



Effects of prescribed burning on mixed prairie vegetation in southeastern Montana  
by Robert Banks Rennick

A thesis submitted in partial fulfillment of the requirements for the degree of MASTERS OF SCIENCE  
in Range Science

Montana State University

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Abstract:

Controlled burning was applied to approximately 4 ha of mixed prairie on April 6 and 20, 1979 near Colstrip, Montana. The fires burned three plant communities: *Artemisia tridentata*/*Stipa viridula*, *Calamovilfa longifolia*/*Andropogon scoparius*, and *Artemisia cana*/*Stipa viridula*. Vegetation data consisted of canopy cover, frequency, above ground biomass production, phenology, and vigor and vitality estimates. Soil measurements included organic matter, total nitrogen, pH, phosphorus, and electrical conductivity, infiltration rates and soil moisture. Tempilstik's were used to estimate the maximum temperature reached at the mineral soil surface and at a depth of 1 cm.

Results indicated very high surface temperatures ( $>371^{\circ}\text{C}$ ) over a large proportion of the study area. Temperatures at 1 cm did not rise above  $65^{\circ}\text{C}$ . Burning almost completely eliminated big sagebrush.

Silver sagebrush resprouted the first growing season and increased production in the second season. Skunkbush sumac, western snowberry, prairie rose, and winterfat were not permanently damaged and resprouted in the first post-fire growing season. The response of herbaceous species was related to phenology and burning time, fire intensity, post-burning competition for soil moisture, and possible allelopathic effects. Perennial grass and forb production was similar or greater on burned compared to unburned sites. Annual grasses were temporarily reduced by the later fire. Some perennial grass species had extended growing seasons and more flowering culms on burned compared to unburned areas. Chemical properties of the soil were generally unaltered by burning. Soil moisture in the upper 15 cm was unaffected by burning. Infiltration rates may be reduced on burned sites.

Controlled burning in this portion of the semi-arid mixed prairie, under proper conditions of weather, soil moisture, and plant phenology may not adversely affect herbaceous species as a whole. Spring burning should follow winters and/or falls with above-average precipitation. Burning should be accomplished before the active growth of cool-season perennial grasses.

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EFFECTS OF PRESCRIBED BURNING ON MIXED PRAIRIE  
VEGETATION IN SOUTHEASTERN MONTANA

by

Robert Banks Rennick

A thesis submitted in partial fulfillment  
of the requirements for the degree

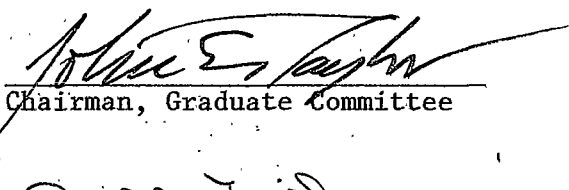
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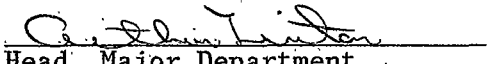
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# TABLE OF CONTENTS

|                                                             | Page |
|-------------------------------------------------------------|------|
| VITA . . . . .                                              | ii   |
| ACKNOWLEDGEMENTS . . . . .                                  | iii  |
| TABLE OF CONTENTS. . . . .                                  | iv   |
| LIST OF TABLES . . . . .                                    | vii  |
| LIST OF FIGURES. . . . .                                    | ix   |
| ABSTRACT . . . . .                                          | xii  |
| INTRODUCTION . . . . .                                      | 1    |
| LITERATURE REVIEW. . . . .                                  | 6    |
| Fire and Soil . . . . .                                     | 6    |
| Characterizing Soil Temperature and Fire Intensity. . . . . | 6    |
| Measuring Soil Temperature . . . . .                        | 6    |
| Visual Characterization of Fire Intensity. . . . .          | 7    |
| Soil Temperature During Rangeland Fires . . . . .           | 7    |
| Effect of Fire on Soil. . . . .                             | 9    |
| Soil Organic Matter (Humus). . . . .                        | 10   |
| Soil Chemistry . . . . .                                    | 12   |
| Litter . . . . .                                            | 16   |
| Infiltration . . . . .                                      | 17   |
| Soil Moisture. . . . .                                      | 18   |
| Temperature. . . . .                                        | 19   |
| Effect of Fire on the Individual Vascular Plant . . . . .   | 19   |
| Phenology. . . . .                                          | 21   |
| Vitality (Flowering Activity). . . . .                      | 22   |
| Vigor. . . . .                                              | 23   |
| Effect of Fire on Plant Communities . . . . .               | 25   |
| Species Composition. . . . .                                | 25   |
| Production . . . . .                                        | 27   |

|                                                                          |    |
|--------------------------------------------------------------------------|----|
| Effect of Fire on Plant Communities<br>of the Mixed Prairie. . . . .     | 30 |
| The Semi-arid Mixed Prairie. . . . .                                     | 30 |
| The Mesic Mixed Prairie. . . . .                                         | 34 |
| STUDY AREA . . . . .                                                     | 37 |
| METHODS AND PROCEDURES . . . . .                                         | 42 |
| Objectives. . . . .                                                      | 42 |
| Study Site. . . . .                                                      | 42 |
| Location . . . . .                                                       | 42 |
| <u>Artemisia tridentata/Stipa viridula</u> community. . . . .            | 42 |
| <u>Calamovilfa longifolia/Andropogon scoparius</u><br>community. . . . . | 44 |
| <u>Artemisia cana/Stipa viridula</u> community. . . . .                  | 46 |
| Microclimate . . . . .                                                   | 47 |
| Vegetation . . . . .                                                     | 49 |
| Experimental Design and Measurements. . . . .                            | 51 |
| Vegetation Measurements. . . . .                                         | 53 |
| Physical Measurements. . . . .                                           | 57 |
| Field Implementation . . . . .                                           | 61 |
| RESULTS. . . . .                                                         | 65 |
| Vegetation Data . . . . .                                                | 65 |
| Canopy Cover . . . . .                                                   | 65 |
| Biomass Production . . . . .                                             | 72 |
| Phenology. . . . .                                                       | 77 |
| Vigor and Vitality . . . . .                                             | 85 |
| Physical and Chemical Data. . . . .                                      | 92 |
| Soil Chemistry . . . . .                                                 | 92 |
| Infiltration Rate Tests. . . . .                                         | 92 |
| Soil Moisture. . . . .                                                   | 95 |

|                                  |      |
|----------------------------------|------|
| DISCUSSION . . . . .             | .100 |
| SUMMARY AND CONCLUSIONS. . . . . | .113 |
| APPENDICES . . . . .             | .120 |
| LITERATURE CITED . . . . .       | .131 |

## LIST OF TABLES

| Table                                                                                                                                                                                                                 | Page |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1. Dominant species in the climax vegetation of southeastern Montana (after Ross and Hunter 1976). . . . .                                                                                                            | 41   |
| 2. Dominant species (based on canopy cover) on the Broadus study sites during 1979 and 1980 . . . . .                                                                                                                 | 50   |
| 3. Phenology codes (after Taylor and Leininger 1978). . . . .                                                                                                                                                         | 55   |
| 4. Amount of fuel before and after burning in the <u>Artemisia tridentata/Stipa viridula</u> community. . . . .                                                                                                       | 56   |
| 5. The number of 'tempilstik' packets reaching or exceeding specific temperatures. . . . .                                                                                                                            | 59   |
| 6. Visual index of prescribed burn intensity. . . . .                                                                                                                                                                 | 59   |
| 7. Percent canopy cover in the <u>Artemisia tridentata/Stipa viridula</u> community of species with cover $\geq 1\%$ . . . . .                                                                                        | 66   |
| 8. Percent canopy cover in the <u>Calamovilfa longifolia/Andropogon scoparius</u> community of species with cover $\geq 1\%$ . . . . .                                                                                | 68   |
| 9. Percent canopy cover in the <u>Artemisia cana/Stipa viridula</u> community of species with cover $\geq 1\%$ . . . . .                                                                                              | 70   |
| 10. Above ground biomass production (kg/ha) on the <u>Artemisia tridentata/Stipa viridula</u> sites. . . . .                                                                                                          | 73   |
| 11. Above ground biomass production (kg/ha) on the <u>Calamovilfa longifolia/Andropogon scoparius</u> sites. . . . .                                                                                                  | 75   |
| 12. Above ground biomass production (kg/ha) on the <u>Artemisia cana/Stipa viridula</u> sites. . . . .                                                                                                                | 77   |
| 13. The percent of vegetative (V) and reproductive (R) culms and the average number of leaves per culm on the burned (B) and unburned (UB) sites of the <u>Artemisia tridentata/Stipa viridula</u> community. . . . . | 86   |

| Table                                                                                                                                                                                                                         | Page |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 14. Average leaf, culm, and inflorescence length (cm) of perennial grasses on the burned (B) and unburned (UB) sites of the <u>Artemisia tridentata/Stipa viridula</u> community. . . . .                                     | 87   |
| 15. The percent of vegetative (V) and reproductive (R) culms and the average number of leaves per culm on the burned (B) and unburned (UB) sites of the <u>Calamovilfa longifolia/Andropogon scoparius</u> community. . . . . | 90   |
| 16. Average leaf, culm, and inflorescence length (cm) of perennial grasses on the burned (B) and unburned (UB) sites of the <u>Calamovilfa longifolia/Andropogon scoparius</u> community. . . . .                             | 90   |
| 17. The percent of vegetative (V) and reproductive (R) culms and the average number of leaves per culm on the burned (B) and unburned (UB) sites of the <u>Artemisia cana/Stipa viridula</u> community. . . . .               | 91   |
| 18. Average leaf, culm, and inflorescence length (cm) of perennial grasses on the burned (B) and unburned (UB) sites of the <u>Artemisia cana/Stipa viridula</u> sites . . . . .                                              | 91   |
| 19. Chemical properties of the soil before burning and at three dates after burning at four depths in 1979. . . . .                                                                                                           | 93   |

# LIST OF FIGURES

| Figure                                                                                                                                                                             | Page |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1. Natural vegetation of the northwestern Great Plains grasslands (Wright and Bailey 1980). . . . .                                                                                | 31   |
| 2. Location of Broadus ranch and study area in southeastern Montana . . . . .                                                                                                      | 38   |
| 3. Representative slope profile and soil series which develop on various parent materials at each geomorphic position in the Colstrip, Montana area (Schafer et al. 1979). . . . . | 39   |
| 4. <u>Artemisia tridentata/Stipa viridula</u> treated site . . . . .                                                                                                               | 43   |
| 5. <u>Artemisia tridentata/Stipa viridula</u> untreated site . . . . .                                                                                                             | 44   |
| 6. <u>Calamovilfa longifolia/Andropogon scoparius</u> treated site . . . . .                                                                                                       | 45   |
| 7. <u>Calamovilfa longifolia/Andropogon scoparius</u> untreated site . . . . .                                                                                                     | 45   |
| 8. <u>Artemisia cana/Stipa viridula</u> treated site . . . . .                                                                                                                     | 46   |
| 9. <u>Artemisia cana/Stipa viridula</u> untreated site . . . . .                                                                                                                   | 47   |
| 10. 1978 climograph for Colstrip, Montana. . . . .                                                                                                                                 | 48   |
| 11. 1979 climograph for Colstrip, Montana. . . . .                                                                                                                                 | 48   |
| 12. 1980 climograph for Colstrip, Montana. . . . .                                                                                                                                 | 49   |
| 13. Representation of exclosure and transects used on the <u>Artemisia tridentata/Stipa viridula</u> sites. . . . .                                                                | 52   |
| 14. Representation of transects used on the <u>Calamovilfa longifolia/Andropogon scoparius</u> and the <u>Artemisia cana/Stipa viridula</u> sites. . . . .                         | 53   |
| 15. Representation of 'tempilstik' packet. . . . .                                                                                                                                 | 57   |
| 16. "Tempilstik" packet being placed below the soil surface . . . . .                                                                                                              | 58   |

| Figure                                                                                                                  | Page |
|-------------------------------------------------------------------------------------------------------------------------|------|
| 17. Location of the study sites relative to the areas<br>burned . . . . .                                               | 62   |
| 18. Phenology profile for green needlegrass on the<br><u>Artemisia tridentata/Stipa viridula</u> sites. . . . .         | 78   |
| 19. Phenology profile for western wheatgrass on the<br><u>Artemisia tridentata/Stipa viridula</u> sites. . . . .        | 78   |
| 20. Phenology profile for the prairie junegrass on the<br><u>Artemisia tridentata/Stipa viridula</u> sites. . . . .     | 79   |
| 21. Phenology profile for the blue grama on the<br><u>Artemisia tridentata/Stipa viridula</u> sites. . . . .            | 79   |
| 22. Phenology profile for cheatgrass on the<br><u>Artemisia tridentata/Stipa viridula</u> sites. . . . .                | 80   |
| 23. Phenology profile for bluebunch wheatgrass on the<br><u>Artemisia tridentata/Stipa viridula</u> sites. . . . .      | 80   |
| 24. Phenology profile for prairie sandreed on the<br><u>Calamovilfa longifolia/Andropogon scoparius</u> sites. . . . .  | 81   |
| 25. Phenology profile for little bluestem on the<br><u>Calamovilfa longifolia/Andropogon scoparius</u> sites. . . . .   | 81   |
| 26. Phenology profile for on the prairie junegrass<br><u>Calamovilfa longifolia/Andropogon scoparius</u> sites. . . . . | 82   |
| 27. Phenology profile for green needlegrass on the<br><u>Artemisia cana/Stipa viridula</u> sites. . . . .               | 82   |
| 28. Phenology profile for western wheatgrass on the<br><u>Artemisia cana/Stipa viridula</u> sites. . . . .              | 83   |
| 29. Phenology profile for prairie junegrass on the<br><u>Artemisia cana/Stipa viridula</u> sites. . . . .               | 83   |
| 30. Phenology profile for blue grama on the<br><u>Artemisia cana/Stipa viridula</u> sites. . . . .                      | 84   |

| Figure                                                                                                                                              | Page |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 31. Infiltration rates on the burned and unburned <u>Artemisia tridentata</u> / <u>Stipa viridula</u> sites in 1979 and 1980 . . . . .              | 94   |
| 32. Percent soil moisture (weight) in the upper 15 cm of soil on the <u>Artemisia tridentata</u> / <u>Stipa viridula</u> sites. . .                 | 96   |
| 33. Percent soil moisture (weight) in the upper 15 cm of soil on the <u>Calamovilfa longifolia</u> / <u>Andropogon scoparius</u> sites. . . . .     | 97   |
| 34. Percent soil moisture (weight) in the upper 15 cm of soil on the <u>Artemisia cana</u> / <u>Stipa viridula</u> sites . . . .                    | 98   |
| 35. Bluebunch wheatgrass in 1980 on the burned <u>Artemisia tridentata</u> / <u>Stipa viridula</u> site. Note abundant seedhead production. . . . . | 106  |
| 36. Scarlet globemallow in 1980 spreading into openings that were formerly occupied by big sagebrush . . . . .                                      | 108  |
| 37. Skunkbush sumac and western snowberry as they appeared in June, 1980 on the area burned April 6, 1979. . . . .                                  | 110  |
| 38. Winterfat during 1979 on the area burned April 20, 1979 . . . . .                                                                               | 111  |



## ABSTRACT

Controlled burning was applied to approximately 4 ha of mixed prairie on April 6 and 20, 1979 near Colstrip, Montana. The fires burned three plant communities: Artemisia tridentata/Stipa viridula, Calamovilfa longifolia/Andropogon scoparius, and Artemisia cana/Stipa viridula. Vegetation data consisted of canopy cover, frequency, above ground biomass production, phenology, and vigor and vitality estimates. Soil measurements included organic matter, total nitrogen, pH, phosphorus, and electrical conductivity, infiltration rates and soil moisture. 'Tempilstik's were used to estimate the maximum temperature reached at the mineral soil surface and at a depth of 1 cm.

Results indicated very high surface temperatures ( $>371^{\circ}\text{C}$ ) over a large proportion of the study area. Temperatures at 1 cm did not rise above  $65^{\circ}\text{C}$ . Burning almost completely eliminated big sagebrush. Silver sagebrush resprouted the first growing season and increased production in the second season. Skunkbush sumac, western snowberry, prairie rose, and winterfat were not permanently damaged and resprouted in the first post-fire growing season. The response of herbaceous species was related to phenology and burning time, fire intensity, post-burning competition for soil moisture, and possible allelopathic effects. Perennial grass and forb production was similar or greater on burned compared to unburned sites. Annual grasses were temporarily reduced by the later fire. Some perennial grass species had extended growing seasons and more flowering culms on burned compared to unburned areas. Chemical properties of the soil were generally unaltered by burning. Soil moisture in the upper 15 cm was unaffected by burning. Infiltration rates may be reduced on burned sites.

Controlled burning in this portion of the semi-arid mixed prairie, under proper conditions of weather, soil moisture, and plant phenology may not adversely affect herbaceous species as a whole. Spring burning should follow winters and/or falls with above-average precipitation. Burning should be accomplished before the active growth of cool-season perennial grasses.

## INTRODUCTION

Northern Great Plains grasslands are characterized by broad, unbroken, level plains or rolling hills, periodic droughts, thunderstorms and wind. Herbaceous vegetation periodically dries out, remains erect, is loosely arranged and finely divided. Together these characteristics make grasslands easy to ignite and allow for the free spread of fire. From evidence provided by Aldous (1934), Cooper (1961), Humphrey (1962), Komarek (1964, 1965), Daubenmire (1968a), and Vogl (1974, 1979) it is clear that fire was a natural and integral part of North American grasslands prior to the arrival of European man. Fire frequency for grasslands can be extrapolated from forests having grassland understories such as ponderosa pine (Pinus ponderosa) in the West and longleaf pine (Pinus palustris) in the Southeast. The frequency of fire in these forests varied from 2 to 25 years. In the prairie, natural frequency probably varied from 5 to 10 years. In semi-arid areas conflagrations occurred during drought years that followed 1 to 3 years of above average precipitation, which provided abundant and continuous fuel (Wright and Bailey 1980).

Sauer (1950) and Stewart (1956) considered fire the most important or controlling factor in the origin and development of grassland vegetation. However, Vogl (1974) pointed out that grasses, rushes and sedges probably evolved as opportunistic pioneers, responding as much to climatic fluctuations as to fire. The heat associated with burning

plant material and the electrical discharge accompanying a lightning strike can have mutagenic effects on the reproducing plant (Komarek 1965). These two factors along with genetic variation have enabled some species to adapt to a fire environment.

Herbaceous grassland vegetation has adapted to survive with frequent fire. Rhizomes, stolons and the growing points of perennials lie at or below the soil surface where the heat from the fire is less intense. The annual habit, abundant seed production, adaptation of fruits to rapid distribution and burial, and rapid culm elongation and maturation aid in survival during fire and in the rapid colonization of burned areas (Heady 1975). Some species of plants have evolved characteristics that enhance the flammability of expendable portions (Mutch 1970).

Vogl (1974) separated grasslands into three types based on their origin and discussed the impact fire has had in the maintenance of each. True or natural grasslands lack woody plants, primarily because climatic and edaphic conditions favor herbaceous species. In these grasslands fire is just one of the many factors responsible for the presence of herbaceous plants. In anthropogenic and derived grasslands fire plays a more significant role in maintaining the herbaceous cover at the expense of shrubs and trees.

Lightning and man are the two primary causes of fire. Lightning, the universal natural cause of fire, has been frequent enough throughout history to have had a continuing effect on plants and animals. Man has employed fire for at least a quarter of a million years. Once primitive man learned to produce fire (10 to 20 thousand years ago) he exerted his maximum effect on world vegetation (West 1971). Reasons why primitive man used fire are well documented (Cooper 1961; Daubenmire 1968a; Hensel 1923; Komarek 1965; Sauer 1950; Stewart 1956; Vogl 1974). Whether hunting, agriculture, or herding was the primary goal of early man, his fires, along with those occurring naturally, were frequent and widespread occurrences that had a profound effect on world vegetation.

Modern uses of fire in rangeland management have been discussed by various authors (Heady 1975; Vallentine 1971; Vogl 1974; Wright 1974). In range management the most common use for prescribed burning is the eradication of undesirable shrubs. This facilitates livestock movement and in general increases the production of forage species. In areas where land prices have risen sharply, ranchers are being forced to use marginal lands which often are occupied by trees and shrubs (Love 1970). Conversion of these sites to grasslands through burning can be successful and economically feasible. Fire can be an effective way to reduce or eliminate plants that are toxic or

damaging to livestock. On sites where mechanical treatment is not feasible prescribed burning can be effective in controlling some noxious weeds.

In wildlife management fire can be used to burn out dense stands of brush. Repeated burning creates a mosaic of vegetation types in different seral stages. This varied habitat generally increases populations of game and non-game species. Certain bird and mammal species increase their numbers following grassland fires, including some species that are not usually associated with grasslands (Vogl and Beck 1970).

Incorporating prescribed burning into the management of natural areas, particularly grasslands, is being widely practiced. Periodic burning can reduce or eliminate invading woody plants and remove stifling accumulations of organic matter. Burning along with grazing can help ensure the healthy maintenance of these grasslands.

Researchers studying the effects of fire in the mixed grass prairie have presented varying results (Clarke et al. 1943; DeJong and MacDonald 1975; Dix 1960; Gartner and Thompson 1972; Kirsch and Kruse 1972; Redmann 1978). Discrepancies may, in part, be due to conscious or unconscious biases about the effects fire should have on a particular assemblage of plants. The variable nature of fires and the environments in which they occur can produce different plant responses.

No two fires or the conditions under which they occur are alike. Factors such as climate, soil, plant associations, fire intensity, range condition, season of burning, type of fire (wildfire vs. controlled burn), moisture conditions and post-burning management all contribute to vegetation response. There is an attitude among some researchers that burning in the semi-arid portion of the Northern Great Plains will have unfavorable effects on the vegetation because of the unpredictable moisture regime. Much of the evidence presented is based largely on wildfires or burns made without relation to ideal weather conditions (Vallentine 1971). Plant species in this part of the mixed prairie have probably adapted to survive conditions of periodic drought and fire. Under the proper conditions prescribed burning can produce favorable results. This research project was therefore undertaken to help fill a void in our understanding of the effects early spring burning has on vegetation in this portion of the semi-arid mixed prairie.

## LITERATURE REVIEW

### Fire and Soil

Changes in soil properties that occur during a fire can be related to the degree and duration of soil heating. The degree of soil heating is highly variable and depends on the types of fuel, the fuel load, fire intensity (this is proportional to flame height and rate of spread), the nature of the litter layer and soil properties (U.S.D.A. 1979).

### Characterizing Soil Temperature and Fire Intensity

#### Measuring Soil Temperature

Soil temperature during a fire can be measured in two ways. Continuous measurements are taken using thermocouples or thermistors attached to a recording instrument (Scotter 1971; Stinson and Wright 1969; Aston and Gill 1976). Maximum soil temperatures are measured with heat sensitive materials that melt at particular temperatures. These include mica plates covered with heat sensitive paint (Whittaker 1961), glass tubes containing organic compounds of known melting points (Beadle 1940), and chemical sticks that melt when specific temperatures are reached (Nimir and Payne 1978; Stinson and Wright 1969).

### Visual Characterization of Fire Intensity

The intensity of a fire can be classified subjectively using the appearance of the litter and soil after burning. Bentley and Fenner (1958), Tarrant (1965), and Young et al. (1976) developed burning indices based on the amount of leaf litter incinerated. Tarrant (1965) also noted that on the most severely burned areas mineral soil structure and color were altered. Blaisdell (1953) used the degree that big sagebrush (Artemisia tridentata) branches were burned as a guide to fire intensity.

### Soil Temperature During Rangeland Fires

Grassland fuels tend to ignite readily and burn quickly. Grassland fires generally produce a narrow belt of flames that spreads rapidly because of the low plant growth, open terrain, level to gently rolling topography, and the general presence of wind (Vogl 1974). For these reasons grassland fires generally do not create high ground surface temperatures. Temperatures vary over short distances due to fuel differences and local burning conditions (DeBano et al. 1979). Slow moving back-fires tend to generate more heat than head-fires (Heyward 1938; Lindenmuth and Byram 1948). Where litter or woody plant material has accumulated, fires take long to burn and produce high temperatures for long periods of time (Conrad and Poulton 1966;



Stinson and Wright 1969; Wright 1971). Time-temperature relationships are crucial to understanding the effects a fire will have in an ecosystem (Davis and Martin 1960; Smith and Sparling 1966; Wright 1971).

Stinson and Wright (1969) reported maximum soil surface temperatures ranging from 83°C to 682°C for fuels that varied from 1855 to 8430 kg/ha. They found that temperatures above 66°C lasted for 54 to 324 seconds. Scotter (1971) reported that during a savanna fire the maximum surface temperature was 300°C but temperatures above 100°C lasted for only 80 seconds. In grasslands with limited fuels, soil surface temperatures generally vary from 93°C to 121°C (Bentley and Fenner 1958). During big sagebrush-grass burning, soil surface temperatures ranged from 175°C to 205°C (Nimir and Payne 1978). In the chaparral type of California surface temperatures ranged from 320°C to 650°C (DeBano et al. 1979). Maximum soil surface temperature was 204°C during an early spring burn in the mixed prairie of South Dakota (Gartner and Thompson 1972). In comparing temperature profiles during fires of different intensities, Smith and Sparling (1966) found that during cool fires the maximum temperature was at ground level. During warm and hot fires the greatest temperature was between 5 and 10 cm above the soil surface. They reasoned that the lack of oxygen at the soil surface during the intense fire limited combustion. They concluded that the maximum ground surface temperatures during a hot fire may not be much higher than surface temperatures during cooler fires.

Below the mineral soil surface, temperatures decrease rapidly. Heat is transferred through the soil by conduction, convection, and vapor movement. Temperatures in the soil will not exceed 100°C until all moisture evaporates. Burning over moist soil increased the temperature at 1 cm to 96°C while burning over dry soil increased the temperature to 175°C (Aston and Gill 1976). Heyward (1938) reported that under longleaf pine, where the principal fuel was grass, temperatures ranged from 66°C to 79°C in the 0.3 cm to 0.6 cm depth. Under burning shrubs temperatures may exceed 288°C at a depth of 0.8 cm (Bentley and Fenner 1958). Under burning big sagebrush, maximum temperatures at 1 cm ranged from 65°C to 80°C (Nimir and Payne 1978). At 2 cm Scotter (1971) found that maximum temperature was only 36°C and no temperature change occurred at the 4 cm depth. Scotter (1971) reported that when litter was consumed but shrubs were only charred, temperatures reached 177°C at 2.5 cm. However, when shrubs were incinerated, temperatures reached 177°C at 7.3 cm. Gartner and Thompson (1972), working in mixed prairie, reported that temperatures reached 93°C at 5 cm.

#### Effect of Fire on Soil

Fire reduces the amount of litter, consumes most of the standing dead material, and can remove a portion of the above ground living plant material, all of which have an indirect effect on the soil.

Following a fire, changes may occur in soil organic matter, available nutrients, acidity, microorganism populations, temperature, moisture, porosity, structure and infiltration rate. Generally, grassland burning does not permanently damage these soil properties (Ehrenreich and Aikman 1957; Heady 1975; Vallentine 1971). Under normal circumstances grassland fires generally improve the soil (Vogl 1979). Conditions are most improved for 1 to 3 years after burning. Burning creates long lasting effects on the soil by contributing ash and charred organic matter to the soil profile. Charred organic matter, along with dead and decaying root systems, improve soil porosity, water retaining capacity, aeration, texture, and provide new colonization sites for microorganisms (Vogl 1979).

#### Soil Organic Matter (Humus)

Fire intensity is the most important factor influencing the amount of organic matter remaining in burned-over soil. Grassland fires are seldom hot enough to directly oxidize organic matter below a few centimeters (Daubenmire 1968a). Soils will lose appreciable amounts of organic matter only when temperatures exceed 300°C (Orioli and Curvetto 1978).

After 48 years of annual burning in the tallgrass prairie, Owensby and Wyrill (1973) found that soil organic matter increased on sites burned in winter or early spring. On sites burned in middle to

late spring organic matter decreased. Greene (1935) found organic matter content in the upper 15 cm of soil under longleaf pine to be 1.6 times greater after eight years of annual burning than before burning. Increases came from the decaying roots of the luxuriant plant growth, which was more than twice that on the area protected from burning. After six years of annual burning in eastern Kansas, Aldous (1934) reported that humus in the upper 15 cm of soil remained unchanged.

In forest soils, when burning has been intense, decreased amounts of organic matter have been reported (Barnette and Hester 1930; Beaton 1959). Under burned mesquite, Reynolds and Bohning (1956) reported decreased soil organic matter. After a prescribed big sagebrush-grass burn, Nimir and Payne (1978) could not detect a change in organic matter. Blaisdell (1953) reported reduced soil humus after a sagebrush-grass burn, however the effect was temporary.

In general, soil organic matter increases following a fire. This can be attributed to warm spring soils which stimulate the growth of pioneer species, and also from the roots of plants killed by the fire (Daubenmire 1968a). Soil organic matter is governed more by root development than by the accumulation of litter (Aldous 1934). A high rate of microbial activity may decrease the humus content of the soil (Daubenmire 1968a).

