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THE EFFECT OF FIRE ON GRASSLANDS
IN THE ALBERTA ASPEN PARKLAND

by

(C) MURRAY L. ANDERSON

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Effect of Fire on Grasslands in the Alberta Aspen Parkland" submitted by Murray L. Anderson in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The effect of fire was studied on two grassland communities found in the grassland of the aspen parkland of central Alberta. The purpose of this study was to examine the effect of fire on species composition and to determine the temperature at various heights above the ground during burning.

The highest mean maximum temperature measured in a spring, 1971 fire in the *Symphoricarpos occidentalis* community of 1087°F was 567°F higher than the highest mean maximum temperatures of 520°F measured in the *Festuca scabrella* - *Stipa spartea* var. *curtiseta* community. Fuel weights averaged 16,000 kg/ha in the *Symphoricarpos* community and 3,500 kg/ha in the *Festuca-Stipa* community. Maximum temperatures in the headfire were greater at all heights than in the backfire. The maximum temperature in the headfire occurred at a height of 15 - 20 cm while that in the backfire occurred at a height of 5 - 8 cm. Differences in maximum temperatures between headfires and backfires were attribured to wind.

In both communities, canopy coverage of grasses and grass-likes decreased with burning. Shrubs increased and forbs increased greatly with burning. The increase in canopy coverage of forbs was probably due to an increase in both the quantity and availability of nutrients after burning.

In the *Festuca-Stipa* community, fall burning reduced the canopy coverage of *Festuca scabrella* by six per cent and *Stipa spartea* var. *curtiseta* by eight per cent. The density of seed heads of *Stipa spartea* var. *curtiseta* was reduced 77 per cent while the density of *Festuca scabrella* seed heads was not affected.

Spring burning reduced the canopy coverage of _Festuca scabrella_ and _Stipa spartea_ var. _curtiseta_ by 26 per cent and two per cent, respectively. There was a 97 per cent reduction in the density of seed heads of _Festuca scabrella_ while that of _Stipa spartea_ var. _curtiseta_ did not change. The difference in the response to these two species to spring burning was probably related to a greater kill of apical shoots and vegetative growing points in _Festuca scabrella_ than in _Stipa spartea_ var. _curtiseta_. It appears that _Gramineae_, adapted to drier climatic conditions, are less detrimentally affected during the first growing season after burning.

In the _Festuca-Stipa_ community during the first year after burning, annual forage production, among the treatments of unburned (1180 kg/ha), fall burned (1145 kg/ha) and spring burned (1365 kg/ha), were not significantly different. There must have been a corresponding increase in herbage yield of species not affected or increased by burning to counteract the decrease in canopy coverage of some of the major species.

In the _Symphoricarpos_ community, the canopy coverage of _Symphoricarpos occidentalis_ was decreased slightly, but non-significantly by spring burning, but its stem density increased five fold. In the spring burn, there was an increase in the number and canopy coverage of palatable forbs and shrubs. A burned _Symphoricarpos_ community would be preferred by livestock to an unburned _Symphoricarpos_ community because of a greater abundance of preferred species and because of a removal of the barrier effect caused by dead stems of _Symphoricarpos occidentalis_.

Burning may be a useful range management tool in improving the distribution of livestock on range lands.

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INTRODUCTION

Fire has been an ecological factor important to the welfare and well being of man for many thousands of years. Stewart (1956) reports that fire has been useful to man since he became human. Odum (1971) reports that fire is and has been a major factor in most terrestrial environments of the world.

On the Canadian prairies, fire has been prevalent in our past. Nelson and England (1971) report that many early explorers referred to the common incidence of fire on the prairies. The prairie and parkland regions were settled during the latter 1800's and early 1900's. Some early settlers noted that fire could be useful to them. Nyland (1969) reports that fire was used in 1395 to clear brush in the Beaverhills region of Alberta. He reports that sometimes these fires escaped out of control and burned large tracts of land. However, in general, most settlers feared fire, because of the potential threat that fire would destroy them and everything they had. Therefore, they made more and better attempts to extinguish fires shortly after they started.

Since the early part of the 1900's fires have largely been controlled in the aspen parkland of Alberta. Some changes in vegetation have been obvious. Wroe (1971) reports that brush species, mostly Populus tremuloides[1], have increased in area 1700 per cent from 1907 to 1966 in the southern portion of the aspen parkland. Scheffler and Bailey (1972) report that brush species have increased in area 780 per cent from 1903 to 1963 in the more northerly portion of the aspen parkland. These large increases in area of Populus tremuloides in the parkland regions are probably largely a result of the control of fire.

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1 The nomenclature of vascular plants follows Moss (1959)

In the groves of Populus tremuloides, most of the production is in the form of leaf and woody growth. The leaves and succulent twigs are out of the reach of most wild and domestic animals and the woody growth is not readily eaten; therefore, most of the production is unavailable to wild and domestic animals. The production of understory species available to wild and domestic animals is reduced under the trees. Therefore, the carrying capacity of Populus-dominated ranges is reduced.

Fire is one of natures' methods of releasing nutrients biochemically tied up in plant materials. However, research on the effect of fire on vegetation in the aspen parkland and on the prairies is limited. The intent of the present study was to investigate the effect of controlled burning on a grassland (Festuca scabrella - Stipa spartea var. curtiseta) and a shrubland (Symphoricarpos occidentalis) community.

The objectives of this study were to determine:

1) the effect of fire upon species composition one and two years after burning.

2) the effect of burning in spring and fall upon species composition.

3) the effect of fire on reproduction of the dominant grasses.

4) the effect of fire on shrub densities.

5) the maximum temperatures that occur at various heights during burning.

DESCRIPTION OF THE AREA

A. Location

The study area was located on the University of Alberta Ranch at Kinsella, Alberta in Section 4, Township 47, Range 11, West of the 4th meridian. Kinsella is 95 miles southeast of Edmonton.

B. History of the Ranch

The University of Alberta Ranch was established in September, 1960 with the purchase of 5,600 acres of land using a grant from the Alberta Horned Cattle Trust fund. Further grants from the Alberta Horned Cattle Trust fund added another section and three quarters to the ranch holdings (Berg, 1971). The original purpose of the ranch was for genetical research on beef cattle. However, one section, recently added to the ranch, was set aside specifically for range research.

C. Climate

Alberta is located in the northern cool temperate zone and is characterized by short cool summers and cold winters (Longley, 1967). Longley (1967) suggests that height and width of the Rocky Mountains and the prevailing winds are probably the most important factors which determine the temperatures and precipitation. The prevailing winds in Alberta are from the southwest, west and northwest. A common phenomenon in Alberta is the "chinook wind" during the winter months which is caused by a mass of air from British Columbia being voided of its precipitation as it passes over the Rocky Mountains. This dry air is warmed as it rushes down the easterly slopes of the Rocky Mountains onto the plains causing rapid increases in temperature (Longley, 1967).

Carder (1970) reports using the Köppen - Trewartha classification of climate, that parkland areas are included in three climatic regions, the "middle latitude dry" climatic type characterized by high

evaporation compared to precipitation, the "humid continental cool summer" climatic type characterized by cool summer temperatures (warmest month below 72°F) and fairly moist (driest month of summer over 1.2 inches) and the "subarctic microthermal" zone characterized by less than four months having temperatures above 50°F. The Kinsella area borders between the "middle latitude dry" and the "humid continental cool summer" climatic types.

The Kinsella area lies within the precipitation zone of 14 to 16 inches (Wonders, 1969; Longley, 1967). The mean annual precipitation recorded at Kinsella from 1962 to 1971 was 14.32 inches (Appendix 1). Wonders (1969) reports that the greatest precipitation is received from July 1 to 15. The frost free period varies from 100 to 120 days (Longley, 1967). The mean annual temperature is about 65°F. The prevailing wind direction for the area in April and October is from the south.

D. Geology

The Kinsella area is generally located on the Upper Cretaceous Strata (Wonders; 1969). Stelck (1967) lists the main components of this strata as sandstone, shale and coal. Allan (1944) has described the area as being of the Pale Beds formation. This formation consists of interbedded sandstones, shales, carbonaceous shales and several coal seams. Bentonite was described as being present in the sandstone of the upper part of the formation. Most of this formation is covered by glacial drift. Allan (1944) describes the surficial deposits of the area as being part of the Viking moraine. This was part of the glacial deposits which were transported by the Keewatin ice-sheets during the Wisconsin glaciation. The ice in the Wisconsin glaciation began to ablate

approximately 12,000 years ago. The Viking moraine marks the limits of advance of the great ice sheets from the northeast. In the area there are many depressions called kettle holes. These inverted conical depressions were formed during the retreat of the ice and they now contain small lakes or sloughs. Sodium sulphate frequently occurs as a white deposit around the shores of many of the lakes. Allan estimates that about three quarters of the Wainwright and Vermilion sheets have morainal or resorted material in the surface deposits.

E. Soils

The Kinsella area is generally located in the Black soil zone of Alberta (Wonders, 1969). Wyatt et al (1944) reports the soil in the area as unsorted glacial loam with an average of three to four inches of black topsoil. The approximate composition of the soil is 53 per cent sand, 41 per cent silt and six per cent clay. One-half of the sand fraction is reported as being coarse sand. These soils are variable in profile depth depending upon the topographic position. They are fairly heavy and shallow on the knolls but relatively deep and friable in the valley bottoms. Wyatt et al (1944) report that the depth to the lime horizons ranges from 15 to 24 inches. However, personal observation indicates that the depth to the lime horizon in the Kinsella area is less than 15 inches on the tops of the hills and greater than 24 inches in positions lower on the slopes. The stoniness of the area varies considerably. The topography of the study area is rolling to hilly.

F. Fauna of the Area

Bird (1961) reports that when white man first came to the prairies the dominant animals were buffalo (Bison bison L.) and elk

(*Cervus canadensis* Erxl.). Johnston and MacDonald (1967) suggest that buffalo utilized the mixed prairie during the summer and then, during the fall and winter months, they moved into the fescue grasslands of the Rocky Mountain foothills and aspen parklands. It is likely that many buffalo remained year round in the Kinsella area.

Beaver (*Castor canadensis canadensis* Kuhl.) were abundant in years past. Evidences of past beaver activity were noted in the study area.

Several animal species were observed in the study area. The most prevalent animal was the hare. Bird (1961) reports that the prairie hare (*Lepus townsendii campanius* Hollister) was the most common hare in the grassland and the varying hare or snowshoe rabbit (*Lepus americanus americanus* Erxleben) was the most prevalent hare in the forest. Numerous white-tailed deer (*Odocoileus virginianus dacotensis* Goldman & Kellogg) were observed and mule deer (*Odocoileus hemionus* Rafinesque) were reported to be present in the area. The porcupine (*Erethizon dorsatum epixanthus* Brandt) was observed in the area. The Richardson's ground squirrel (*Citellus richardsonii richardsonii* Sabine) was noted because of its large colonies. The thirteen-striped ground squirrel (*Citellus tridecemineatus tridecemineatus* Mitchell) was noted to be present as well. Evidences of the pocket gopher (*Thomomys talpoides talpoides* Richardson) were present in the study area. The chipmunk (*Eutamias minimus borealis* Allen) was noted in the forest. The skunk (*Mephitis mephitis hudsonica* Richardson) was noted to be present.

The prairie coyote (*Canis tatrans tatrans* Say) was noted frequently. The red fox (*Vulpes fulva regalis* Merriam) was noted to be present. The white footed mouse (*Peromycus maniculatus* Mearns) was

noted to be present also.

The ruffed grouse (*Bonasa umbellus* L.) was observed to be most abundant in the recently burned aspen forests. The Ring-necked pheasant (*Phasianus colchicus* Linnaeus) was observed in the area.

G. Vegetation

The physiognomy of the area is generally described as aspen parkland. Moss (1955) describes the parkland as a "mosaic of prairie patches and aspen groves, with prairie occupying the drier situations and aspen the more moist and sheltered places". Coupland and Brayshaw (1953) consider the parkland to consist of an intermingling of grassland and forest communities with an ecotone occurring around each grove. The forest communities present in the study area were small poplar, large poplar, and poplar-willow (Hilton, 1970). In the grasslands, there were *Stipa spartea* var. *curtiseta* and *Festuca scabrella* - *Stipa spartea* var. *curtiseta* communities. The common shrub community was dominated by *Symphoricarpos occidentalis*. A *Carex*-slough community occurred in the lowland depressions and was usually surrounded by forest.

The *Stipa* community occupies the area from the tops of the hills to the intermediate slope position on the south-facing slopes. This community is dominated by *Stipa spartea* var. *curtiseta* with *Agropyron subsecundum*, *Bouteloua gracilis* and *Koeleria cristata* being the main grasses present. The dominant forbs are *Artemisia frigida* and *Anemone pattens* var. *wolfgangiana*.

The *Festuca*-*Stipa* community occupies the area from the intermediate slope position to the groves of *Populus tremuloides* on the south slopes and the entire north slope to the groves of *Populus tremuloides*. The dominant grasses are *Festuca scabrella* and *Stipa*

spartea var. curtiseta. Other grasses and grasslikes present are Carex obtusata, Agropyron subsecundum, Agropyron trachycaulum and Helictotrychon hookeri. The dominant forbs present are Geum triflorum, Artemisia ludoviciana var. gnaphloides, Artemisia frigida and Anemone pattens var. wolfgangii. The dominant shrub is Rosa arkansana.

The Symphoricarpos occidentalis community occupies shallow depressions on the grassland and in many instances it occupies positions of higher elevations adjacent to the small poplar community. This community is dominated by Symphoricarpos occidentalis. A large quantity of dead stems of Symphoricarpos is an important component of the community.

The small poplar community occupies the higher elevation and shallow soils within the Populus tremuloides grove. This is the region of recent encroachment of Populus tremuloides on to the grassland. The small poplar community is dominated by Populus tremuloides with an understory of Symphoricarpos occidentalis, Rosa woodsii, Rosa acicularis and Rubus strigosus (Hilton, 1970).

The large poplar community occupies the intermediate elevation of the Populus tremuloides grove. The dominant species is Populus tremuloides. The oldest trees are found in this community. The average age of Populus tremuloides in this community was about 30 years (Scheffler and Bailey, 1972). The canopy coverage of shrubby species is less than in the small poplar community. The herb layer is characterized by shade tolerant species such as Viola adunca and Pyrola secunda.

The poplar-willow community occupies the lower elevation of the Populus tremuloides grove. This is the region of recent encroachment

of *Populus tremuloides* into the *Salix*-and *Carex*-dominated meadows. This community is dominated by *Populus tremuloides* and *Salix* spp. The *Salix* spp. are slowly dying out. The understory is dominated by *Carex* spp., *Polygonum* spp. and *Mentha* spp.

