78-11	Pes-Sti I	S	14	15	18	>100	16	10	10
78-12	Pes-Sti I	S	14	10	15	80	12	7	10
78-13	Pes-Sti I	S	15	8	12	52	10	11	10
78-14	Sti-Pes	S	15	7	12	42	10	11	9
78-15	Sti-Pes	S	14	5	10	32	12	9	9
78-16	Sti-Pes	S	14	5	10	32	13	12	7
78-17	Sti-Pes	S	13	5	8	28	11	10	9
78-18	Sti-Pes	S	10	5	8	28	11	9	6
78-19	Sti-Pes	S	10	5	8	28	13	10	8
78-20 *	Pes-Sti I	S	6	5	10	32	14	10	9
79-1	Sys	ENE	1	20	25	65	15	15	29
79-2	Sys	ENE	1	19	23	65	13	11	22
79-3 *	Sys	ENE	1	16	28	56	11	6	15
79-4	Sys	END	1	10	25	65	16	11	8
79-5	Sys	ENE	1	6	22	60	20	13	22
79-6	Sys	ENE	1	9	29	48	25	9	13
79-7	Sys	ENE	1	10	28	45	19	15	20
79-8	Sys/Pes	ENE	1	14	30	52	16	14	17
79-9	Pes-Sti I	ENE	2	12	35	58	17	14	21
79-10 *	Pes-Sti I	ENE	2	10	41	68	16	8	7
79-11	Pes-Sti I	ENE	2	32	38	>100	19	8	15
79-12	Pes-Sti II	ENE	2	29	32	90	20	10	7
79-13	Pes-Sti I	ENE	4	15	30	64	16	6	8
79-14	Pes-Sti I	ENE	4	20	26	105	17	8	8
79-15	Pes-Sti I	ENE	4	22	29	83	17	8	8
79-16	Pes-Sti I	ENE	4	16	20	59	18	8	12

Appendix 4.

Plots included in each plant community delimited from the cluster-ordination of the Symphoricarpos occidentalis study.

Symphoricarpos community

4-1; 13-1; 16-1, 2, 3, 4, 5; TEXT 4 11 31-4, 5, 6; 37-1, 2, 3, 4; 45-1, 2, 3; 55-1, 2, 3, 4, 5; 78-1, 2, 3, 4, 5, 6, 10; 79-1, 2, 3, 4, 5, 6, 7.

Symphoricarpos/Festuca community

4-2, 3; 16-6; 22-1; 31-1, 2, 3, 7, 8; 37-5; 50-2; 64-1, 2, 3; 78-7, 8, 9; 79-8.

Festuca-Stipa community (I)

4-4, 5, 6, 7; 13-2, 3, 4, 6; 16-7, 8, 10, 11; 22-4, 5, 6; 31-9; 37-6; 39-1, 4, 6; 45-4, 5, 6, 7; 50-1, 5; 55-6, 8; 78-11, 12, 13, 20; 79-9, 10, 11, 13, 14, 15, 16.

Festuca-Stipa community (II)

4-8; 13-5, 7, 8; 16-9, 12; 22-2, 3, 7, 8, [illegible], 10, 11, 12; 31-10, 11, 12; 37-7, 8, 9, 10, 11, 12; 39-3, 5; 50-3, 4, 6; 55-9, 10, 12; 64-4, 5, 6, 7, 8, 9, 10; 79-12.

Stipa-Festuca community

39-2; 45-8; 55-7, 11; 67-1, 2, 3, 4, 5, 6, 7, 8; 78-14, 15, 16, 17, 18, 19.

Appendix 5.

Plots included in each cluster of the cluster-ordination of the 150 plots used in the *Symphoricarpos occidentalis* study.

CLUSTER	PLOTS
1.	4-1; 16-3, 4, 5; 31-4, 5, 6; 37-1, 2, 4; 55-1, 2, 3, 4, 5; 78-1, 2; 79-1, 5, 6.
2.	4-4, 5, 7, 8; 16-10, 11, 12; 22-7, 8, 9, 11, 12; 31-10, 11, 12; 37-6, 7, 8, 9, 10, 11, 12; 50-3, 4, 6; 55-9, 10, 12; 64-4, 5, 6, 7, 8, 9, 10; 79-9.
3.	4-2; 31-8; 50-2; 64-1, 3; 79-8.
4.	55-11; 67-1, 2, 5, 6, 7, 8; 78-14, 15, 16, 17, 18, 19.
5.	13-3; 22-4, 5; 31-9; 78-13.
6.	79-10, 11.
7.	13-4, 7.
8.	78-12; 79-14, 15, 16.
9.	13-2, 6; 45-6; 78-11.
10.	16-7, 9; 22-3.
11.	39-2; 45-8; 55-7.
12.	4-3; 31-2, 3.
13.	13-5, 8.
14.	78-3, 5.
15.	39-1; 50-1; 55-6; 78-20.
16.	79-12, 13.
17.	22-6; 55-8.
18.	79-4, 7.
19.	37-3; 78-4.
20.	78-7, 9.
21.	31-7; 78-8.
22.	39-4; 45-7.
23.	16-8; 50-5.
24.	4-6.
25.	13-1.
26.	22-1.
27.	22-2.
28.	22-10.
29.	64-2.
30.	67-3.
31.	67-4.
32.	16-1.
33.	16-2.
34.	16-6.
35.	31-1.
36.	37-5.
37.	45-1.
38.	45-2.
39.	45-3.
40.	45-4.
41.	45-5.
42.	78-6.
43.	78-10.
44.	79-2.
45.	79-3.

Appendix 6.