## Soil Chemistry

### Macronutrients other than Nitrogen

Fire oxidizes organic materials contained in above ground vegetation and litter. As a result, fire is the primary decomposition agent and key nutrient recycler in many grasslands (Vogl 1974). Fire increases the supply of available nutrients at the soil surface (Ehrenreich and Aikman 1963; Heady 1975; Vallentine 1971; Vogl 1974).

Infiltrating water carries ash, composed mainly of potassium, calcium, magnesium and phosphorus, into the soil profile. These soluble salts are subject to loss through lateral movements of wind and water and by leaching if not absorbed by plants.

Phosphorus reportedly increased after brush burning (Vlams and Gowans 1961) and after slash burning in Douglas fir (Pseudotsuga menziesii) (Tarrant 1965). Phosphorus decreased after grass burning in the southeastern United States (Christensen 1976). Lewis (1974) could not detect a change in the concentration of phosphorus under a pine forest in South Carolina. Christensen (1976) reported an increase in magnesium, while Nimir and Payne (1978) reported no change. Potassium can increase under grass (Christensen 1976) and slash burning (Tarrant 1965), decrease following fire in the Arizona desert grass-shrub range (Reynolds and Bohning 1956) or not change after grassland burning in Iowa (Ehrenreich and Aikman 1963). Calcium may

increase (Christensen 1976), decrease (Wahlenberg 1935) or remain unchanged (Nimir and Payne 1978). Chemical changes in burned-over range soils have shown considerable variation. These differences are due to differences in weather at the time of burning, season of burning, moisture content of the litter and soil, and the distribution, type and amount of fuel. Generally there is no direct loss of soil nutrients except for the volatilization of nitrogen and sulfur (Dauenmire 1968a).

#### Nitrogen

Nitrogen losses depend on the degree of combustion (White et al. 1973). Nitrogen in the litter began to decrease when surface temperatures rose above 200°C. At 400°C approximately 1/2 to 2/3 volatilized and only a trace remained at 500°C. DeBano et al. (1979) reported that approximately 80 percent of the total nitrogen contained in the litter and the upper 2 cm of mineral soil was released when soil surface temperature reached 825°C. Forty percent was released at 600°C and 20 percent at 486°C. Most nitrogen is volatilized as nitrogen gas but some is converted into ammonia and bound to humus particles (Viro 1974). Nitrogen losses can be substantial but are recovered through precipitation and the increased action of nitrogen fixing plants (particularly legumes), soil algae, bacteria, and certain fungi (Jorgensen and Wells 1971; Vogl 1974). The slight rise in pH due to

burning is not an important factor in increasing nitrification. Higher soil temperatures after a fire are responsible for increased nitrification (Daubenmire 1968a; Heady 1975). However, where roots are active there may be a lower concentration of nitrates due to the rapid uptake into plants (Sharrow and Wright 1977). Decaying roots of plants killed by the fire and the increased productivity and turnover rate can increase soil nitrogen (Greene 1935). Following burning in forest with a grassland understory, nitrogenous compounds in the soil have increased (Christensen 1976; Fowells and Stephenson 1934; Greene 1935; Klemmedson et al. 1962; Maryland 1967; Reynolds and Bohning 1956; Sharrow and Wright 1977; Vlamis and Gowans 1961). Other researchers have reported no change (Aldous 1934; DeBano et al. 1979; Lewis 1974). On severely burned sagebrush-grass range, Blaisdell (1953) reported decreased nitrogen in the upper 12 mm of soil, but these reductions were only temporary.

Nitrogen may be preserved on a site by avoiding intense fires through periodic burning (Klemmedson et al. 1962). Season of burning will alter the concentration of nitrogen. In the tallgrass prairie, Owensby and Wyrill (1973) found that early spring burning increased nitrogen levels while late spring burning severely reduced soil nitrogen.

### Nutrient Availability

Nutrient availability is often evaluated by pot experiments, whereby growth or nutrient content of indicator plants is compared after plants have grown in soil from burned and unburned areas. Vlamis et al. (1955) reported that burning increased the available nitrogen and phosphorus in the soil and this stimulated lettuce and barley plants. In a later study, Vlamis and Gowans (1961) attributed the greater production of lettuce plants grown in burned soil to the increased availability of nitrogen, phosphorus, and sulfur. Barley grown in burned-over soil from under chaparral had a greater concentration of nitrogen in the plant tissues than did plants grown in non-burned soil (Maryland 1967). In the tallgrass prairie of Illinois, Old (1969) found that burning increased the nitrogen and phosphorus in foliage.

Soil fertility generally improves following a fire. However, ashes are usually too scarce to account for this improvement (Aldous 1934; Daubenmire 1968a). Important sources of nutrients following burning are decaying roots and nitrogen fixing plants. The most important source of nitrogen is increased nitrification (Old 1969).

### Soil pH

The acidity of the surface soil is reduced by burning because basic cations (calcium, magnesium, and potassium) are released during



the combustion of organic matter. Owensby and Wyrill (1973) reported increased soil pH after winter, early spring, and midspring burning in the tallgrass prairie. Soon after a fire in New Zealand rangeland soil pH increased, but was lower thereafter (Miller and Fitzpatrick 1959). Slight increases have been reported in Arizona chaparral (Maryland 1967) and in the tallgrass prairie of Iowa (Ehrenreich and Aikman 1963). Reynolds and Bohning (1956) and Christensen (1976) could not detect changes. The pH changes in grasslands after fire is probably insignificant and usually persists for only a year or two (Daubenmire 1968a).

#### Litter

The amount of precipitation reaching the ground depends upon the type of mulch, the amount of mulch and the intensity of the precipitation (Ehrenreich and Aikman 1963). Mulch increases snow accumulation, melting time, infiltration rate, and reduces evaporation from the soil surface (Weaver and Rowland 1952). Under low rainfall conditions the removal of litter will increase water loss by evaporation and lower the plant available soil moisture (Hadley 1970). Plant residues on the soil surface can decidedly reduce evaporation losses during periods of frequent rains but may be of little or no value when rains are few and scattered (Russel 1939). Rangelands require from 3 to 6 growing seasons to accumulate pre-burn mulch levels (Dwyer and Pieper

1967; Pechanec and Stewart 1954; Vogl 1965). With few exceptions mulches are the primary factor determining infiltration (Dyksterhuis and Schmutz 1947).

### Infiltration

Destroying surface mulch generally increases evaporation and decreases infiltration rates (Beutner and Anderson 1943; Daubenmire 1968a; Duley and Russel 1939; Hanks and Anderson 1957; Hopkins 1954).

Duley and Domingo (1949), using a sprinkler infiltrometer on native range in Nebraska, found infiltration reduced in proportion to the amount of bare ground. In addition, the total cover, including live plants and litter, had a more significant effect on infiltration than the species of grass or the type of soil. Heavy grazing further reduced infiltration by compacting the soil and removing live and dead grass. Rauzi (1960) reported that the standing vegetation contributed more to infiltration than did mulch. Infiltration rates were reduced following burning in the chaparral type of northern California (Sampson 1944), the pinyon-juniper type in southwestern Utah (Buckhouse and Gifford 1976), and under lodgepole pine (Pinus contorta) in the northern Rocky Mountains (Trimble and Tripp 1949).

Soil texture and fire intensity affect infiltration rate. In the Missouri Ozarks, Arend (1941) reported reductions of from 20 to 62 percent on burned areas depending on soil texture. Following a fire

in pinyon-juniper woodland in Nevada, Roundy et al. (1978) reported reduced infiltration in areas where woody plant material had accumulated. Duvall and Linnartz (1967) could not detect a difference in infiltration rate on burned areas under longleaf pine in Louisiana.

#### Soil Moisture

Soil moisture content in burned-over rangeland soils has varied, however there seems to be a general reduction due to higher surface temperatures which increase evaporative loss and by reduced infiltration (Daubenmire 1968a). Luxuriant plant growth on a burned area may reduce soil moisture to a greater extent than losses through evaporation (Hulbert 1969; Sharrow and Wright 1977). Season of burning can affect soil moisture. In the tallgrass prairie of Kansas, Anderson (1965), McMurphy and Anderson (1965), and Anderson et al. (1970) reported that late spring burning reduced soil moisture less than burning at earlier dates. Late spring burning permits more water to reach the deeper soil layers (Anderson 1965). On the Texas High Plains, Trilica and Shuster (1969) reported no differences in soil moisture on plots burned in the spring or fall, once plant growth had begun. In the annual grassland of California, Hervey (1949) could not detect a difference in soil moisture between an area burned in the spring and an unburned area.

### Temperature

Removing insulating mulch increases soil surface temperatures (Aldous 1934; Penfound and Kelting 1950; Vallentine 1971). Increased soil temperatures in the spring can bring about early growth (Daubenmire 1968a; Ehrenreich 1959; Ehrenreich and Aikman 1963; Hadley 1970; Hopkins 1954; Vallentine 1971; Weaver and Rowland 1952). Early growth in the spring may increase frost damage to seedlings (Vallentine 1971). Warm soil in the spring on burned areas promotes early microorganism activity and nitrification (Alhgren 1971).

### Effect of Fire on the Individual Vascular Plant

The degree of direct damage to plant tissue depends on the intensity of the fire and the duration of heating (Daubenmire 1968a; Heady 1975; Wright 1971). Other factors include the physiological state of protoplasm, which appears related to tissue moisture content, the quality of the insulating dead material (bark) and initial plant temperature (Wright 1971). Growth stage, growth form, and plant size influence the susceptibility of live tissue to heat damage (Heady 1975). When plants are actively growing or near full size their carbohydrate reserves are nearly depleted. Fire at this time can seriously injure plants (Aldous 1934). Proper burning dates are set by the plants and not the calendar. Elevation and local weather conditions affect phenology. Warm-season species are less susceptible

to damage by spring fire than cool-season species (Anderson et al. 1970; Curtis and Partch 1948; Robocker and Miller 1955; Wright and Klemmedson 1965).

Growth form influences species damage. Rhizomatous and annual grasses may be stimulated by fire, while bunchgrasses are damaged (Blaisdell 1953). Location of growth points can be crucial to plant survival. Species with elevated growing points are generally damaged (Daubenmire 1968a; Pechanec and Stewart 1954). Idaho fescue (Festuca idahoensis) was more easily damaged by the same fire than bluebunch wheatgrass (Agropyron spicatum) (Conrad and Poulton 1966). The former species has buds closely spaced and at or above the surface of the ground, while the latter species has more loosely arranged buds that are slightly below the soil surface and therefore relatively protected from damage by heat. The position of buds within a bunchgrass can influence its susceptibility to heat damage. Growth points near the perimeter of bunchgrasses were less damaged by the same fire than buds near the center (Wright 1971). Buds at the perimeter are at greater depths, have a greater ratio of living to dead material and are positioned where heat can disperse rapidly and in more directions than buds at the center. Large bunchgrasses may develop higher temperatures and sustain more damage than small bunches (Wright and Klemmedson 1965).

Seeds that have yet to disperse or are lodged in the upper por-

tion of the litter are more susceptible to damage by heat than seeds at or below the soil surface. Disseminules that bury themselves are well protected (Bentley and Fenner 1958; Biswell 1956). High seed moisture can make seeds susceptible to damage (McKell et al. 1962). Seeds not killed by a fire may be altered to germinate early (Daubenmire 1968a).

Ecotypic variation within a species can cause a differential response to fire (Daubenmire 1968a).

### Phenology

Where moisture is not limiting, the initiation of spring growth is governed primarily by soil temperature (Ehrenreich 1959; Ehrenreich and Aikman 1963). The removal of insulating litter encourages early growth in the spring (Aldous 1934; Ehrenreich and Aikman 1963; Hadley and Kieckhefer 1963; Old 1969; Peet et al. 1975; Vogl 1965). Once plants emerge the increased light intensity at the soil surface promotes photosynthetic efficiency and promotes rapid growth (Hulbert 1969; Old 1969; Peet et al. 1975).

Phenological development was delayed after spring burning of mixed prairie in west-central Kansas (Hopkins et al. 1948) and sagebrush-grass in south-central Montana (Nimir and Payne 1978). Vegetation may remain green longer (Pechanec and Hull 1945) or cure earlier (Ehrenreich 1959) on burned relative to unburned areas.

### Vitality (Flowering Activity)

Flowering activity is controlled primarily by microclimatic conditions (specifically temperature) at the beginning of the growing season (Ehrenreich and Aikman 1957, 1963; Old 1969). Increased storage of carbohydrates before flower primordia are initiated results in abundant seedstalk production (Curtis and Partch 1950; Ehrenreich and Aikman 1957). Biswell and Lemon (1943), working in the wiregrass (Cynodon dactylon) type, noted that many grass clumps grow for years without producing seedstalks but flower profusely after being burned. Ehrenreich and Aikman (1963) reported that flowering activity was high on areas with the earliest spring growth, less on areas where growth began later, and least on unburned areas. Old (1969) reported a tenfold increase in flowering activity after burning in the tallgrass prairie of Illinois. He found that adding mulch to denuded plots lowered the flowering rate in proportion to the thickness of the mulch. Furthermore, shading a plot would reduce flowering. Lloyd (1972), working in a Derbyshire grassland, reported that burning, not clipping, increased the production of flowering stems. He reasoned that on the burned area a blackened tussock created warmer temperatures within the bunch itself and this directly or indirectly affected seedstalk production.

Vitality changes following fire have been reported for a variety of locations: tallgrass prairie in Iowa (Ehrenreich 1959; Ehrenreich and Aikman 1957; Ehrenreich and Aikman 1963), Illinois (Old 1969), southwestern Wisconsin (Dix and Butler 1954), Oklahoma (Penfound 1964); Texas High Plains (Trilica and Shuster 1969); southeastern wiregrass (Biswell and Lemon 1943); sagebrush-grass in southeastern Idaho (Pechanec and Stewart 1954); Washington bunchgrass (Uresk et al. 1976); Derbyshire grassland (Lloyd 1972); and mixed prairie in western North Dakota (Dix 1960).

Vigorous flowering response may be delayed until the second post-burn growing season (Blaisdell 1953). Stimulated vitality is temporary, lasting about two growing seasons (Ehrenreich and Aikman 1963; Trilica and Shuster 1969). Following a fire a shift may occur from vegetative to flowering activity (Curtis and Partch 1950; Dix and Butler 1954).

### Vigor

Plant vigor is most commonly estimated by plant height, leaf length, number of leaves, and basal area. Among annuals, vigor changes can be attributed to microclimatic differences while with perennials the changes may be due to heat injury (Daubenmire 1968a).

Perennial grass heights have increased after fire in southwestern Wisconsin (Dix and Butler 1954), Iowa (Ehrenreich and Aikman 1957; .



1963; Ehrenreich 1959), and southcentral Washington (Uresk et al. 1976). Heights of western wheatgrass (Agropyron smithii) and blue grama (Bouteloua gracilis) were reduced following wildfire and drought in the mixed prairie (Launchbaugh 1964). On the Texas High Plains the height of blue grama was reduced for two years following fire (Trilica and Shuster 1969).

Aldous (1934) reported increased leaf length for little bluestem (Andropogon scoparius) and big bluestem (Andropogon gerardii). Average leaf and sheath lengths were unchanged following prescribed burning in Iowa tallgrass prairie (Ehrenreich and Aikman 1957). Leaf length for bluebunch wheatgrass was significantly reduced after burning in Washington (Uresk et al. 1976).

Aldous (1934) reported increased numbers of leaves for little bluestem and big bluestem. Burning may reduce the number of leaves per plant but not affect the total photosynthetic area (Ehrenreich and Aikman 1957).

The basal cover of perennial grasses was reduced 5 percent when burning took place in a light accumulation of litter and 55 percent where accumulations were heavy. Basal cover was reduced 48, 34, and 10 percent for blue grama, little bluestem and big bluestem respectively (Hopkins et al. 1948). Basal area reductions have been reported for Idaho fescue and bluebunch wheatgrass (Conrad and Poulton 1966).

Increased basal diameter of blue grama following burning has been reported (Trilica and Shuster 1969).

### Effect of Fire on Plant Communities

#### Species Composition

Fire affects individual plants differently, depending on plant phenology, the location of growth points, fire intensity, soil, and climate (Vogl 1974). Bunchgrasses with densely clustered culms can burn 2 to 3 hours after a fire has passed (Wright et al. 1979). Thus, many bunchgrass plants will die regardless of the intensity of the passing fire.

Although some shrubs have the ability to resprout after a fire, repeated burning generally promotes herbaceous plants at the expense of woody species (Biswell 1956; Blydenstien 1967; Box et al. 1967; Christensen 1976; Daubenmire 1968a; Dwyer and Pieper 1967; Gartner and Thompson 1972; Hervey 1949; Glover 1971; Rawitscher 1948; Scott 1971; Trollope 1971). Woody plants have difficulty invading grasslands that are healthy and subject to periodic fires (Vogl 1974). Fires can maintain vigorous herbaceous growth which can out-compete shrubs for space, moisture, and light (Blydenstein 1967). Burning at the wrong time can encourage the encroachment of shrubs onto fire maintained grasslands (Van Rensburg 1971). In areas capable of supporting woody

and herbaceous plants, the number of woody plants is often related to fire frequency and intensity (Vogl 1974).

Fire may promote grasses over forbs (Penfound and Kelting 1950) or more commonly favor the reverse (Aldous 1934; Daubenmire 1968a; Harniss and Murray 1973; Hervey 1949; Hodgkins 1958; Vogl 1974). Burning in the spring can favor warm-season grasses (Aldous 1934; Anderson et al. 1970; Ehrenreich 1959; McMurphy and Anderson 1965; Zedler and Loucks 1969).

Burning in native grassland communities generally does not reduce the species diversity and may even increase it by promoting additional growth of grasses, legumes and other forbs, including annual plants (Vogl 1974). Areas protected from fire may contain only those species able to survive under the dense litter (Daubenmire 1968a). These areas may become more diverse as fire destroys the stifling litter, thereby opening up the community. Grassland fires sometimes allow opportunistic pioneers such as annuals or short-lived perennials to invade an area (Vogl 1974). Repeated burning in early summer in sagebrush-grass communities will deplete the stand of perennial grasses and allow annual grasses to increase (Wright et al. 1979).

The germination of seeds can be increased by heat treatment (Capon and Van Asdall 1967). Moist heat is more effective at increasing germination than dry heat (Cushwa et al. 1968; Martin and Cushwa 1966).

Post-burn composition may not reflect the damage to individual plants as much as the ability of some plants to respond quickly to the altered environment (Daubenmire 1968a). Adaptations allowing certain plants to increase rapidly following a disturbance such as fire include the production of many small seeds, seeds that disperse by wind and plants with rhizomes, crown buds, or tillers (Lemon 1949).

The effects of fire on a plant community can be very complex. Daubenmire (1968a) indicated that the influence of fire "should be related to specific habitat types defined on the basis of their potential natural vegetation and described in terms of the current condition of the vegetation". This complexity is increased for rangeland managers who contemplate burning within a mosaic of specific types. If burning each community separately is impractical, it is necessary to consider the effects fire will have in each community, and the relative amounts of each community present, before a burning prescription is recommended (Daubenmire 1968a).

### Production

Production following fire varies with local site conditions, community composition, distribution of rainfall throughout the growing season, and burning time relative to plant phenology (Hadley 1970). Rapid growth is promoted by increased photosynthetic efficiency and the increased activity of nitrifying microorganisms.

Stored soil moisture in the spring and precipitation in the current growing season have been correlated. Redmann (1975), working in western North Dakota, reported that the variations in production that commonly occur from one year to another are largely the result of differences in precipitation and soil-water status. Production and subsoil moisture in July and August were highly correlated. He concluded that subsoil moisture was not affected by midsummer rainfall and was therefore a good indicator of prevailing soil-water status and plant yield. Whitman and Wolters (1967) reported that the sum of the precipitation of September and October of the previous year, and March through August of the current year was closely related to soil moisture and grass yield. In a study near Mandan, North Dakota, Rogler and Hass (1947) found that the important variables affecting yield were the amount of soil moisture the preceding fall and precipitation during the current growing season.

In sagebrush-grassland ecosystems productivity has been studied following fire (Blaisdell 1953; Conrad and Poulton 1966; Harniss and Murray 1973; Mueggler and Blaisdell 1958; Nimir and Payne 1978; Pechanec and Hull 1945; Pechanec and Stewart 1954; Uresk et al. 1976; Wright et al. 1979). Big sagebrush is easily killed by fire but periodic control is necessary (Mueggler and Blaisdell 1958; Uresk et al. 1976). All plants were initially damaged by a fire in the Upper

Snake River Plains (Blaisdell 1953), however 12 years after burning the production of forbs was greater. After a fire near Dubois, Idaho the total grass and forb production was higher although threadleaf sedge (Carex filifolia) and Idaho fescue showed reduced production (Meuggler and Blaisdell 1958). After 30 years of protection from fire, big sagebrush increased while the production of important shrubs, grasses and forbs decreased (Harniss and Murray 1973). Once reestablished, sagebrush seedlings compete directly for soil moisture and nutrients with other species in the community. Subspecies of big sagebrush react differently to fire and reinvade burned-over areas at different rates (Harniss and Murray 1973).

Opinions differ about the effectiveness of using fire as a tool for reducing cheatgrass (Bromus tectorum) stands. Drought, overgrazing, and fire allow cheatgrass a competitive advantage in that fire destroys many perennial grasses and forbs, leaving unoccupied areas for invasion (Klemmedson and Smith 1964). Pickford (1932) and Christensen (1964) reported reduced perennial grass cover with a corresponding increase in cheatgrass. Time of burning is important in determining the effect fire will have on a stand of cheatgrass (Pechanec and Hull 1945; Stewart and Hull 1949). Lippert and Hopkins (1950) reported that late fall and early spring burning reduced cheatgrass stands. Burning may be effective if done before seeds disseminate but is ineffective once seeds fall into cracks in the soil.

Following fire in the tallgrass prairie, production was found to increase (Hadley and Kieckhefer 1963; Hensel 1923; McMurphy and Anderson 1965; Old 1969; Peet et al. 1975; Zedler and Loucks 1969), to decrease (Aldous 1934), or to remain unchanged (Ehrenreich and Aikman 1963; Zedler and Loucks 1969). Increased production on bluestem prairie is caused in part by reduced competition from cool-season grasses that are generally damaged by spring fires. Peet et al. (1975) believed that increased production was due primarily to the more favorable conditions for net photosynthesis from leaf emergence to late June when shading occurred.

#### Effects of Fire on Plant Communities of the Mixed Prairie

The mixed prairie can be divided into the semi-arid mixed prairie and the mesic mixed prairie (Figure 1). The semi-arid mixed prairie is defined as having annual precipitation less than 38 cm in the United States and less than 33 cm in Canada. The mesic portion has annual precipitation ranging from 38 to 48 cm in the United States and precipitation as low as 33 cm in Canada (Wright and Bailey 1980).

#### The Semi-arid Mixed Prairie

Burning has reduced yields in this part of the mixed prairie (Clarke et al. 1943; Coupland 1973; DeJong and MacDonald 1975; Redmann 1978).

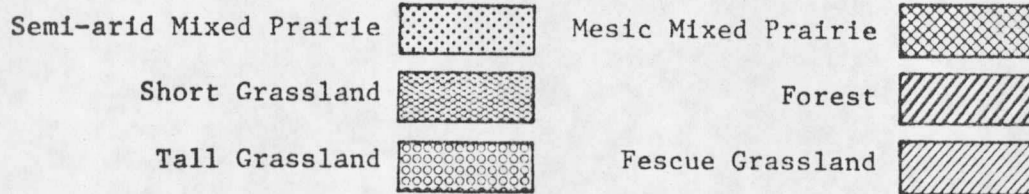
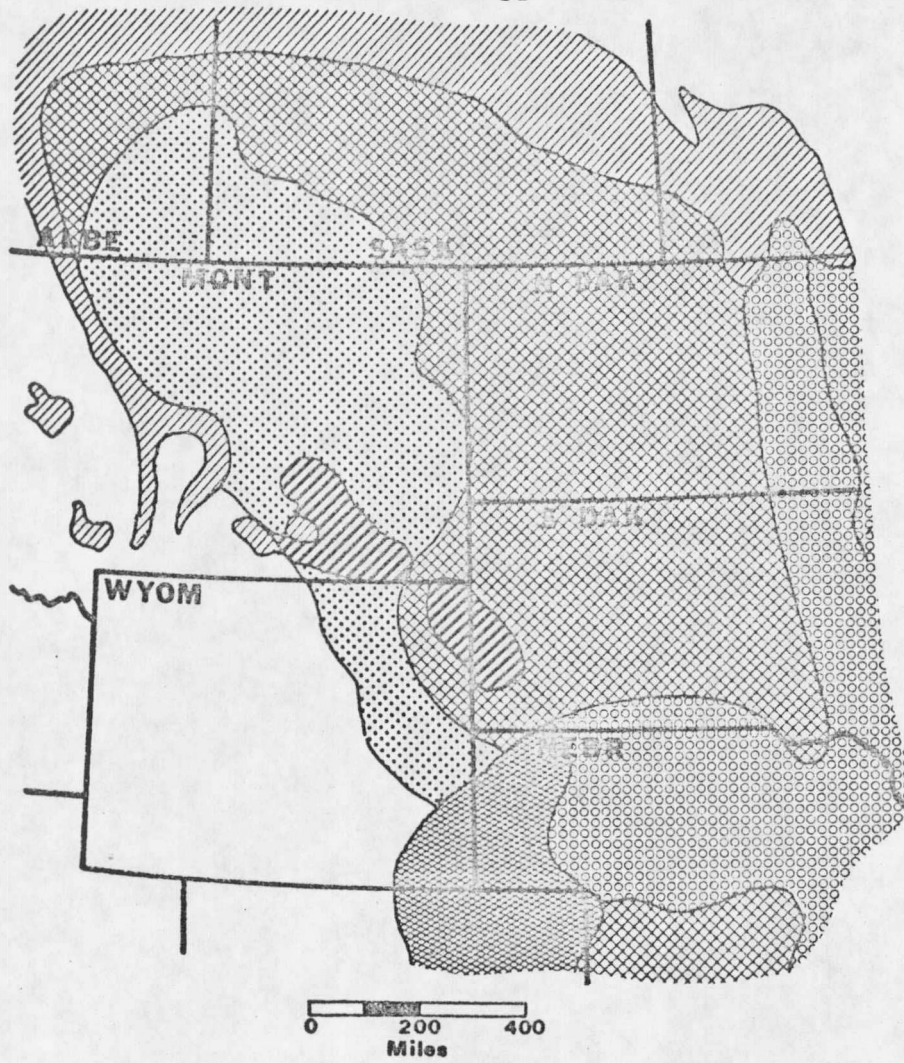


Figure 1. Natural vegetation of the northwestern Great Plains grasslands (Wright and Bailey 1980).



In southeastern Alberta, Clarke et al. (1943) reported that prescribed burning in the spring reduced yields 50 percent the first year and 15 percent the second. Prescribed burning in the fall reduced yields 30 percent the first year with no reduction thereafter. Decline in yield for both spring and fall-burned areas was greater for the western wheatgrass type than for the communities dominated by blue grama and needle-and-thread (Stipa comata). They attributed these reduced yields to the stunted growth of plants caused by an increased rate of water loss from bare ground and vegetation. They concluded that soil moisture is the principal factor determining production, with air and soil temperature being of prime importance for a short interval during the spring.

Coupland (1973) found the production of western wheatgrass reduced 19 percent, prairie junegrass (Koeleria cristata) reduced 63 percent but green needlegrass (Stipa viridula) increased 45 percent in the first post-fire growing season. By the end of the third growing season current production was only 67 to 73 percent of unburned areas.

In southwestern Saskatchewan, DeJong and MacDonald (1975) reported that a fall wildfire reduced production for two growing seasons. The major effects of burning were reduced soil moisture recharge during the first post-fire winter and lower water use in the years following the burn. Less efficient moisture storage on the burned site was probably due to snow blowing from the area.

In a later study in the same area, Redmann (1978) investigated soil and plant water potentials following an October wildfire. Water potentials were lower in the tissues of thickspike wheatgrass (Agropyron dasystachyum) and prairie junegrass on burned compared to unburned plots as the growing season progressed. Increased plant water stress was sufficient to account for the reduced production on burned compared to unburned areas. After three growing seasons production was only 72 percent of unburned areas. Reduced soil moisture was probably caused by the lack of standing dead which traps snow. Trilica and Shuster (1969) noted less favorable soil moisture levels in the spring on a fall-burned grassland because of reduced snow accumulation. Wight et al. (1975) measured greater snow depth and snow cover on undisturbed native grasslands as compared to clipped plots.

Three growing seasons may be needed to recover production under complete protection from grazing and 3 to 5 growing seasons under moderate grazing (Clarke et al. 1943). Prescribed burning may be a useful management tool for controlling shrubs without permanently harming perennial grasses, in the semi-arid mixed prairie, following winters with above normal precipitation (Wright and Bailey 1980).