The *Carex*-slough community occupies the lowland regions. This is a highly variable community in species composition and annual herbage production because of variable moisture conditions. Wroe (1971) reports that this community had a high production one year and very little or no production the next year. This community is dominated by *Carex* spp.and other water tolerant species such as *Glyceria grandis* and *Sium suave*.

REVIEW OF THE LITERATURE

A. *Festuca scabrella* - *Stipa spartea* var. *curtiseta* community

Moss (1955) describes the *Festuca scabrella* association as the "characteristic prairie of the black soil zone and aspen grove belt" which extend from southwestern and central Alberta eastward into Saskatchewan. The *Festuca scabrella* association is also the grassland of the parkland area in the Cypress Hills. Coupland and Brayshaw (1953) report that *Festuca scabrella* and *Stipa spartea* var. *curtiseta* are co-dominants in the northern part of the dark brown soil zone. Moss (1955) reports than Macoun, a naturalist with the Geological Survey of Canada during the latter part of the 1800's and usually a keen observer, failed to mention the presence of *Festuca scabrella* but did note the presence of *Stipa spartea*. Moss (1955) and Wyatt et al (1944) list *Stipa* spp. among the less abundant species present in the area. It would appear that Macoun, the early naturalist, either overlooked *Festuca scabrella*

or more likely, that Stipa spartea var. curtiseta was the dominant and Festuca scabrella was a minor subordinate.

Festuca scabrella has two major growth forms. Moss (1959) reported that Festuca scabrella is usually "densely tufted often as tussocks these enlarging by short rhizomes" but Johnston and Cosby (1966) report that a rhizomatous form of Festuca scabrella also exists. The study area is within the area of best development of the rhizomatous form of Festuca scabrella.

B. Symphoricarpos occidentalis community

Coupland and Brayshaw (1953) in central Saskatchewan, describe Symphoricarpos occidentalis as being occasionally scattered throughout the grassland. Moss and Campbell (1947) in southwestern Alberta, report colonies of Symphoricarpos occidentalis occurred in localized areas throughout the prairies. Pelton (1953), in a general review of Symphoricarpos occidentalis, reports that brush communities may occur locally in favorable spots in grassland. He also suggests that Symphoricarpos occidentalis is one of the few woody plants which can invade grassland in such quantities as to shade out the grasses and permit invasion by trees; hence, its common occurrence in the transition zones between forest and grassland. Wroe (1971), in the Stettler, Alberta area, reported that Symphoricarpos occidentalis contributed 44.9 per cent to the total annual production and only 42 per cent to the total canopy coverage in Symphoricarpos occidentalis communities. He also found that the mean age of Symphoricarpos occidentalis was six years with 96 per cent of the stems falling into the range of two to nine years. However, when the stands were arbitarily classified as to dense, moderate and sparse, he found the mean age to be 7.2, 6.3

and 3.3 years, respectively.

C. Effect of Fire on Rangeland Vegetation

Odum (1971) reports that research during the last 40 years has made us reorient our ideas concerning fire. Fire has been and still is a major ecological factor present in most terrestrial parts of the world (Odum, 1971). Odum (1971) states that "Failure to recognize that ecosystems may be 'fire adapted' has resulted in a great deal of 'mis-management' of man's natural resources". Phillips (1962) reports that wherever there is an accumulation of inflammable material there is bound to be a fire. Fires have been found to have occurred regularly in several vegetation types of the world and the control of fire has resulted in many successional changes.

1. Grasslands in Alberta

Nelson and England (1971) report that fire was a natural occurrence on grasslands of the Canadian prairies. Moss (1944), in southwestern Alberta, credits fire as being a minor factor in counter-acting the encroachment of <u>Populus tremuloides</u> on to the grasslands. Moss (1932) credits fire as being a major factor in preventing the en-croachment of Populus tremuloides in central Alberta.

Anderson and Bailey (1972), in central Alberta, found that spring burning resulted in a decrease in the density of flowering stalks and canopy coverage of <u>Festuca scabrella</u>; however, fall burning resulted in a decrease in canopy coverage and flowering stalk density of <u>Stipa spartea</u> var. <u>curtiseta</u>. They report that there was no difference in herbage yield among the treatments of unburned control, fall burning and spring burning. Moss and Campbell (1947), in southwestern Alberta, reported that <u>Festuca scabrella</u> tussocks were reduced in size when the

litter was removed by grazing, mowing and burning.

Clark et al (1943) report fire as being very detrimental to herbage yield in the Stipa-Bouteloua association. They report that spring burning reduced herbage yield by 50 per cent during the first growing season and 15 per cent during the second growing season. There was no difference in production between burned and unburned areas after the second year. They report that herbage yield was reduced 30 per cent during the first growing season following fall burning after which time there was no difference in production. However, Clarke et al (1943) do not report the herbage weights or do they show how they derived these values.

2. Other grassland areas

Regular burning was found to be an essential factor in maintaining the grasslands under pine forests in the southeastern United States. Stoddard (1962) reports that prior to 1900, annual burning of longleaf pine (Pinus palustris) was a common practise. About this time the United States Forest Service decided that fire was detrimental to the production of forest and consequently, launched an extensive campaign about the adverse effects of fire. Stoddard (1962) reports that the United States Forest Service continued to persist in their efforts even when presented with research evidence to the contrary. He reports that annual burning of the longleaf pine vegetation is essential for a continued and a sustained production of pine; a side benefit is more forage in the understory. Hilmon and Hughes (1965a) report that burning the wiregrass (Aristida stricta and Sporobolus curtisii), which grow under pine, improves the quality and productivity of the forage, aids in distributing cattle, stimulates seed production and checks the growth of undesirable shrubs.

Hilmon and Hughes (1965b) report that annual burning of pine-wiregrass ranges since 1940, has resulted in negligible damage to the pine. They reported that wiregrass maintained dominance in the understory for only eight years when protected from burning. The flush of herbs peaked three years following the last fire and the total herbaceous coverage declined thereafter. Lewis and Hart (1972) report that exclusion of fire from pine-wiregrass range from six to eight years reduced annual herbage production by one-half. They found that fire, reintroduced into this range type, increased yields; however, yields continued to decline if the litter was removed by clipping. Hilmon and Hughes (1965b) report that after ten years of annual burning on the pine-bluestem vegetation type (dominated by *Andropogan scoparius* and *A. tener*) annual forage production was twice as great as on the unburned plots. They report that there was a marked decline in total plant cover in the protected area and that cattle preferred forage on burned areas. The preference shown by cattle for forage on burned areas may have been related to increased protein, phosphorous and calcium contents. However, Duvall and Linnartz (1967) report that in a similar vegetation type grazing intensity had a greater effect on herbage yield than did one or two burns over a 12 year period. The key to high herbage yields, in the pine-wiregrass is apparently to prevent large accumulations of herbaceous litter (Duvall, 1962; Grelen and Epps, 1967.)

Anderson (1964) reports that burning at different times of the year reduced yields on the bluestem ranges (*Andropogan gerardi*) of the Flint Hills of Kansas. He found that early spring burning reduced yields more than did burning later in the spring after growth had commenced. McMurphy and Anderson (1962) report that late spring burning was less detrimental than burning in the fall, early or mid-spring. Owensby

and Anderson (1967) found that yields were reduced with early and mid-spring burning but late-spring burning caused no reduction. Anderson (1965) reports that there was a greater reduction in soil moisture in winter, early and mid-spring burns than with late spring burns. He found that the earliest burns caused the greatest reduction. Anderson et al (1970) report that herbage yield was reduced by early and mid-spring burnings but the yield in the late spring burning was the same as the unburned. However, weight gains of steers were greater under mid and late-spring burnings. They found that cool-season species were reduced after burning and that warm-season species were favored.

Old (1969) found in the tall grass prairie of Illinois that burning caused a two to three fold increase in herbage yield and a ten fold increase in flowering. She reports that clipping and removing the litter resulted in a greater increase in yield but the seed head production was only one-half of the spring burned treatment. She also found that just one year's litter would decrease both flowering and herbage yield. Hadley and Kieckhefer (1963), on the same prairie site, found that spring burned areas during the first growing season showed an increase in living shoot and flowering stalk production and a more rapid rate of phenological development when compared to unburned control areas. They report that a one year period of non-burning resulted in marked decreases in living shoot and flowering stalk production. They found that the root biomass increased as a result of burning frequency; however, Old (1969) found that there was no difference. Old (1969) reports a root turnover rate (ratio of annual root growth to the total root biomass) of 0.45. Kucera et al (1967) report a root turnover rate of 0.25 in the tall grass prairie of Missouri. They also report

that yield was doubled in burned areas during years with favorable rainfall but during drought years the herbage yield was almost the same as on unburned areas. They suggest that the stimulus of fire to dry matter production in the humid prairie indicate a more efficient use of solar energy. Kucera and Koelling (1964) found a sharp decline in the number of broadleaved species and a uniform cover of prairie grass after five years of annual burning in Missouri.

In the prairie association in Iowa, Ehrenreich (1959) found that vegetation on burned areas began growing and matured earlier and produced more flower stalks than on unburned areas. He found a slight, but non-significant, increase in herbage yield on the burned areas. Ehrenreich and Aikman (1963) report that plants on the unburned area grew faster during the latter part of the season; consequently, there was no difference in herbage yield between burned and unburned areas. They report that the greater abundance of flower stalks in the burned area continued until the third growing season after the burn. They suggest that the chief factor limiting plant growth was the amount of litter. The amount of litter covering the soil surface, in turn, influenced the soil temperature which influenced plant growth. To support this statement, they found that air and soil temperatures were greater during the early part of the growing season in the burned area; however, during the latter part of the growing season they found no difference in soil temperature between burned and unburned areas. They also report an increase in available phosphorus in the burned areas which they suggest accounts, in part, for the earlier plant maturity on burned areas.

Vogl (1965), on a humid brush-prairie savanna in northwestern Wisconsin, found that herbage production the first season after burning

was 2110 lb/acre compared to 772 lb/acre in the unburned areas. He also reports that the high production of grasses and forbs was evident the second year.

Wright and Klemmedson (1965), in the sagebrush-grass region of southern Idaho, found that Stipa comata and S. thurberiana suffered more from fire than did Sitanion hystrix. No flower stalks were produced during the first year by Stipa comata while some were produced by Stipa thurberiana. There was no difference found in flower stalk production of Sitanion hystrix on burned versus unburned areas. They report that Stipa species were reduced more by burning in June and July than by burning in August. Wright (1971) suggests that a low density of plant material, such as that found for Sitanion hystrix, burns quickly, thereby keeping heat penetration to the growing points at a minimum. On the other hand, a high density of plant material such as that found for Stipa comata, burns at a higher temperature and for a longer period of time, thereby, killing more growing points.

In the High Plains of Texas of North America, Wright (1969) found that more herbage was produced on burned plots than on unburned plots; however, there was almost as great an increase from clipping as there was from burning. In the semidesert grass-shrub type, Cable (1967) found an 85 per cent decrease in the shrub burroweed (Happlopappus tenuisectus) with fire; however, the other shrubs present were harmed very little by the fire. He found no difference in annual herbage yield between burned and unburned areas. Pond and Cable (1960) report that shrub live oak (Quercus turbinella) was difficult to control and annual burning over five successive years was required to reduce the density of oak stems to the level found prior to burning. Annual burning over five successive years also reduced the density of some desirable species.

In western North Dakota, Dix (1960) found that spring burning reduced herbage production in both Stipa comata and Agropyron smithii communities. He reports that herbage production was not retarded beyond the second growing season.

Conrad and Poulton (1966) report that Festuca idahoensis was more critically affected than was Agropyron spicatum by a July fire in northeastern Oregon. In the steppe vegetation of the Voroshilovagrad region of Russia, Osychnyuk and Istomina (1970) report that Stipa lessingiana Trin. et Rupr. increased in abundance and Festuca sulcata (Hack) Nym. decreased.

In northern Australia, Norman (1963) reports that after five years, in pastures burned annually and biennially in January and September, the total dry matter yield was only 77 per cent of the unburned area. He adds that the floristic composition in the burned areas contained a higher proportion of other species which were mainly annual grasses and forbs. Norman (1969) found that, during the next five years of annual and biennial burning in January and September, that the herbage production, during the wet season was greater on the burned areas. Norman (1969) attributes the differences to a decrease in production in the unburned area following ten years of protection from fire. Unfortunately, his methods of measuring differences in production between burned and unburned areas do not lead the reader to the same conclusions. Differences in herbage production between burned and unburned areas were not adequately determined because total standing crop (current growth plus litter) was measured during the first five years. During the next five years, annual production was determined by clipping plots before the wet season and by clipping the same plots at the end of the wet season.

In Africa, West (1965) reports that flowering was induced on several grass species when areas were burned during the dormant season; whereas, no flower stalks were produced in unburned areas or areas burned at times other than during the dormant season.

3. Brush control

Prescribed burning is probably the oldest method of brush control (Subcom. Weed Contr., 1968). The results of burning vary greatly and depend on the susceptibility of a species to fire, the amount of fuel accumulation from all species present, time of year and moisture relationships (Subcom. Weed Contr., 1968). McLean (1969) reports that the fire resistance of a species is related to its type of root system. Species with deep rooting systems are usually more fire resistant than are those with shallow rooting systems. Mutch (1970) hypothesizes that some ecosystems, which have developed under fire, are actually more conducive to fire during certain periods of their life cycle. Hence, this allows the self-perpetuation of some species through periodic burning.

In southern Texas, Stinson and Wright (1969) found that fire temperatures of $1000^{o}F$ at ground level were effective in killing mesquite (Prosopis glandulosa var. glandulosa). Valentine (1971) reports that fire has been effective in controlling nonsprouting juniper. Dwyer and Pieper (1967) found that 24 per cent of juniper and 14 per cent of pinyon pine were killed by fire in New Mexico. In California, chaparral has been burned for improvement of game ranges (Vallentine, 1971).

In Scotland, Kayll (1967) reports that heather (Calluna vulgaris) has been burned regularly for over 300 years. He reports that regular burning maintains heather in its most productive form for sheep and for red grouse, a valuable game bird. In Australia

fire has been effective in controlling *Eucalyptus obliqua*, in Eucalypt Forests (Hodgson, 1968; Mount, 1969). In Kenya, Thomas and Pratt (1967) found that *Acacia brewispica* was partially tolerant of fire. Thus, fire has been used with varying success in the control of shrub species throughout the world.