Plots included in each cluster of the cluster-ordination of the *Festuca-Stipa* community in the *Symphoricarpos occidentalis* study.[1]

CLUSTER	PLOTS
1.	4-8; 22-7, 8, 9, 12; 31-10, 11; 37-8, 9, 10, 11, 12; 39-5; 50-3, 4, 6; 55-9, 10, 12; 64-4, 5, 6, 7, 8, 9, 10.
2.	4-4, 5, 7; 16-10; 37-6; 39-6; 79-9.
3.	16-12; 39-3.
4.	22-11; 31-12.
5.	13-3; 22-4, 5; 31-9; 78-13.
6.	79-10, 11.
7.	13-4, 7.
8.	16-7, 8, 11.
9.	79-14, 16.
10.	13-2; 78-11.
11.	22-3, 10; 37-7.
12.	78-12.
13.	79-15.
14.	79-12.
15.	79-13.
16.	39-1.
17.	78-20.
18.	55-6.
19.	50-1.
20.	45-6.
21.	13-6.
22.	4-6.
23.	22-6.
24.	55-8.
25.	50-5.
26.	16-9.
27.	13-5.
28.	13-8.
29.	39-4.
30.	45-7.
31.	39-2.
32.	45-8.
33.	55-7.
34.	22-2.

[1] After this cluster-ordination was done, plot numbers 39-2, 45-8 and 55-7 were moved from the *Festuca-Stipa* to the *Stipa-Festuca* community. Plot numbers 45-4 and 45-5 were moved from the *Stipa-Festuca* to the *Festuca-Stipa* community. This resulted in the 78 plots in the *Festuca-Stipa* community as listed in Appendix 4.

Appendix 7.

Daily water balance (June 1 to July 15, 1970 and June 1 to July 16, 1971) calculated using the method of Thornthwaite and Mather (1957).

June 1970	T°C	PET[1]	Ppct[2]	S M St[3]
1	18.6	4		127
2	21.1	5		124
3	22.8	5		120
4	24.4	6		117
5	16.1	4		115
6	19.7	5		112
7	22.5	5		109
8	17.2	4		107
9	13.3	3	1	106
10	14.7	4		104
11	13.9	3		102
12	15	4		100
13	17.5	4	4	100
14	19.7	5	13	108
15	15.8	4	40	144
16	15	4	1	142
17	13.9	3		140
18	17.2	4	1	138
19	15.8	4		135
20	18.6	5		131
21	21.7	5		128
22	17.8	4		125
23	17.8	4		123
24	18.9	5		120
25	17.8	4	1	118
26	19.4	5		115
27	19.7	5	3	114
28	14.2	4	2	113
29	14.4	4	5	114
30	13.9	3	11	122

[1] Potential evapotranspiration in millimeters of water.
[2] Precipitation in millimeters of water.
[3] Soil moisture storage in millimeters of water assuming a field capacity storage of 200 mm of water. Starting point for soil moisture storage was the monthly water balance calculated for the end of May, 1970.

Appendix 7, continued.

July 1970	T°C	PET	Ppct	S M St
1	12.2	3	9	128
2	14.2	4		126
3	16.9	4		124
4	21.4	5		120
5	19.7	5	1	118
6	18.9	4	1	116
7	20.3	5		113
8	18.9	4		110
9	19.4	5	17	122
10	18.3	4		119
11	18.6	4	7	121
12	16.1	4	1	119
13	16.1	4		117
14	18.1	4		115
15	20.0	5		112

Appendix 7, continued.

June 1971	T°C	PET	Ppct	S M St[1]
1	13.6	3		85
2	16.1	4		84
3	18.1	4		82
4	19.4	5		80
5	13.1	3	13	90
6	9.7	2	7	95
7	11.9	3		94
8	11.9	3	1	93
9	10.8	3		91
10	14.4	3	1	90
11	15.8	4		88
12	16.7	4		87
13	16.9	4		85
14	14.4	3	4	86
15	11.4	3	6	89
16	10.6	3	3	89
17	13.6	3		88
18	13.6	3		87
19	14.4	3		86
20	15.8	4		84
21	18.6	4		82
22	20.0	5		80
23	10.6	3	15	92
24	12.2	3		90
25	15.6	4		88
26	14.2	3		87
27	11.4	3		86
28	11.9	3		85
29	13.3	3		83
30	13.9	3	6	86

[1] Starting point for soil moisture storage was the monthly water balance ccalculated for the end of May, 1971.

Appendix 7, continued.

July 1971	T°C	PET	Ppct	S M St
1	16.7	4		84
2	11.7	3	8	89
3	10.3	3	9	95
4	14.7	4		93
5	14.4	3	5	95
6	12.8	3	3	95
7	13.1	3		94
8	12.2	3	4	95
9	12.2	3	3	95
10	12.2	3	13	105
11	12.5	3	5	107
12	14.4	3		105
13	15.3	4	1	104
14	17.5	4		102
15	21.1	5		99
16	20	5		96

Appendix 8.

Frequency distribution (%) of soil subgroups in four plant communities, 1971.

Symphoricarpos community

Orthic Dark Brown Chernozems	3%
Eluviated Dark Brown Chernozems	31%
Orthic Black Chernozems	3%
Eluviated Black Chernozems	64%

Symphoricarpos/*Festuca* community

Eluviated Dark Brown Chernozems	11%
Orthic Black Chernozems	17%
Eluviated Black Chernozems	72%

Festuca-*Stipa* (I) community

Orthic Dark Brown Chernozems	10%
Eluviated Dark Brown Chernozems	38%
Orthic Black Chernozems	5%
Eluviated Black Chernozems	46%

Festuca-*Stipa* (II) community

Orthic Dark Brown Chernozems	3%
Eluviated Dark Brown Chernozems	49%
Eluviated Black Chernozems	49%

Stipa-*Festuca* community

Orthic Dark Brown Chernozems	11%
Eluviated Dark Brown Chernozems	89%