### The Mesic Mixed Prairie

In the mesic mixed prairie of western North Dakota, Dix (1960) studied the effects of three wildfires (May 1958, August 1954 and September 1955). All study sites had been subject to grazing and were studied at the end of the 1958 growing season. Production after one growing season for the area burned in May was significantly less than the control. The lateness of the fire removed all the top growth that had occurred prior to burning and probably retarded further plant growth. Production was probably not depressed beyond the second growing season. The fall-burned areas had recovered production at the time of sampling. The late May fire reduced the frequency of thick-spike wheatgrass, blue grama, prairie sandreed (Calamovilfa longifolia), plains muhly (Muhlenbergia cuspidata), needle-and-thread and green needlegrass. The frequency remained the same or increased for western wheatgrass, needleleaf sedge (Carex stenophylla), Pennsylvania sedge (Carex pensylvanica), threadleaf sedge and prairie junegrass. On the fall-burned areas significant reductions in frequency were reported for threadleaf sedge, Pennsylvania sedge, prairie sandreed, hairy goldaster (Chrysopsis villosa), leafy spurge (Euphorbia esula), blue lettuce (Lactuca pulchella), purple prairieclover (Petalostemon purpureum) and little clubmoss (Selaginella densa). Using an index of stand similarity, the author noted that although a few individual

species were strongly influenced, a single fire did not greatly alter the overall species composition of the stands.

Gartner and Thompson (1972) studied two prescribed burns (early and late spring) on bluestem sites of the forest-grass ecotone in the Black Hills. Precipitation ranged from 43 to 64 cm per year. After one growing season pine seedlings were reduced 79 percent. On the late spring-burned area, little bluestem and prairie junegrass were undamaged while needle-and-thread and western wheatgrass were stimulated. Species of Rosa were eliminated and Carex species were reduced. In general, the frequency of grasses, forbs and shrubs was unchanged on the area burned in the early spring. The authors concluded that forage production will not be reduced if bluestem grasslands are burned before May 1.

Kirsch and Kruse (1972) studied the effects of prescribed spring burning (May) in east-central North Dakota. Annual precipitation averages 44 cm (17 in). The cover of most grasses and forbs increased or showed no significant change. Increasers included big bluestem, little bluestem, prairie sandreed, blue grama, needle-and-thread, green needlegrass, purple prairieclover and silverleaf scurfpea (Psoralea argophylla). Species that did not change included prairie junegrass, Kentucky bluegrass (Poa pratensis), sedges, western yarrow

(Achillea millefolium) and fringed sagewort (Artemisia frigida). The greatest measured change after burning was an increase in the number of species. Fifty-three species were identified before burning and 69 species were identified after burning. Burning increased the rate of flowering, seed production and height of many plants.

## STUDY AREA

The study was conducted on the Hugh Broadus ranch which is located approximately 14 km south of Colstrip in southeastern Montana (Figure 2). Southeastern Montana is situated on the Missouri plateau, an unglaciated region of the Northern Great Plains (Sindelar et al. 1974). The study area lies in the Midland physiographic province with geologic materials consisting primarily of Cenozoic sedimentary rock (Southard 1973).

The landscape consists of terrain dominated by sandstone or porcellanite (scoria) ridges and broad valleys lined with alluvial fans, footslopes and stream terraces (Sindelar et al. 1974). Landforms change rapidly because of the high rate of natural erosion. Most streams flow only intermittently during the spring runoff period. The nearest perennial stream to the study area is Rosebud Creek, which flows in a northerly direction to the Yellowstone River.

Colstrip lies in a soil transition zone of aridisols, alfisols, and mollisols (Schafer et al. 1979). Aridisols are common in the drier climate of the southeastern Powder River basin. Alfisols are abundant in the Big Horn mountains and Black Hills region. Mollisols are common in the moister Great Plains to the east. Entisols are abundant on steep slopes and in areas of fluvial activity (Figure 3).

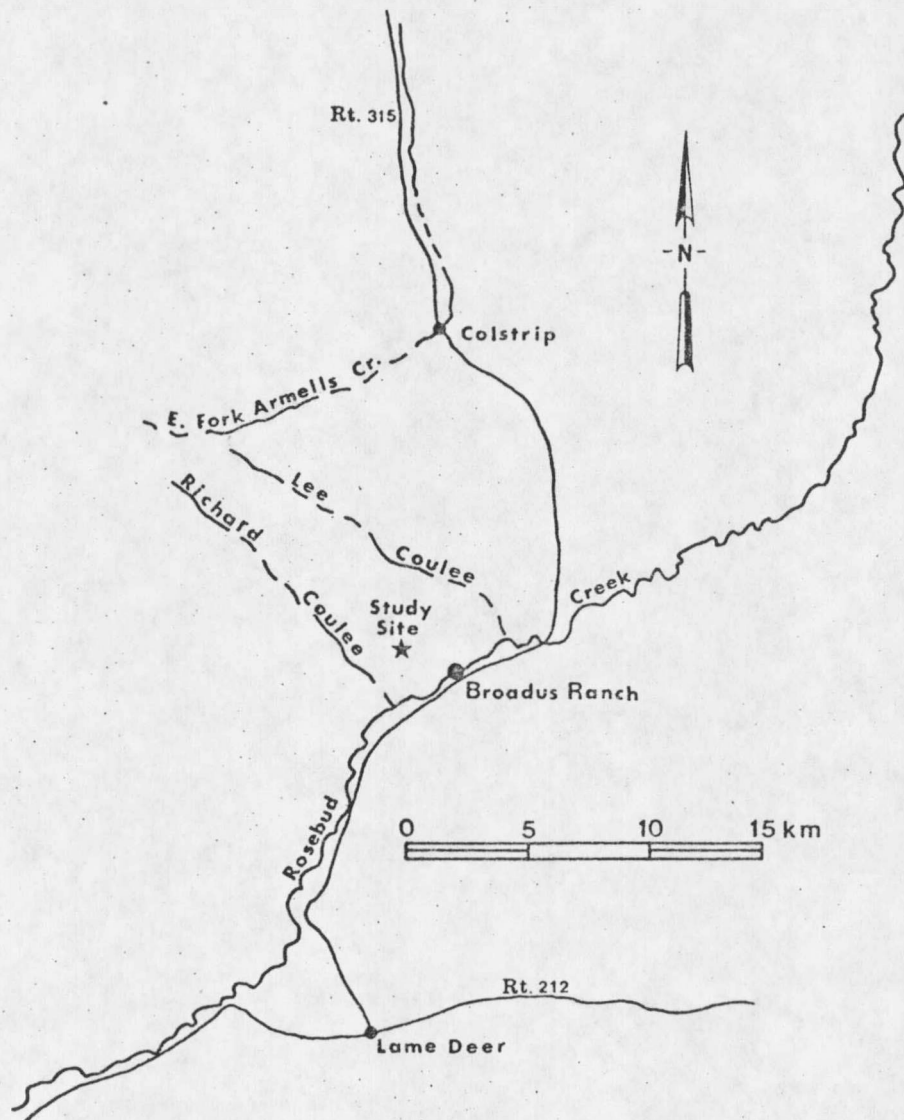


Figure 2. Location of Broadus ranch and study area in southeastern Montana.

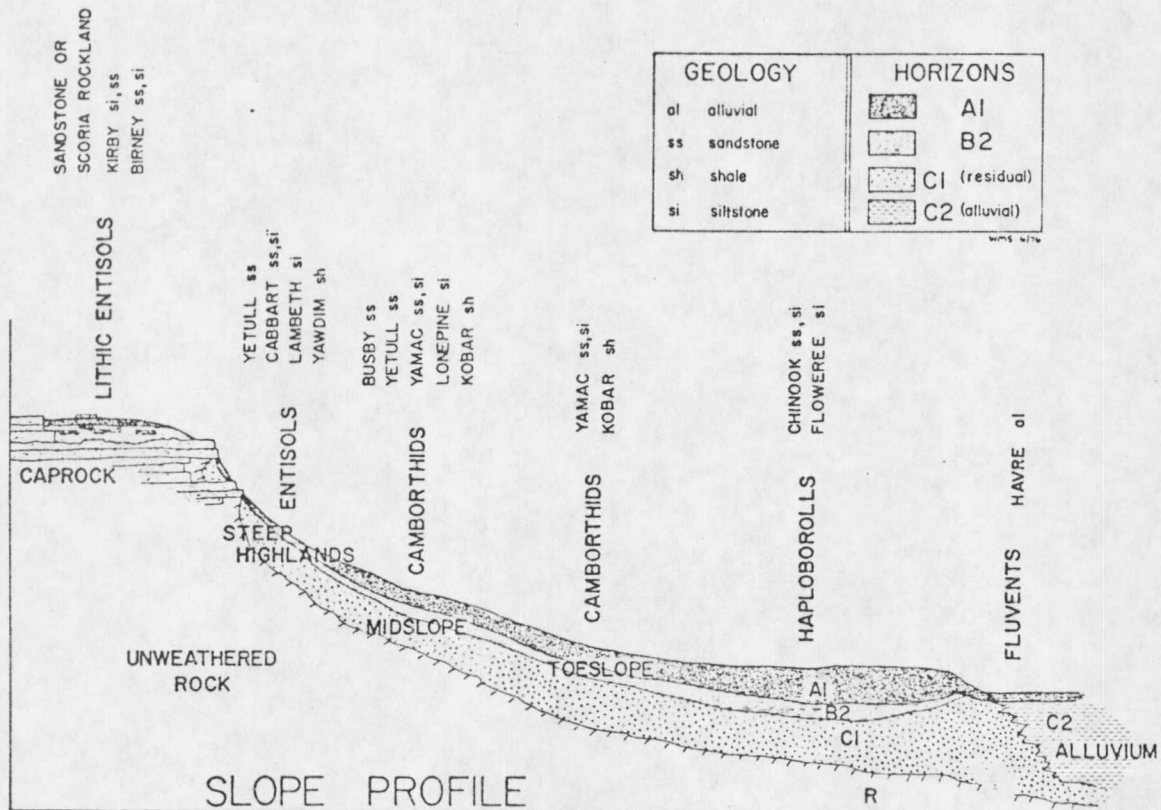


Figure 3. Representative slope profile and soil series which develop on various parent materials at each geomorphic position in the Colstrip, Montana area (Schafer *et al.* 1979).

The semi-arid continental climate is cold in the winter and warm in the summer. Mean monthly temperatures range from  $-5^{\circ}\text{C}$  to  $24^{\circ}\text{C}$ . The average annual precipitation for Colstrip is 40.1 cm with about 50 percent of this occurring as rain in the months April through July (DePuit *et al.* 1980). Approximately 30 percent of the annual precipitation occurs as snow (Sindelar *et al.* 1974).



The average frost-free season is 120 to 140 days (Sindelar et al. 1974). The last spring freeze usually occurs between May 15 and 25, and the first fall frost can be expected from September 15 to 22 (Skilbred 1979).

Vegetation of the study area is primarily mixed prairie grassland with pine woodlands and riparian vegetation in localized areas (DePuit et al. 1980). The range type of the study site is ponderosa pine savannah (Payne 1973). Grasses on native range are predominantly cool-season species, although a number of warm-season species are common. Important grasses are bluebunch wheatgrass, western wheatgrass, needle-and-thread, green needlegrass, blue grama, prairie junegrass, little bluestem and prairie sandreed. Big sagebrush, silver sagebrush (Artemisia cana) and skunkbush sumac (Rhus trilobata) are important shrubs (DePuit et al. 1980). Dominant species in the climax vegetation of the study area are presented in Table 1.

Table 1. Dominant species in the climax vegetation of southeastern Montana (after Ross and Hunter 1976).

SILTY-CLAYEY RANGE SITES

| SCIENTIFIC NAME               | COMMON NAME           |
|-------------------------------|-----------------------|
| <u>Agropyron dasystachyum</u> | Thickspike wheatgrass |
| <u>Agropyron smithii</u>      | Western wheatgrass    |
| <u>Agropyron spicatum</u>     | Bluebunch wheatgrass  |
| <u>Andropogon gerardii</u>    | Big bluestem          |
| <u>Andropogon scoparius</u>   | Little bluestem       |
| <u>Bouteloua curtipendula</u> | Sideoats grama        |
| <u>Bouteloua gracilis</u>     | Blue grama            |
| <u>Calamovilfa longifolia</u> | Prairie sandreed      |
| <u>Elymus cinereus</u>        | Basin wildrye         |
| <u>Eurotia lanata</u>         | Winterfat             |
| <u>Festuca idahoensis</u>     | Idaho fescue          |
| <u>Koeleria cristata</u>      | Prairie junegrass     |
| <u>Stipa comata</u>           | Needle-and-thread     |
| <u>Stipa viridula</u>         | Green needlegrass     |
| <u>Artemisia cana</u>         | Silver sagebrush      |
| <u>Artemisia tridentata</u>   | Big sagebrush         |
| <u>Atriplex nuttallii</u>     | Nuttall saltbush      |

SANDS AND SANDY RANGE SITES

|                               |                   |
|-------------------------------|-------------------|
| <u>Andropogon gerardii</u>    | Big bluestem      |
| <u>Andropogon hallii</u>      | Sand bluestem     |
| <u>Andropogon scoparius</u>   | Little bluestem   |
| <u>Bouteloua curtipendula</u> | Sideoats grama    |
| <u>Bouteloua gracilis</u>     | Blue grama        |
| <u>Calamovilfa longifolia</u> | Prairie sandreed  |
| <u>Carex filifolia</u>        | Threadleaf sedge  |
| <u>Oryzopsis hymenoides</u>   | Indian ricegrass  |
| <u>Stipa comata</u>           | Needle-and-thread |
| <u>Rhus trilobata</u>         | Skunkbush sumac   |
| <u>Rosa spp.</u>              | Rose species      |
| <u>Yucca glauca</u>           | Yucca             |

## METHODS AND PROCEDURES

### Objectives

The overall goal of this study was to determine the effects of early spring burning on vegetation in this portion of the semi-arid mixed prairie.

Specific objectives were to:

- (1) describe plant species response to early spring burning as reflected in species composition (based on canopy cover), production, phenology, vigor and vitality, and
- (2) measure changes in physical and chemical properties of the soil that influence the growth and reproduction of the vegetation.

### Study Site

#### Location

A 6.4 ha area was selected on April 1, 1979 on the Hugh Broadus ranch for the implementation of this study. This area is located 2.5 km north of the Broadus ranch headquarters (Section 10, T1S, R41E of the Montana Principal Meridian). Three plant communities were selected for study.

#### Artemisia tridentata/Stipa viridula community

The treated and untreated sites of this community were located 285 m apart on an alluvial footslope of approximately 3 percent (Figures 4 and 5). The aspect on the treated site was north-northeast.

while the untreated site was oriented northeast. Elevation on both sites was 985 m. The soil was a Borollic Camborthid, fine-loamy and mixed. This soil was in the Yamac series.



Figure 4. Artemisia tridentata/Stipa viridula treated site.





Figure 5. Artemisia tridentata/Stipa viridula untreated site.

Calamovilfa longifolia/Andropogon scoparius community

The treated and untreated sites of this community were located 95 m apart on hillsides whose parent material was sandstone (Figure 6 and 7). The slope on both sites varied from 3 to 6 percent. The treated site was oriented north northeast while the untreated site was oriented north. Elevation on both sites was 980 m. The soil was a Borollic Camborthid, coarse-loamy and mixed.





Figure 6. Calamovilfa longifolia/Andropogon scoparius treated site.



Figure 7. Calamovilfa longifolia/Andropogon scoparius untreated site.



Artemisia cana/Stipa viridula community

The treated and untreated sites of this community were located 55 m apart in a small swale between two sandstone hills (Figures 8 and 9). The slope on both sites was less than 2 percent and both sites were oriented toward the east. Elevation was approximately 975 m on both sites. The soil was an Ustic Torriorthent, fine-loamy, mixed (calcareous) and frigid.



Figure 8. Artemisia cana/Stipa viridula treated site.





Figure 9. Artemisia cana/Stipa viridula untreated site.

#### Microclimate

The climate of the study sites corresponds to Colstrip's climate; with the mean annual temperature, precipitation and frost-free period being similar. Within each of the three plant communities the microclimates for the treated and untreated sites were alike, due to similarities of slope, aspect, soils, plant growth forms and species composition.

Climographs for 1978, 1979 and 1980 at Colstrip are presented in Figures 10, 11 and 12. In 1978, Colstrip received above average precipitation in September, November and December. In September,



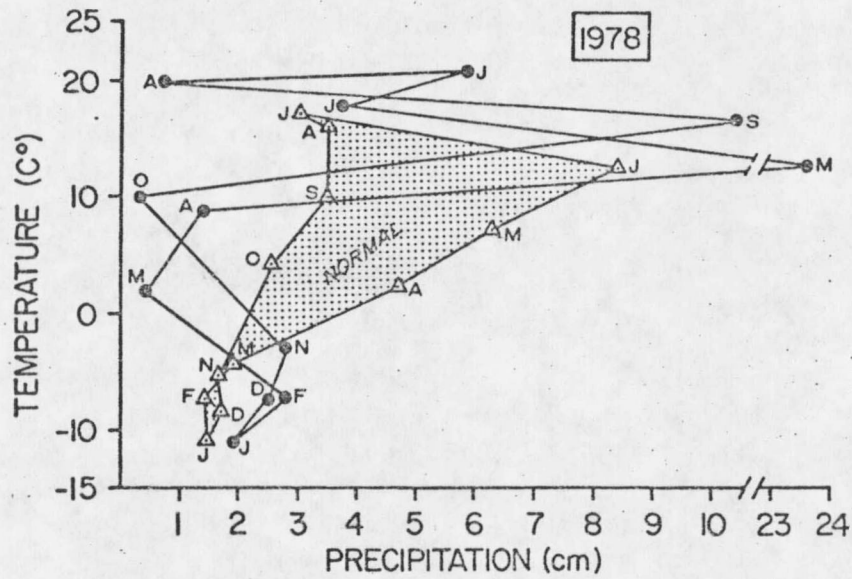


Figure 10. 1978 climograph for Colstrip, Montana.

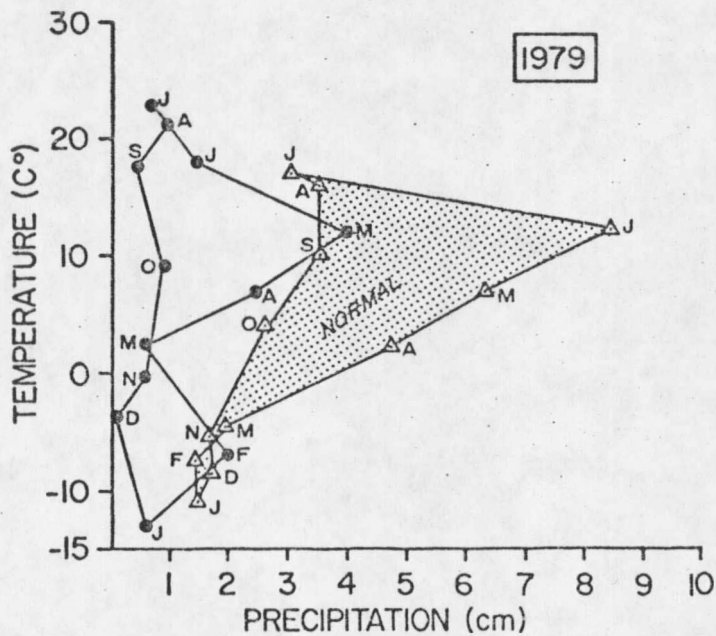


Figure 11. 1979 climograph for Colstrip, Montana.

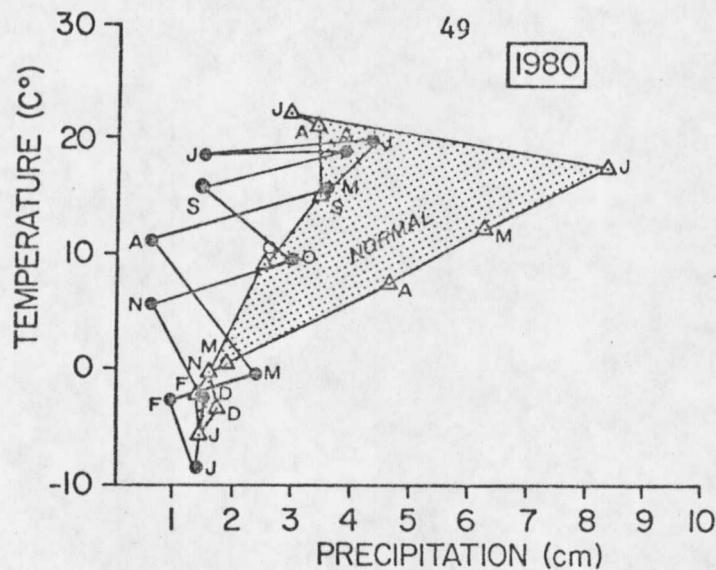


Figure 12. 1980 climograph for Colstrip, Montana.

approximately four-times the normal amount of precipitation was received. The 1979 climograph illustrates the severe drought during that year. Precipitation was below normal every month except February. Annual precipitation during 1979 was 13.3 cm or 33 percent of the normal 40.1 cm. Monthly temperatures during 1979 were approximately normal. This severe drought carried over into the 1980 growing season. Though the 1980 drought was less severe than the 1979 drought, by October Colstrip had received only 60 percent of the precipitation that is normally received by that time each year. Monthly temperatures were above normal from March through June during 1980.

### Vegetation

Based on canopy cover, the dominant species of each community are presented in Table 2. A complete species list for each study site

Table 2. Dominant species (based on canopy cover) on the Broadus study sites during 1979 and 1980.

| COMMUNITY                                                      | DOMINANT SPECIES    |                               |
|----------------------------------------------------------------|---------------------|-------------------------------|
|                                                                | COMMON NAME         | SCIENTIFIC NAME               |
| <u>Artemisia tridentata</u> /<br><u>Stipa viridula</u>         | Green needlegrass   | <u>Stipa viridula</u>         |
|                                                                | Western wheatgrass  | <u>Agropyron smithii</u>      |
|                                                                | Prairie junegrass   | <u>Koeleria cristata</u>      |
|                                                                | Bromegrass          | <u>Bromus</u> spp.            |
|                                                                | Common dandelion    | <u>Taraxacum officinale</u>   |
|                                                                | Scarlet globemallow | <u>Sphaeralcea coccinea</u>   |
|                                                                | Big sagebrush       | <u>Artemisia tridentata</u>   |
| <u>Calamovilfa longifolia</u> /<br><u>Andropogon scoparius</u> | Prairie sandreed    | <u>Calamovilfa longifolia</u> |
|                                                                | Little bluestem     | <u>Andropogon scoparius</u>   |
|                                                                | Needle-and-thread   | <u>Stipa comata</u>           |
|                                                                | Threadleaf sedge    | <u>Carex filifolia</u>        |
|                                                                | Skunkbush sumac     | <u>Rhus trilobata</u>         |
| <u>Artemisia cana</u> /<br><u>Stipa viridula</u>               | Green needlegrass   | <u>Stipa viridula</u>         |
|                                                                | Western wheatgrass  | <u>Agropyron smithii</u>      |
|                                                                | Blue grama          | <u>Bouteloua gracilis</u>     |
|                                                                | Scarlet gaura       | <u>Gaura coccinea</u>         |
|                                                                | Silver sagebrush    | <u>Artemisia cana</u>         |
|                                                                | Big sagebrush       | <u>Artemisia tridentata</u>   |

appears in Appendix A. Scientific nomenclature follows Hitchcock and Cronquist (1973) and Booth and Wright (1966), with the former given preference.

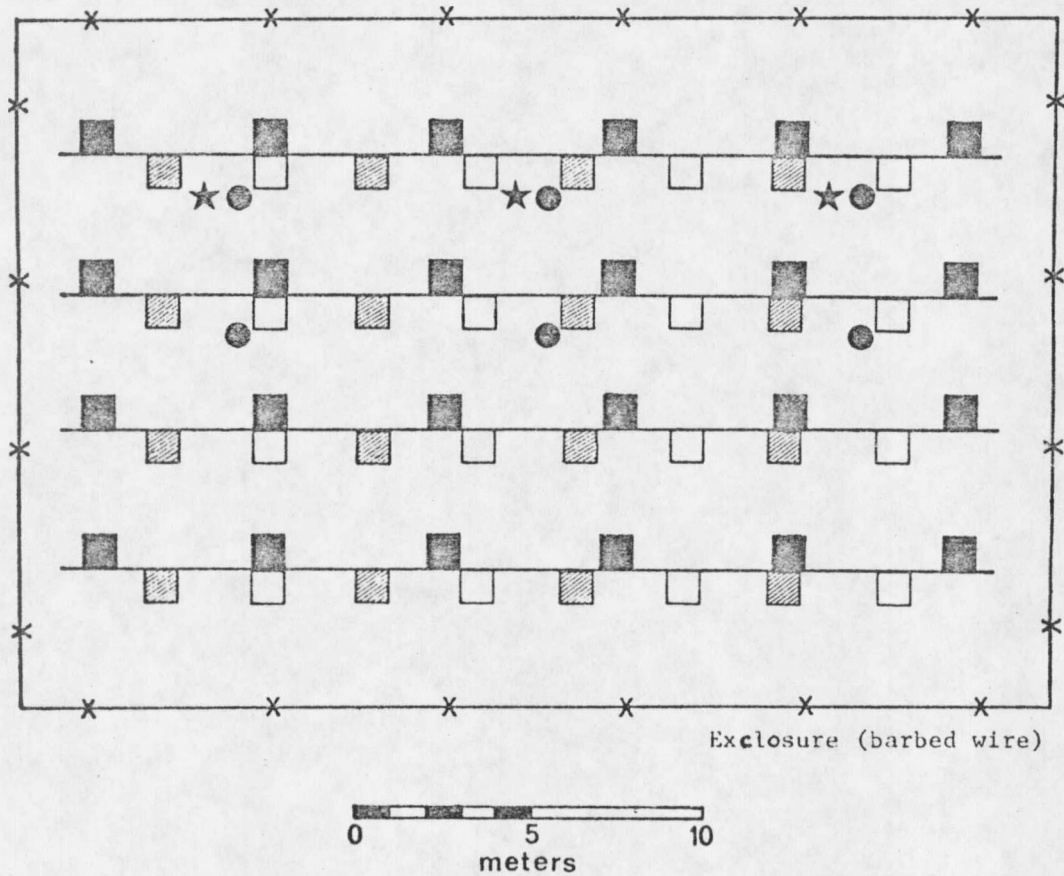
#### Experimental Design and Measurements

This study was originally designed to monitor the response of the vegetation in the Artemisia tridentata/Stipa viridula community. The Calamovilfa longifolia/Andropogon scoparius and the Artemisia cana/Stipa viridula communities were added to the study after the fireline burned through these areas. The emphasis of the field work was therefore placed on sampling in the Artemisia tridentata/Stipa viridula community. For this reason procedures and measurements varied slightly between the plant communities.

To protect the Artemisia tridentata/Stipa viridula sites from grazing disturbance, permanent exclosures were established. Permanent exclosures were not established in the Calamovilfa longifolia/Andropogon scoparius or the Artemisia cana/Stipa viridula communities. Care was taken to locate the exclosures in areas with similar compositions of big sagebrush and perennial grasses. Slope, aspect and position on the footslope were also considered before the exclosures were established.

A 20 x 30 m fenced exclosure was erected on the treated and untreated Artemisia tridentata/Stipa viridula sites. Four, 27 m transects were established in each exclosure (Figure 13).





- 1979, 0.5 x 0.5 m biomass clipping quadrat
- 1980, 0.5 x 0.5 m biomass clipping quadrat
- ▨ 0.2 x 0.5 m canopy cover quadrat
- placement of 'tempilstik' packets below the soil surface
- ★ soil moisture and chemical measurements

Figure 13. Representation of enclosure and transects used on the Artemisia tridentata/Stipa viridula sites.

### Vegetation Measurements

On the Artemisia tridentata/Stipa viridula sites 24, 0.2 x 0.5 m quadrats were used for canopy cover estimates. Six permanent quadrats were systematically located along the west side of each transect at 2.4 m intervals; two metal rods were staked in opposite corners of each quadrat. On the Calamovilfa longifolia/Andropogon scoparius and the Artemisia cana/Stipa viridula sites, two, 24 m transects were established in the treated and untreated areas (Figure 14). Twenty-four, 0.2 x 0.5 m quadrats were used to estimate canopy cover.

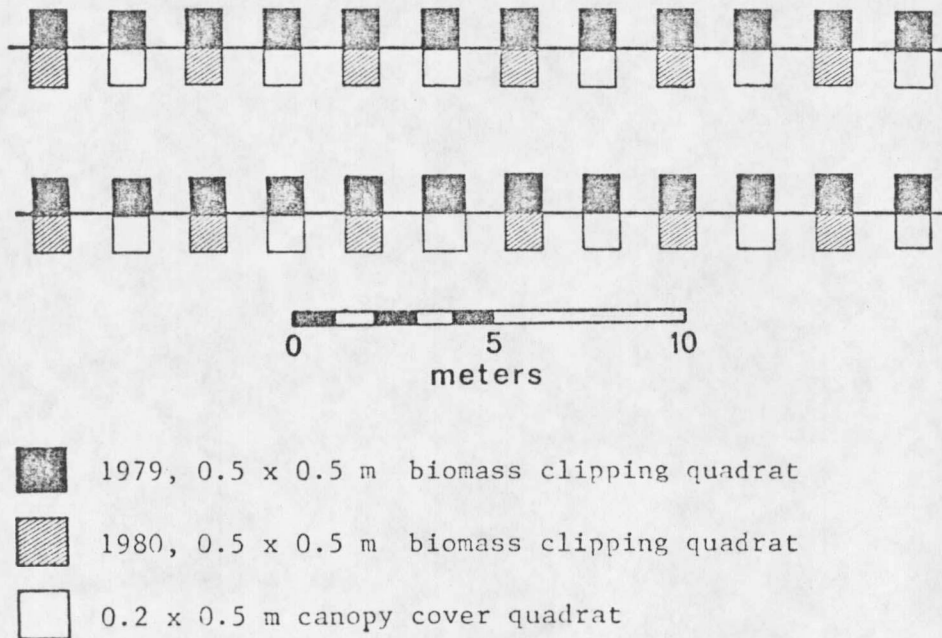


Figure 14. Representation of transects used on the Calamovilfa longifolia/Andropogon scoparius and the Artemisia cana/Stipa viridula sites.