D. Fire temperatures

Stinson and Wright (1969), in the southern mixed prairies in Texas, report that temperatures ranged from 182°F. to 1260°F. in fuels that varied from 1546 to 7025 lb/acre.

Iwanami and Iizumi (1969) report that a maximum temperature of 500°C. was reached in the *Zosia* type grassland of Japan. The fuel weights were about 4,000 kg/ha. Ito and Iizumi (1960) studied the temperatures at various heights and depths in the *Miscanthus* type grassland. The heights used were 2, 5, 15, 20 and 30 cm above the surface and the depths were 1, 2 and 5 cm. A maximum temperature of 300°C. occurred at a height of 5 cm. At the soil surface the temperature varied from 55 to 230°C. Iwanami (1969) studied temperatures and the duration of the temperature in *Miscanthus* type grassland. The heights studied were 0, 2, 5, 8, 11, 14, 17, 20, 25, 30, 50, 100 and 200 cm. and depths studied were 1, 2, 3 and 4 cm. He found that the maximum temperatures were recorded at the height of 11 - 17 cm.

METHODS

A. Burning

1. Spring, 1970 burn

A lightly grazed area was selected in the spring of 1970 on the University of Alberta ranch. On May 8, 1970 one-half of the area was burned and the other half was left as a control. The burned treatment was burned by igniting and burning a small section of the treatment area at a time. Approximately five acres were burned.

Following the fire, five 20cm x 50cm plots were randomly located in the control area in each of the Festuca-Stipa (Festuca scabrella - Stipa spartea var. curtiseta) and the Symphoricarpos (Symphoricarpos occidentalis) communities. All burnable material above ground level was collected in each plot. The quantity of fuel and its moisture content were determined under oven dry conditions from these measurements. The study area was fenced soon after the fire to exclude cattle.

2. Fall, 1970 burn

Another area in the same field and near the 1970 spring burn was selected for fall burning. The field had been lightly grazed during 1970. The area was divided into four 75m x 15m transects. One-half of each transect was then randomly selected for burning. Each strip included both the Festuca-Stipa and the Symphoricarpos community. Prior to igniting the fire the total quantity of material above ground level (fuel) was measured by locating ten 20 x 50m plots per transect. Each plot was randomly located within each 7.5 segment of the one-half of the transect that was to be burned.

The fire was started at approximately 2 p.m. on October 3, 1970.

The wind speed was light. Unfortunately, the fire escaped out of control due to inadequate control procedures and a lack of manpower. The fire burned as a natural headfire until it was brought under control about two hours later when additional help arrived. Approximately 25 acres were burned.

3. Spring, 1971 burn

An area adjacent to the fall, 1970 burn was selected to be burned in 1971. This area was selected because an old cultivated fire guard bordered the southern portion of the area and the fall, 1970 burned treatment area bordered the north. Additional fire guards were completed around the remaining parts of the study area.

Prior to burning, fifteen 20cm x 50cm microplots were randomly located in a macroplot. Four macroplots had been randomly located in each of the _Festuca-Stipa_ and the _Symphoricarpos_ communities. The total dry fuel above ground level was measured. Five microplots from each macroplot were clipped just prior to igniting the fire and stored in plastic bags. The samples were weighed, oven dried and weighed again to determine the quantity and moisture content of the fuel.

The fire was ignited at about 12 Noon. The leeward side of the area was ignited first. The fire was allowed to continue to burn as a backfire, ie. against the wind, until the small spot fires that had jumped the fire line were controlled. The windward side of the area was then ignited and the headfire (a fire burning with the wind) burned the remaining half of the treatment area. Approximately 45 acres were burned.

B. Temperature Measurements in the Spring, 1971 Burn

Prior to the 1971 spring burn, four macroplots in each of the _Festuca-Stipa_ community and the _Symphoricarpos_ community were selected.

Fifteen metal posts were randomly located in an area of approximately 15 square meters. Asbestos cards containing a number of pellets which melt at certain specific temperatures were attached at the heights of 0, 5, 15, 30 and 45cm in the Festuca-Stipa community and at 0, 8, 20 45 and 75cm in the Symphoricarpos community. A description of the asbestos cards and temperature pellets is given in Appendix 2. The cards were attached to the south side of each post because it was anticipated that the wind would be blowing from a southerly direction during burning. It was anticipated that all macroplots would be burned as headfires; however, some macroplots were burned by the backfire before the headfire reached these macroplots.

Following the fire, the cards were removed from the metal posts and the temperatures were determined in the laboratory. The highest temperature indicating pellet that appeared to be melted as revealed under a 20 X binocular microscope was used as the maximum temperature for that specific location.

C. Vegetation Measurements in the Spring 1970 Burn

Permanent plots were set out in both the burned and unburned treatment areas. A distance of 2m to 3m was left unsampled on each side of the fire line in each community to remove the edge effect. The burned and unburned areas were marked off into 2m strips. A transect was randomly located within each strip. Along each transect, a 20 x 50cm plot was randomly located and permanently marked in each 2m segment. Canopy coverage of all plant species, density of seed heads of Festuca scabrella and Stipa spartea var. curtiseta, and density of the shrub species were measured on these plots. Canopy coverage was estimated following the method of Daubenmire (1959;1968b) using the

canopy coverage classes in Table 1.

The canopy coverage values were transformed from a binomial to a normal distribution using the inverse sine. The differences between the growing seasons in 1970 (year 1) and 1971 (year 2) in each treatment were compared using a paired plot Student's t-test.

D. Vegetation Measurements in the Fall, 1970 and Spring, 1971 Burns in *Festuca-Stipa* Community

In the *Festuca-Stipa* community five 5m x 7m macroplots were randomly selected from a number of possible macroplots in each of the unburned control, the fall, 1970 burned and the spring, 1971 burned treatments. The unburned control macroplots were randomly selected from unburned *Festuca-Stipa* communities immediately surrounding the burned treatment areas. Each macroplot was divided into meter square microplots. A 20cm x 50cm plot was randomly located in each microplot. Canopy coverage estimates for all plant species, following the method of Daubenmire (1959;1968b) using the canopy coverage classes in Table 1, density of the seed heads of *Festuca scabrella* and *Stipa spartea* var. *curtiseta*, and density of the shrub species were measured.

At the end of the growing season total annual herbage production was measured by randomly locating in each macroplot three 0.86 square meter microplots. The herbage was clipped to ground level, oven dried, and weighed.

The depth of the Ah soil horizon was measured at each of the four corners and at the center of each macroplot in the unburned control, fall 1970 burn, and spring 1971 burn.

The canopy coverage values were transformed from a binomial to a normal distribution using the inverse sine. A one-way

Table 1 Canopy coverage classes used in the study

Class Number	Canopy Cover Range	Mid-Point
1	0 - 1	0.5
2	2 - 5	3.0
3	6 - 25	15.0
4	26 - 50	37.5
5	51 - 75	62.5
6	76 - 95	85.0
7	96 - 100	97.5

analysis of variance with subsamples was used to analyze the data. Duncan's new multiple range test was used to compare the means.

E. Vegetation Measurements in the Comparison of the Spring, 1971 Burn and the Unburned Control in the Symphoricarpos Community

Five 5m x 5m macroplots were randomly selected from a number of possible macroplots in each of the unburned control and spring, 1971 burned treatments. An inadequate number of macroplots were found in the fall, 1970 burned treatment; therefore, it was not included in the comparison. Each macroplot was subdivided into meter square microplots. A 20 x 50 cm plot was randomly located within each square meter. Canopy coverage estimates, following the method of Daubenmire (1959;1968b) using the canopy coverage classes in Table 1, and density of the shrub species were measured. The canopy coverage values were transformed from a binomial to a normal distribution using the inverse sine. The data were analyzed using an unpaired Student's t-test.

F. Weather Data

Temperature and precipitation readings for Kinsella were taken from the Canada Department of Environment meteorological station located on the University of Alberta ranch at Kinsella approximately one mile from the study areas. Wind measurements were obtained from the Department of Animal Science, University of Alberta, which maintained a wind meter adjacent to the meteorological station. The nearest meteorological station recording hourly relative humidity measurements was the Canada Department of Environment meteorological station at the

Edmonton Industrial Airport, 95 miles northwest of the study area. Measurements of relative humidity were taken prior to the spring 1971 fire at the study area using a sling psychrometer.

RESULTS

A. Weather conditions

The precipitation recorded at Kinsella was very light for the 30 day period prior to each fire (Table 2). The quantity of precipitation ranged from 0.10 inches in the spring, 1971 burn to 0.69 inches in the fall, 1970 burn. Moderate weather conditions prevailed during the period seven days prior to each fire. Mean maximum temperatures ranged from 64°F for the spring, 1971 burn to 72°F for the fall, 1970 burn. The wind speed was light during this period and ranged from 10 to 12 miles per hour. The mean relative humidity during this seven day period at the Edmonton Industrial Airport was 10 per cent lower in 1971 compared to the other two burning periods.

On the day of the burn, the maximum temperature was highest for the spring, 1971 burn and lowest for the spring, 1970 burn. The mean wind speed, however, was highest (14 miles per hour) the day of the spring, 1970 burn, which contrasts sharply with a mean wind speed of 8 - 9 miles per hour on the day of the other burns. During the burns, the relative humidity ranged from 19 to 25 per cent. The high winds from the south helped to make up for the low temperatures during the spring, 1970 burn. In the spring, 1970 and spring, 1971 burns, gusts of wind were recorded in excess of the means. No measurements of relative humidity were taken at Kinsella at the start of the spring, 1970 and fall, 1970 burns; however at Edmonton, the relative humidities

Table 2. A comparison of weather conditions at Kinsella and the Edmonton Industrial Airport prior to and during the three fires.

		Spring 1970 Burn	Fall 1970 Burn	Spring 1971 Burn
Total precipitation during previous 30 days (inches)		0.15	0.69	0.10
Weather conditions during previous 7 days				
Mean maximum temperature (°F)	Kinsella	66	72	64
	Edmonton	64	74	65
Mean minimum temperature (°F)	Kinsella	37	43	41
	Edmonton	40	45	43
Mean daily temperature (°F)	Kinsella	51	58	52
	Edmonton	52	60	54
Mean wind speed (mph)	Kinsella	12	10	12
	Edmonton	11	9	11
Mean relative humidity (%)	Edmonton	44	44	34
Weather on day of burn				
Maximum temperature (°F)	Kinsella	67	76	78
	Edmonton	69	78	81
Minimum temperature (°F)	Kinsella	42	40	41
	Edmonton	48	42	46
Mean daily temperature (°F)	Kinsella	54	58	60
	Edmonton	59	60	64
Mean wind speed (mph)	Kinsella	14	8	8
	Edmonton	16	8	11
Relative humidity	Edmonton	42	47	29
Weather during burn				
Wind speed (mph)	Kinsella	21	9	8
	Edmonton	21	9	9
Maximum gust and hour	Edmonton	33(1 p.m.)	9[2]	25(1 p.m.)
Relative humidity (%)				
At start of fire	Kinsella	nd[1]	nd	22
	Edmonton	31	27	18
During the fire	Edmonton	25	25	19

[1] no data

[2] A steady wind was recorded during the fire

recorded were 31 and 27 per cent, respectively.

Weather measurements recorded at the Edmonton Industrial Airport appear to be similar to those recorded at Kinsella (Table 2). Relative humidities recorded at both stations compare favorably from 8 to 12 A.M. (Figure 1). Wind measurements recorded at Edmonton were more variable than those at Kinsella. The methods used for measuring hourly wind speed were different. At Kinsella the hourly wind speed measured was the average wind speed during the entire hour. At Edmonton the hourly wind speed reported was taken at the time of regular hourly weather observation and was measured by observing the constant wind speed for one minute.

B. Fire temperature

1. *Festuca scabrella* - *Stipa spartea* var. *curtiseta* community

The maximum temperature of the headfire occurred at a height of 15 cm while the maximum temperature of the backfire occurred at a height of 5 cm (Table 3). The maximum temperature in the backfire tended to peak at a height closer to the ground than in the headfire (Figure 2). The maximum temperatures in the headfire were hotter than those in the backfire at all heights.

The mean maximum temperature for all heights was lowest in the backfire, macroplot three, and the highest in the headfire of macroplot two. The maximum measurable temperature of 650°F was exceeded 1, 2, 3, 1, times at the heights of 0, 5, 15, 30 and 45 cm, respectively, in macroplot two.

The quantity of fuel in the headfire was not different from that in the backfire. The greatest fuel weight (4490 kg/ha) was for macroplot three and the lowest (2830 kg/ha) was for macroplot one.

Figure 1. A comparison of hourly relative humidity (%) and wind (mph) measured at Kinsella and Edmonton Industrial Airport on May 11, 1971.