Quadrats were systematically located along the west side of both transects at 2 m intervals. Although the location of each quadrat was not permanently marked, an effort was made to place each cover quadrat in the same location during both field seasons. Canopy cover and frequency estimates were made using the technique of Daubenmire (1968b).

Above ground biomass production on the Artemisia tridentata/Stipa viridula sites was estimated by directly harvesting 16, 0.5 x 0.5 m quadrats. On the east side of each transect four quadrats were systematically located at 3 m intervals (Figure 13). Biomass production on the Calamovilfa longifolia/Andropogon scoparius and the Artemisia cana/Stipa viridula sites were estimated using 12, 0.5 x 0.5 m quadrats. Quadrats were systematically located along the east side of each transect at 2 m intervals. Plants were clipped at ground level. The dominant perennial grasses as well as all the shrubs and half-shrubs were separated by species. Annual grasses were collected and considered together. Except for plains pricklypear (Opuntia polyacantha) all forbs were consolidated. This cactus was considered separately because its weight drastically increased the weight of the total forbs. Biomass samples were oven-dried and weighed. Yield estimates were made from these data.

Phenology was estimated for the dominant perennial and annual grasses approximately monthly from the beginning of the growing season

until after seed-set. The phenology codes used were modified from Taylor and Leininger (1978) and are presented in Table 3. During 1979, the phenology of a particular species was estimated after making a reconnaissance of the study area. During 1980, 15 individual plants of each species were permanently marked at the beginning of the growing season. On each field trip, the phenological development of these 15 plants was noted. These observations were used to generate a mean phenology estimate for that species.

Table 3. Phenology codes (after Taylor and Leininger 1978).

---

| Code | Stages                                   |
|------|------------------------------------------|
| 1    | Cotyledon (newly germinated)             |
| 2    | Seedling                                 |
| 3    | Basal rosette                            |
| 4    | Early greenup, veg. buds swelling        |
| 5    | Vegetative growth, twig elongation       |
| 6    | Bootstage, flower buds swelling          |
| 7    | Shooting seed stalk, floral buds opening |
| 8    | Early flowering                          |
| 9    | Flowering, anthesis                      |
| 10   | Late flowering                           |
| 11   | Fruit formed                             |
| 12   | Seed shatter, dehiscence                 |
| 13   | Vegetative growth*                       |
| 14   | Vegetative maturity**                    |
| 15   | Summer dormancy, leaf drop               |
| 16   | Fall greenup                             |
| 17   | Winter dormancy                          |
| 18   | Dead                                     |

---

\* plants green; not showing signs of dying back

\*\*plants just beginning to die back



Vigor was estimated by measuring the height of plants and the length of inflorescences during 1979. These measurements also were recorded during 1980 along with the number of leaves per culm and leaf lengths. Vitality was estimated by comparing the ratio of vegetative to reproductive culms. During 1979, 15 individual plants of each species were chosen at the time of sampling. During 1980, the plants that had been marked for phenology measurements, were also used to estimate vigor and vitality. Quadrats were placed over the selected plants to facilitate the counting of culms. Quadrat size varied depending on the species being sampled. Culms of blue grama were counted using 0.2 x 0.2 m quadrats while all other species were sampled using 0.5 x 0.5 m quadrats.

The amount of fuel was estimated by clipping the vegetation in 16 randomly located 50 x 50 cm quadrats before and after the Artemisia tridentata/Stipa viridula fire (Table 4).

Table 4. Amount of fuel before and after burning in the Artemisia tridentata/Stipa viridula community.

| WEIGHT (kg/ha) |               |                      |                      |
|----------------|---------------|----------------------|----------------------|
|                | <u>Shrubs</u> | <u>Standing Dead</u> | <u>Ground litter</u> |
| Pre-burn       | 9326          | 890                  | 7072                 |
| Post-burn      | 2752*         | 13*                  | 3078*                |

\*Significantly different at the  $P \leq .05$  level.

### Physical Measurements

'Tempilstik's were used to estimate the maximum temperatures generated during the Artemisia tridentata/Stipa viridula fire. 'Tempilstik's are pencil-shaped rods made of a chemical with a known melting point. Thirteen rods were used, with melting points from 65°C to 371°C.

Small pieces of each rod were sliced off with a razor blade and folded into 1 x 1 cm aluminum foil packets. These packets were then placed side by side on a piece of foil (Figure 15). The top and bottom of this larger piece of foil was then folded over to secure the small packets.

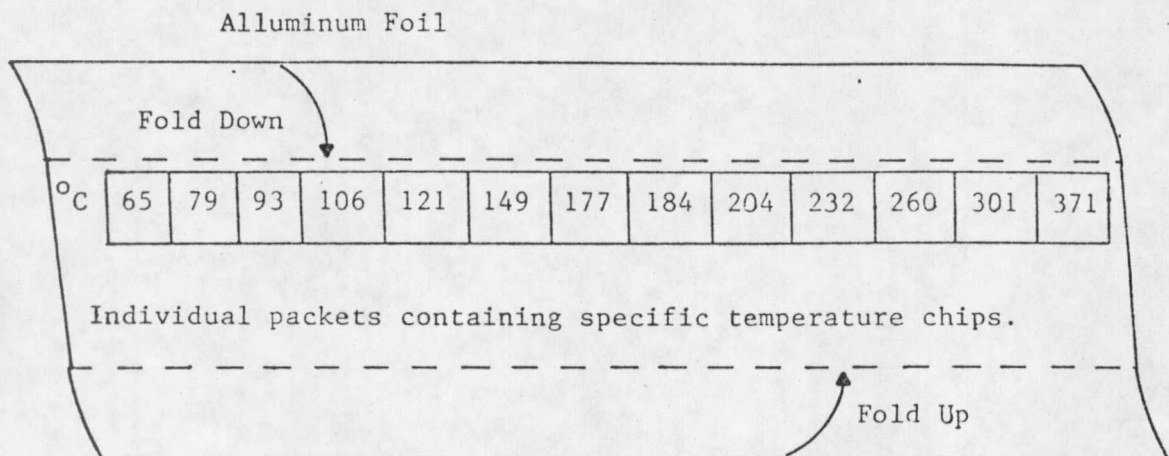


Figure 15. Representation of 'tempilstik' packet.

Twenty-one packets were placed on the soil surface and six packets were placed 1 cm below the mineral soil surface (Figure 16).



Packets on the soil surface generally indicated very high temperatures, especially near big sagebrush plants (Table 5). Maximum temperatures at the 1 cm depth did not exceed 65°C even under big sagebrush plants where the soil surface temperature was greater than 371°C.



Figure 16. 'Tempilstik' packet being placed below the soil surface.

A visual burning index was used to estimate the relative severity of the fire (Table 6). The percentage of leaf litter incinerated in each of the permanently marked cover quadrats was estimated: slightly burned 0 to 25 percent, moderately burned 26 to 75 percent and

Table 5. The number of 'tempilstik' packets reaching or exceeding specific temperatures.

| Temperature<br>C° | 'TEMPILSTIK' PACKETS <sup>1</sup> |                   |                           |      |
|-------------------|-----------------------------------|-------------------|---------------------------|------|
|                   | At Soil Surface                   |                   | Below Soil Surface (1 cm) |      |
|                   | Shrub <sup>2</sup>                | Open <sup>3</sup> | Shrub                     | Open |
| >371              | 10                                | 1                 | 0                         | 0    |
| 301-371           | 2                                 | 1                 | 0                         | 0    |
| 232-260           | 1                                 | 1                 | 0                         | 0    |
| 177-184           | 1                                 | 1                 | 0                         | 0    |
| <65               | 3                                 | 0                 | 4                         | 2    |
| Totals            | 17                                | 4                 | 4                         | 2    |

<sup>1</sup>'Tempilstik' packets contain chips of 13 individual 'tempilstik's representing a temperature range from 65°C to 371°C.

<sup>2</sup>'Tempilstik' packets placed within 1 m of a big sagebrush plant.

<sup>3</sup>'Tempilstik' packets placed more than 1 m from a big sagebrush plant.

Table 6. Visual index of prescribed burn intensity.

| Burn Class/Range  | Total <sup>1</sup> (%) |
|-------------------|------------------------|
| Slightly/0-25%    | 16 ( 21.9)             |
| Moderately/26-75% | 16 ( 21.9)             |
| Severely/76-100%  | 35 ( 47.9)             |
| Not Burned        | 6 ( 8.3)               |
| Total             | 73 (100.0)             |

<sup>1</sup>Total includes both diagonal and cover quadrat estimates.



severely burned 76 to 100 percent. In addition, a 100 m tape was stretched diagonally across the enclosure and the severity of the fire estimated at each meter. Although the range of each burn class was uneven, the table illustrates that a large portion of the study area was severely burned.

Soil samples were collected on the burned Artemisia tridentata/Stipa viridula site to determine if important chemical properties had been altered. Three sampling points were permanently marked the morning preceding the prescribed burn. Using an Oakfield sampler, samples were collected the morning before the fire, two hours after the fire, and one and two months after the fire. Samples were always collected within 1 m of the designated sampling point. At each sampling point 10 to 15 cores were removed and composited in four intervals: 0 to 2.5 cm, 2.5 to 5 cm, 5 to 10 cm, and 10 to 15 cm. Soil analyses were conducted by the Montana State University Soil Testing Laboratory.

Infiltration rate on the Artemisia tridentata/Stipa viridula sites was estimated using the method and apparatus described by Meeuwig (1971). The device consists of a plexiglass water reservoir which delivers a raindrop effect onto the soil surface through capillary tubes. A flowmeter registers the water application rate while surface runoff is funneled into a collection container. Simulated

rainfall was applied at a rate of 9.6 cm/hr. The volume of runoff was measured every three minutes for a 30 minute test period. During 1979, seven infiltration rate tests were conducted on the burned site and three on the unburned control. During 1980, five tests were conducted on the burned site and three on the unburned control.

Soil moisture content was determined with a Troxler neutron probe on the burned and unburned sites of each community. This probe estimates soil moisture in the upper 15 cm of mineral soil. Sampling was conducted at approximately monthly intervals during both field seasons.

### Field Implementation

#### Burning the Fireline

A natural firebreak on the west and south sides of the study area consisted of porcellanite ridges or severely eroded sandstone hills. To contain the prescribed burn a fireline was established around the north and east perimeters of the study area.

Burning began at the northwest corner of the study area at approximately 9:00 am on April 6, 1979 and proceeded in a semicircle toward the southeastern corner (Figure 17). Air temperature at the outset of burning was 2°C and the wind was calm.

A small flamethrower, using a mixture of gasoline and diesel fuel, was used to ignite the vegetation. Two technicians using burlap

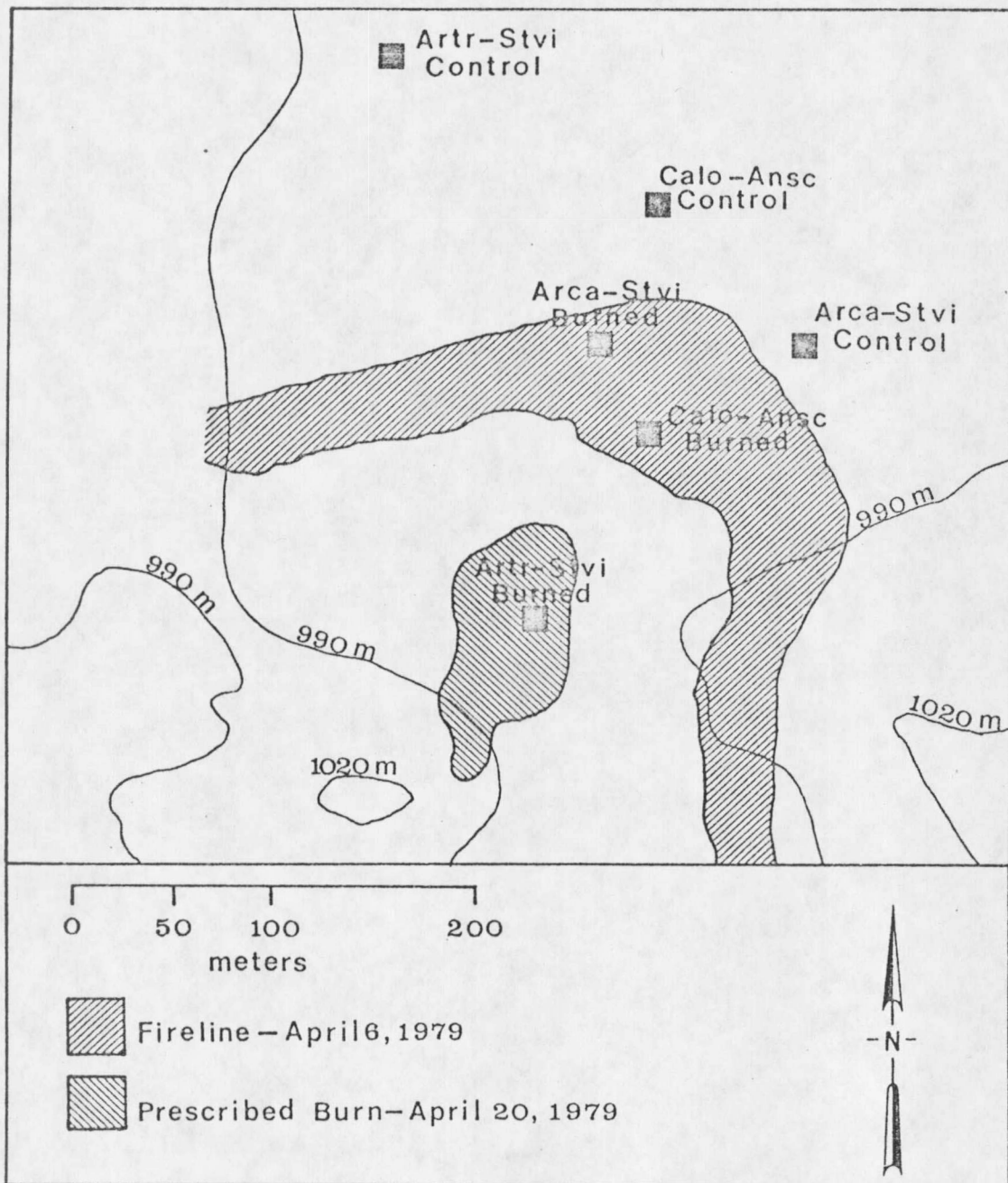


Figure 17. Location of the study sites relative to the areas burned.

sacks and shovels, helped direct the flames.

The fire was easy to control where fuel was primarily grass or where grazing had been excessive. When the fire spread into dense stands of big sagebrush control was difficult at best. As the day progressed air temperature increased and control became more difficult. As a result the fire had to be watched closely. The fireline was approximately 450 m long, 10 to 25 m wide and took a day to complete.

Treated study sites for the Calamovilfa longifolia/Andropogon scoparius and the Artemisia cana/Stipa viridula communities were located in the area burned for the fireline (Figure 17).

#### The Prescribed Burn

The prescribed burn was conducted in the Artemisia tridentata/Stipa viridula community on April 20, 1979.

Two technicians ignited the vegetation while two others extinguished fires that crossed the fireline. Using the flamethrower and roadflares, a line of fire was started about 30 m north and west of the enclosure (Figure 17).

The fire was started at 1:30 pm under a clear sky. Air temperature was 19°C and relative humidity was 26 percent. Wind speed varied from 2 to 12 mph, from the northwest.

The canopy cover of big sagebrush was estimated prior to burning



using the line interception technique (Canfield 1941). Four, 20 m transects yielded a mean cover value of 67.9 percent. Flames traveled well in the dense areas of big sagebrush. Grazing the previous year had reduced understory fuel. Burning was thorough where the flames carried directly from one big sagebrush plant to another. Burning was incomplete where surface fuel was inadequate between sagebrush plants. The fire moved through the study area at a rate of about 0.45 km/hr.

## RESULTS

### Vegetation Data

#### Canopy Cover

##### Artemisia tridentata/Stipa viridula community

Perennial grass canopy cover was not significantly different between the burned and the unburned sites during 1979 or 1980 (Table 7). Perennial grass cover increased on the burned site and decreased on the unburned site from 1979 to 1980.

Western wheatgrass had significantly greater canopy cover on the burned compared to the unburned site in both growing seasons. Prairie junegrass had greater cover on the unburned site in 1979 and significantly greater cover on this site in 1980. Green needlegrass had significantly greater cover on the unburned site in 1979. In 1980, green needlegrass cover was similar between sites due to an increase on the burned site and a decrease on the unburned site. The canopy cover of bluebunch wheatgrass, blue grama and needle-and-thread was similar between burned and unburned sites during both growing seasons.

Annual grass cover was not significantly different between sites during either growing season. Cover reductions occurred on both sites from 1979 to 1980.

Table 7. Percent canopy cover in the *Artemisia tridentata*/*Stipa viridula* community of species with cover  $\geq 1\%$ .

| Plant Class                 | 1979           |                 |                | 1980 |    |      |
|-----------------------------|----------------|-----------------|----------------|------|----|------|
|                             | B <sup>1</sup> | UB <sup>2</sup> | D <sup>3</sup> | B    | UB | D    |
| Perennial Grasses           | 38             | 49              | -11            | 42   | 38 | 4    |
| Annual Grasses              | 4              | 6               | -2             | 2    | T  | 2    |
| Forbs                       | 12             | 3               | 9*             | 4    | 1  | 3    |
| Shrubs/Half-Shrubs          | 1              | 28              | -27*           | 2    | 20 | -18* |
| <u>Perennial Grasses</u>    |                |                 |                |      |    |      |
| <u>Agropyron smithii</u>    | 12             | 3               | 9*             | 11   | 2  | 9*   |
| <u>Agropyron spicatum</u>   | 3              | 2               | 1              | 3    | 4  | -1   |
| <u>Bouteloua gracilis</u>   | 1              | 2               | -1             | 1    | 1  | 0    |
| <u>Koeleria cristata</u>    | 4              | 8               | -4             | 2    | 6  | -4*  |
| <u>Stipa comata</u>         | -              | 2               | -2*            | -    | 1  | -1*  |
| <u>Stipa viridula</u>       | 18             | 32              | -14*           | 24   | 24 | 0    |
| <u>Annual Grasses</u>       |                |                 |                |      |    |      |
| <u>Bromus japonicus</u>     | 1              | 6               | -5*            | 1    | T  | T    |
| <u>Bromus tectorum</u>      | 2              | -               | 2*             | 2    | -  | 2    |
| <u>Forbs</u>                |                |                 |                |      |    |      |
| <u>Sphaeralcea coccinea</u> | 1              | 2               | -1             | 2    | 1  | 1    |
| <u>Taraxacum officinale</u> | 9              | -               | 9*             | 1    | T  | T    |
| <u>Tragopogon dubius</u>    | 2              | -               | 2*             | T    | T  | T    |
| <u>Shrubs/Half-Shrubs</u>   |                |                 |                |      |    |      |
| <u>Artemisia tridentata</u> | 1              | 27              | -26*           | 2    | 19 | -17* |
| <u>Eurotia lanata</u>       | 1              | T               | T              | -    | T  | T    |
| <u>Litter</u>               | 31             | 74              | -43*           | 37   | 73 | -36* |
| <u>Bare Ground</u>          | 64             | 21              | 43*            | 58   | 22 | 36   |

<sup>1</sup>Burned<sup>2</sup>Unburned<sup>3</sup>Difference between burned and unburned sites

T = &lt; 1% cover.

\* Significantly different between the burned and unburned sites at the  $P \leq .05$  level.

Forbs had significantly greater cover on the burned compared to the unburned site during 1979. This greater cover can be attributed to common dandelion (Taraxacum officinale) and yellow salsify (Tragopogon dubius). Forb cover was reduced on both sites from 1979 to 1980.

Because of the nearly complete elimination of big sagebrush on the burned site, the canopy cover of shrubs and half-shrubs was significantly lower on the burned site during both years.

Calamovilfa longifolia/Andropogon scoparius community

Perennial grass cover was not significantly different between the burned and the unburned sites during 1979 or 1980 (Table 8). Cover was less on both sites in 1980 than in 1979. Little bluestem, the dominant species in this community, accounted for most of this reduced cover. Prairie sandreed and prairie junegrass had reduced cover on the burned and unburned sites from 1979 to 1980.

The cover of threadleaf sedge was significantly greater on the burned site during 1979. The difference was not significant in 1980 due to a reduction on the burned and an increase on the unburned site.

Forb cover was significantly greater on the burned site during 1979. This was primarily the result of silverleaf scurfpea and species of milkvetch (Astragalus spp.). In 1980 these species were reduced or completely absent.

Table 8. Percent canopy cover in the Calamovilfa longifolia/  
Andropogon scoparius community of species with cover  $\geq 1\%$ .

| Plant Class                   | B <sup>1</sup> | 1979<br>UB <sup>2</sup> | D <sup>3</sup> | B  | 1980<br>UB | D   |
|-------------------------------|----------------|-------------------------|----------------|----|------------|-----|
| Perennial Grasses             | 57             | 51                      | 6              | 36 | 32         | 4   |
| Sedges                        | 11             | 5                       | 6*             | 10 | 7          | 3   |
| Annual Grasses                | -              | -                       | -              | -  | -          | -   |
| Forbs                         | 10             | 3                       | 7*             | 1  | 2          | -1* |
| Shrubs/Half-Shrubs            | -              | 14                      | -14*           | T  | 4          | -4* |
| <u>Perennial Grasses</u>      |                |                         |                |    |            |     |
| <u>Agropyron spicatum</u>     | 3              | 1                       | 2              | 2  | 3          | -1  |
| <u>Andropogon scoparius</u>   | 22             | 18                      | 4              | 13 | 7          | 6   |
| <u>Aristida longiseta</u>     | 2              | -                       | 2              | T  | T          | T   |
| <u>Bouteloua gracilis</u>     | 2              | 4                       | -2             | 2  | 4          | -2  |
| <u>Calamovilfa longifolia</u> | 10             | 8                       | 2              | 8  | 4          | 4   |
| <u>Koeleria cristata</u>      | 9              | 9                       | 0              | 7  | 3          | 4*  |
| <u>Poa compressa</u>          | 1              | 1                       | 0              | T  | -          | T   |
| <u>Stipa comata</u>           | 8              | 10                      | -2             | 4  | 11         | -7  |
| <u>Sedges</u>                 |                |                         |                |    |            |     |
| <u>Carex filifolia</u>        | 11             | 5                       | 6*             | 10 | 7          | 3   |
| <u>Forbs</u>                  |                |                         |                |    |            |     |
| <u>Antennaria parvifolia</u>  | -              | 1                       | -1             | -  | T          | T*  |
| <u>Astragalus spp.</u>        | 3              | T                       | 3              | -  | T          | T   |
| <u>Lithospermum incisum</u>   | 1              | T                       | T              | T  | T          | T   |
| <u>Lygodesmia juncea</u>      | 1              | -                       | 1              | T  | T          | T   |
| <u>Psoralea argophylla</u>    | 3              | -                       | 3*             | -  | -          | -   |
| <u>Ratibida columnifera</u>   | 1              | T                       | T              | -  | -          | -   |
| <u>Shrubs/Half-Shrubs</u>     |                |                         |                |    |            |     |
| <u>Artemisia cana</u>         | -              | 1                       | -1             | T  | 1          | T   |
| <u>Artemisia dracunculus</u>  | -              | T                       | T              | -  | 1          | -1  |
| <u>Artemisia tridentata</u>   | -              | 1                       | -1             | -  | -          | -   |
| <u>Gutierrezia sarothrae</u>  | -              | T                       | T              | -  | 1          | -1  |
| <u>Oenothera serrulata</u>    | -              | 10                      | -10            | -  | 1          | -1  |
| <u>Rhus trilobata</u>         | -              | 1                       | -1             | -  | -          | -   |
| <u>Yucca glauca</u>           | -              | 1                       | -1             | -  | T          | T   |

continued

Table 8. Continued.

| Plant Class        | 1979 |    |     | 1980 |    |    |
|--------------------|------|----|-----|------|----|----|
|                    | B    | UB | D   | B    | UB | D  |
| <u>Litter</u>      | 38   | 53 | -15 | 27   | 36 | -9 |
| <u>Bare Ground</u> | 57   | 42 | 15  | 68   | 59 | 9  |

1

Burned

2

Unburned

3

Difference between burned and unburned sites

T = &lt; 1% cover.

\* Significantly different between the burned and unburned sites at the  $P \leq .05$  level.

The cover of shrubs and half-shrubs was significantly greater on the unburned site during 1979 and 1980. Shrubby evening primrose, which produced the majority of the cover in this class during 1979, was severely reduced in 1980.

Artemisia cana/Stipa viridula community

Perennial grass cover was greater on the burned compared to the unburned site during both growing seasons but this was significant only during 1979 (Table 9). Perennial grass cover was reduced on both sites in 1980. Western wheatgrass and green needlegrass had significantly greater cover on the burned site during both years. These species had reduced cover on both sites from 1979 to 1980. However, plants on the burned site were reduced more than plants on the unburned site. In 1980, the canopy cover of prairie junegrass was significantly greater on the unburned site.

Table 9. Percent canopy cover in the *Artemisia cana*/*Stipa viridula* community of species with cover  $\geq 1\%$ .

| Plant Class                      | 1979           |                 |                | 1980 |    |      |
|----------------------------------|----------------|-----------------|----------------|------|----|------|
|                                  | B <sup>1</sup> | UB <sup>2</sup> | D <sup>3</sup> | B    | UB | D    |
| Perennial Grasses                | 96             | 64              | 32*            | 64   | 52 | 12   |
| Annual Grasses                   | 2              | 1               | 1              | T    | -  | T    |
| Forbs                            | 14             | 8               | 6              | 6    | 5  | 1    |
| Shrubs/Half-Shrubs               | 4              | 16              | -12*           | 2    | 11 | -9   |
| Perennial Grasses                |                |                 |                |      |    |      |
| <i>Agropyron smithii</i>         | 20             | 6               | 14*            | 9    | 5  | 4*   |
| <i>Agropyron spicatum</i>        | -              | 4               | -4*            | -    | 2  | -2   |
| <i>Bouteloua curtipendula</i>    | -              | 7               | -7             | -    | 2  | -2   |
| <i>Bouteloua gracilis</i>        | 16             | 10              | 6              | 11   | 8  | 3    |
| <i>Calamagrostis montanensis</i> | -              | 1               | -1             | -    | -  | -    |
| <i>Koeleria cristata</i>         | 4              | 2               | 2              | 2    | 4  | -2*  |
| <i>Poa pratensis</i>             | 1              | T               | T              | 1    | 1  | 0    |
| <i>Stipa comata</i>              | 1              | 1               | 0              | T    | -  | T    |
| <i>Stipa viridula</i>            | 55             | 34              | 21*            | 42   | 31 | 11*  |
| Annual Grasses                   |                |                 |                |      |    |      |
| <i>Bromus japonicus</i>          | 2              | 1               | 1              | T    | -  | T    |
| Forbs                            |                |                 |                |      |    |      |
| <i>Achillea millefolium</i>      | 1              | T               | T*             | 1    | -  | 1    |
| <i>Artemisia ludoviciana</i>     | -              | -               | -              | -    | 1  | -1   |
| <i>Cirsium undulatum</i>         | -              | 1               | -1             | -    | -  | -    |
| <i>Gaura coccinea</i>            | 6              | 3               | 3              | 4    | 1  | 3    |
| <i>Linum perenne</i>             | 1              | T               | T              | T    | 1  | T    |
| <i>Phlox hoodii</i>              | T              | 1               | T              | T    | T  | T    |
| <i>Psoralea tenuiflora</i>       | 1              | T               | T              | -    | -  | -    |
| <i>Ratibida columnifera</i>      | 1              | 1               | 0              | -    | T  | T    |
| <i>Sphaeralcea coccinea</i>      | 2              | 2               | 0              | 1    | 2  | -1   |
| <i>Tragopogon dubius</i>         | 2              | T               | 2*             | T    | T  | T    |
| Shrubs/Half-Shrubs               |                |                 |                |      |    |      |
| <i>Artemisia cana</i>            | 4              | 5               | -1             | 2    | T  | 2    |
| <i>Artemisia tridentata</i>      | -              | 8               | -8             | -    | 10 | -10* |
| <i>Gutierrezia sarothrae</i>     | -              | 1               | -1             | -    | T  | T    |
| <i>Rosa arkansana</i>            | 1              | T               | T              | -    | T  | T    |

continued



Table 9. Continued.

| Plant Class        | B  | 1979 |      | B  | 1980 |      |
|--------------------|----|------|------|----|------|------|
|                    |    | UB   | D    |    | UB   | D    |
| <u>Litter</u>      | 40 | 73   | -33* | 66 | 78   | -12* |
| <u>Bare Ground</u> | 55 | 22   | 33*  | 29 | 17   | 12*  |

<sup>1</sup> Burned

<sup>2</sup> Unburned

<sup>3</sup> Difference between burned and unburned sites

T = < 1% cover

\* Significantly different between burned and unburned sites at the  
P ≤ .05 level.

Japanese brome (Bromus japonicus) was reduced to a trace on the burned site and was absent from the unburned site during 1980.

The cover of forbs appeared to be greater on the burned site during both years and was reduced on both sites from 1979 to 1980. Western yarrow and yellow salsify had significantly greater cover on the burned site in 1979. Scarlet gaura (Gaura coccinea) had greater cover on the burned site in 1979 and 1980, although the means were not significantly different.

The cover of shrubs and half-shrubs was apparently greater on the unburned site during both years, however the difference was significant in 1979 only. Big sagebrush was completely eliminated from the burned site. The cover of silver sagebrush was similar between sites during both years.

### Biomass Production

#### Artemisia tridentata/Stipa viridula community

Perennial grasses had similar above ground biomass production on the burned compared to the unburned site in 1979 (Table 10). In 1980, perennial grass production increased on the burned site and decreased on the unburned site, making the difference significant. Green needlegrass showed the same pattern: increased production on the burned and decreased production on the unburned site from 1979 to 1980. In 1980, western wheatgrass maintained production on the burned site while production on the unburned site decreased. Prairie junegrass had similar yields on the burned and unburned sites in 1979, but had significantly greater yields on the unburned site in 1980.

Annual grass production appeared to be greater on the unburned site in 1979. In 1980, annual grasses produced significantly more above ground biomass on the burned site.

In 1979, forb production appeared to be greater on the burn compared to the unburned site, although the means were similar. In 1980, production increased on the burned site and decreased on the unburned site, making the difference significant.

Big sagebrush had significantly greater production on the unburned site during both years.

Table 10. Above ground biomass production (kg/ha) on the Artemisia tridentata/Stipa viridula sites.

| Species                                 | 1979           |                 |                | 1980   |        |          |
|-----------------------------------------|----------------|-----------------|----------------|--------|--------|----------|
|                                         | B <sup>1</sup> | UB <sup>2</sup> | D <sup>3</sup> | B      | UB     | D        |
| <u>Perennial Grasses</u>                |                |                 |                |        |        |          |
| <u>Agropyron smithii</u>                | 173.9          | 30.2            | 143.7*         | 175.1  | 17.9   | 157.2*   |
| <u>Koeleria cristata</u>                | 21.6           | 38.0            | -16.4          | 7.9    | 35.6   | -27.7*   |
| <u>Stipa viridula</u>                   | 98.7           | 149.6           | -50.9          | 152.5  | 93.5   | 59.0     |
| Other Perennial Grasses                 | 2.6            | 84.7            | -82.1*         | 4.4    | 49.9   | -45.5    |
| <u>Shrubs/Half-Shrubs</u>               |                |                 |                |        |        |          |
| <u>Artemisia tridentata</u>             | 128.6          | 259.3           | -130.7*        | -      | 329.1  | -329.1*  |
| <u>Eurotia lanata</u>                   | -              | 9.4             | -9.4           | -      | 2.5    | -2.5     |
| <u>Opuntia polyacantha</u> <sup>4</sup> | -              | -               | -              | 20.0   | 77.1   | -57.1    |
| <u>Totals</u>                           |                |                 |                |        |        |          |
| Perennial Grasses                       | 296.9          | 302.4           | -5.6           | 339.8  | 197.0  | 142.8*   |
| Annual Grasses                          | 46.5           | 121.7           | -75.2          | 49.5   | 2.8    | 46.7*    |
| Forbs <sup>5</sup>                      | 84.2           | 28.1            | 56.1           | 125.9  | 5.6    | 120.3*   |
| Shrubs                                  | 128.6          | 259.3           | -130.7*        | -      | 329.1  | -329.1*  |
| Half-Shrubs                             | -              | 9.4             | -9.4           | -      | 2.5    | -2.5     |
| Vegetation                              | 556.0          | 720.9           | -164.9*        | 535.2  | 614.1  | -78.9    |
| <u>Litter</u>                           |                |                 |                |        |        |          |
| Standing Dead                           | 2890.9         | 3205.4          | -314.5         | 801.1  | 3261.4 | -2460.3* |
| Ground                                  | 2264.3         | 4109.6          | -1845.3*       | 1031.9 | 5154.8 | -4122.9* |

<sup>1</sup>Burned<sup>2</sup>Unburned<sup>3</sup>Difference between burned and unburned sites<sup>4</sup>This species was clipped separately in 1980. In 1979 it was not encountered in a clipping quadrat.<sup>5</sup>Total forbs does not include Opuntia polyacantha.\*Significantly different between burned and unburned sites at the  $P \leq .05$  level.

Total vegetation produced during 1979 was significantly greater on the unburned site. This was due, in part, to the reduced

production of big sagebrush on the burned site. From 1979 to 1980 total vegetation production was reduced on both sites. This reduction was greater on the unburned site as perennial grasses, annual grasses and forbs produced less in 1980 compared to 1979.

Calamovilfa longifolia/Andropogon scoparius community

Perennial grasses had similar above ground biomass production on the burned compared to the unburned site during both years (Table 11). Perennial grass production was reduced on both sites from 1979 to 1980. Prairie junegrass produced significantly more biomass on the burned compared to the unburned site during each year and had reduced production on both sites from 1979 to 1980.

There were no shrubs encountered on the burned site during either year. Shrubs had reduced production on the unburned site during 1980. The same patterns were observed for most half-shrubs. Broom snakeweed (Gutierrezia sarothrae) increased production in 1980 compared to 1979.

Forbs appeared to have greater production on the burned site during both years although the means were similar. Forb production was similar on the burned and unburned sites from 1979 to 1980.

Total vegetation produced was similar on the burned and the unburned sites during 1979. In 1980, total production was reduced on both sites but more drastically on the unburned site. This reduction was attributed to perennial grasses and shrubs.

Table 11. Above ground biomass production (kg/ha) on the Calamovilfa longifolia/Andropogon scoparius sites.

| Species                                 | 1979           |                 |                | 1980  |        |         |
|-----------------------------------------|----------------|-----------------|----------------|-------|--------|---------|
|                                         | B <sup>1</sup> | UB <sup>2</sup> | D <sup>3</sup> | B     | UB     | D       |
| <u>Perennial Grasses</u>                |                |                 |                |       |        |         |
| <u>Andropogon scoparius</u>             | 254.1          | 154.4           | 99.7           | 98.5  | 36.7   | 61.8    |
| <u>Calamovilfa longifolia</u>           | 53.1           | 176.9           | -123.8         | 19.7  | 111.6  | -91.9   |
| <u>Koeleria cristata</u>                | 109.1          | 41.6            | 67.5*          | 72.1  | 35.8   | 36.3*   |
| <u>Stipa comata</u>                     | -              | -               | -              | 45.3  | 37.8   | 7.5     |
| Other Perennial Grasses                 | 162.6          | 132.8           | 29.8           | 193.1 | 155.9  | 37.2    |
| <u>Shrubs/Half-Shrubs</u>               |                |                 |                |       |        |         |
| <u>Artemisia cana</u>                   | -              | 32.9            | -32.9          | -     | 27.4   | -27.4   |
| <u>Artemisia dracunculus</u>            | -              | 5.7             | -5.7           | -     | 4.6    | -4.6    |
| <u>Artemisia frigida</u>                | 1.9            | -               | 1.9            | -     | 1.7    | -1.7    |
| <u>Artemisia ludoviciana</u>            | -              | 14.3            | -14.3          | -     | 0.9    | -0.9    |
| <u>Artemisia tridentata</u>             | -              | -               | -              | -     | 27.1   | -27.1   |
| <u>Gutierrezia sarothrae</u>            | -              | 1.2             | -1.2           | -     | 10.6   | -10.6*  |
| <u>Oenothera serrulata</u>              | -              | 64.7            | -64.7          | -     | 11.7   | -11.7*  |
| <u>Yucca glauca</u>                     | -              | 15.2            | -15.2*         | -     | 3.4    | -3.4    |
| <u>Opuntia polyacantha</u> <sup>4</sup> | -              | -               | -              | 78.7  | -      | 78.7    |
| <u>Totals</u>                           |                |                 |                |       |        |         |
| Perennial Grasses                       | 578.7          | 505.8           | 72.9           | 428.6 | 377.9  | 50.7    |
| Annual Grasses                          | -              | -               | -              | -     | -      | -       |
| Forbs <sup>5</sup>                      | 116.0          | 48.9            | 67.1           | 105.5 | 49.9   | 55.6    |
| Shrubs                                  | -              | 112.8           | -112.8*        | -     | -76.8  | -76.8*  |
| Half-Shrubs                             | 1.9            | 21.1            | -19.2          | -     | 10.7   | -10.7*  |
| Vegetation                              | 696.6          | 688.6           | 8.0            | 612.8 | 515.3  | 97.5    |
| <u>Litter</u>                           |                |                 |                |       |        |         |
| Standing Dead                           | -              | 474.6           | -474.6*        | 157.3 | 286.1  | -128.8  |
| Ground                                  | 478.9          | 1100.9          | -622.0*        | 359.9 | 1173.8 | -813.9* |

<sup>1</sup>Burned<sup>2</sup>Unburned<sup>3</sup>Difference between burned and unburned sites<sup>4</sup>This species was clipped separately in 1980. In 1979 it was not encountered in a clipping quadrat.<sup>5</sup>Total forbs does not include Opuntia polyacantha.\*Significantly different between burned and unburned sites at the  $P \leq .05$  level.

Artemisia cana/Stipa viridula community

Perennial grasses had greater above ground biomass production on the burned compared to the unburned site during 1979 (Table 12). In 1980, perennial grass production was similar between sites. Perennial grass production was reduced on both sites from 1979 to 1980, but more severely on the burned site. This was due to the complete lack of western wheatgrass plants in clipping quadrats in 1980. Green needlegrass had similar production on the burned and the unburned sites during each year and had reduced production on both sites in 1980 compared to 1979.

Silver sagebrush appeared to produce more on the burned compared to the unburned site during each year, although the means were similar. Big sagebrush was eliminated by burning.

Annual grass production was similar between sites during each year. However, the mean on the burned site appeared to be greater during both years. Production was reduced on both sites from 1979 to 1980.

Forb production was similar between burned and unburned sites in 1979 and 1980 and was reduced on both sites in 1980 compared to 1979.

Total vegetation production was slightly greater on the burned compared to the unburned site in 1979. This trend was reversed in 1980 due to the absence of western wheatgrass. Total vegetation production was reduced on both sites in 1980 compared to 1979.

Table 12. Above ground biomass production (kg/ha) on the Artemisia cana/Stipa viridula sites.

| Plant Class                  | 1979           |                 |                | 1980   |        |          |
|------------------------------|----------------|-----------------|----------------|--------|--------|----------|
|                              | B <sup>1</sup> | UB <sup>2</sup> | D <sup>3</sup> | B      | UB     | D        |
| <u>Perennial Grasses</u>     |                |                 |                |        |        |          |
| <u>Agropyron smithii</u>     | 409.5          | 123.8           | 285.7*         | -      | 24.3   | -24.3*   |
| <u>Agropyron spicatum</u>    | -              | -               | -              | -      | 19.2   | -19.2    |
| <u>Koeleria cristata</u>     | -              | -               | -              | 19.6   | 22.1   | -2.5     |
| <u>Stipa viridula</u>        | 286.7          | 258.0           | 28.7           | 136.7  | 107.1  | 29.6     |
| Other Perennial Grasses      | 145.8          | 253.0           | -107.2         | 205.7  | 126.1  | 79.6*    |
| <u>Shrubs/Half-Shrubs</u>    |                |                 |                |        |        |          |
| <u>Artemisia cana</u>        | 154.4          | 60.3            | 94.1           | 301.2  | 103.3  | 197.9    |
| <u>Artemisia tridentata</u>  | -              | 188.5           | -188.5*        | -      | 375.3  | -375.3   |
| <u>Gutierrezia sarothrae</u> | -              | 23.6            | 23.6           | -      | 28.7   | -28.7    |
| <u>Totals</u>                |                |                 |                |        |        |          |
| Perennial Grasses            | 842.1          | 634.7           | 207.4*         | 362.1  | 298.8  | 63.3     |
| Annual Grasses               | 74.6           | 26.3            | 48.3           | 8.6    | 0.1    | 8.5      |
| Forbs                        | 135.1          | 119.0           | 16.1           | 50.5   | 63.0   | -12.5    |
| Shrubs                       | 154.4          | 248.7           | -94.3          | 301.2  | 478.7  | -177.5   |
| Half-Shrubs                  | -              | 23.6            | -23.6          | -      | 28.7   | -28.7    |
| Vegetation                   | 1206.2         | 1052.4          | 153.8          | 722.4  | 843.5  | -121.1   |
| <u>Litter</u>                |                |                 |                |        |        |          |
| Standing Dead                | 879.7          | 748.0           | 131.7          | 1292.2 | 829.2  | 463.0    |
| Ground                       | 1477.2         | 1831.8          | -354.6         | 1073.5 | 2266.4 | -1193.0* |

<sup>1</sup>Burned<sup>2</sup>Unburned<sup>3</sup>Difference between burned and unburned sites

\*Significantly different between burned and unburned sites at the P ≤ .05 level.

Phenology

Phenology profiles for the dominant perennial and annual grasses of each plant community are presented in Figures 18 through 30. These profiles reflect the typical growth patterns of the warm and



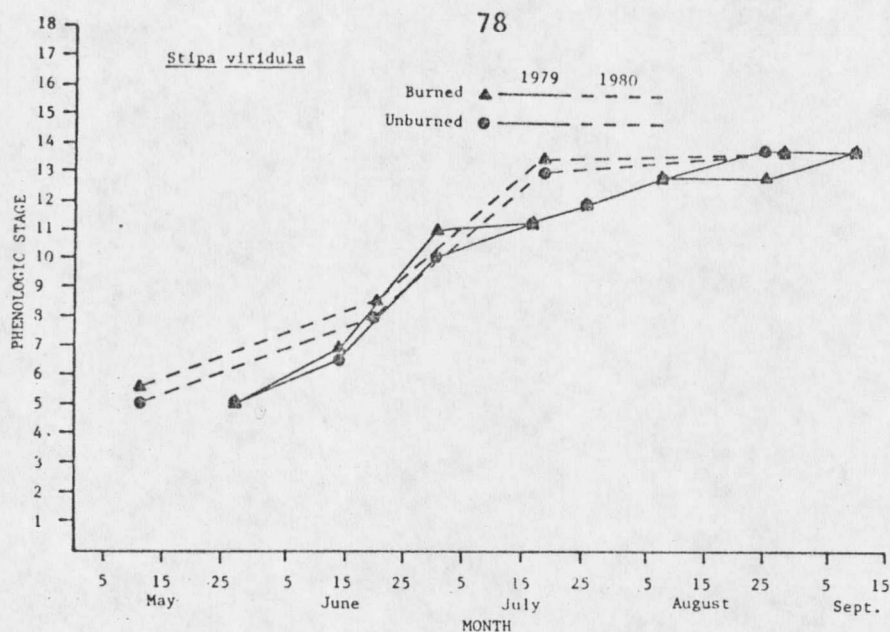


Figure 18. Phenology profile for green needlegrass on the Artemisia tridentata/Stipa viridula sites.

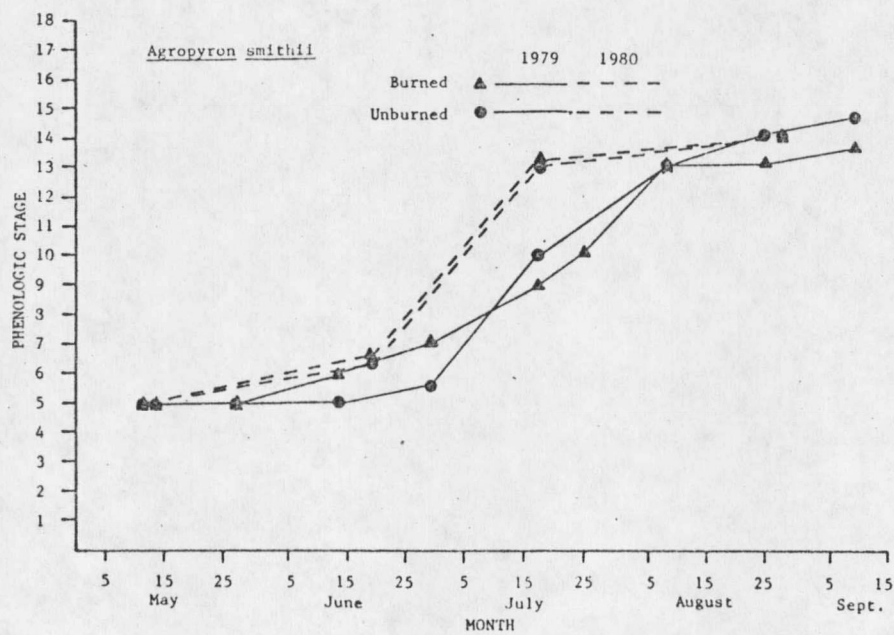


Figure 19. Phenology profile for western wheatgrass on the Artemisia tridentata/Stipa viridula sites.

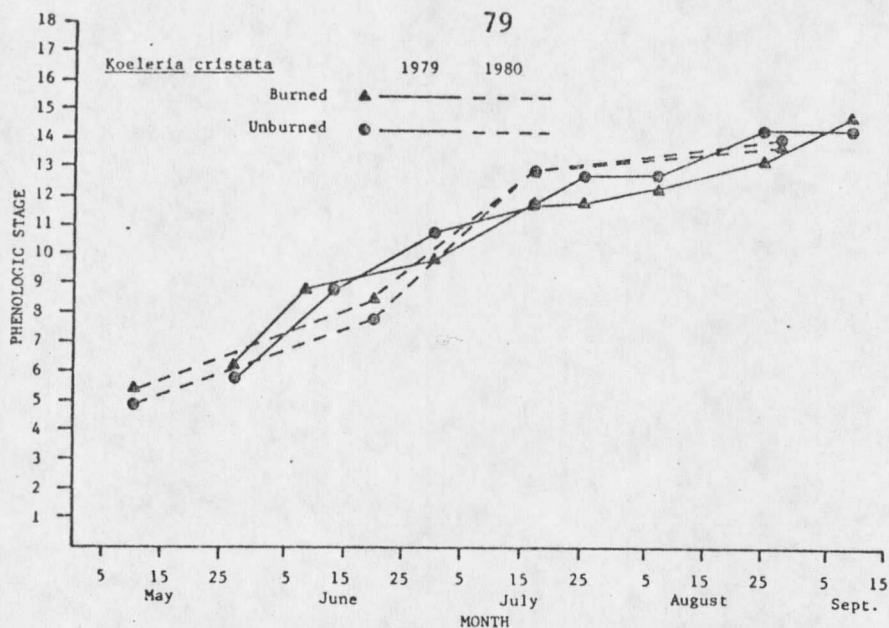


Figure 20. Phenology profile for prairie junegrass on the Artemisia tridentata/Stipa viridula sites.

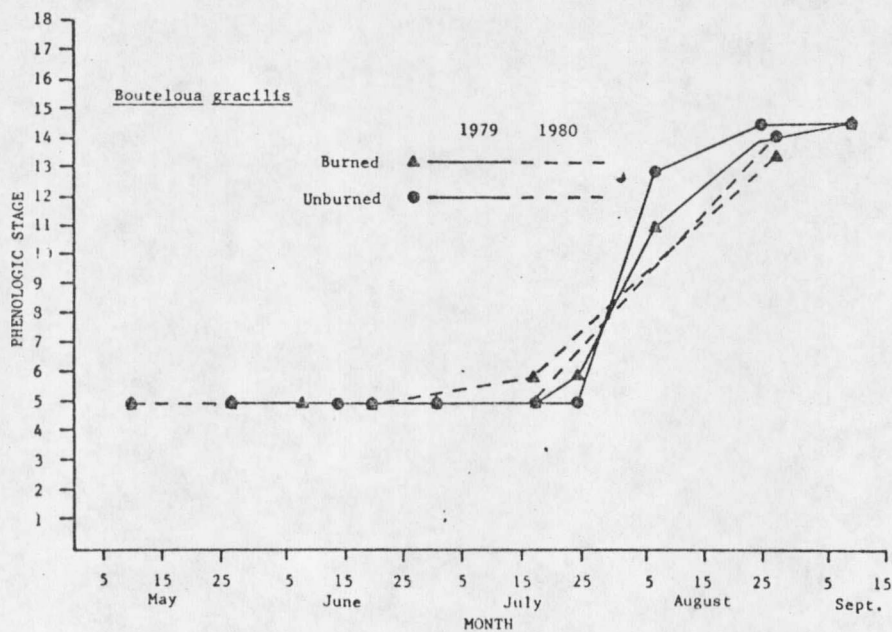


Figure 21. Phenology profile for blue grama on the Artemisia tridentata/Stipa viridula sites.

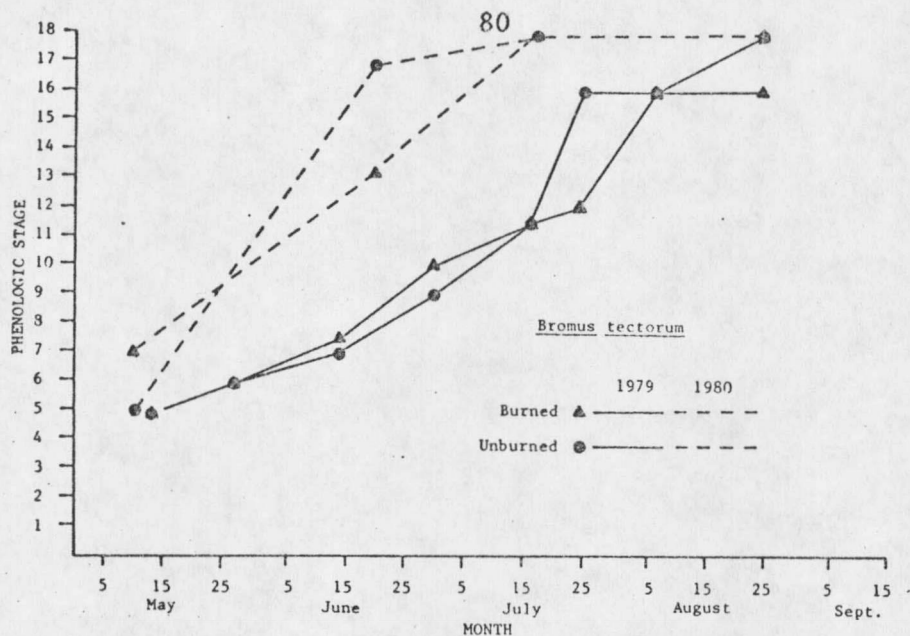


Figure 22. Phenology profile for cheatgrass on the Artemisia tridentata/Stipa viridula sites.

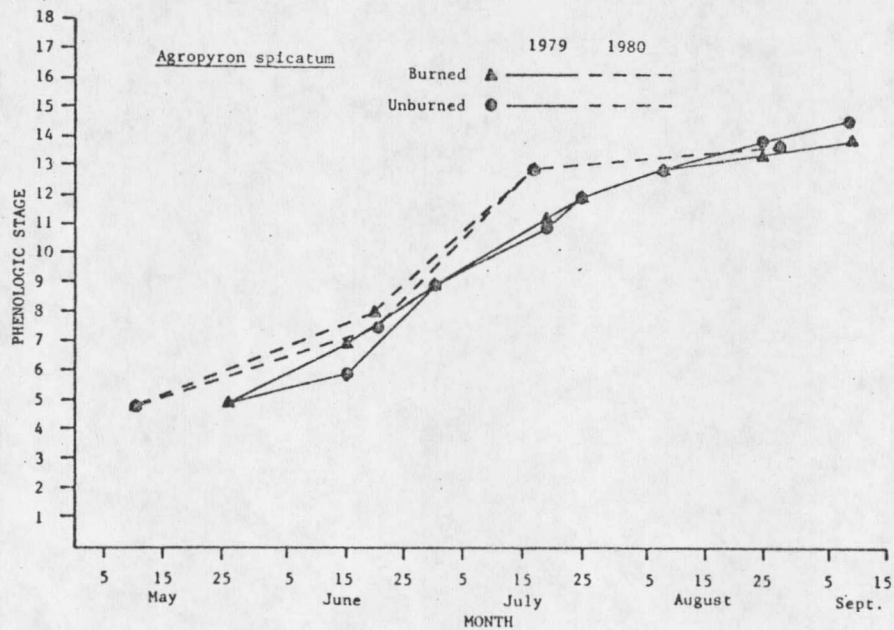


Figure 23. Phenology profile for bluebunch wheatgrass on the Artemisia tridentata/Stipa viridula sites.

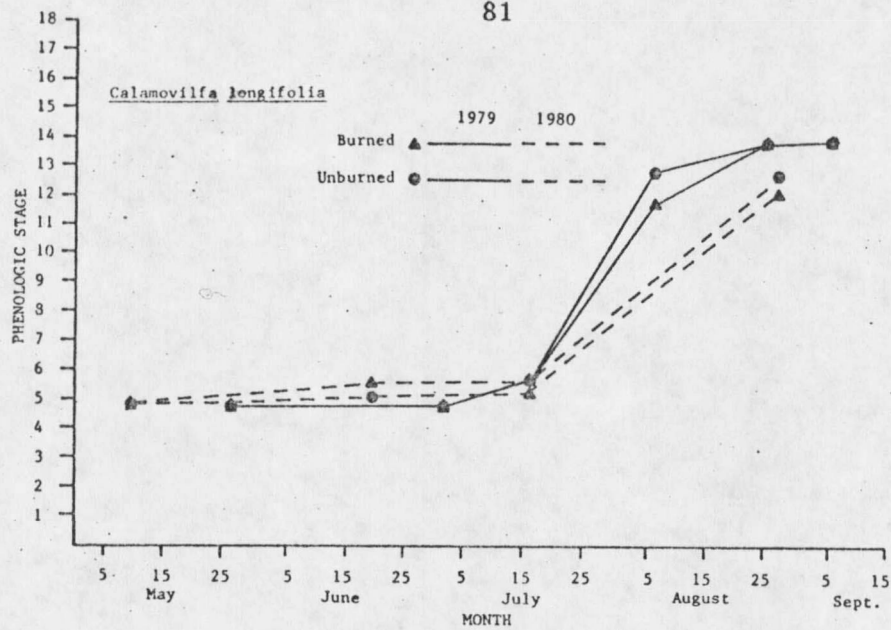


Figure 24. Phenology profile for prairie sandreed on the Calamovilfa longifolia/Andropogon scoparius sites.

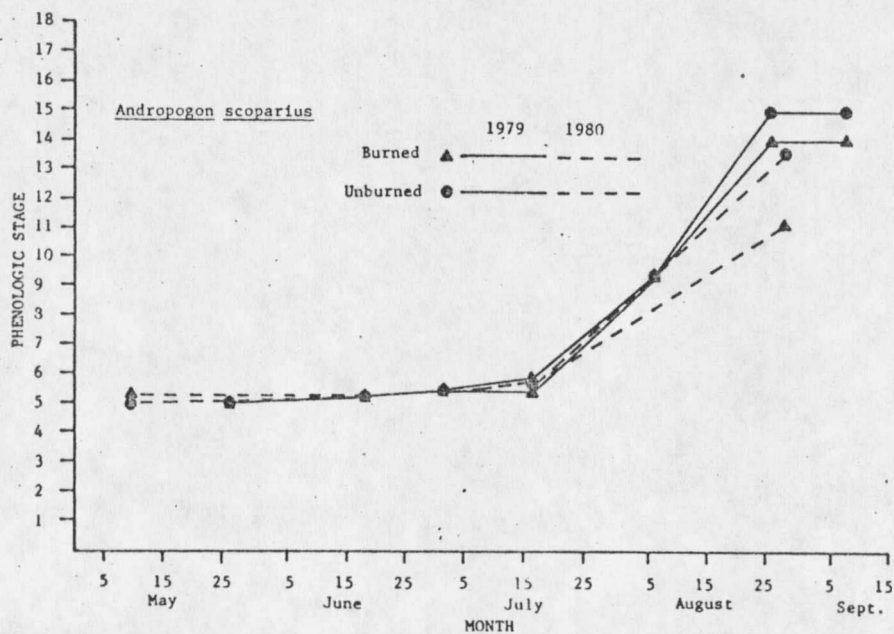


Figure 25. Phenology profile for little bluestem on the Calamovilfa longifolia/Andropogon scoparius sites.