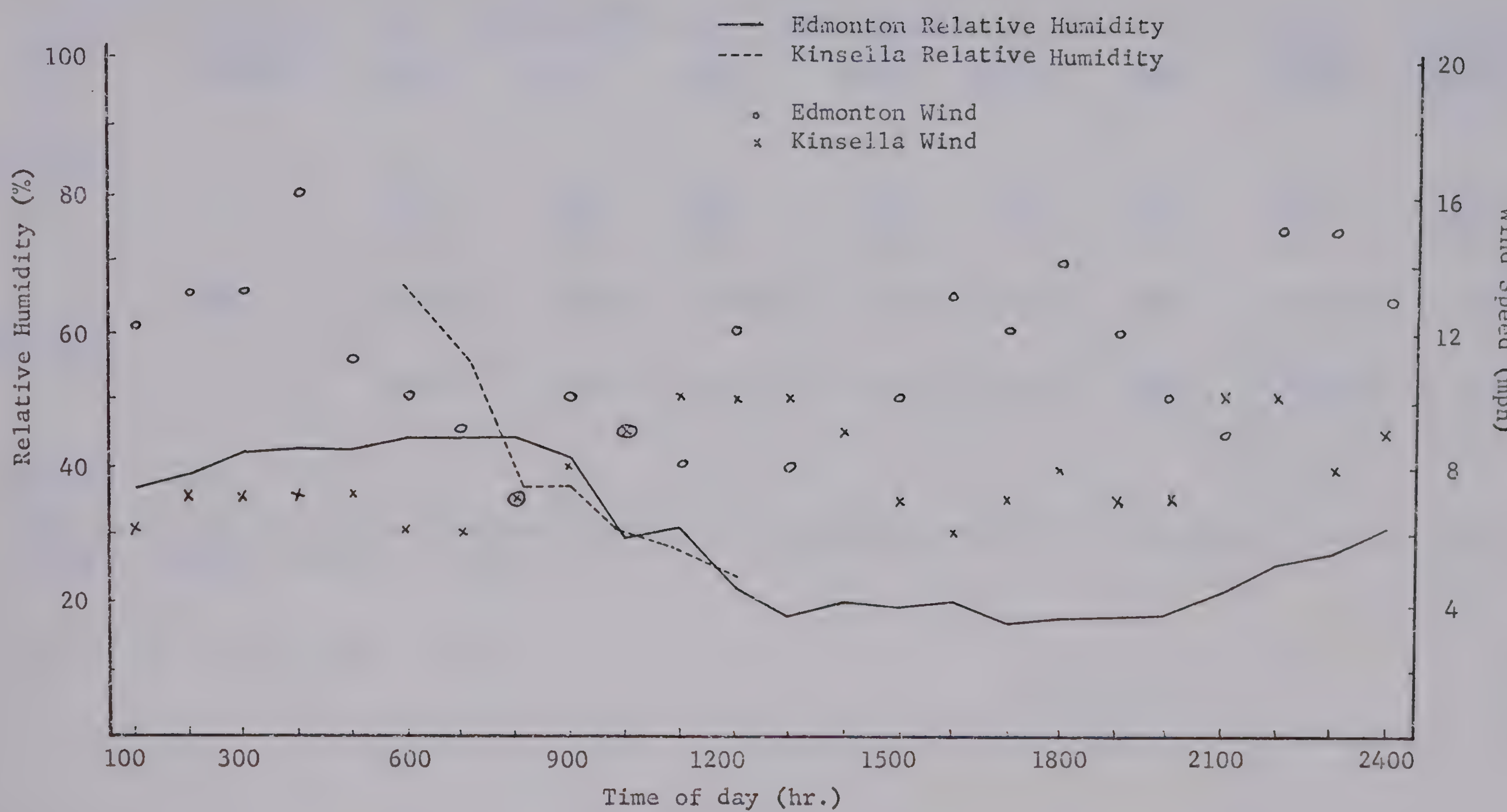


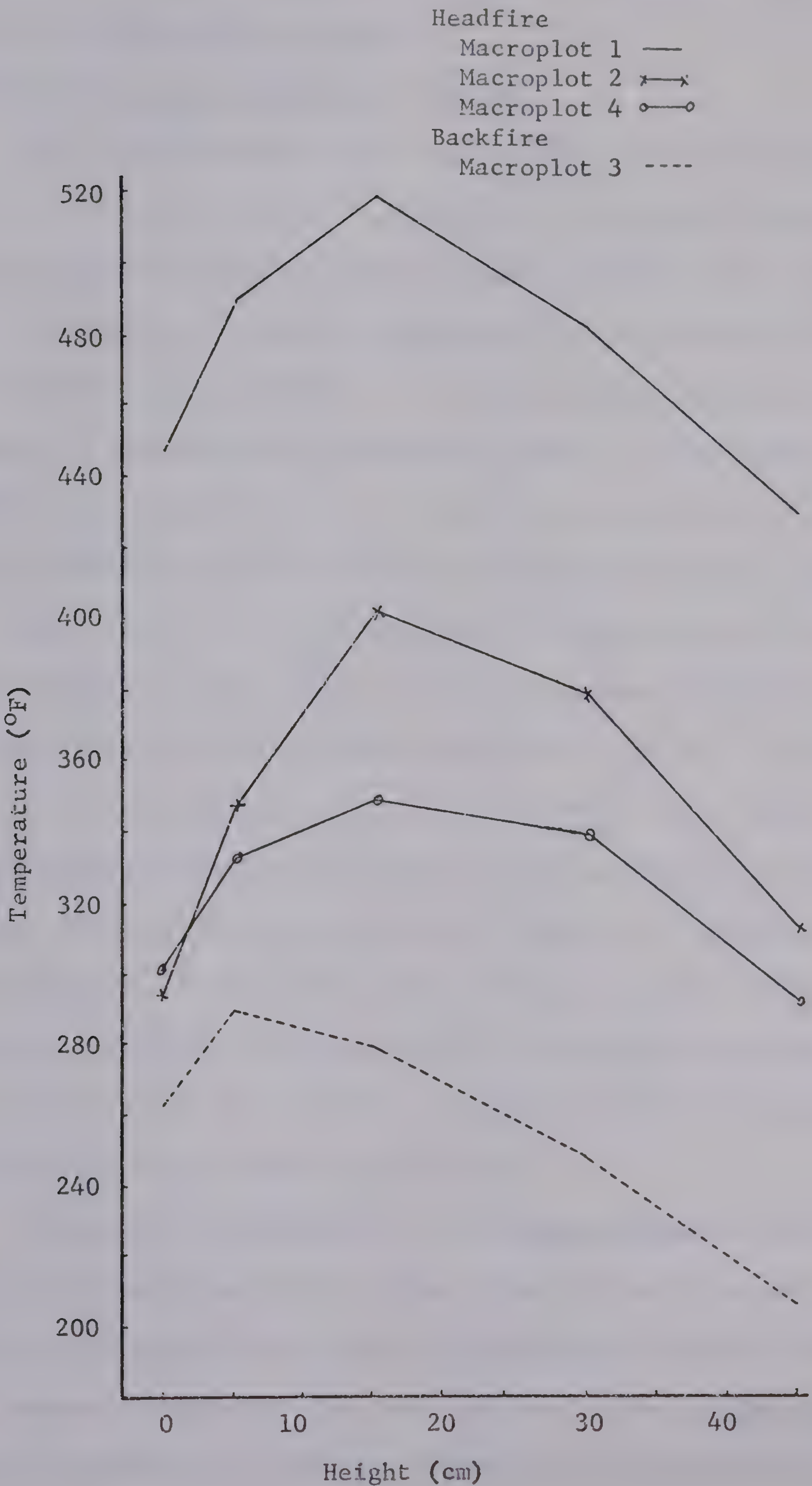
Table 3. Mean maximum temperature (^{o}F) at specific heights (cm), weight of the fuel (kg/ha) and moisture content of the fuel (%) in the spring, 1971 burn for the *Festuca-Stipa* community.

	Macroplot Number	Height (cm) 0 (n=15)	5 (n=15)	15 (n=15)	30 (n=15)	45 (n=15)	Mean	Fuel Weight (n=15)	Moisture Content (n=5)
Headfire									
	1	293	347	403	380	293	343	2830	16.5
	2	447	490	520	483	430	474	3530	17.6
	4	300	333	350	340	313	377	4490	18.5
	Mean	347 ± 50[1]	390 ± 50	424 ± 50	401 ± 43	345 ± 43	380	3617 ± 481	17.5 ± 0.6
Backfire									
	3	263 ± 12**	290 ± 9**	280 ± 10**	250 ± 11**	207 ± 8**	258**	3250 ± 270	12.8 ± 1.6

** Mean in the backfire differs from the mean in the corresponding column in the headfire at the 0.01 level using an unpaired Student's t-test

[1] Standard error of the mean

Figure 2. Mean maximum temperature (^{o}F) versus height (cm) in the Festuca-Stipa community in the spring, 1971 burn.



The fuel moisture content was higher in the macroplots burned by the headfire than it was in the macroplot burned by the backfire. There appears to be no relation between fuel weight and maximum fire temperatures in the *Festuca-Stipa* community.

2. *Symphoricarpos occidentalis* community

The maximum temperature in the headfire and in the backfire occurred at the same height of 8 cm (Table 4). The mean maximum temperature for all heights in the headfire was 275°F higher than that of the backfires. Maximum temperatures in the headfire were also higher than those in the backfire. The mean maximum temperatures at each height in the headfire in descending order were 1087, 1083, 967, 930, and 890°F at the heights of 8, 20, 45 and 75 cm respectively. The number of observations which exceeded the maximum measurable temperature of 1200°F were 4, 9, 10, 3 and 1 at the heights of 0, 8, 20, 45 and 75 cm respectively in macroplot 1. The mean maximum temperatures for each height in the backfire in descending order were 791, 774, 761, 679 and 575°F at the heights of 8, 20, 0, 45, and 75 cm, respectively. The maximum temperature in the backfire tended to peak at the same level or at lower levels than did the headfire (Figure 3). The fuel weight in the headfire was 6590 kg/ha greater than the quantity of fuel in the backfire. There was no difference in the fuel moisture content between stands burned by a headfire and those burned by a backfire.

3. Comparison of the burned communities

The maximum temperatures in the *Symphoricarpos* community in the areas burned by headfires and the areas burned by backfires were higher than the maximum temperatures in the *Festuca-Stipa* community (Table 5). The mean maximum temperatures in the headfires in the *Symphoricarpos* community exceeded the mean maximum temperature in the *Festuca-Stipa*

Table 4. Mean maximum temperature (°F) at specific heights (cm), weight of the fuel (kg/ha) and moisture content of the fuel (%) in the spring, 1971 burn for the <u>Symphoricarpos</u> community.

	Macroplot Number	0 (n=15)	8 (n=15)	20 (n=15)	45 (n=15)	75 (n=15)	Mean	Fuel Weight (n=15)	Moisture Content (n=5)
Backfire	2	803	797	777	667	550	719	12960	17.1
	3	763	807	817	763	677	765	15900	20.8
	4	717	770	727	607	497	664	16970	19.6
	Mean	761±25[1]	791±11	774±26	697±45	575±53	716	15280±1200	19.2±11
Headfire	1	930±45**	1087±45**	1083±42**	967±42**	890±40**	991**	21670±1470	20.4±3.5

** Mean in the headfire differs from the mean in the corresponding column in the backfire at the 0.01 level using an unpaired Student's t-test.

[1] Standard error of the mean

Figure 3. Mean maximum temperature (^{o}F) versus height (cm) in the <u>Symphoricarpos</u> community in the spring, 1971 burn.

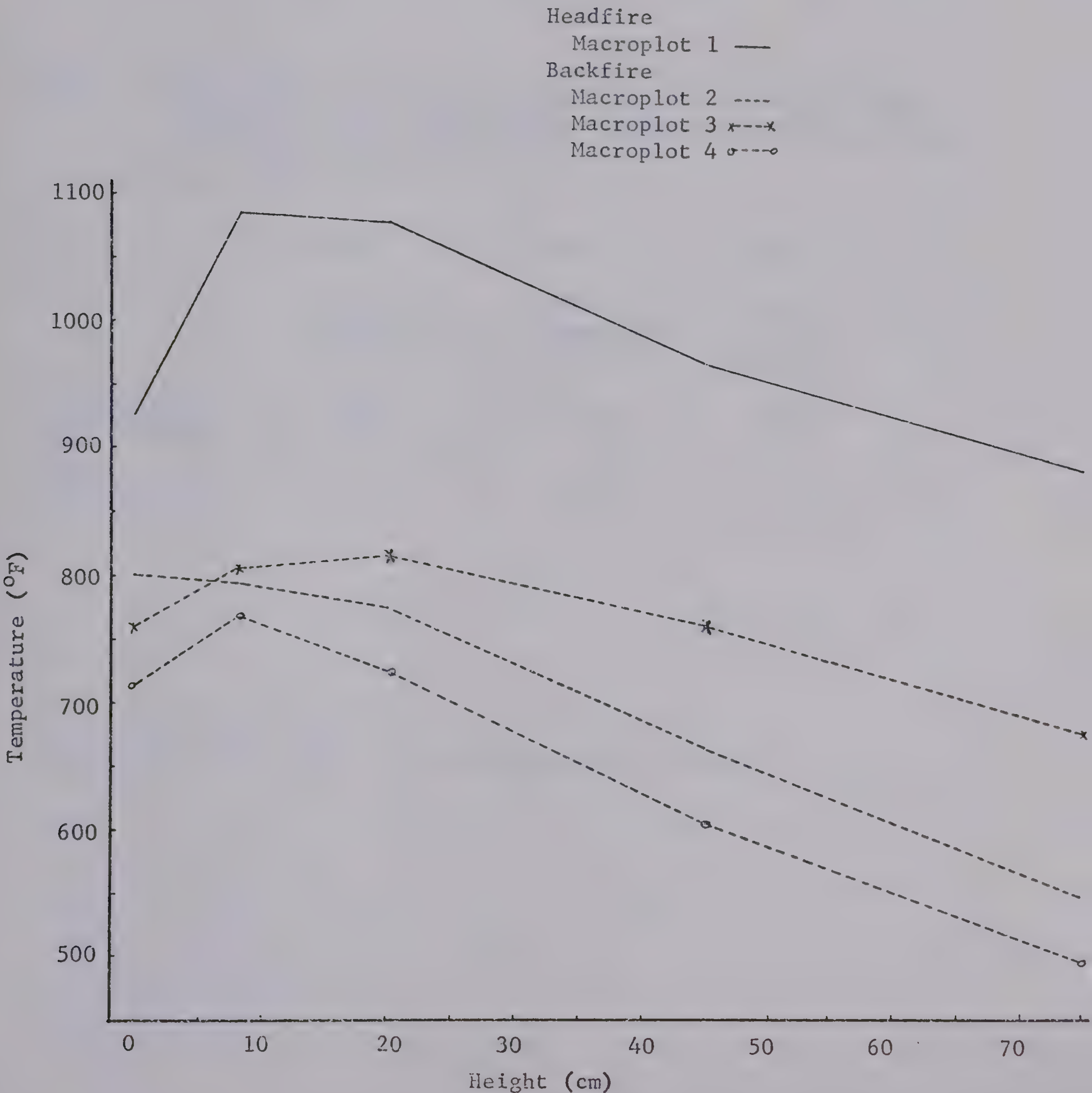


Table 5. Comparison of mean temperatures (°F) of the headfires and backfires and mean fuel weights (kg/ha) in the *Festuca-Stipa* and *Symphoricarpos* communities.

	Mean Headfire Temperature °F	Mean Backfire Temperature °F	Mean Fuel Weight kg/ha
Festuca-Stipa	380	258	3525
Symphoricarpos	990	716	16875
Difference (%)[1]	+160	+178	+379

[1] Expressed as a per cent of the *Festuca-Stipa* community

community by 160 per cent. The mean maximum temperature in the backfire in the *Symphoricarpos* community exceeded the mean maximum temperatures in the *Festuca*-*Stipa* community by 178 per cent. The mean quantity of fuel in the *Symphoricarpos* community was 379 per cent greater than the quantity of fuel in the *Festuca*-*Stipa* community.

C. Vegetation

1. *Festuca scabrella* - *Stipa spartea* var. *curtiseta* community

The total canopy coverage in the *Festuca*-*Stipa* community changed only slightly the first growing season after either a spring or fall burn (Table 6). The total canopy coverage of grasses and grass-likes decreased eleven per cent in the fall, 1970 burned treatment and 21 per cent in the spring, 1971 burned treatment. The major increase in total canopy coverage was from forb species which increased 108 per cent in the fall, 1970 burn and 127 per cent in the spring, 1971 burn. Although shrub coverage was low before and after burning, there were large percentage changes. The canopy coverage of the shrub species increased 26 per cent in the fall, 1970 burn and 82 per cent in the spring, 1971 burn.

From 1970 to 1971, the total canopy coverage of species in the *Festuca*-*Stipa* community increased nine per cent in the unburned treatment and 23 per cent in the spring burned treatment (Table 7). The canopy coverage of grasses and grass-like species decreased four per cent in the unburned treatment and increased 17 per cent in the spring, 1970 burned treatment during the second growing season. Forb species increased in canopy coverage by 128 per cent in the unburned and 56 per cent in the spring, 1970 burned treatment from 1970 to 1971. The canopy coverage of the shrub species increased 52 per cent in the

Table 6. A comparison of canopy coverage (%) of plants by vegetation class and species in the unburned (UB), fall, 1970 burned (FB) and spring, 1971 burned (SB) treatments in the Festuca-Stipa community.

	UB (n 175)	FB (n 175)	SB (n 175)	Change[1] (%) FB	Change[1] (%) SB
Vegetation Class					
Grasses and grass-likes	252	224	200	-11	-21
Forbs Annual	0	0	0	0	0
Perennial	26	54	60	+108	+127
All Forbs	26	54	60	+108	+127
Shrubs	3	3	6	+26[2]	+82
Total	280	282	265	+1	+5
Species					
Festuca scabrella	84a[3]	79b	62c	-6	-26
Helictotrichon hookeri	18a	6b	1b	-67	-94
Artemisia frigida	3a	#b	#b	-92	-97
Carex spp.	54a	55a	44b	+2	-19
Stipa spartea var. curtiseta	86a	79b	84a	-8	-2
Agropyron spp.[4]	6	4	8	-24	+36
Astragalus spp.[5]	4	12	11	+140	+120
Geum triflorum	1a	11b	10b	+1000	+900
Achillea millefolium	1a	2b	4b	+56	+289
Lappula redowski	0a	1b	#a		
Anemone pattens var. wolfgangiana	7	7	8	0	14

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[1] Expressed as a percentage of the canopy coverage in the unburned treatment

[2] Apparent errors due to rounding

[3] Canopy coverage values within each row followed by a common letter a, b, or c do not differ significantly at the 0.05 level using Duncan's multiple range test

[4] Includes Agropyron trachycaulum and A. subsecundum

[5] Includes Astragalus agrestis, A. striatus and A. flexuosus

Canopy coverage was 0.5 per cent or less

Table 7. A comparison of mean canopy coverage (%) of plant species by vegetation class and species during the first year (1970) and the second year (1971) following the spring, 1970 fire in the unburned and burned treatments in the Festuca-Stipa community.

	Unburned		Burned		Change[1] (%)	
Vegetation Class	1st yr (n=30)	2nd yr (n=30)	1st yr (n=34)	2nd yr (n=34)	Unburned	Burned
Grasses and grasslikes	270	259	200	234	-4	+17
Forbs Annual	0	0	0	0	0	0
Perennial	18	41	43	67	+128	+56
All forbs	18	41	43	67	+128	+56
Shrubs	29	44	14	17	+52	+21
Total	317	345	258	318	+9	+23
Species						
Festuca scabrella	92	85	36	59	-8	+64
Carex spp.	68	55	65	72	-19	+11
Stipa spartea var. curtiseta	87	90	87	90	+2	+2
Aster spp.[2]	2	5	16	20	+130	+26
Commandra pallida	2	7	5	9	+250	+80
Achillea millefolium	1	3	3	6	+200	+100
Antennaria spp.	1	2	5	7	+100	+40
Agropyron spp.	18	26	8	10	+44	+25
Elaeagnus commutata	20	29	5	6	+45	+20
Rosa arkansana	6	11	9	10	+83	+11
Astragalus spp.[4]	4	8	2	2	+95	0

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[1] Expressed as a percentage of the first year

[2] Mostly Aster laevis var. geyeri

[3] Includes Agropyron trachycaulum and A. subsecundum

[4] Includes Astragalus agrestis, A. flexuosus and A. striatus

unburned treatment and only 21 per cent in the spring, 1970 burned treatment during the second growing season.

The canopy coverage of several species decreased significantly in both the fall, 1970 and the spring, 1971 burned treatments. The canopy coverage of *Festuca scabrella* decreased 26 per cent in the spring, 1971 burned treatment and 6 per cent in the fall, 1970 burned treatment (Table 6). The canopy coverage of *Stipa spartea* var. *curtiseta* decreased 8 per cent in the fall burned treatment. The canopy coverage of *Carex* species decreased 19 per cent in the spring, 1971 burned treatment. The canopy coverage of *Helictotrichon hockeri* decreased 67 and 94 per cent in the fall, 1970 and spring, 1971 burned treatments, respectively. The canopy coverage of *Artemisia frigida* was decreased 92 and 97 per cent by fall and spring burning, respectively; however, its canopy coverage value in the unburned treatment was only 3 per cent. The canopy coverage value of several forbs increased in both the fall, 1970 and spring, 1971 burned treatments. The canopy coverage of *Astragalus* spp. increased by 140 and 120 per cent (fall and spring burns, respectively) while that of *Geum triflorum* increased by 1000 and 900 per cent (fall and spring burns, respectively). The canopy coverage of *Achillea millefolium* increased 56 and 289 per cent (fall and spring burns, respectively) while that of *Aster* species increased 200 and 100 per cent (fall and spring burns, respectively). *Lappula redowski* and *Fragaria virginiana* var. *glauca* were present in the two burned treatments but were absent from the unburned treatment. The frequency and canopy coverage values for species found in the unburned, fall, 1970 and spring, 1971 burned treatments are reported in Appendix 3.

The canopy coverage of *Festuca scabrella* decreased eight per cent from year 1 to year 2 in the unburned treatment but increased 64 per

cent during this same period in the spring, 1970 burned treatment (Table 7). In the unburned treatment, the canopy coverage of Carex species decreased 19 per cent from year 1 to year 2 but increased 11 per cent during this same period in the spring, 1970 burned treatment. The canopy coverage of Stipa spartea var. curtiseta increased slightly (2 per cent) from 1970 to 1971 in both the unburned and spring, 1970 burned treatments. The increase in canopy coverage from 1970 to 1971 for the species Aster spp, Commandra pallida, Achillea millefolium, Antennaria spp., Agropyron spp., Elaeagnus commutata, Rosa arkansana and Astragalus species, increased more in the unburned treatment than in the spring, 1970 burned treatment. The frequency and canopy coverage values of species found in the unburned and spring, 1970 burned treatments are reported in Appendix 4.

The reproductive ability of Festuca scabrella was reduced by 97 per cent in the spring, 1971 burned treatment but was not affected by the fall burn (Table 8). There were no seed heads of Festuca scabrella produced in either the unburned or the spring, 1970 burned treatments in 1970 but in 1971, both treatments had the same density of seed heads. The reproductive ability of Stipa spartea var. curtiseta was reduced (77 per cent) by the fall, 1970 burn but the spring, 1971 burn had no effect. The spring 1970 burn treatment had a stimulatory effect on the production of seed heads of Stipa spartea var. curtiseta in the second year, increasing the mean density 575 per cent compared to 293 per cent in the unburned treatment.

The total annual production in the spring, 1971 burned treatment increased 16 per cent while the total annual production in the fall, 1970 burned treatment, decreased 3 per cent (Table 9). There were no significant differences in mean annual production among treatments.

Table 8 . A comparison of density of seed heads (culms/0.1 sq. m.) in the fall, 1970 and spring, 1971 burned treatments and between the growing seasons of 1970 (1st yr) and 1971 (2nd yr) in the spring, 1970 burn in the *Festuca-Stipa* community.

	Unburned (n=175)	Burned: Fall, 1970 (n=175)	Burned: Spring, 1971 (n=175)	Change[1] (%) FB	Change[1] (%) SB
Festuca scabrella	3.4a[3]	3.5a	0.1b	+3	-97
Stipa spartea var. curtiseta	4.8a	1.1b	4.8a	-77	0

	Unburned: 1st yr (n=30)	Unburned: 2nd yr (n=30)	Spring, 1970: 1st yr (n=34)	Spring, 1970: 2nd yr (n=34)	Change[2] (%) UB	Change[2] (%) B
Festuca scabrella	0	2.6	0	2.6		
Stipa spartea var. curtiseta	1.4	5.5	2.4	16.2	+293	+575

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[1] Expressed as a percentage of the unburned treatment

[2] Expressed as a percentage of the first year

[3] Mean seed head densities followed by a common letter a or b are not significantly different at the 0.05 level using Duncan's multiple range test.

Table 9 . A comparison of mean annual forage production (kg/ha) in the *Festuca-Stipa* community in the fall, 1970 (FB) and spring, 1971 (SB) burns.

Macroplot Number	Unburned (n=3)	Fall, 1970 Burned (n=3)	Spring, 1971 Burned (n=3)	Change[1] (%)	
				FB	SB
1	1265	1285	1350		
2	1025	1040	1230		
3	950	1120	1380		
4	1135	1005	1585		
5	1540	1275	1275		
Mean	1180±104[2]	1145±58	1365±61	-3	+16

[1] Expressed as a percentage of the unburned treatment

[2] Standard error

The mean depth of the Ah soil horizon ranged from 13.3 cm to 15.7 among the treatments of unburned, fall, 1970 burned and spring, 1971 burned (Table 10). There was more variation in the depth of the Ah horizon within each treatment than there was among the treatments. The uniform depth of the Ah horizon is one of the parameters indicating that there was little difference in the soil environment amongst the three treatments.

2. _Symphoricarpos_ community

The total canopy coverage in the _Symphoricarpos_ community increased 53 per cent in the spring, 1971 burned treatment (Table 11). The canopy coverage of forbs increased 1062 per cent in the spring, 1971 burn. The canopy coverage of annual forbs (20 per cent) accounted for almost one-half of the total forb canopy coverage of 43 per cent. The canopy coverage of shrub species increased 24 per cent in the spring, 1971 burned treatment. The total canopy coverage of the grasses and grass-likes decreased 106 per cent in the spring, 1971 burned treatment.

From 1970 to 1971, the total canopy coverage in the _Symphoricarpos_ community increased 9 per cent in the unburned treatment and 7 per cent in the spring burned treatment (Table 12). There was no change in the canopy coverage of grasses and grass-likes in the unburned treatment from year 1 to year 2, but in the burned treatment the canopy coverage increased by 43 per cent. The canopy coverage of shrub species increased 15 per cent in the unburned treatment from year 1 to year 2, but shrubs increased only 4 per cent in the burned treatment. From year 1 to year 2, canopy coverage of forb species decreased from 5 to 2 per cent in the unburned treatment and from

Table 10. Mean depth to the Ah horizon in treatment macroplots in the *Festuca-Stipa* community

Macroplot Number	Unburned (n=5)	Fall, 1970 Burned (n=5)	Spring, 1971 Burned (n=5)
1	19.2	13.8	15.6
2	17.2	11.4	12.0
3	13.8	11.4	17.0
4	15.2	15.0	9.8
5	13.0	21.0	12.2
Treatment mean	15.7±0.8[1]	14.5±0.9	13.3±0.9

[1] Standard error of the mean

Table 11. A comparison of canopy coverage (%) of plant species by vegetation class and species in the unburned (UB) and spring, 1971 burned (SB) treatments in the Symphoricarpos community

Vegetation Class	Canopy Coverage UB (n=125)	Canopy Coverage SB (n=125)	Change[1] (%) SB
Grasses and grasslikes	7	#	-106
Forbs Annual	0	20	
Perennial	4	23	+475
All forbs	4	43	+1062
Shrubs	91	113	+24
Total	102	156	+53
Species			
Symphoricarpos occidentalis	87	78	-10
Carex spp	5	#*	-92
Elaeagnus commutata	2	#*	-99
Rubus strigosus	0	32**	
Stachys palustris var. pilosa	0	18**	
Leguminosae[2]	1	15*	+700
Galium boreale	#	4	+733

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[1] Expressed as a per cent of the unburned treatment

[2] This includes the three species Vicia americana, Lathyrus ochroleucus and Lathyrus venuosus var. intonsus.

* Significantly different at the 0.05 level using an unpaired Student's t-test

** Significantly different at the 0.01 level using an unpaired Student's t-test

\# Canopy coverage was 0.5 per cent or less

Table 12. A comparison of mean canopy coverage (%) of plant species by vegetation class and species during the first year (1970) and the second year (1971) following the spring, 1970 burn in the *Symphoricarpos* community.

	Unburned		Burned		Change[1] (%)	
Vegetation Class	1st yr (n=23)	2nd yr (n=23)	1st yr (n=28)	2nd yr (n=28)	Unburned	Burned
Grasses and grass-likes	19	19	42	60	0	+43
Forbs Annual	0	0	14	2	0	-8
Perennial	5	2	31	34	-60	+10
All forbs	5	2	45	36	-54	-20
Shrubs	100	114	112	116	+15	+4
Total	124	135	199	212	+9	+7
Species						
Symphoricarpos occidentalis	92	89	94	88	-3	-6
Carex spp.	7	12	14	25	+71	+79
Rubus strigosus	7	23	15	22	+229	+47
Galium boreale	0	2	8	9		6
Calamagrostis neglecta	5	1	12	16	+80	+33
Agropyron spp.[2]	6	6	4	5	0	+25
Artemisia ludoviciana var. gnaphloides	0	0	9	11	0	+22
Chenopodium album	0	0	8	#	0	+96

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[1] Expressed as a percentage of the first year

[2] Includes *Agropyron trachycaulum* and *A. subsecundum*

Mean canopy coverage was 0.5 per cent or less

45 to 36 per cent in the burned treatment. The perennial forbs decreased by 60 per cent from year 1 to year 2, but they increased by 10 per cent in the burned treatment. In contrast, the annual forbs were absent from the unburned treatment and decreased by 86 per cent in the burned areas.

During the first growing season (Table 11), the canopy coverage of Carex spp. and Elaeagnus commutata decreased 92 and 99 per cent, respectively, in the spring, 1971 burn. The canopy coverage of Galium boreale and Leguminosae spp. increased 733 and 700 per cent, respectively, in the spring, 1971 burn. Rubus strigosus and Stachys palustris var. pilosa were not found in the unburned treatment but the mean canopy coverage for these species in the spring, 1971 burned treatment was 32 and 18 per cent, respectively. The frequency and canopy coverage values of species found in the unburned and spring, 1971 burned treatments are reported in Appendix 5.