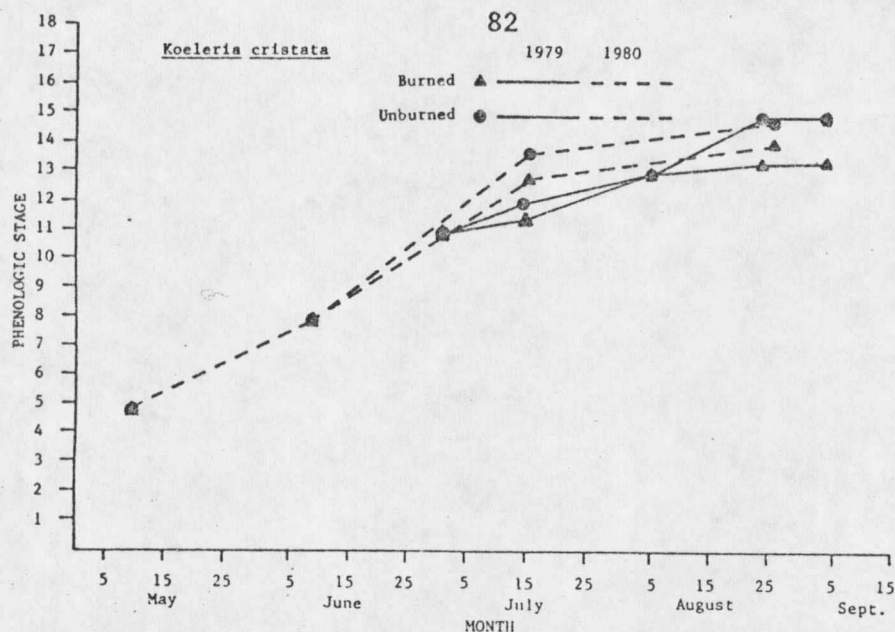


Figure 26. Phenology profile for prairie junegrass on the Calamovilfa longifolia/Andropogon scoparius sites.

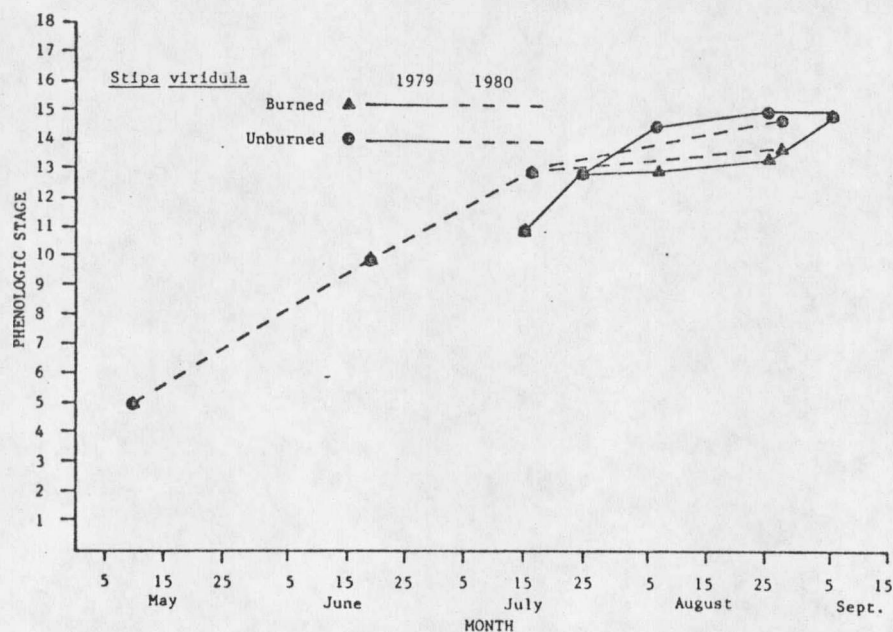


Figure 27. Phenology profile for green needlegrass on the Artemisia cana/Stipa viridula sites.

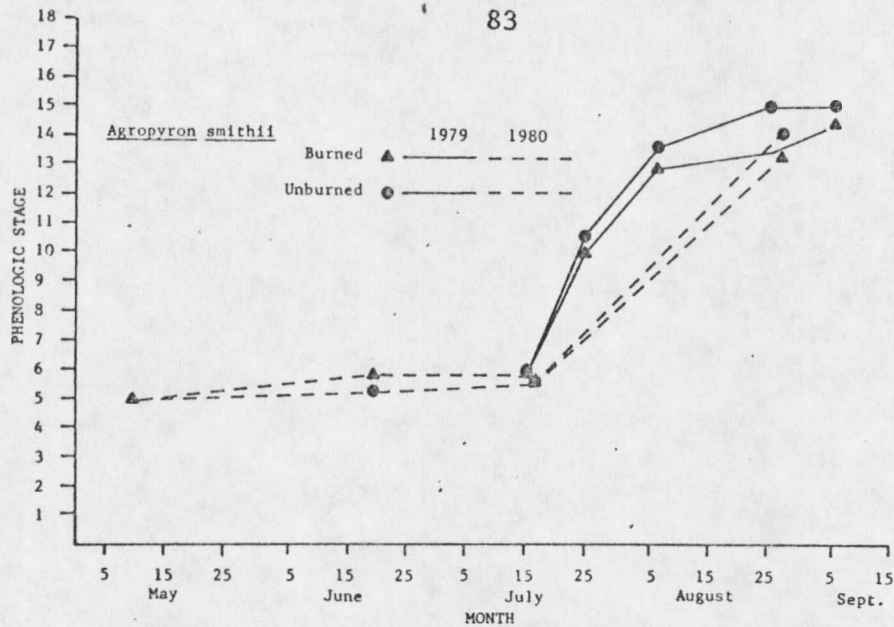


Figure 28. Phenology profile for western wheatgrass on the *Artemisia cana*/*Stipa viridula* sites.

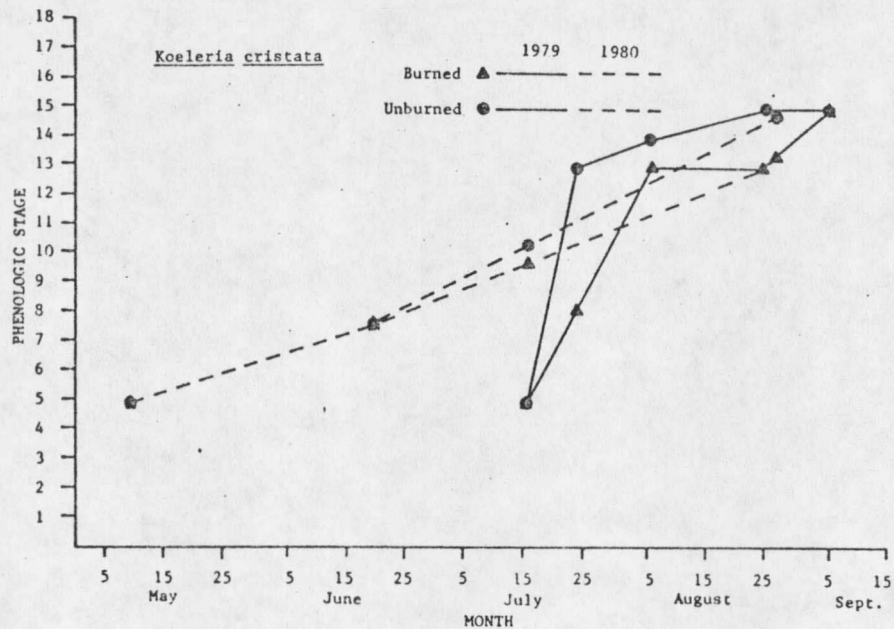


Figure 29. Phenology profile for prairie junegrass on the *Artemisia cana*/*Stipa viridula* sites.

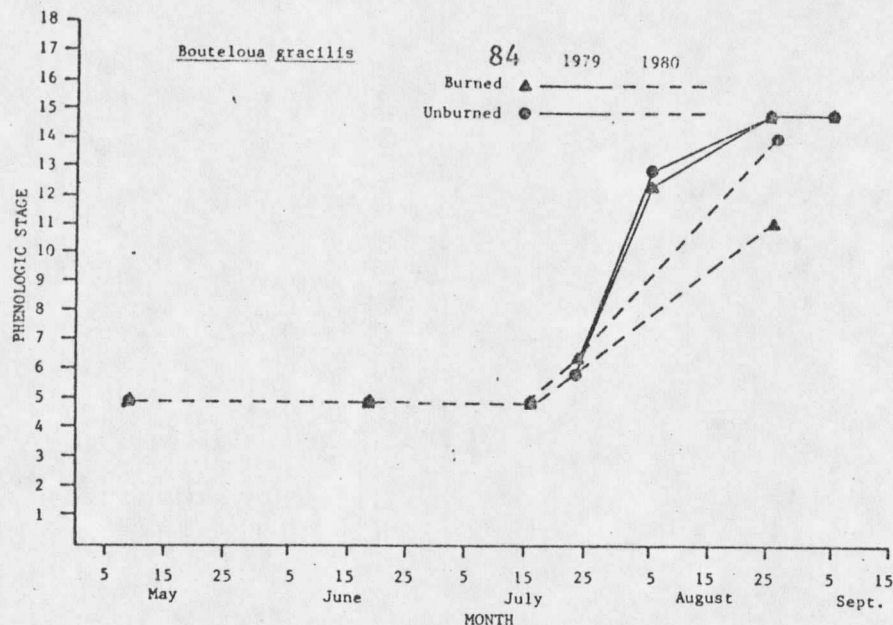


Figure 30. Phenology profile for blue grama on the Artemisia cana/Stipa viridula sites.

cool-season species. The warm-season species, (prairie sandreed, little bluestem and blue grama) flowered from the last week of July until the third week in August. Flowering for the cool-season species ranged from the first week in June until the last week in July.

Since the stages of the phenology codes represent an unscaled series, the resulting phenological profiles should be viewed as general representations of plant development and not subjected to quantitative analysis (Taylor and Leininger 1978).

A noteworthy feature of these profiles is the extended growing season exhibited by some species. Some species on burned sites remained green and showed no signs of water stress for weeks longer than the same species on a corresponding unburned site. Burning did not shorten the green period of any species sampled.



Prairie junegrass exhibited an extended growing season on the burned site of all three plant communities during both years (Figures 20, 26, and 29). In the Artemisia tridentata/Stipa viridula community during 1979, western wheatgrass, bluebunch wheatgrass, prairie junegrass and green needlegrass remained green longer on the burned than on the unburned site (Figures 18, 19, 20 and 23). However, in this community during 1980 these species matured at about the same time on the burned and the unburned sites. In the burned Artemisia cana/Stipa viridula community, western wheatgrass, blue grama and green needlegrass had extended periods of growth at the end of the 1979 and 1980 growing seasons (Figures 27, 28, and 30).

#### Vigor and Vitality

##### Artemisia tridentata/Stipa viridula community

Western wheatgrass had a significantly greater ratio of reproductive to vegetative culms on the burned compared to the unburned site during both growing seasons (Table 13). In 1980, the length of leaves and the height of culms were significantly greater for western wheatgrass plants on the burned site (Table 14).

During 1979, bluebunch wheatgrass produced a significantly higher ratio of reproductive to vegetative culms on the unburned compared to the burned site. This response was reversed in 1980 as plants on the burned site produced a significantly higher ratio of reproductive to

Table 13. The percent of vegetative (V) and reproductive (R) culms and the average number of leaves per culm on the burned (B) and unburned (UB) sites of the *Artemisia tridentata*/*Stipa viridula* community.

| Species           | Culms |    |     |     |      |    |     |    | Leaves/Culm |    |      |     |
|-------------------|-------|----|-----|-----|------|----|-----|----|-------------|----|------|-----|
|                   | 1979  |    |     |     | 1980 |    |     |    | 1979        |    | 1980 |     |
|                   | B     |    | UB  |     | B    |    | UB  |    | B           | UB | B    | UB  |
|                   | V     | R  | V   | R   | V    | R  | V   | R  |             |    |      |     |
| Agsm <sup>1</sup> | 94    | 6  | 99  | 1*  | 91   | 9  | 100 | 0* | NS          | NS | 4.4  | 3.8 |
| Agsp              | 90    | 10 | 82  | 18* | 61   | 39 | 98  | 2* | NS          | NS | 3.9  | 4.7 |
| Bogr              | 84    | 16 | 100 | 0*  | 85   | 15 | 99  | 1* | NS          | NS | 4.2  | 3.8 |
| Kocr              | 94    | 6  | 89  | 11* | 97   | 3  | 99  | 1* | NS          | NS | 2.9  | 3.0 |
| Stvi              | 96    | 4  | 97  | 3   | 86   | 14 | 99  | 1* | NS          | NS | 3.0  | 2.9 |

<sup>1</sup> Four letter abbreviations for the scientific name.

NS Not sampled

\* The ratio of vegetative to reproductive culms on the burned site is significantly different at the  $P \leq .05$  level than the ratio of culms on the unburned site using Chi-square.

Table 14. Average leaf, culm, and inflorescence length (cm) of perennial grasses on the burned (B) and unburned (UB) sites of the Artemisia tridentata/Stipa viridula community.

| Species           | Leaf Length |    |      |      | Culm Height |      |      |        | Inflorescence Length |      |      |      |
|-------------------|-------------|----|------|------|-------------|------|------|--------|----------------------|------|------|------|
|                   | 1979        |    | 1980 |      | 1979        |      | 1980 |        | 1979                 |      | 1980 |      |
|                   | B           | UB | B    | UB   | B           | UB   | B    | UB     | B                    | UB   | B    | UB   |
| Agsm <sup>1</sup> | NS          | NS | 12.2 | 8.3* | 46.6        | 49.0 | 20.9 | 16.0*  | 7.6                  | 5.0  | 7.0  | NR   |
| Agsp              | NS          | NS | 7.0  | 7.6  | 48.8        | 54.5 | 16.3 | 123.1* | 9.0                  | 9.1  | 8.4  | 5.3* |
| Bogr              | NS          | NS | 4.3  | 3.0  | 15.2        | NR*  | 4.1  | 5.1    | 2.5                  | NR*  | 3.8  | 3.5  |
| Kocr              | NS          | NS | 4.5  | 5.6* | 23.7        | 24.5 | 6.6  | 7.7    | 5.2                  | 5.1  | 3.7  | 3.5  |
| Stvi              | NS          | NS | 15.8 | 14.1 | 47.6        | 52.4 | 23.2 | 21.5   | 11.8                 | 12.5 | 13.7 | 9.4  |

<sup>1</sup>Four letter abbreviations for the scientific name.

NS Not sampled

NR No reproductive culms in sampling quadrat.

\* Significantly different between burned and unburned sites at the  $P \leq .05$  level.

vegetative culms. In 1980, the height of culms was significantly greater for bluebunch wheatgrass on the unburned site. Plants appeared taller on the unburned site than on the burned site in 1979. In 1980, bluebunch wheatgrass plants on the burned site had significantly longer inflorescences than plants on the unburned site.

During 1979, blue grama did not flower on the unburned site but many seedheads were observed on the burned site. The same basic pattern was observed during 1980, however some sexual reproduction occurred on the unburned site.

The ratio of culms of prairie junegrass followed the same pattern as bluebunch wheatgrass. During 1979, the ratio of reproductive to vegetative culms was significantly greater for plants on the unburned compared to the burned site. In 1980, the ratio of culms was significantly greater on the burned site. In 1980, leaves were significantly longer on the unburned site.

The ratios of green needlegrass culms on the burned and the unburned sites during 1979 were similar. In 1980, the ratio of reproductive to vegetative culms was significantly greater on the burned site. Although not significant, inflorescences appeared longer on the burned site during 1980.

Calamovilfa longifolia/Andropogon scoparius community

Prairie sandreed had similar ratios of reproductive to vegetative culms on the burned and unburned sites during 1979 and 1980 (Table 15). The number of leaves per culm was significantly greater on the burned site in 1980. Mean leaf length and culm height was significantly greater on the unburned site during 1980 (Table 16).

Little bluestem had similar ratios of reproductive to vegetative culms on the burned and unburned sites during 1979. In 1980, the ratio of culms was significantly greater on the burned site. Leaves were significantly longer on the unburned site during 1980. The height of culms and length of inflorescences were significantly greater on the burned site during 1979. In 1980, these means were similar.

Artemisia cana/Stipa viridula community

Western wheatgrass and blue grama did not flower on the unburned site in 1979 (Table 17). Of the western wheatgrass and blue grama plants observed in 1980 none were found to be reproducing sexually. These species had significantly greater numbers of leaves per culm on the burned site during 1980.

Prairie junegrass and green needlegrass produced similar ratios of reproductive to vegetative culms on the burned and unburned sites during 1979 and 1980. Few prairie junegrass or green needlegrass

Table 15. The percent of vegetative (V) and reproductive (R) culms and the average number of leaves per culm on the burned (B) and unburned (UB) sites of the Calamovilfa longifolia/Andropogon scoparius community.

| Species           | Culms |    |    |    |      |   |    |    | Leaves/Culm |    |      |      |
|-------------------|-------|----|----|----|------|---|----|----|-------------|----|------|------|
|                   | 1979  |    |    |    | 1980 |   |    |    | 1979        |    | 1980 |      |
|                   | B     |    | UB |    | B    |   | UB |    | B           | UB | B    | UB   |
|                   | V     | R  | V  | R  | V    | R | V  | R  |             |    |      |      |
| Calo <sup>1</sup> | 90    | 10 | 90 | 10 | 98   | 2 | 99 | 1  | NS          | NS | 8.2  | 6.4* |
| Ansc              | 81    | 19 | 79 | 21 | 96   | 4 | 99 | 1* | NS          | NS | 4.0  | 3.2  |

<sup>1</sup>Four letter abbreviations for scientific name.

NS Not sampled

\* The ratio of vegetative to reproductive culms or the difference between means on the burned compared to the unburned site is significant at the  $P \leq .05$  level.

90

Table 16. Average leaf, culm, and inflorescence length (cm) of perennial grasses on the burned (B) and unburned (UB) sites of the Calamovilfa longifolia/Andropogon scoparius community.

| Species           | Leaf Length |    |      |       | Culm Height |       |      |       | Inflorescence Length |       |      |    |
|-------------------|-------------|----|------|-------|-------------|-------|------|-------|----------------------|-------|------|----|
|                   | 1979        |    | 1980 |       | 1979        |       | 1980 |       | 1979                 |       | 1980 |    |
|                   | B           | UB | B    | UB    | B           | UB    | B    | UB    | B                    | UB    | B    | UB |
| Calo <sup>1</sup> | NS          | NS | 19.0 | 23.0* | 68.7        | 80.1  | 32.1 | 41.8* | 10.6                 | 10.9  | 20   | 11 |
| Ansc              | NS          | NS | 5.4  | 7.4*  | 45.7        | 39.1* | 13.8 | 12.3  | 25.5                 | 19.1* | 19   | 18 |

<sup>1</sup>Four letter abbreviations for scientific name.

NS Not sampled

\* Significantly different between burned and unburned sites at the  $P \leq .05$  level.



Table 17. The percent of vegetative (V) and reproductive (R) culms and the average number of leaves per culm on the burned (B) and unburned (UB) sites of the Artemisia cana/Stipa viridula community.

| Species           | Culms |    |     |    |      |   |     |    | Leaves/Culm |    |      |      |
|-------------------|-------|----|-----|----|------|---|-----|----|-------------|----|------|------|
|                   | 1979  |    |     |    | 1980 |   |     |    | 1979        |    | 1980 |      |
|                   | B     |    | UB  |    | B    |   | UB  |    | B           | UB | B    | UB   |
|                   | V     | R  | V   | R  | V    | R | V   | R  |             |    |      |      |
| Agsm <sup>1</sup> | 96    | 4  | 100 | 0* | 100  | 0 | 100 | 0  | NS          | NS | 4.9  | 3.1* |
| Bogr              | 95    | 5  | 100 | 0* | 97   | 3 | 100 | 0* | NS          | NS | 4.5  | 3.3* |
| Kocr              | 89    | 11 | 83  | 17 | 99   | 1 | 100 | 0  | NS          | NS | 3.1  | 3.4  |
| Stvi              | 96    | 4  | 94  | 6  | 99   | 1 | 100 | 0* | NS          | NS | 3.1  | 2.6  |

<sup>1</sup> Four letter abbreviations for scientific name.

NS Not sampled

\* The ratio of reproductive to vegetative stems or the difference between means on the burned compared to the unburned site is significant at the  $P \leq .05$  level.

91

Table 18. Average leaf, culm, and inflorescence length (cm) of perennial grasses on the burned (B) and unburned (UB) sites of the Artemisia cana/Stipa viridula community.

| Species           | Leaf Length |    |      |       | Culm Height |      |      |      | Inflorescence Length |      |      |    |
|-------------------|-------------|----|------|-------|-------------|------|------|------|----------------------|------|------|----|
|                   | 1979        |    | 1980 |       | 1979        |      | 1980 |      | 1979                 |      | 1980 |    |
|                   | B           | UB | B    | UB    | B           | UB   | B    | UB   | B                    | UB   | B    | UB |
| Agsm <sup>1</sup> | NS          | NS | 9.2  | 9.4   | 48.5        | NR   | 15.9 | 14.4 | 8.8                  | NR   | NR   | NR |
| Bogr              | NS          | NS | 4.8  | 4.5   | 14.2        | NR   | 7.3  | 6.8  | 2.2                  | NR   | 3.9  | NR |
| Kocr              | NS          | NS | 5.2  | 5.4   | 26.4        | 28.0 | 7.2  | 6.8  | 5.0                  | 5.3  | 3.5  | NR |
| Stvi              | NS          | NS | 11.3 | 15.0* | 45.2        | 48.0 | 21.8 | 21.6 | 11.7                 | 13.1 | 7.8  | NR |

<sup>1</sup> Four letter abbreviations for scientific name.

NS Not sampled

NR No reproductive culms in sampling quadrat.

\* Significantly different between burned and unburned sites at the  $P \leq .05$  level.



plants flowered on either site during 1980. Average leaf, culm, and inflorescence lengths were similar between sites during both years for all species except green needlegrass (Table 18). This species had longer leaves on the unburned site in 1980.

### Physical and Chemical Data

#### Soil Chemistry

Organic matter, total nitrogen and electrical conductivity on the Artemisia tridentata/Stipa viridula sites remained unchanged as a result of burning (Table 19). Post-burning values for these parameters were not significantly different at any soil depth sampled.

The concentration of phosphorus was unchanged at all depths immediately after burning, however significant changes were observed three weeks and two months after burning. Three weeks after the fire a significant decrease was detected in the 5 to 10 cm depth. After two months there was a significant decrease in the 2.5 to 5, 5 to 10 and 10 to 15 cm depths.

Soil pH was significantly greater in the 10 to 15 cm depth three weeks after the fire than before or immediately after the fire.

#### Infiltration Rate Tests

Due to inherent sampling problems the data were not subjected to statistical analysis. The graphs should be viewed as generalized profiles of infiltration rates (Figure 31).

Table 19. Chemical properties of the soil before burning and at three dates after burning at four depths in 1979.<sup>1</sup>

|                    | Before Burning | After Burning |        |       |
|--------------------|----------------|---------------|--------|-------|
|                    | 4/20           | 4/20          | 5/11   | 6/14  |
| Depth (cm)         |                |               |        |       |
| 0 - 2.5            |                |               |        |       |
| Organic Matter (%) | 7.7            | 8.3           | 8.1    | 9.5   |
| Total Nitrogen (%) | 34.0           | 37.0          | 35.3   | 38.3  |
| E. C. (mmhos/cm)   | 0.79           | 0.88          | 0.77   | 0.73  |
| Phosphorus (ppm)   | 50.3           | 55.3          | 41.0   | 48.0  |
| pH                 | 7.3            | 7.4           | 7.3    | 7.5   |
| 2.5 - 5            |                |               |        |       |
| Organic Matter (%) | 5.2            | 4.7           | 5.6    | 5.1   |
| Total Nitrogen (%) | 22.7           | 22.7          | 25.0   | 23.3  |
| E. C. (mmhos/cm)   | 0.75           | 0.71          | 0.57   | 0.55  |
| Phosphorus (ppm)   | 33.0a          | 36.0a         | 29.3ab | 20.3b |
| pH                 | 7.5            | 7.5           | 8.0    | 7.8   |
| 5 - 10             |                |               |        |       |
| Organic Matter (%) | 3.3            | 3.0           | 3.2    | 3.0   |
| Total Nitrogen (%) | 15.7           | 14.3          | 16.7   | 14.0  |
| E. C. (mmhos/cm)   | 0.60           | 0.65          | 0.42   | 0.44  |
| Phosphorus (ppm)   | 22.7a          | 21.3a         | 16.3b  | 12.7b |
| pH                 | 7.5            | 7.5           | 7.6    | 7.7   |
| 10 - 15            |                |               |        |       |
| Organic Matter (%) | 2.7            | 2.7           | 3.0    | 2.4   |
| Total Nitrogen (%) | 12.7           | 12.0          | 13.0   | 12.3  |
| E. C. (mmhos/cm)   | 0.57           | 0.61          | 0.40   | 0.35  |
| Phosphorus (ppm)   | 22.7a          | 23.0a         | 17.0ab | 12.3b |
| pH                 | 7.6ab          | 7.4a          | 8.0c   | 7.9bc |

<sup>1</sup>Values in rows followed by a different letter are significantly differently at the  $P \leq .05$  level (Duncan's New Multiple Range Test).

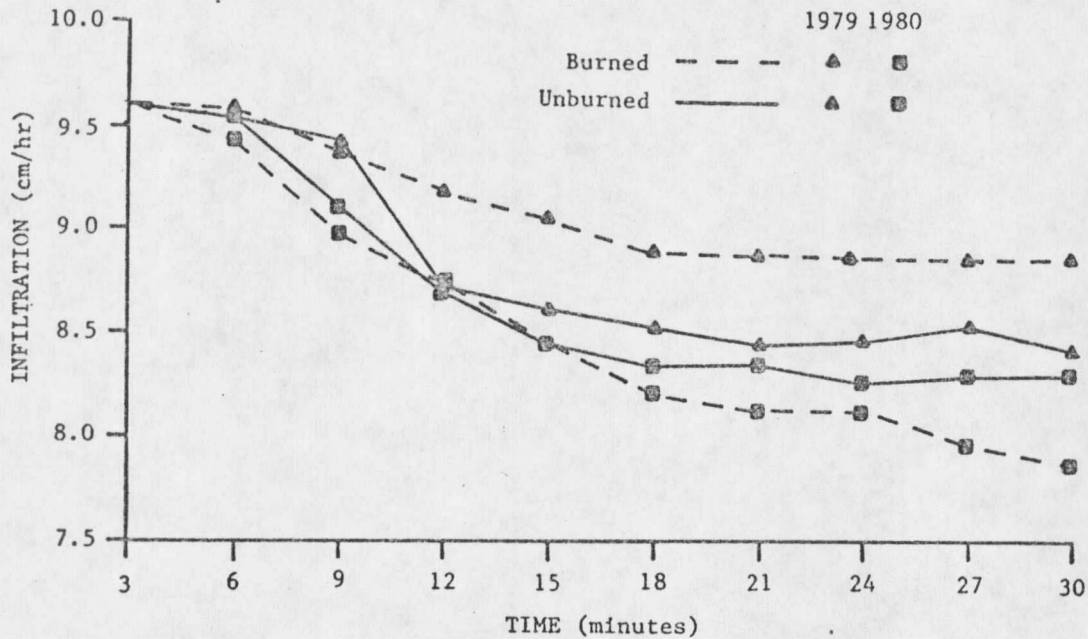


Figure 31. Infiltration rates on the burned and unburned Artemisia tridentata/Stipa viridula sites in 1979 and 1980.

On the unburned Artemisia tridentata/Stipa viridula site the mean infiltration rate during each three minute period was similar during the 1979 and 1980 tests. After 18 minutes the infiltration rate began to stabilize at 8.4 cm/hr.

On the burned site during 1979, the mean infiltration rate appeared considerably greater than during 1980 or during either year on the unburned site. The infiltration rate on the burned site during 1980 was the least of both sites during either year. During 1979 the

infiltration rate on the burned site began to level off after 18 minutes at 8.9 cm/hr. Infiltration during 1980 on the burned site failed to stabilize by the end of the 30 minute test period.

### Soil Moisture

Plant, climatic and soil factors influence the amount of water which plants can absorb efficiently. Plant factors include rooting habits, resistance to drought, and stage and rate of growth. Air temperature and humidity influence the efficient use of water. Soil characteristics include moisture tension relationships, salt content, soil depth and soil layering. The most important moisture tension factors are the amount of clay and organic matter.

Available moisture is generally considered as that held between field capacity and wilting point. During this study, 15 bars was used to approximate the wilting point. This water potential was estimated using the following equation from Decker (1972);

$$15 \text{ bars} = 2.0 + 0.3 (\text{percent clay}) + 0.6 (\text{organic matter}).$$

Using 15 bars as the wilting point does not infer that all the perennial grasses had the same drought resistance.

Trends in soil moisture were measured in the upper 15 cm of soil on the burned and unburned sites of each community during 1979 and 1980 (Figures 32, 33 and 34).