In the spring, 1970 burn, the canopy coverage of Symphoricarpos occidentalis did not change from 1970 (year 1) to 1971 (year 2) (Table 12). From 1970 (year 1) to 1971 (year 2), the canopy coverage of Carex spp. increased 71 per cent in the unburned treatment and 79 per cent in the spring, 1970 burned treatment. From 1970 (year 1) to 1971 (year 2), the canopy coverage of Rubus strigosus increased 229 per cent in the unburned treatment and only 47 per cent in the burned treatment. During the same period, the canopy coverage of Calamagrostis neglecta decreased 80 per cent in the unburned treatment and was increased 33 per cent in the spring, 1970 burned treatment. From 1970 (year 1) to 1971 (year 2), the canopy coverage of Agropyron spp. increased 25 per cent in the spring, 1970 burned treatment but remained the same in the unburned treatment. During the same period, the canopy coverage of Artemisia ludoviciana var. gnaphloides was increased 22

per cent in the spring, 1970 burned treatment; however, none was found in the unburned treatment in either year. During the second growing season, the canopy coverage of *Chenopodium album*, an annual forb, decreased 96 per cent in the spring, 1970 burned treatment; however, none was found in the unburned treatment. The frequency and canopy coverage values for species found in the unburned and spring, 1970 burned treatments are reported in Appendix 6. The stem density of all woody species was 440 per cent greater in the spring, 1971 burn than in the unburned treatment while *Symphoricarpos occidentalis* stems were 364 per cent greater in the burned treatment (Table 13). The shrub species found in the spring, 1971 burned treatment but not in the unburned treatment were *Rubus strigosus* and *Populus tremuloides*. The stem density of *Rosa woodsii* and *R. acicularis* was the same in both treatments. The stem density of *Elaeagnus commutata* in the unburned treatment (0.1) was not significantly different from the spring, 1971 burned treatment (0).

From 1970 (year 1) to 1971 (year 2), the total stem density in the *Symphoricarpos community* decreased 14 per cent in the unburned treatment and 13 per cent in the spring, 1970 burned treatment (Table 13). *Symphoricarpos occidentalis* followed a similar pattern. From 1970 (year 1) to 1971 (year 2), density of stems of *Rubus strigosus* increased 200 per cent in the unburned treatment and 113 per cent in the spring, 1970 burned treatment. During the same period, the number of stems of *Rosa* spp. increased 150 per cent in the unburned treatment; however, no stems were found in the spring, 1970 burned treatment.

3. Comparison of the two communities

The total canopy coverage of all species in the spring, 1971 burn was greater in the *Festuca-Stipa* community (265%) than in the *Symphoricarpos* community (156%) (Figure 4). There was an even greater

Table 13. A comparison of density of woody stems (number/0.1 sq. m.) in the unburned and spring, 1971 burned treatments and between the growing seasons of 1970 (1st yr) and 1971 (2nd yr) in the spring, 1970 burn in the *Symphoricarpos* community.

	Unburned (n=125)	Spring, 1971 Burned (n=125)	Change[1] (%)
Rubus strigosus	0	1.8**	
Populus tremuloides	0	0.02	
Symphoricarpos occidentalis	2.2	10.2**	+364
Rosa spp.[3]	0.1	0.1	0
Elaeagnus commutata	0.1	0	
Total	2.4	12.1	+440

	Unburned (n=23)		Spring, 1970 Burned (n=28)		Change[2] (%)	
	1st yr	2nd yr	1st yr	2nd yr	UB	SB
Symphoricarpos occidentalis	8.4	6.5	23.8	19.8	-23	-17
Rubus strigosus	0.3	0.9	0.8	1 7	+200	+113
Rosa spp.[3]	0.04	0.1	0	0	+150	0
Total	8.7	7.5	24.6	21.5	-14	-13

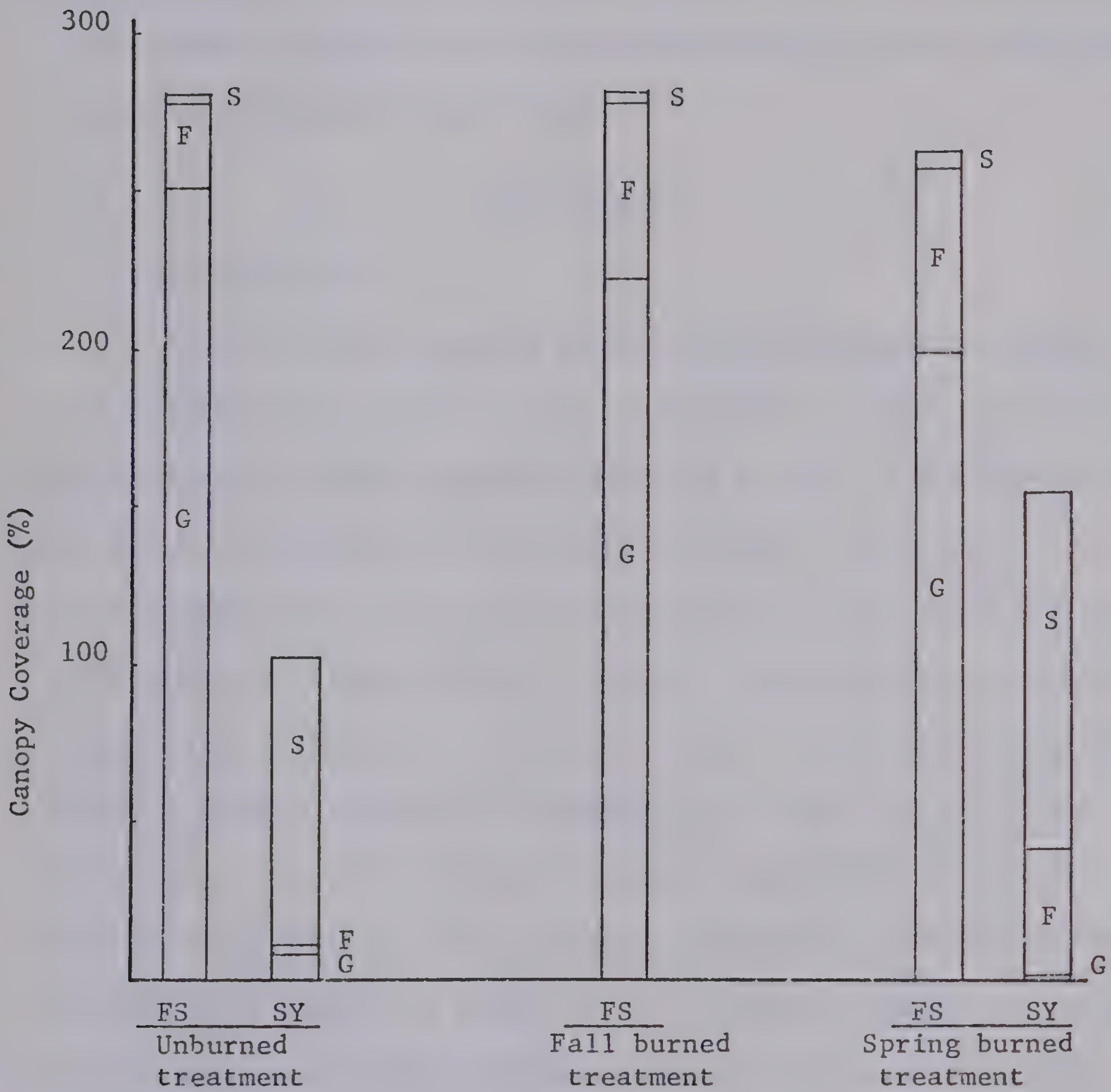
**Significant at the 0.01 level using an unpaired Student's t-test

[1]Expressed as a percentage of the unburned treatment

[2]Expressed as a percentage of the first year

[3]Includes *Rosa woodsii* and *Rosa acicularis*

Figure 4. A comparison of canopy coverage (%) by vegetation class of grasses and grass-likes (G), forbs (F) and shrubs (S) in the in the *Festuca-Stipa* (FS) and *Symphoricarpos* (SY) communities in the fall, 1970 and spring, 1971 burns.



difference in total canopy coverage in the unburned treatment between the Festuca-Stipa community (280%) and the Symphoricarpos community (102%). There was a proportionately greater increase in the total canopy coverage in the spring, 1970 burned treatment from 1970 (year 1 to 1971 (year 2) in the Festuca-Stipa community (23%) than in the Symphoricarpos community (7%)(Figure 5). During the same period, the total canopy coverage of the unburned treatments in both communities increased in the same proportions.

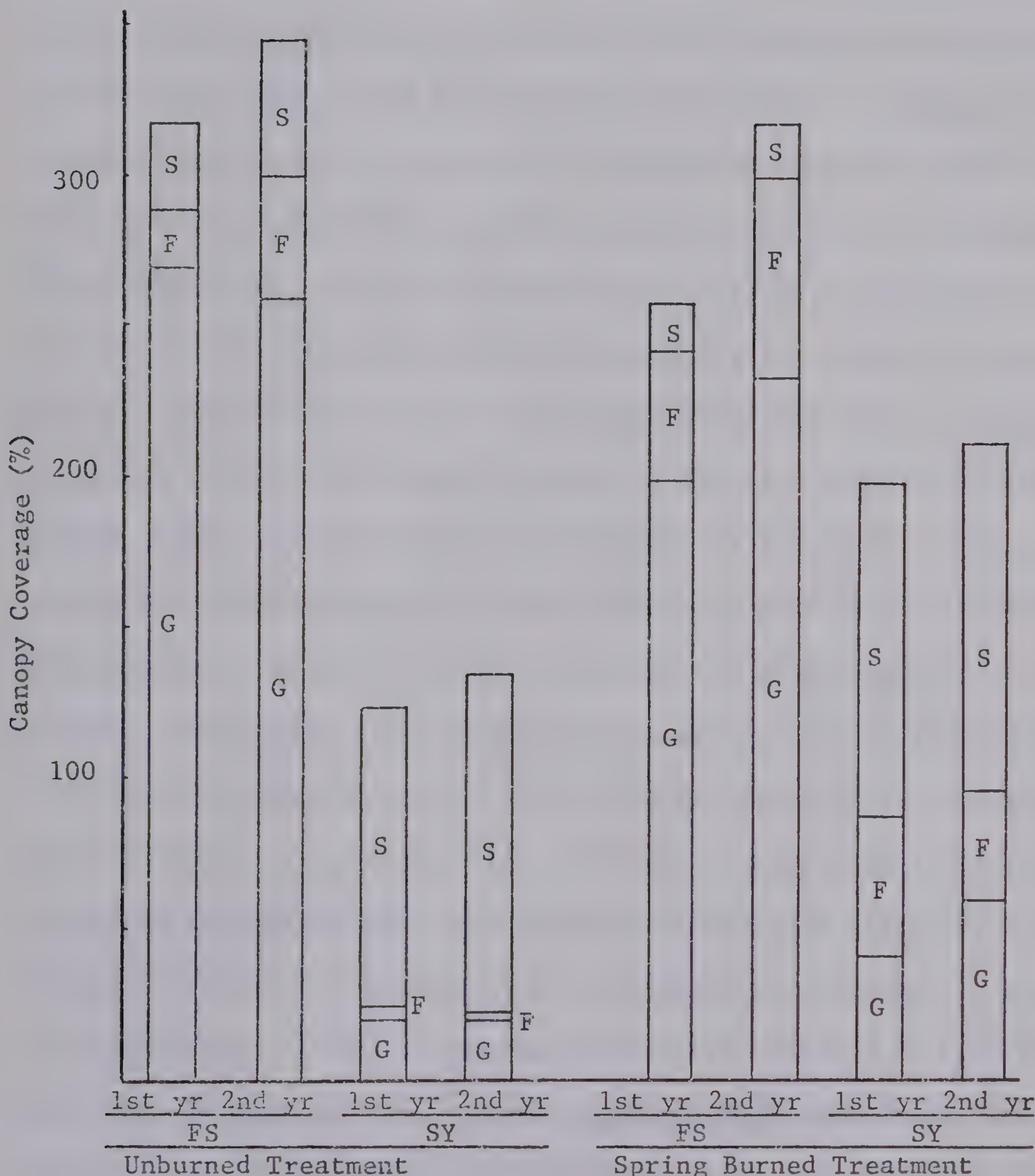
DISCUSSION

A. Fire temperatures

Weather data recorded at the Edmonton Industrial Airport were similar to the data recorded at Kinsella. Relative humidity measurements from the Edmonton Industrial Airport and from Kinsella on the day of the spring, 1971 fire were similar. The difference between the two stations in the early morning hours was apparently a microclimate effect (Geiger, 1966). However, the normal rise in ambient temperatures and the increased air movements at Kinsella apparently caused a greater mixing of air layers in the lower levels of the atmosphere. Thus, the relative humidity measurements at the two stations were similar during the day. Therefore, because these two stations were similar in respect to the weather measurements of maximum temperature, mean daily wind speed and relative humidity in early May, the weather conditions recorded at the Edmonton Industrial Airport probably give close approximations of weather conditions for Kinsella during the spring burning period.

The maximum temperatures of headfires in both the Festuca-

Figure 5. A comparison of canopy coverage (%) by vegetation class of grasses and grass-likes (G), forbs (F) and shrubs (S) between the growing season of 1970 (1st yr) and 1971 (2nd yr) in the Festuca-Stipa (FS) and Symphoricarpos (SY) communities in the spring, 1970 burn.



Stipa (Festuca scabrella - Stipa spartea var. curtiseta) and the Symphoricarpos (Symphoricarpos occidentalis) communities were higher at all heights measured than were maximum temperatures in the backfire. These results agree with those reported by Fahnestock and Hare (1964) in the Longleaf pine vegetation type in Louisiana who found that maximum temperatures in headfires were consistently hotter than backfires. In a similar vegetation type in South Carolina, Lindenmuth and Byram (1948), on the other hand, found that maximum temperatures in backfires were higher than maximum temperatures in headfires. Beaufait (1965) reported that by using a fuel bed of ponderosa pine needles in a controlled laboratory study, backfires burned longer, slower, and deeper than headfires. He also found that increasing the air velocity in backfires had no effect on the rate of spread but increasing the air velocity in headfires greatly increased its rates of spread. Fahnestock and Hare (1964) report that the average wind speed was 2.6 to 4.3 miles per hour during the headfires and 1.3 to 2.7 miles per hour during the backfires. Lindenmuth and Byram (1948) do not report the wind speed but it was probably very light. The average wind speed during the spring, 1971 burn was nine miles per hour, but during the fire, there were gusts up to 25 miles per hour reported at Edmonton,and personal observation indicated that there were wind gusts of at least 25 miles per hour at Kinsella as well. The variability of maximum temperatures in headfires was considerably greater than the variability measured in backfires; this was particularly true in the Symphoricarpos community. This is in agreement with the results reported by Beaufait (1965). Thus, macro-plots burned by backfires were not appreciably affected by wind speed and the variability in the quantity of heat released per unit of time

was not as great as was the variability in macroplots burned by headfires. Thus, the difference between headfires and backfires can be attributed mainly to wind.

The maximum temperature of headfires in both communities occurred at heights of 15 to 20 cm above the ground. These results are close to the 11 to 17 cm height of maximum temperatures found in the Miscanthus type of grassland by Iwanami (1969) and in the Sasa type of grassland by Naito et al (1968) in Japan. A maximum temperature at a height of 5 to 8 cm in the backfires in both communities agrees with the results of Ito and Iizumi (1968) for the Miscanthus type of grassland and with Iwanami and Iizumi (1969) for the Zoisia type of grassland in Japan. Fahnestock and Hare (1964) found that the maximum temperature in both headfires and backfires occurred at ground level while Lindenmuth and Byram (1948) found that the maximum temperatures in both headfires and backfires occurred at a height of five inches (12.7 cm) in the Longleaf pine vegetation type. Iwanami and Iizumi (1966), in the Zoisia type of grasslands in Japan, found that maximum temperatures from burning with a wind of 1.7 meters per second were higher and occurred at a greater height above ground level than were maximum temperatures from burning with a wind of 0.7 meters per second. For a tobosa (Hilaria mutica) grassland in Texas, Britton and Wright (1971) found that of the independent variables tested, wind speed, air temperature, relative humidity, total fuel, grass fuel, soil moisture and fuel moisture, none were significantly correlated with temperature at ground level; however, they noted that wind speed had the highest correlation coefficient and it accounted for the most variation. Stinson and Wright (1969) report that wind had an effect on temperatures

but its effect was not significant. Thus, the effect of wind on fire temperatures and the height that these temperatures occur has been difficult to determine because of the great variability in wind. However, wind does play an important role in determining quantity and rate of heat that is released per unit of time. Therefore, wind was an important factor in determining the differences in maximum temperatures between headfires and backfires during the spring, 1971 fire.

Maximum temperatures measured in the Symphoricarpos community were higher than maximum temperatures measured in the Festuca-Stipa community. Daubenmire (1968a) reports that the classes of factors affecting the rate and amount of heat released by burning vegetation are: (1) Weather conditions prior to and during the fire, (2) topography and (3) the kind, amount and disposition of the fuel. In our fires, weather conditions were the same for both communities because stands of both communities were interspersed in a complex mosaic and were burned together. There were only minor variations in topography among all the macroplots. Macroplots in the Symphoricarpos community occurred in shallow depressions which would have had the tendency to lower the rate of heat release. There was about four times more fuel available in the Symphoricarpos ocmmunity than there was available in the Festuca-Stipa community. The main component of the fuel in the Symphoricarpos community was the dead woody stems of Symphoricarpos occidentalis. Wroe (1971) reported that the average age of dense stands of Symphoricarpos occidentalis in the Stettler, Alberta area was 7.2 years, and the age of the oldest stems were 11 years. Pelton (1953), in Minnesota, reports that the stems of Symphoricarpos occidentalis normally die naturally within a period of less than 15

years. The dead stems remain upright allowing the fuel to accumulate. In the *Festuca-Stipa* community, the maximum litter that accumulates is the growth from one to three years. The fuel in the *Festuca-Stipa* community was comprised of leafy herbage material, mostly from grasses, and was all within a layer from ground level to six inches above the ground. The fuel in the *Symphoricarpos* community was within a layer from ground level to approximately two feet above the ground. Thus, differences in the kind, quantity and disposition of fuel was apparent between the two communities. Therefore, the differences in temperatures between the two communities are largely attributable to differences in fuel weight, kind and disposition.

B. Vegetation

Canopy coverage of forbs in the *Festuca-Stipa* community increased and canopy coverage of grasses and grasslikes decreased with both fall and spring burning. Daubenmire (1968a) reported from many sources that burning favors forbs over grasses. Anderson (1970) reported that, in the Flint Hills of Kentucky, forbs were increased by early-spring burning and decreased by mid and late-spring burning. Ehrenreich and Aikman (1963) report that, in the tall grass prairie, forbs increased with burning and they suggest that it was a result of an increase in available nutrients. Daubenmire (1968a) reported that burning increased both the quantity and availability of nutrients. Ehrenreich and Aikman (1963) found that with burning, there was an increase in inorganic cations and available nutrients. Kilcher et al (1965) report that forb species increased when inorganic fertilizers were applied to different grassland vegetation types at several locations throughout western Canada. Johnston (1961) and Smith et al (1968) report that forbs

increased when inorganic fertilizers were applied to the Festuca scabrella grassland of southwestern Alberta. Therefore, the increase in the canopy coverage of forbs in burned areas is apparently a response to a greater quantity of available nutrients.

The canopy coverage of grasses and grass-likes declined with both fall and spring burning in the Festuca-Stipa community. The co-dominants in this community were included in the vegetation class of grasses and grass-likes; therefore, major changes in the canopy coverage of these species will be reflected in the canopy coverage of grasses and grass-likes. The canopy coverage and density of seed heads of Festuca scabrella were greatly decreased in the spring, 1971 burned treatment but canopy coverage of Festuca scabrella was only slightly reduced in the fall, 1970 burned treatment. Osychnyuk and Istomina (1970), in Russia, found that Festuca sulcata was reduced in abundance by spring burning. Johnston and MacDonald (1967) reported that the seed set of Festuca scabrella is determined during the August - September period of the previous growing season. Festuca scabrella does not produce seed heads every year but Johnston and MacDonald (1967) could find no factors responsible for induction and initiation of the floral primordia. Seed heads of Festuca scabrella were not produced during the 1970 growing season but seed heads were produced during the 1971 growing season. Seed heads of Festuca scabrella were produced during the second growing season following the spring, 1970 burn; therefore, burning prior to induction and initiation of the floral primordia did not affect seed head production of Festuca scabrella in this study. The density of seed heads was not reduced by the fall, 1970 burned treatment which indicates burning immediately after induction and initiation of the floral

primordia during the August - September period did not affect the density of seed heads of Festuca scabrella. The density of seed heads of Festuca scabrella was greatly reduced in the spring, 1971 burned treatment. Johnston and MacDonald (1967) report that the average height of the shoot apices above the root-stem transition was 12.6 mm in October and 39.6 mm in May of the following year. Thus, greater height of the shoot apices in May would make them more vulnerable to the heat produced during the spring, 1971 fire.

The canopy coverage and the density of seed heads of Stipa spartea var. curtiseta was not affected by spring burning. Smoliak and Johnston (1968) found that Festuca scabrella seedlings had greater leaf growth and produced a greater number of roots at lower germination temperatures and over a shorter period of time than did Stipa comata seedlings. If Stipa spartea var. curtiseta grew similarly to Stipa comata, its growing points would probably not be elevated as high as those of Festuca scabrella at the time of the spring, 1971 fire, thus they would be less likely to be killed from the heat of the spring fire.

The canopy coverage of Festuca scabrella and the canopy coverage and density of seed heads of Stipa spartea var. curtiseta were reduced by fall burning. Ehrenreich and Aikman (1963) report that the maximum daily air temperature one inch above the ground was about 10 ^{o}F higher and the minimum daily air temperature was generally lower in burned areas than in unburned areas. These differences were apparent until the early summer months. Johnston et al (1971) report that, in the Festuca scabrella grassland of southwestern Alberta, soil temperature increases significantly with a decrease in the grass cover. Smoliak and Johnston (1968) report that after 30 days, seedlings of Stipa comata grew more rapidly at higher root zone temperatures than did seedlings of

Festuca scabrella. The growth of established plants was usually greater and earlier than was the growth of seedlings. Geiger (1966) reported that black surfaces absorb more incoming radiation which increased the surface temperature. He also reported that warmer soil surface temperatures will stimulate premature growth in plants. This is important in temperate latitudes during the critical spring period because of the danger of early spring frosts. Green growth was observed first in the spring of 1971 on the fall, 1970 burned treatment. Premature growth was probably initiated in both Stipa spartea var. curtiseta and Festuca scabrella on the fall, 1970 burned area. If the early growth of Stipa spartea var. curtiseta was similar to that reported by Smoliak and Johnston (1968) for Stipa comata, it would be greater than that of Festuca scabrella making the growing points, in particular the shoot apices, more vulnerable to spring frosts.

In the Festuca-Stipa community, differences in the response of Festuca scabrella and Stipa spartea var. curtiseta to fall and spring burning were apparent. Osychnyuk and Istomina (1970) found in the Steppe vegetation of Russia that Festuca sulcata was decreased in abundance by spring burning while Stipa lessingiana increased. In the Flint Hills of Kansas, Anderson (1970) reported that warm season grasses were favored by burning and that cool season grasses were reduced. Wright (1971a) found that the usual dominant in the area, Stipa spp., were reduced by burning and clipping but Sitanion hystrix, a species that increases in abundance with a disturbance, was not affected by burning. Conrad and Poulton (1966), in an area with two major plant associations of Artemisia tridentata - Festuca idahoensis and Artemisia tridentata - Agropyron spicatum, report that Festuca

idahoensis was more susceptible to fire than was *Agropyron spicatum*. Daubenmire (1970) reported that in vegetation comprised of these two plant associations, *Festuca idahoensis* occupies the moister areas and *Agropyron spicatum*, the drier areas. He states "*Festuca* is not as tolerant to dryness or heat as *Agropyron*". Daubenmire (1970) reported that any increase in abundance of *Festuca idahoensis* in the *Artemisia* - *Agropyron* zone is "a reflection of the critical point on the scale of gradually increasing moisture and/or decreasing temperature". Thus, burning changes the microclimate of a grassland in a manner such that species better adapted to a drier, warmer climate are favored.

Fire was important during the period when whiteman first came to the Canadian prairies. Nelson and England (1971) reported that many early explorers were impressed by the frequent occurrence of fire and by the extensive areas burned. Rowe(1969) and Komarek (1966) report that dry prairie grass is ignited very readily by lightning and it probably was the major cause of fires and it still is a major cause of fire on the prairies. Moss (1955) reported that Macoun, a naturalist with the Geological Survey of Canada, failed to note the presence of *Festuca scabrella* while noting the presence of *Stipa spartea*. Moss (1955), on the basis of Moss (1932, 1944), interpreted Macoun's observation as mistaken identification of *Festuca scabrella*. However, Moss (1955) points out that Macoun did note the presence of *Festuca* in the Cypress Hills of Alberta. In this study, *Festuca scabrella* was noted to decrease with both fall and spring burning while *Stipa spartea* var. *curtiseta* was noted to only decrease with fall burning. The reproductive ability of both species was reduced by fire. Thus, with Macoun's travels occurring at the time just prior to the rapid settlement of the prairie and parkland

regions it seems reasonable that his observations on the prairie and parkland area were correct. That is, *Stipa spartea* var. *curtiseta* was the dominant grass but *Festuca scabrella* would have been present in its vegetative state as a subordinate. Fire began to be controlled with the arrival of settlers because fire posed a threat to their existence. Therefore, the control of fire probably enabled *Festuca scabrella* to become the dominant grass species prior to the time when Moss began his work. This change would have occurred over a period of 40 to 60 years. Johnston et al (1971) reported that in the *Festuca scabrella* grassland in southwestern Alberta the per cent basal area of vegetation of ungrazed or lightly grazed fields changed, from 1949 to 1967, from dominance by *Danthonia parryi* to dominance by *Festuca scabrella* in southwestern Alberta. Thus, changes in dominance may occur quickly. Therefore, the control of wild fire may have caused a rapid change in the species composition in grasslands in the parkland area of central Alberta. Prior to white settlement, *Stipa spartea* var. *curtiseta* may have been the dominant grass but with the control of fire, *Festuca scabrella* assumed dominance.

Symphoricarpos occidentalis decreased slightly in the spring, 1971 burned treatment, but the density of live stems was approximately five fold greater in the burned area than the density of live stems in the unburned area. McLean (1966) classified *Symphoricarpos albus* as a species that is very fire resistant because of its deep rhizomes. Pelton (1963) suggested that the deep rhizomes enable *Symphoricarpos occidentalis* to resist any disturbances. Apparently, *Symphoricarpos occidentalis* has adapted to fire similarly to *Symphoricarpos albus*. Vallentine (1971) reported that, in many plants, the number of new shoots produced is controlled by apical dominance. The apical meristems located in the

tips of stems and the tips of leaves produce hormones that inhibit the growth of meristematic tissue or buds located on the lower stem or underground on roots and rhizomes. When the apical buds are removed, hormones are no longer produced and the meristematic tissue or buds grow to produce new shoots. Vallentine (1971) reported that with the removal of apical dominance, the result is a rapid increase in the number of stems. Thus, the removal of the topgrowth of *Symphoricarpos occidentalis* by fire destroyed the apical buds thereby removing the hormonal control on the meristematic tissue in the deep rhizomes. Thus, a greater number of stems of *Symphoricarpos occidentalis* would be expected to be present in the burned area than in the unburned area.

The total canopy coverage in the *Symphoricarpos* community was increased in the spring, 1971 burned treatment. Ahlgren and Ahlgren (1960) report that the sudden release of nutrients previously incorporated into plant tissue is responsible for changes in plant growth found on burned areas. More species were found in the burned treatment than in the unburned treatment; thus, it seems reasonable that an increase in nutrients may be responsible for an increase in the number of species and in their total canopy coverage. Ahlgren and Ahlgren (1960) and Ehrenreich and Aikman (1963) report that the pH of the soil was increased with burning. The increases in pH were due to the large amount of alkaline materials present in ash. Vlamis and Gowans (1961a) and Vlamis and Gowans (1961b) report that in California, burning increased the amount of nitrogen, phosphorus and sulfur. Daubenmire (1968a) reported that burning increases the quantity of soluble nutrients. Ahlgren and Ahlgren (1960) report from many sources that calcium, phosphorus, potassium and other nutrients in-

creased with burning and that nitrogen has been found to both increase and decrease after fire. However, Alhgren and Ahlgren (1960) report that the biological processes which restore available nitrogen increase. They report that the ammonification process is less, while the nitrification process is increased. They report that there was a large increase in the growth of legumes following fire. In this study, the growth of Lathyrus spp. and Vicia americana increased greatly with burning. Odum (1971) reported that species in the family Leguminosae tend to grow well following a fire. In Alberta, phosphorus is the limiting nutrient for growth in cultivated legumes (Anon., 1972). Ehrenreich and Aikman (1963) report that the amount of phosphorus in the surface layers following a fire is dependent on the quantity of vegetation burning. There was approximately 16,000 kg/ha of fuel consumed in the community in the spring, 1971 burned treatment. Thus, it appears that there was probably sufficient phosphorus available for the growth of legumes.