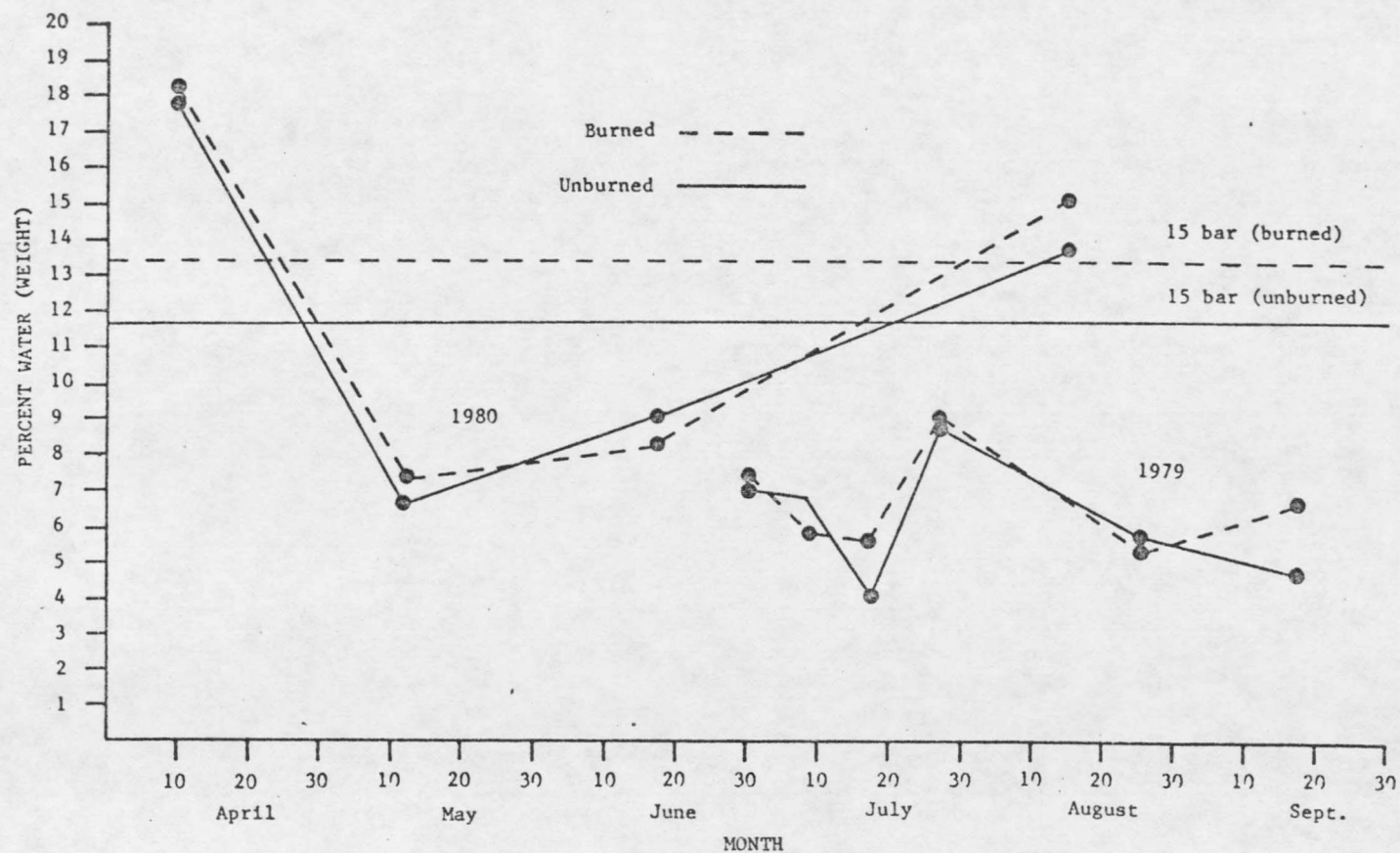


Figure 32. Percent soil moisture (weight) in the upper 15 cm of soil on the Artemisia tridentata/Stipa viridula sites.



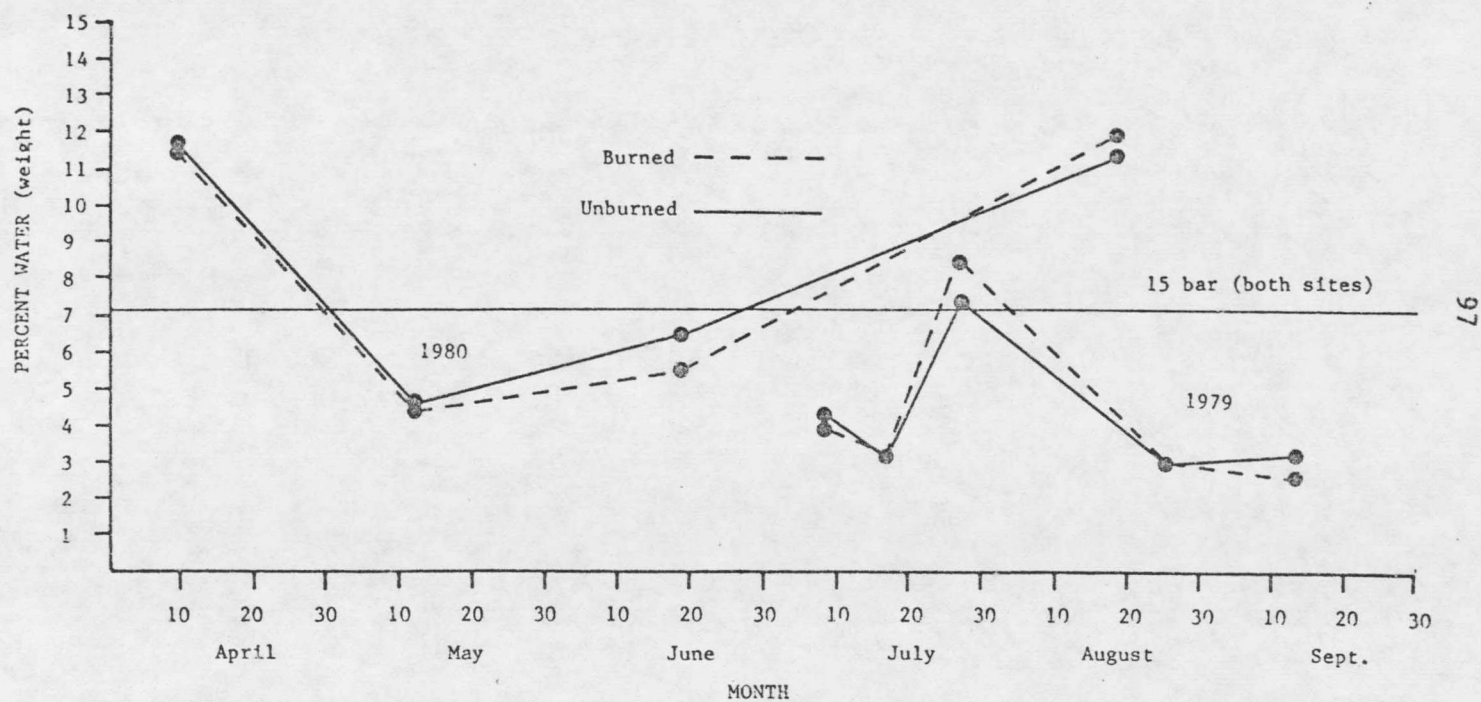


Figure 33. Percent soil moisture (weight) in the upper 15 cm of soil on the Calamovilfa longifolia/Andropogon scoparius sites.

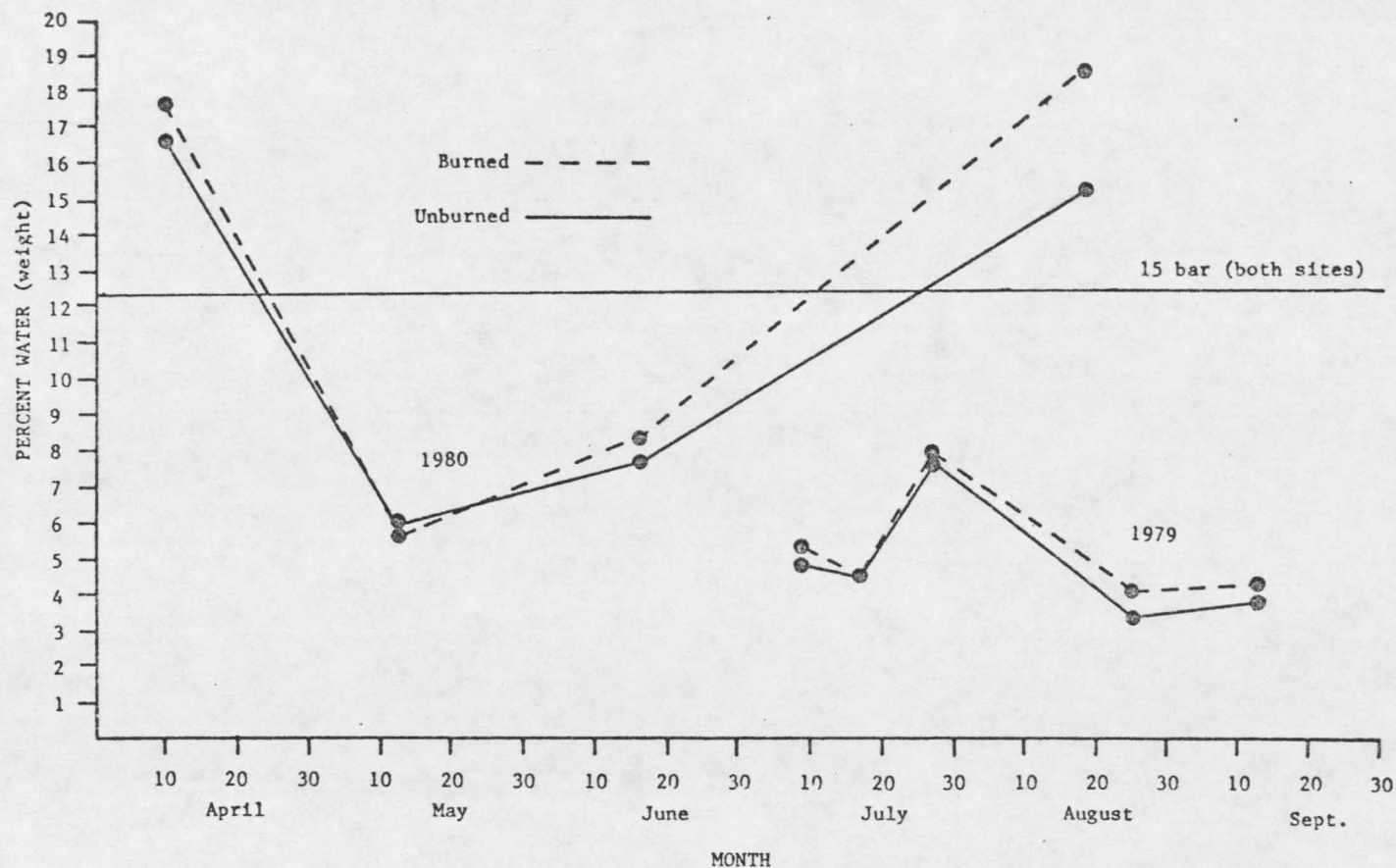


Figure 34. Percent soil moisture (weight) in the upper 15 cm of soil on the *Artemisia cana*/*Stipa viridula* sites.



Soil water potential was less than 15 bars on only one site and one sampling date in 1979. This occurred in the Calamovilfa longifolia/Andropogon scoparius community on July 27, two days after a short but intense thunderstorm. Soil moisture during the 1980 growing season had improved. Soil water potential was less than 15 bars in each community at the beginning and towards the end of the growing season. The length of time that water was theoretically unavailable to the plants was influenced by soil texture. Soil moisture was greater than 15 bars in the Calamovilfa longifolia/Andropogon scoparius community for approximately 60 days. In the Artemisia tridentata/Stipa viridula and the Artemisia cana/Stipa viridula communities water potential was greater than 15 bars for approximately 92 and 86 days respectively. Soil water potential was greater than 15 bars in all communities during May and June 1980.

Soil moisture trends were similar between the burned and the unburned sites of each community. Soil moisture was not significantly different between the burned and the unburned sites of a particular community on any of the sampling dates.

## DISCUSSION

Production in the semi-arid mixed prairie has generally declined following spring and fall fires due to unfavorable soil moisture conditions (Coupland 1973; DeJong and MacDonald 1975; Redmann 1978). For example, Clarke et al. (1943) found that production was still less on burned compared to unburned areas after three growing seasons.

When comparing the response of the vegetation in these studies to the present study, two factors appeared to have a pronounced effect on soil moisture: 1) season of burning (spring vs. fall), and 2) the composition of lifeforms.

Fires in the fall generally leave sites denuded through the winter. Consequently snow is blown from the site and less is available for infiltration. High correlations have been found between fall precipitation plus precipitation during the current growing season and production following spring burning.

In addition to precipitation and soil moisture, air and soil temperature at the beginning of the growing season can be important to production. The conversion of litter to a dark layer of ash and charcoal is generally considered to produce early spring growth by creating warm surface temperatures on burned areas. This early growth can increase yield by effectively extending the growing season.

Despite the 1979 drought, production and cover of perennial grasses and forbs in the present study were not reduced in any plant

community as a result of burning. This, in part, was attributed to the fall rains in 1978 and the above average precipitation that winter. Also, standing dead grasses and dormant shrubs probably contributed to the accumulation of snow on the sites. Reduced shrub competition for moisture was undoubtedly a factor, especially in the Artemisia tridentata/Stipa viridula community. Production and cover of perennial grasses was reduced on most sites from 1979 to 1980 due to the continued drought.

In the mixed prairie in Canada, shrubs are conspicuous on some sites but are not a major component of the plant communities (Coupland 1950). In view of this, the Artemisia tridentata/Stipa viridula and the Artemisia cana/Stipa viridula communities of the present study, more closely resembled plant communities of the sagebrush-grass rangeland. Big sagebrush competes directly with perennial grasses for soil moisture by laterally projecting roots into the grass root zones (Frischknecht 1963). Removing big sagebrush chemically (Cook and Lewis 1963) or with fire (Wright et al. 1979) can release perennial grasses and forbs from competition, resulting in increased yields.

When comparing the response of plant lifeforms and individual species among plant communities of the present study, three factors appeared to have a key influence: 1) time of burning relative to plant phenology, 2) burning intensity, and 3) post-burning competition for soil moisture.

The Artemisia cana/Stipa viridula and the Calamovilfa longifolia/Andropogon scoparius sites were burned on April 6, 1979. The Artemisia tridentata/Stipa viridula site was burned on April 20, 1979. During this two week period cool-season perennial grasses and annual grasses were actively growing. Some species appeared to be directly injured during the later fire but were unaffected by the earlier burn.

Burning was the least intense on the Calamovilfa longifolia/Andropogon scoparius site because of the absence of shrubs and the low air temperatures at the time of burning. Comparing the two shrub sites, burning was probably more intense on the Artemisia tridentata/Stipa viridula site. This area had a greater density of shrubs and higher air temperatures during burning.

Comparing vegetation data between sites and between communities suggested that shrub competition for soil moisture was an important factor affecting plant development. Post-burning competition was probably more intense on the Artemisia cana/Stipa viridula site compared to the Artemisia tridentata/Stipa viridula site. Silver sagebrush, which resprouted vigorously after the fire, competed directly with perennial grasses, forbs and annual grasses. Plants on the burned Artemisia tridentata/Stipa viridula site were released from competition with the big sagebrush.

The response of prairie junegrass to the fires varied with plant phenology and fire intensity. On the Calamovilfa longifolia/Andropogon scoparius site, where burning was less intense and occurred prior to active growth, production was stimulated and cover was not reduced relative to the unburned site. On the intensely burned Artemisia tridentata/Stipa viridula site production and cover appeared to be lower in 1979 and were significantly lower in 1980 compared to the unburned site.

The flowering activity of prairie junegrass supported the idea that this species was initially damaged by the intense Artemisia tridentata/Stipa viridula fire. In 1979, the ratio of reproductive to vegetation culms was significantly higher on the unburned site. This ratio on the Artemisia cana/Stipa viridula sites was similar during both years.

Production and cover of prairie junegrass had not recovered on the burned Artemisia tridentata/Stipa viridula site by the end of the second growing season. However, the ratio of reproductive to vegetative culms was higher on the burned site in 1980. This indicated that the remaining prairie junegrass plants were vigorous and actively reproducing.

Green needlegrass may also have been initially harmed by the intense Artemisia tridentata/Stipa viridula fire. Production appeared

to be less and cover was significantly less on the burned compared to the unburned site in 1979. However, in 1980 production appeared to be greater and cover was similar to the unburned site. This species responded favorably to the lack of big sagebrush competition.

On the Artemisia cana/Stipa viridula site, where burning was less intense and occurred two weeks before the Artemisia tridentata/Stipa viridula fire, the production of green needlegrass was similar between sites in both years. Canopy cover was significantly greater on the burned site during both years. This species was not directly harmed by this early fire and was apparently able to respond favorably despite the increased production of silver sagebrush.

In general, western wheatgrass had significantly greater production and cover on the burned Artemisia tridentata/Stipa viridula and Artemisia cana/Stipa viridula sites in both years. The complete lack of this species from clipping quadrats on the burned Artemisia cana/Stipa viridula site in 1980 was surprising. Production and cover increases following burning are typical for this species. Western wheatgrass spread vegetatively into areas where dense clumps of big sagebrush were removed. This species maintained production and cover on the burned Artemisia tridentata/Stipa viridula site from 1979 to 1980. In contrast, production and cover of western wheatgrass on the burned Artemisia cana/Stipa viridula site declined in 1980. These

responses were attributed to the lack of shrub competition on the Aremisia tridentata/Stipa viridula site and the possible increased competition from silver sagebrush on the Artemisia cana/Stipa viridula site. Flowering activity of western wheatgrass was improved on the burned compared to the unburned sites.

Little bluestem and prairie sandreed were not harmed by the fire. Production and cover were similar between sites during both growing seasons. These results were expected since these warm-season species generally respond favorably to spring burning.

Cover data for bluebunch wheatgrass and blue grama were low but seemed to indicate that these species were not permanently harmed by burning. Flowering activity of bluebunch wheatgrass was reduced on the burned Artemisia tridentata/Stipa viridula site in 1979. This response suggested that this species was initially damaged. However, in 1980 this species produced a significantly higher ratio of reproduction to vegetative culms on the burned site. Some plants consisted almost entirely of reproductive culms (Figure 35).

Blue grama did not appear to be damaged by the fires of either shrub community and may have been stimulated. A significantly greater ratio of reproductive to vegetative culms on the burned sites during both years suggested that microclimatic conditions early in the growing season had improved.





Figure 35. Bluebunch wheatgrass in 1980 on the burned Artemisia tridentata/Stipa viridula site. Note abundant seedhead production.

Forb production and cover were not reduced by burning in any plant community during either year. Forb yield appeared to increase on the burned Artemisia tridentata/Stipa viridula site in 1980 while the yield on the unburned site decreased. This was probably in response to reduced shrub competition and possibly the absence of allelopathic affects of big sagebrush litter (Odum 1971). In contrast, forb yield decreased on both Artemisia cana/Stipa viridula sites from 1979 to 1980. This was attributed to the continued drought combined with silver sagebrush competition.

Frequency data (Appendix B) suggest that some forb species responded immediately to the effects of the fires. Common dandelion, a weedy exotic, was abundant on the burned Artemisia tridentata/Stipa viridula site soon after the fire. This species was less abundant in 1980 but was still conspicuous. Yellow salsify was frequent on the burned shrub sites in 1979 but was reduced in 1980 apparently due to the continued drought.

Two perennials, scarlet globemallow (Sphaeralcea coccinea) and scarlet gaura appeared to be stimulated by burning. Both species increased their frequency on burned sites from 1979 to 1980. In 1980, scarlet globemallow spread into openings that were formerly occupied by big sagebrush (Figure 36). Dix (1960) reported similar frequencies of these species on burned and unburned areas after a late May fire.

Some species, mostly annuals, were not present on the burned sites until the second post-fire growing season. Western tansymustard (Descurainia pinnata), western sticktight (Lappula redowskii), alpine bladderpod (Lesquerella alpina), littlepod falseflax (Camelina microcarpa) and prairie pepperweed (Lepidium densiflorum) were found on the burned Artemisia tridentata/Stipa viridula site in 1980 only. The removal of stifling litter, improved seedbed and reduced competition contributed to increases of these species.





Figure 36. Scarlet globemallow in 1980 spreading into openings that were formerly occupied by big sagebrush.

In the first post-fire growing season annual grass production appeared to be reduced on the burned Artemisia tridentata/Stipa viridula site. This was probably related to the time burning occurred relative to plant phenology. Annual grasses on this site were from 3 to 6 cm tall at the time of burning. Other researchers have reported reductions following spring burning (Pechanec and Hull 1945; Stewart and Hull 1949; Vogl 1974). In contrast, annual grasses on the burned Artemisia cana/Stipa viridula site were apparently stimulated during the first post-fire growing season. These annual grasses were not

directly harmed by the fire and took advantage of the improved growing conditions. Annual grasses maintained production on the burned Artemisia tridentata/Stipa viridula site from 1979 to 1980. An apparent reduction occurred on the unburned Artemisia tridentata/Stipa viridula site and both Artemisia cana/Stipa viridula sites from 1979 to 1980. This was attributed to reduced soil moisture conditions brought about by the continued drought and from shrub competition.

Skunkbush sumac, western snowberry (Symphoricarpos occidentalis) and prairie rose (Rosa arkansana) responded favorably to the fires (Figure 37). Other researchers have reported that frequency of cover remained unchanged or increased for these species following fire (Dix 1960; Gartner and Thompson 1972; Kirsch and Kruse 1972; Wright et al. 1979; Wright and Bailey 1980). Winterfat (Eurotia lanata) was not harmed by the April 20, 1979 fire (Figure 38).

Phenology data indicated that some species on burned sites had a growing season that was as much as three weeks longer than the same species on a corresponding unburned site. In 1979, the major perennial grasses on both burned shrub sites had an extended green period at the end of the growing season, compared to unburned sites. In 1980, this extended green period was observed on the Artemisia cana/Stipa viridula site but not on the Artemisia tridentata/Stipa viridula site. This appeared to be contradictory, assuming that increased



silver sagebrush competition decreased the amount of available soil moisture.

The Artemisia cana/Stipa viridula site was located in a small drainage and probably received some run-in moisture. Thunderstorms were common during July and August. Furthermore, the burned site was at the head of this drainage and could have received a greater amount



Figure 37. Skunkbush sumac and western snowberry as they appeared in June, 1980 on the area burned April 6, 1979.

of run-in water than the control site. The extended growing season of perennial grasses on the burned silver sagebrush site in 1980 was attributed to additional soil moisture from midsummer thunderstorms.

Flowering activity in the present study was generally stimulated



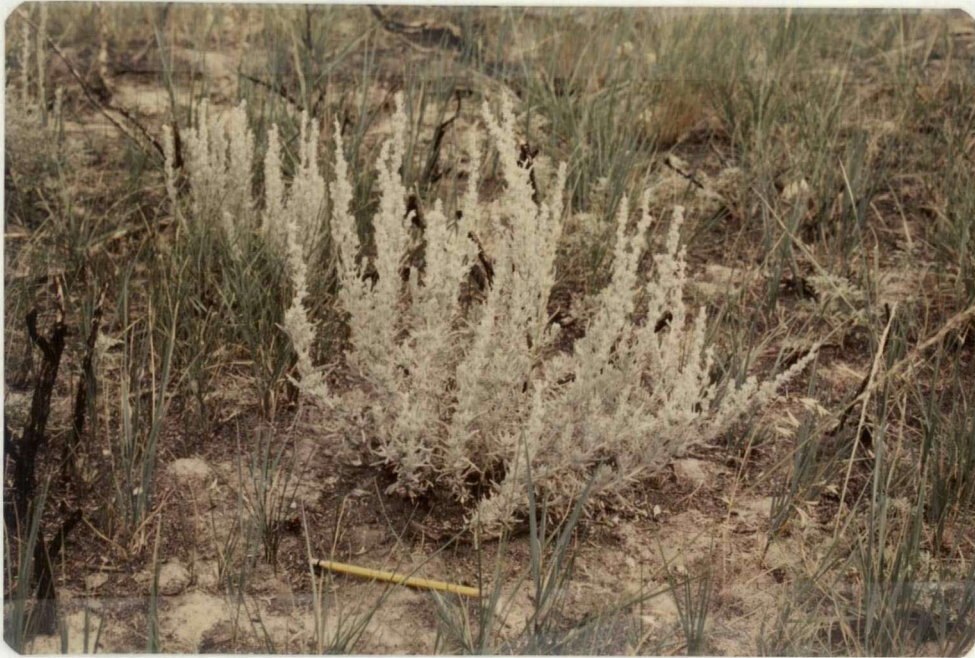


Figure 38. Winterfat during 1979 on the area burned April 20, 1979.

by burning which agrees with the literature. In the first post-fire growing season, prairie junegrass and bluebunch wheatgrass were detrimentally affected by the late and intense Artemisia tridentata/Stipa viridula fire. These species produced more flowering culms on the unburned compared to the burned site. However, this response was reversed in 1980. In 1980, all perennial grass species on the burned Artemisia tridentata/Stipa viridula site produced more flowering culms than those species on the unburned site. Blue grama was the most consistently stimulated species. On the Calamovilfa longifolia/Andropogon scoparius site, little bluestem was stimulated, whereas prairie sandreed was not. These responses were attributed to warm spring

soil and/or higher temperatures within bunches on the burned sites.

Vigor data showed that the response of perennial grasses to burning depended upon the species and the particular parameter measured.

Phosphorus was the only chemical characteristic of the soil that showed a consistent change following burning. Significantly less phosphorus was present three weeks and two months after burning. This difference may have resulted from a rapid uptake of phosphorus by the plants, as reported in the literature.

Infiltration rates between the burned and unburned big sagebrush sites were not compared statistically, however some generalizations were made. Soil on the burned site in 1979 appeared to have a higher rate of infiltration than in 1980. By the spring of 1980, the ash and unburned litter had settled, forming a thin crust on the soil surface. This crusted soil surface probably accounted for increased runoff and lowered infiltration. This lowered infiltration rate was not viewed as an erosion hazard because: 1) the water application rate exceeded most natural storms, 2) the area left uncrusted was large enough to slow overland flow and allow for infiltration, and 3) the slope of the study area was nearly level.

Soil moisture in the 0 to 15 cm zone was unaffected by burning. On the dates sampled, soil moisture in this zone was not significantly different between burned and unburned sites.



## SUMMARY AND CONCLUSIONS

The main objective was to estimate the response of mixed prairie vegetation to prescribed spring burning. The second objective was to measure changes in chemical and physical properties of the soil that are key influences on the growth and development of the vegetation.

Three plant communities were selected for study. One community, Artemisia tridentata/Stipa viridula, was dominated by big sagebrush and cool-season perennial grasses. Another community Artemisia cana/Stipa viridula, was dominated by silver sagebrush, big sagebrush and cool-season perennial grasses. The third community, Calamovilfa longifolia/Andropogon scoparius, was dominated by warm-season perennial grasses but cool-season perennial grasses and forbs were conspicuous.

Within each community an area was selected for treatment and one as the control. Transects were established in each area. Vegetation data consisted of canopy cover, frequency, above ground biomass production, phenology, and vigor and vitality estimates. Soil measurements included organic matter, total nitrogen, pH, phosphorous, electrical conductivity, infiltration rate and soil moisture.

'Tempilstik's were used to estimate the maximum temperatures reached at the mineral soil surface and at a depth of 1 cm on the burned Artemisia tridentata/Stipa viridula site. The amount of fuel was estimated by direct harvest before and after the big sagebrush fire.

Two fires were conducted at the study area. The fireline was burned on April 6, 1979 and burned through the Calamovilfa longifolia/Andropogon scoparius and the Artemisia cana/Stipa viridula communities. The prescribed burn was conducted on April 20, 1979 and burned through the Artemisia tridentata/Stipa viridula community.

A review of the literature revealed that the response of vegetation after a spring fire depends primarily on stored soil moisture before the fire and precipitation in the early part of the growing season after the fire. The composition of lifeforms prior to burning can aid in predicting the response of vegetation following a fire. Post-burning competition effects herbage production by influencing the soil-water status.

Precipitation in the latter months of 1978 was abnormally high. Drought conditions prevailed in the Colstrip area in 1979 and 1980.

Results showed that burning caused extremely high surface temperatures. However, soil temperatures at 1 cm were unchanged and damage to vegetation other than big sagebrush was minor. Burning almost completely eliminated big sagebrush. Silver sagebrush resprouted the first growing season and increased production in the second season. Valuable shrubs and half-shrubs, namely skunkbush sumac, western snowberry, prairie rose, and winterfat were unharmed by burning.

The response of herbaceous species was related to phenological stage and the time burning occurred, fire intensity, post-burning competition for soil moisture and the possible release from allelopathic affects.

Perennial grass production was similar or greater on the burned compared to the unburned sites during both years. On the burned Artemisia cana/Stipa viridula site in 1979, perennial grass production was significantly greater than the unburned site due to the greater production of western wheatgrass. In 1980, perennial grass yield in the Artemisia tridentata/Stipa viridula community was greater on the burned than on the unburned site. This was due to the increased production of green needlegrass and the consistent production of western wheatgrass. Perennial grass production decreased on all sites from 1979 to 1980 due to the drought except on the burned Artemisia tridentata/Stipa viridula site. The release of perennial grasses from big sagebrush competition on this site offset the effects of the continued drought.

Green needlegrass was initially harmed by the late and intense Artemisia tridentata/Stipa viridula fire but recovered production in the second growing season. In contrast, prairie junegrass had not recovered production on this site. However, on the burned Artemisia cana/Stipa viridula site, prairie junegrass production was stimulated

and cover was similar, relative to the unburned site. Western wheatgrass spread rapidly into areas formerly occupied by big sagebrush and generally had greater production and cover on burned sites. Bluebunch wheatgrass may have been initially harmed by the late fire. However, vitality data suggested that this species had recovered by the second growing season. Flowering activity of blue grama was stimulated during both years. Prairie sandreed and little bluestem were unharmed by spring burning.

Forb production was similar or greater on the burned compared to the unburned sites in both years. Forb yield appeared to increase on the burned Artemisia tridentata/Stipa viridula site from 1979 to 1980. This was attributed to reduced competition with big sagebrush. On the burned Artemisia cana/Stipa viridula site, forb yield declined in 1980 apparently due to increased competition from silver sagebrush and due to the continued drought.

Frequency data for forbs indicated that some species responded positively in the first post-fire growing season. Two biennials, common dandelion and yellow salsify were abundant on the burned Artemisia tridentata/Stipa viridula site in 1979 but were reduced in 1980. Two perennials, scarlet gaura and scarlet globemallow were not directly harmed by burning and increased their frequency in 1980. Some species, mostly annuals were present on the burned sites in 1980 only.

Annual grasses responded differently depending on the time burning occurred relative to phenological development. Annual grasses were reduced by the late fire but were not directly harmed by the early fire.

Phenology data revealed that some perennial grass species had extended green periods at the end of their growing seasons on burned and not on unburned sites. For some species this extended growing period was as much as three weeks and occurred during both growing seasons.

Flowering activity was generally stimulated on burned sites due to a warmer microclimate early in the growing season. Two bunchgrasses, prairie junegrass and bluebunch wheatgrass were initially damaged by the late and intense Artemisia tridentata/Stipa viridula fire.

The chemical properties of the soil were generally unaltered by burning. However, the concentration of phosphorus in the soil was significantly less three weeks and two months after burning. This may have been due to plant uptake or to sampling variability.

Soil moisture in the 0 to 15 cm zone was similar between burned and unburned sites during both years.

The infiltration rate was slightly higher on the burned site in 1979 than in 1980. In 1980, the lowered infiltration rate on the burned site was attributed to a thin crust that had formed on the soil

surface. This lowered infiltration was not viewed as an erosion hazard but may have increased evaporation.

Based on the experimental evidence and observations made during this study, the following conclusions are presented:

1. Controlled burning in this portion of the semi-arid mixed prairie under proper conditions of weather, soil moisture, and plant phenology generally did not have an adverse affect on herbaceous species.
2. Prairie junegrass and bluebunch wheatgrass may be initially damaged if burning occurs during active growth. Prairie junegrass may not recover after two growing seasons.
3. Warm-season perennial grass species respond favorably to spring burning.
4. To avoid direct damage by heat, spring burning should be completed prior to the active growth stages of the dominant cool-season perennial grasses.
5. Burning following a fall and winter with above average precipitation may not reduce the production of perennial grasses and forbs even under conditions of severe drought.
6. Burning in the spring rather than the fall enhances the soil water status of the site.



7. Prescribed burning can be an effective and relatively inexpensive method to remove a dense stand of big sagebrush and thereby permit deep rooted perennials to take advantage of the additional soil moisture.
8. Burning may not be effective in increasing the production of herbaceous species in areas where silver sagebrush predominates.
9. Annual grasses may be temporarily reduced if burning occurs when plants are actively growing. Burning at earlier dates may not reduce these grasses.
10. The growing season of some perennial grasses is extended as a result of burning.
11. The flowering activity of some perennial grasses may increase following burning. This response may be delayed until the second post-fire growing season.
12. Infiltration rate may decrease following burning where big sagebrush litter had accumulated.

## APPENDICES

APPENDIX A. Table 1. List of plant species collected on the burned (B) and unburned (UB) Artemisia tridentata/Stipa viridula sites.

| SCIENTIFIC NAME                 | COMMON NAME          | 1979 |    | 1980 |    |
|---------------------------------|----------------------|------|----|------|----|
|                                 |                      | B    | UB | B    | UB |
| <u>Achillea millefolium</u>     | Western yarrow       | X    | X  | X    | X  |
| <u>Agropyron smithii</u>        | Western wheatgrass   | X    | X  | X    | X  |
| <u>Agropyron spicatum</u>       | Bluebunch wheatgrass | X    | X  | X    | X  |
| <u>Allium</u> sp.               | Wild onion           | X    | X  |      |    |
| <u>Artemisia campestris</u>     | Common sagewort      | X    | X  |      | X  |
| <u>Artemisia frigida</u>        | Fringed sagewort     |      | X  |      | X  |
| <u>Artemisia tridentata</u>     | Big sagebrush        | X    | X  | X    | X  |
| <u>Astragalus</u> spp.          | Milkvetch            | X    | X  | X    | X  |
| <u>Bouteloua gracilis</u>       | Blue grama           | X    | X  | X    | X  |
| <u>Bromus japonicus</u>         | Japanese brome       | X    | X  | X    | X  |
| <u>Bromus tectorum</u>          | Cheatgrass           | X    | X  | X    | X  |
| <u>Camelina microcarpa</u>      | Littlepod falseflax  |      |    | X    |    |
| <u>Carex filifolia</u>          | Threadleaf sedge     | X    |    |      |    |
| <u>Chenopodium leptophyllum</u> | Narrowleaf goosefoot |      |    | X    |    |
| <u>Crepis acuminata</u>         | Tapertip hawkbeard   |      | X  |      | X  |
| <u>Descurainia pinnata</u>      | Western tansymustard |      |    | X    |    |
| <u>Erysimum asperum</u>         | Plains wallflower    | X    |    | X    |    |
| <u>Eurotia lanata</u>           | Winterfat            | X    | X  | X    | X  |
| <u>Gutierrezia sarothrae</u>    | Broom snakeweed      | X    | X  | X    | X  |
| <u>Hedeoma hispida</u>          | Rough pennyroyal     |      | X  |      |    |
| <u>Helianthus petiolaris</u>    | Prairie sunflower    | X    |    |      |    |
| <u>Koeleria cristata</u>        | Prairie junegrass    | X    | X  | X    | X  |
| <u>Lactuca serriola</u>         | Prickly lettuce      |      |    | X    |    |
| <u>Lappula redowskii</u>        | Western sticktight   |      |    | X    |    |
| <u>Lesquerella alpina</u>       | Alpine bladderpod    |      |    | X    |    |
| <u>Lepidium densiflorum</u>     | Prairie pepperweed   |      |    | X    |    |
| <u>Leucocrinum montanum</u>     | Star lily            | X    | X  |      | X  |
| <u>Musineon divaricatum</u>     | Sheathed musineon    | X    | X  | X    | X  |

continued

APPENDIX A. Table 1. Continued.

| SCIENTIFIC NAME              | COMMON NAME         | 1979 |    | 1980 |    |
|------------------------------|---------------------|------|----|------|----|
|                              |                     | B    | UB | B    | UB |
| <u>Opuntia polycantha</u>    | Plains pricklypear  | X    | X  | X    | X  |
| <u>Phlox hoodii</u>          | Hoods phlox         | X    | X  | X    | X  |
| <u>Plantago patagonica</u>   | Woolly plantain     | X    | X  | X    |    |
| <u>Poa pratensis</u>         | Kentucky bluegrass  | X    | X  | X    | X  |
| <u>Poa sandbergii</u>        | Sandberg bluegrass  | X    | X  | X    | X  |
| <u>Sisymbrium altissimum</u> | Tumblemustard       |      |    | X    |    |
| <u>Sphaeralcea coccinea</u>  | Scarlet globemallow | X    | X  | X    | X  |
| <u>Stipa comata</u>          | Needle-and-thread   | X    | X  | X    | X  |
| <u>Stipa viridula</u>        | Green needlegrass   | X    | X  | X    | X  |
| <u>Taraxacum officinale</u>  | Common dandelion    | X    | X  | X    | X  |
| <u>Tragopogon dubuis</u>     | Yellow salsify      | X    | X  | X    | X  |

APPENDIX A. Table 2. List of plant species collected on the burned (B) and the unburned (UB) Calamovilfa longifolia/Andropogon scoparius sites.

| SCIENTIFIC NAME               | COMMON NAME            | 1979 |    | 1980 |    |
|-------------------------------|------------------------|------|----|------|----|
|                               |                        | B    | UB | B    | UB |
| <u>Achillea millefolium</u>   | Western yarrow         | X    |    | X    |    |
| <u>Agoseris glauca</u>        | Pale agoseris          |      | X  |      | X  |
| <u>Agropyron smithii</u>      | Western wheatgrass     | X    |    | X    |    |
| <u>Agropyron spicatum</u>     | Bluebunch wheatgrass   | X    | X  | X    | X  |
| <u>Ambrosia psilostachya</u>  | Western ragweed        |      |    | X    |    |
| <u>Andropogon hallii</u>      | Sand bluestem          | X    | X  | X    | X  |
| <u>Andropogon scoparius</u>   | Little bluestem        | X    | X  | X    | X  |
| <u>Antennaria parvifolia</u>  | Small leaf pussytoes   |      | X  |      | X  |
| <u>Aristida longiseta</u>     | Red threeawn           | X    | X  | X    | X  |
| <u>Artemisia campestris</u>   | Common sagewort        | X    | X  | X    | X  |
| <u>Artemisia cana</u>         | Silver sagebrush       |      | X  |      | X  |
| <u>Artemisia dracunculus</u>  | Falsetarragon sagewort |      | X  |      | X  |
| <u>Artemisia frigida</u>      | Fringed sagewort       | X    | X  | X    | X  |
| <u>Artemisia ludoviciana</u>  | Prairie sagewort       | X    | X  | X    | X  |
| <u>Artemisia tridentata</u>   | Big sagebrush          | X    | X  | X    | X  |
| <u>Asclepias pumila</u>       | Plains milkweed        |      | X  |      | X  |
| <u>Aster falcatus</u>         | White prairieaster     | X    | X  | X    | X  |
| <u>Astagalus gilviflorus</u>  | Threeleaved milkvetch  |      | X  |      | X  |
| <u>Astagalus gracilis</u>     | Slender milkvetch      |      | X  |      | X  |
| <u>Bouteloua curtipendula</u> | Sideoats grama         | X    | X  | X    | X  |
| <u>Bouteloua gracilis</u>     | Blue grama             |      | X  |      | X  |
| <u>Bromus japonicus</u>       | Japanese brome         | X    |    | X    |    |
| <u>Bromus tectorum</u>        | Cheatgrass             | X    |    | X    |    |
| <u>Calamovilfa longifolia</u> | Prairie sandreed       | X    | X  | X    | X  |
| <u>Carex filifolia</u>        | Threadleaf sedge       | X    | X  | X    | X  |
| <u>Chrysopsis villosa</u>     | Hairy goldaster        | X    | X  | X    | X  |
| <u>Cirsium undulatum</u>      | Wavyleaf thistle       | X    | X  | X    | X  |
| <u>Cryptantha celosioides</u> | Miners candle          | X    | X  | X    | X  |
| <u>Delphinium bicolor</u>     | Little larkspur        | X    |    | X    |    |

continued



APPENDIX A. Table 2. Continued.

| SCIENTIFIC NAME               | COMMON NAME              | 1979 |    | 1980 |    |
|-------------------------------|--------------------------|------|----|------|----|
|                               |                          | B    | UB | B    | UB |
| <u>Descurainia pinnata</u>    | Western tansymustard     |      |    | X    |    |
| <u>Echinacea pallida</u>      | Purple coneflower        | X    | X  | X    | X  |
| <u>Eriogonum annuum</u>       | Annual buckwheat         |      |    |      | X  |
| <u>Gaura coccinea</u>         | Scarlet gaura            | X    | X  | X    | X  |
| <u>Gutierrezia sarothrae</u>  | Broom snakeweed          | X    | X  | X    | X  |
| <u>Juniperus scopulorum</u>   | Rocky Mountain juniper   |      | X  |      | X  |
| <u>Koeleria cristata</u>      | Prairie junegrass        | X    | X  | X    | X  |
| <u>Lactuca pulchella</u>      | Blue lettuce             |      | X  | X    | X  |
| <u>Liatis punctata</u>        | Dotted gayfeather        |      |    |      | X  |
| <u>Linum perenne</u>          | Perennial flax           | X    | X  |      | X  |
| <u>Linum rigidum</u>          | Yellow flax              |      |    | X    | X  |
| <u>Lithospermum incisum</u>   | Narrowleaf gromwell      | X    | X  | X    | X  |
| <u>Lygodesmia juncea</u>      | Rush skeletonweed        | X    | X  | X    | X  |
| <u>Oenothera serrulata</u>    | Shrubby evening primrose |      | X  |      | X  |
| <u>Opuntia polyacantha</u>    | Plains pricklypear       |      | X  |      | X  |
| <u>Petalostemon purpureum</u> | Purple prairieclover     | X    | X  | X    | X  |
| <u>Penstemon albidus</u>      | White penstemon          |      | X  |      | X  |
| <u>Phlox hoodii</u>           | Hoods phlox              | X    | X  | X    | X  |
| <u>Physaria didymocarpa</u>   | Common twinpod           | X    | X  | X    | X  |
| <u>Pinus ponderosa</u>        | Ponderosa pine           | X    | X  | X    | X  |
| <u>Poa compressa</u>          | Canada bluegrass         | X    | X  | X    | X  |
| <u>Poa sandbergii</u>         | Sandberg bluegrass       | X    | X  | X    | X  |
| <u>Polygala alba</u>          | White milkwort           | X    | X  | X    |    |
| <u>Psoralea argophylla</u>    | Silverleaf scurfpea      | X    | X  | X    | X  |
| <u>Psoralea tenuiflora</u>    | Slimflowered scurfpea    |      | X  |      | X  |
| <u>Ratibida columnifera</u>   | Prairie coneflower       | X    |    |      |    |
| <u>Rhus trilobata</u>         | Skunkbush sumac          | X    | X  | X    | X  |
| <u>Solidago missouriensis</u> | Missouri goldenrod       |      | X  | X    | X  |
| <u>Stipa comata</u>           | Needle-and-thread        | X    | X  | X    | X  |
| <u>Stipa viridula</u>         | Green needlegrass        | X    | X  | X    | X  |
| <u>Tragopogon dubius</u>      | Yellow salsify           | X    | X  | X    | X  |
| <u>Yucca glauca</u>           | Yucca                    | X    | X  | X    | X  |



APPENDIX A. Table 3. List of plant species collected on the burned (B) and unburned (UB) Artemisia cana/Stipa viridula sites.

| SCIENTIFIC NAME                  | COMMON NAME            | 1979 |    | 1980 |    |
|----------------------------------|------------------------|------|----|------|----|
|                                  |                        | B    | UB | B    | UB |
| <u>Achillea millefolium</u>      | Western yarrow         | X    | X  | X    |    |
| <u>Agoseris glauca</u>           | Pale agoseris          | X    |    |      |    |
| <u>Agropyron smithii</u>         | Western wheatgrass     | X    | X  | X    | X  |
| <u>Agropyron spicatum</u>        | Bluebunch wheatgrass   | X    | X  | X    | X  |
| <u>Allium</u> sp.                | Wild onion             |      |    |      | X  |
| <u>Ambrosia psilostachya</u>     | Western ragweed        |      | X  |      |    |
| <u>Aristida longiseta</u>        | Red threeawn           | X    | X  | X    | X  |
| <u>Artemisia cana</u>            | Silver sagebrush       | X    | X  | X    | X  |
| <u>Artemisia dracunculoides</u>  | Falsetarragon sagewort |      |    | X    |    |
| <u>Artemisia frigida</u>         | Fringed sagewort       | X    | X  | X    | X  |
| <u>Artemisia ludoviciana</u>     | Prairie sagewort       |      | X  |      |    |
| <u>Artemisia tridentata</u>      | Big sagebrush          | X    | X  | X    | X  |
| <u>Aster falcatus</u>            | White prairieaster     |      |    |      | X  |
| <u>Astragalus</u> sp.            | Milkvetch              | X    | X  | X    | X  |
| <u>Besseyia wyomingensis</u>     | Wyoming besseyia       |      | X  |      | X  |
| <u>Bouteloua gracilis</u>        | Blue grama             | X    | X  | X    | X  |
| <u>Bouteloua curtipendula</u>    | Sideoats grama         | X    | X  | X    | X  |
| <u>Bromus japonicus</u>          | Japanese brome         | X    | X  | X    | X  |
| <u>Bromus tectorum</u>           | Cheatgrass             | X    | X  | X    | X  |
| <u>Calamagrostis montanensis</u> | Plains reedgrass       |      | X  |      | X  |
| <u>Carex filifolia</u>           | Threadleaf sedge       | X    |    | X    |    |
| <u>Chenopodium leptophyllum</u>  | Narrowleaf goosefoot   |      |    |      | X  |
| <u>Chrysopsis villosa</u>        | Hairy goldaster        | X    |    | X    |    |
| <u>Cirsium undulatum</u>         | Wavyleaf thistle       | X    | X  | X    |    |
| <u>Crepis acuminata</u>          | Tapertip hawksbeard    |      |    |      | X  |
| <u>Descurainia pinnata</u>       | Western tansymustard   |      |    | X    |    |
| <u>Echinacea pallida</u>         | Purple coneflower      | X    | X  | X    | X  |
| <u>Erysimum asperum</u>          | Plains wallflower      |      | X  |      | X  |

continued

APPENDIX A. Table 3. Continued.

| SCIENTIFIC NAME                    | COMMON NAME            | 1979 |    | 1980 |    |
|------------------------------------|------------------------|------|----|------|----|
|                                    |                        | B    | UB | B    | UB |
| <u>Eurotia lanata</u>              | Winterfat              | X    | X  | X    | X  |
| <u>Gaura coccinea</u>              | Scarlet gaura          | X    | X  | X    | X  |
| <u>Gutierrezia sarothrae</u>       | Broom snakeweed        | X    | X  | X    | X  |
| <u>Hedeoma hispida</u>             | Rough pennyroyal       | X    | X  |      |    |
| <u>Juniperus scopulorum</u>        | Rocky Mountain juniper |      | X  |      | X  |
| <u>Koeleria cristata</u>           | Prairie junegrass      | X    | X  | X    | X  |
| <u>Linum perenne</u>               | Perennial flax         | X    | X  | X    | X  |
| <u>Lithospermum incisum</u>        | Narrowleaf gromwell    | X    | X  |      |    |
| <u>Opuntia polyacantha</u>         | Plains pricklypear     | X    |    | X    |    |
| <u>Phlox hoodii</u>                | Hoods phlox            | X    | X  | X    | X  |
| <u>Plantago patagonica</u>         | Woolly plantain        |      | X  |      |    |
| <u>Poa pratensis</u>               | Kentucky bluegrass     | X    | X  | X    | X  |
| <u>Psoralea argophylla</u>         | Silverleaf scurfpea    |      | X  |      |    |
| <u>Psoralea tenuiflora</u>         | Slimflowered scurfpea  |      | X  |      |    |
| <u>Ratibida columnifera</u>        | Prairie coneflower     | X    | X  | X    |    |
| <u>Rhus trilobata</u>              | Skunkbush sumac        | X    | X  | X    | X  |
| <u>Rosa arkansana</u>              | Prairie rose           | X    | X  | X    | X  |
| <u>Solidago missouriensis</u>      | Missouri goldenrod     |      |    | X    | X  |
| <u>Sphaeralcea coccinea</u>        | Scarlet globemallow    | X    | X  | X    | X  |
| <u>Stipa comata</u>                | Needle-and-thread      | X    | X  | X    | X  |
| <u>Stipa viridula</u>              | Green needlegrass      | X    | X  | X    | X  |
| <u>Symphoricarpos occidentalis</u> | Western snowberry      | X    |    | X    |    |
| <u>Taraxacum officinale</u>        | Common dandelion       | X    | X  | X    | X  |
| <u>Tragopogon dubius</u>           | Yellow salsify         | X    | X  | X    |    |

APPENDIX B. Table 1. Frequency of species in the Artemisia tridentata/Stipa viridula community using 24, 0.2 x 0.5 m quadrats.

|                             | 1979   |          | 1980   |          |
|-----------------------------|--------|----------|--------|----------|
|                             | Burned | Unburned | Burned | Unburned |
| Perennial Grasses           |        |          |        |          |
| <u>Agropyron smithii</u>    | 67     | 54       | 75     | 67       |
| <u>Agropyron spicatum</u>   | 17     | 38       | 13     | 42       |
| <u>Bouteloua gracilis</u>   | 8      | 25       | 4      | 25       |
| <u>Koeleria cristata</u>    | 46     | 88       | 41     | 83       |
| <u>Poa sandbergii</u>       | -      | 8        | -      | 4        |
| <u>Stipa comata</u>         | -      | 17       | -      | 25       |
| <u>Stipa viridula</u>       | 79     | 83       | 67     | 75       |
| Annual Grasses              |        |          |        |          |
| <u>Bromus japonicus</u>     | 46     | 83       | 29     | 33       |
| <u>Bromus tectorum</u>      | 38     | -        | 2      | -        |
| Forbs                       |        |          |        |          |
| <u>Achillea millefolium</u> | 4      | -        | -      | -        |
| <u>Camelina microcarpa</u>  | -      | -        | 8      | 4        |
| <u>Descurainia pinnata</u>  | -      | -        | 25     | -        |
| <u>Hedeoma hispida</u>      | -      | 13       | -      | -        |
| <u>Lappula redowskii</u>    | -      | -        | 13     | -        |
| <u>Lesquerella alpina</u>   | -      | -        | 4      | -        |
| <u>Lepidium densiflorum</u> | -      | -        | 4      | -        |
| <u>Opuntia polyacantha</u>  | -      | 4        | -      | 4        |
| <u>Phlox hoodii</u>         | 4      | 13       | 4      | 17       |
| <u>Plantago patagonica</u>  | 4      | 4        | -      | -        |
| <u>Sphaeralcea coccinea</u> | 25     | 38       | 38     | 29       |
| <u>Taraxacum officinale</u> | 50     | -        | 17     | 4        |
| <u>Tragopogon dubius</u>    | 33     | -        | 4      | 4        |
| Shrubs and Half-Shrubs      |        |          |        |          |
| <u>Artemisia tridentata</u> | 4      | 79       | 4      | 79       |
| <u>Eurotia lanata</u>       | -      | 13       | -      | 13       |



APPENDIX B. Table 2. Frequency of species in the Calamovilfa longifolia/Andropogon scoparius community using 16, 0.2 x 0.5 m quadrats.

|                               | 1979   |          | 1980   |          |
|-------------------------------|--------|----------|--------|----------|
|                               | Burned | Unburned | Burned | Unburned |
| <u>Perennial Grasses</u>      |        |          |        |          |
| <u>Agropyron smithii</u>      | 13     | -        | 6      | -        |
| <u>Agropyron spicatum</u>     | 44     | 38       | 75     | 63       |
| <u>Andropogon scoparius</u>   | 81     | 44       | 69     | 44       |
| <u>Aristida longiseta</u>     | 6      | -        | 13     | 13       |
| <u>Bouteloua gracilis</u>     | 44     | 63       | 63     | 69       |
| <u>Calamovilfa longifolia</u> | 44     | 38       | 44     | 38       |
| <u>Koeleria cristata</u>      | 100    | 75       | 100    | 88       |
| <u>Poa compressa</u>          | 6      | 6        | 6      | -        |
| <u>Stipa comata</u>           | 63     | 50       | 63     | 81       |
| <u>Sedges</u>                 |        |          |        |          |
| <u>Carex filifolia</u>        | 94     | 69       | 100    | 88       |
| <u>Forbs</u>                  |        |          |        |          |
| <u>Antennaria parvifolia</u>  | -      | 19       | -      | 25       |
| <u>Astragalus spp.</u>        | 6      | 13       | -      | 13       |
| <u>Chrysopsis villosa</u>     | -      | 6        | -      | -        |
| <u>Echinacea pallida</u>      | -      | 6        | 6      | 31       |
| <u>Gaura coccinea</u>         | 6      | 6        | -      | 6        |
| <u>Lithospermum incisum</u>   | 38     | 25       | 13     | 38       |
| <u>Linum perenne</u>          | -      | 12       | 13     | 6        |
| <u>Lygodesmia juncea</u>      | 6      | -        | 6      | 6        |
| <u>Opuntia sp.</u>            | 6      | -        | 6      | -        |
| <u>Petalostemon purpureum</u> | -      | -        | -      | 13       |
| <u>Phlox hoodii</u>           | -      | 13       | 6      | 19       |
| <u>Psoralea argophylla</u>    | 44     | -        | -      | -        |
| <u>Ratibida columnifera</u>   | 6      | 13       | -      | -        |
| <u>Solidago missouriensis</u> | 13     | -        | 6      | 13       |
| <u>Tragopogon dubius</u>      | 6      | -        | -      | -        |
| <u>Shrubs and Half-Shrubs</u> |        |          |        |          |
| <u>Artemisia cana</u>         | -      | 6        | 6      | 19       |
| <u>Artemisia dracunculus</u>  | -      | 6        | -      | 19       |
| <u>Artemisia frigida</u>      | -      | 13       | -      | -        |
| <u>Artemisia tridentata</u>   | -      | 13       | -      | -        |
| <u>Gutierrezia sarothrae</u>  | -      | 13       | -      | 19       |
| <u>Oenothera serrulata</u>    | -      | 38       | -      | 25       |
| <u>Rhus trilobata</u>         | -      | 6        | -      | -        |
| <u>Yucca glauca</u>           | -      | 6        | -      | 6        |

APPENDIX B. Table 3. Frequency of species in the Artemisia cana/  
Stipa viridula community using 16, 0.2 x 0.5 m quadrats.

|                                  | 1979   |          | 1980   |          |
|----------------------------------|--------|----------|--------|----------|
|                                  | Burned | Unburned | Burned | Unburned |
| Perennial Grasses                |        |          |        |          |
| <u>Agropyron smithii</u>         | 100    | 88       | 92     | 88       |
| <u>Agropyron spicatum</u>        | -      | 33       | -      | 17       |
| <u>Bouteloua curtipendula</u>    | -      | 17       | -      | 17       |
| <u>Bouteloua gracilis</u>        | 13     | 11       | 63     | 42       |
| <u>Calamagrostis montanensis</u> | -      | 4        | -      | -        |
| <u>Koeleria cristata</u>         | 63     | 67       | 54     | 79       |
| <u>Poa pratensis</u>             | 13     | 4        | 17     | 13       |
| <u>Poa sandbergii</u>            | 13     | -        | -      | -        |
| <u>Stipa comata</u>              | 4      | 8        | 4      | -        |
| <u>Stipa viridula</u>            | 96     | 96       | 100    | 96       |
| Annual Grasses                   |        |          |        |          |
| <u>Bromus japonicus</u>          | 71     | 88       | 8      | -        |
| Forbs                            |        |          |        |          |
| <u>Achillea millefolium</u>      | 29     | 4        | 17     | -        |
| <u>Artemisia ludoviciana</u>     | -      | -        | -      | 13       |
| <u>Aster falcatus</u>            | -      | -        | -      | 13       |
| <u>Astragalus spp.</u>           | 4      | 8        | -      | 13       |
| <u>Cirsium undulatum</u>         | -      | 4        | -      | -        |
| <u>Crepis acuminata</u>          | -      | -        | -      | 4        |
| <u>Descurainia pinnata</u>       | -      | -        | 4      | -        |
| <u>Echinacea pallida</u>         | -      | 4        | -      | 8        |
| <u>Erysimum asperum</u>          | -      | -        | -      | 4        |
| <u>Gaura coccinea</u>            | 42     | 29       | 46     | 17       |
| <u>Hedeoma hispida</u>           | 4      | 13       | -      | -        |
| <u>Lithospermum incisum</u>      | -      | 13       | 13     | -        |
| <u>Linum perenne</u>             | 13     | 21       | 13     | -        |
| <u>Opuntia polyacantha</u>       | -      | 4        | -      | -        |
| <u>Opuntia sp.</u>               | -      | 4        | -      | 4        |
| <u>Phlox hoodii</u>              | 4      | 21       | 8      | 17       |
| <u>Plantago patagonica</u>       | 38     | 38       | -      | -        |
| <u>Psoralea tenuiflora</u>       | 4      | 4        | -      | -        |
| <u>Ratibida columnifera</u>      | 25     | 25       | -      | 4        |
| <u>Sphaeralcea coccinea</u>      | 46     | 58       | 46     | 54       |
| <u>Taraxacum officinale</u>      | -      | -        | 13     | 13       |
| <u>Tragopogon dubius</u>         | 58     | 33       | 8      | 21       |

continued

APPENDIX B. Table 3. Continued.

| <u>Shrubs and Half-Shrubs</u> | 1979          |                 | 1980          |                 |
|-------------------------------|---------------|-----------------|---------------|-----------------|
|                               | <u>Burned</u> | <u>Unburned</u> | <u>Burned</u> | <u>Unburned</u> |
| <u>Artemisia cana</u>         | 33            | 25              | 21            | 8               |
| <u>Artemisia frigida</u>      | -             | 4               | 8             | -               |
| <u>Artemisia tridentata</u>   | -             | 38              | -             | 29              |
| <u>Gutierrezia sarothrae</u>  | -             | 8               | -             | 17              |
| <u>Rosa arkansana</u>         | 4             | 4               | -             | 4               |



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