The canopy coverage of annuals increased greatly in the Symphoricarpos community in the first growing season following fire in the spring, 1970 and 1971 burned treatments. In the 1970 spring burn, however, the canopy coverage of annuals declined during the second growing season. In Oregon, West and Chilcote (1968) report that, Senecio sylvaticus, an annual, increased greatly during the first growing season following a fire and then declined They report that the increase in Senecio was a response to increased nutrients being available for plant growth. Trabaud (1970), in the mediterranean region of Europe, reported that annuals were greater in abundance after burning, although the pre-fire vegetation was composed mostly of

perennials. Thus, the increase in annuals was probably a response to an increased quantity of soluble nutrients immediately available for plant growth.

The canopy coverage and stem density of Rubus strigosus increased in the spring, 1971 burned treatment. Wright (1971b) reported that Rubus spp. tend to be a fire following species as it increases dramatically following fire and then decreases during subsequent years. Bailey and Poulton (1968) report that Rubus spp. were common in most plant communities after the Tillamook burn in northwestern Oregon. Ahlgren and Ahlgren (1960) report, from several sources in Europe, that Rubus idaeus increases following fire. They also report that Rubus idaeus requires and accumulates very large quantities of nitrates in its tissues. An increase in nutrients available for plant growth has been reported (Ahlgren and Ahlgren, 1960; Vlamis and Gowans, 1961a; Vlamis and Gowans, 1961b). Therefore, the increase in abundance of Rubus strigosus appears to be a result of increased nutrients available for growth. The canopy coverage and stem density of Rubus strigosus increased during the second growing season in the unburned treatment adjacent to the spring, 1970 burned treatment. The increase in abundance of Rubus strigosus probably resulted from a disruption of the normal canopy coverage of dead woody stems when permanent plots were set out and when canopy coverage was measured allowing more light to reach the soil surface. This would probably also result in an increased soil temperature in the early spring (Geiger, 1966). Therefore, the response of Rubus strigosus to fire is probably a result of an increase in soluble nutrients and the removal of old stems of Symphoricarpos occidentalis.

Livestock would readily eat most forbs found in the Symphoricarpos

community in the spring, 1971 burn treatment. Rubus strigosus is readily eaten by livestock as well (Bailey, 1972). In addition, the burned Symphoricarpos community would be more accessible to livestock. In unburned stands, the standing live and dead stems act as a barrier to grazing animals. Therefore, more forage would be available for livestock in burned areas and forage produced in these areas would be more readily accessible.

C. Relationship of burning to range management

At Kinsella, cattle preferred forage in the burned areas to the unburned areas when they were turned into the study area in the fall, 1971. In the grassland, burning did not reduce yields in the Festuca-Stipa community but it increased the palatability because of the lack of litter and possibly more nutrients were present in the forage (Vallentine, 1971). Wroe (1971) reported that, in the Stettler, Alberta area, north-facing slopes were not as readily grazed as were south-facing slopes and that, using moderate stocking rates, the south-facing slopes would deteriorate while the north-facing slopes would remain in excellent condition. Burning the north-facing slope would increase their palatability and, hence, their use. In shrubland areas, more forage was available to grazing animals in burned areas. There was an increase in the number and canopy coverage of species in the burned Symphoricarpos community, most of which were readily eaten by livestock. Burning improved the accessibility to grazing animals in areas of shrubland and forest where Symphoricarpos occidentalis, Rosa acicularis and Rosa woodsii were present. In addition, suckers of Populus tremuloides in the burned forest were readily browsed by cattle. Therefore, the grazing use of forest and shrubland areas would be increased, decreasing the use on the grasslands, and, consequently, improving the overall distribution of cattle on these ranges.

SUMMARY AND CONCLUSIONS

The effect of fire was studied in a grassland and a shrubland community. The two communities differed in their response to fire.

Maximum temperatures measured in the Symphoricarpos occidentalis community, during the spring, 1971 fire, averaged 500°F higher than maximum temperatures measured in the Festuca scabrella-Stipa spartea var. curtiseta community. Fuel weights in the Festuca-Stipa community averaged 3,500 kg/ha and in the Symphoricarpos community averaged 16,000 kg/ha. The difference in maximum temperatures between the two communities were attributed mainly to a four fold difference in fuel weights. In headfires, the maximum mean temperature of 424°F in the Festuca-Stipa community occurred at a height of about 15 cm while in the Symphoricarpos community, the maximum mean temperature averaged 1,090°F at a height ranging from 8 to 20 cm. In backfires, the maximum mean temperature of 290°F occurred at a height of 5 cm in the Festuca-Stipa community while in the Symphoricarpos community, the maximum mean temperature of 791°F occurred at a height of 8 cm. Differences in maximum temperatures between headfired and backfired areas were attributed to wind.

Total canopy coverage was two to three fold greater in the Festuca-Stipa community than in the Symphoricarpos community in both burned and unburned areas. In the Festuca-Stipa community, total canopy coverage did not differ among the treatments. In both the fall, 1970 and spring, 1971 burning treatments, the canopy coverage of grasses and grass-likes decreased but there was a corresponding increase in the canopy coverage of perennial forbs. In the burned areas, the increase in forb canopy coverage can probably be attributed to an increase in the

quantity and availability of plant nutrients. During the second year after the spring, 1970 burn, total canopy coverage was 23 per cent greater in the burned and nine per cent greater in the unburned treatments than during the first year. In the Symphoricarpos community, in the spring burn, total canopy coverage was 53 per cent greater, while that of shrubs was 24 per cent greater. The canopy coverage of annual and perennial forbs was 1,060 per cent greater with spring burning. The increase in forb canopy coverage can probably be attributed to an increase in the quantity and availability of plant nutrients from burning. However, the canopy coverage of annual forbs decreased eight per cent during the second growing season, but perennial forbs increased 10 per cent.

The major species in each community responded differently to burning. In the Festuca-Stipa community, fall burning decreased the canopy coverage of Stipa spartea var. curtiseta eight per cent and Festuca scabrella six per cent. These reductions were likely caused by spring frosts which kill the unprotected young growth. Fall burning reduced the density of seed heads of Stipa spartea var. curtiseta by 77 per cent while the density of seed heads of Festuca scabrella increased three per cent. Spring burning decreased the canopy coverage and density of seed heads of Festuca scabrella by 26 and 97 per cent, respectively; the canopy coverage of Stipa spartea var. curtiseta was reduced by two per cent and the density of seed heads not at all. This difference was attributed to a greater growth of the apical shoots and leaf growing points by Festuca scabrella which was killed by the spring fire. The differences in response to fire by Festuca scabrella and Stipa spartea var. curtiseta were related to responses of other Gramineae

species to fire. It appears that Gramineae adapted to drier conditions were least affected by burning.

In the first year after burning, the mean annual herbage yield, measured in the Festuca-Stipa community among the unburned (1180 kg/ha), fall, 1970 burned (1145 kg/ha) and spring, 1971 burned (1365 kg/ha) treatments, was significantly different. Therefore, the reduction in yield by species reduced by burning must have been compensated for by an increase in production from species not affected or increased by burning.

In the Symphoricarpos community, the canopy coverage of Symphoricarpos occidentalis decreased 10 per cent in the spring, 1971 burned treatment but its stem density increased 364 per cent. The large increase in stem density was attributed to the removal from apical dominance of the deep rhizomes. In the spring, 1971 burned treatment, there was an increase in the number and canopy coverage of species readily eaten by livestock. In addition, the barrier effect that the dead stems of Symphoricarpos occidentalis may have were removed by burning. Thus, more forage would be available and would be accessible in burned Symphoricarpos communities; therefore, burned Symphoricarpos communities would be more heavily utilized by livestock.

Burning increased the palatability of burned grassland, shrubland and forest areas because of the reduction in litter and possibly an increase in the nutrient content of the forage. This suggests that the distribution of livestock on range lands may be improved by burning underutilized areas.

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Appendix 1.

Monthly precipitation (inches) recorded at
Kinsella, Alberta from 1962 to 1971.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total Annual
1962	n/r[1]	0.99	0.0	0.0	1.91	2.87	5.94	n/r	0.91	0.50	0.61	0.39	14.12
1963	0.11	2.75	0.92	n/r	0.97	4.79	5.18	1.83	0.34	0.07	0.52	0.0	17.48
1964	1.03	0.0	0.30	0.62	2.57	0.33	2.47	1.63	2.93	0.47	0.17	0.0	12.52
1965	0.0	0.0	0.0	0.0	3.34	n/r	2.01	2.27	0.85	0.0	0.54	0.58	9.95
1966	1.02	0.31	0.20	0.05	0.74	0.72	1.71	4.98	0.46	0.05	0.69	0.34	11.27
1967	0.32	0.15	0.79	0.40	1.31	2.73	1.76	1.10	0.08	1.37	1.38	1.15	12.54
1968	0.98	0.25	1.01	0.95	1.63	2.50	2.96	2.52	3.58	0.73	0.05	0.80	17.96
1969	2.55	0.72	0.28	0.95	1.46	0.26	3.85	0.63	3.00	0.30	0.78	1.42	16.20
1970	0.57	0.45	1.10	0.18	1.74	3.21	5.79	0.73	0.69	1.17	0.95	0.84	17.42
1971	1.15	0.72	0.59	0.09	0.60	2.56	3.46	0.38	0.43	0.71	0.91	0.74	12.34
Mean	0.86	0.63	0.52	0.52	1.63	1.65	3.51	1.61	1.32	0.54	0.66	0.63	14.32[2]

[1] No record

[2] Only the years with complete records were used to calculate the mean

Appendix 2. Construction of temperature cards.

The temperature cards were constructed using two 4 x 4 x 1/16 inch sheets of asbestos board and one 4 x 4 x 0.01 inch sheet of mica. For cards to be used in the Festuca-Stipa community, two rows (1/2 inch apart) of five holes (9/32 inch diameter holes 1/2 inch apart) were drilled in one sheet of asbestos board. The holes were drilled such that when the card was placed in the vertical position, there was a one inch border on the left and right side of the card. Temperature indicating pellets used melted at the specific temperatures of 150, 200, 250, 300, 350, 450, 500, 550 and 650 ^{o}F. The pellet which would melt at the lowest temperature was placed in the hole at the bottom left hand corner of each card. The pellets were placed in order of ascending temperatures from left to right. One sheet of asbestos without holes was placed under the sheet of asbestos having the holes. Temperature pellets were installed and a sheet of mica was placed on top. The cards were then stapled together.

The temperature cards used in the Symphoricarpos occidentalis community were constructed like those above except that three rows of holes ($\frac{1}{2}$ inch apart) were used with the middle row of holes lying at the vertical mid-point of the asbestos sheet. Temperature indicating pellets used were 350, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 1000, 1100, and 1200 ^{o}F. The cards were assembled and stapled in a similar manner to the cards used in the Festuca-Stipa community.

Appendix 3. Mean frequency (%) and mean canopy coverage (%) of species in the Festuca-Stipa community in fall, 1970 and spring, 1971 burns.

Species	Frequency			Canopy Coverage		
	Unburned (n=175)	Fall Burned (n=175)	Spring Burned (n=175)	Unburned (n=175)	Fall Burned (n=175)	Spring Burned (n=175)
Festuca scabrella	100	100	100	84a[1]	79b	62c
Helictotrichon hookeri	56	52	68	18a	6b	1b
Agrostis scabra	8	4	9	1	2	#
Artemisia frigida	26	3	2	2.6a	#b	#b
Potentilla spp.	15	2	2	1	#	#
Carex spp.	100	100	100	54a	55a	44b
Antennaria nitida	11	13	9	2	1	
Stipa spartea var. curtiseta	100	100	100	86	79	84
Agropyron spp.[2]	31	34	57	6	4	8
Astragalus spp.[3]	32	77	60	4	12	11
Geum triflorum	7	62	58	1a	11b	10b
Campanula rotundifolia	1	21	39	#	2	2
Thermopsis rhombifolia	6	27	38	#	4	5
Viola spp.[4]	3	43	58	#	3	5
Aster spp.[5]	13	46	55	1	3	6
Rosa arkansana	26	33	38	2	3	5
Achillea millefolium	15	24	50	1b	2b	4a
Artemisia ludoviciana var. gnaphloides	10	26	24	1	2	3
Cerastium arvense	14	23	10	1	2	#
Commandra pallida	34	51	51	3	3	3
Lappula redowski	0	7	1	0a	1b	#a
Fragaria virginiana var. glauca	0	1	9	0a	a	1b
Anemone pattens var. wolfgangiana	59	61	57	7	7	8
Taraxacum officinale	2	8	6	#	1	1
Galium boreale	1	3	3	#	#	#
Erigeron spp.[6]	1	2	2	#	#	#

Appendix 3. (Cont.)

Species	Unburned (n=175)	Fall Burned (n=175)	Spring Burned (n=175)	Unburned (n=175)	Fall Burned (n=175)	Spring Burned (n=175)
Sisyrinchium montanum	1	3	1	#	#	#
Poa spp.	2	1	2	#	#	#
Anemone canadensis	0	1	1	0	#	#
Danthonia intermedia	2	3	0	#	1	0
Hedysarum alpinum var. americanum	1	1	0	#	#	0
Festuca saximontana	2	0	1	#	0	#
Gutierrezia sarothrae	1	0	1	#	0	#
Thalictrum venulosum	0	1	0	0	#	0
Androsace septentrionalis	7	0	0	1	0	0
Bouteloua gracilis	2	0	0	1	0	0
Haplopappus spinulosus	2	0	0	#	0	0
Phlox hoodi	1	0	0	#	0	0
Elaeagnus commutata	1	0	0	#	0	0

#Mean canopy coverage was 0.5 per cent or less

[1] Canopy coverage values followed by a common letter a,b,c do not differ significantly at the 0.05 level

[2] Mostly *Agropyron subsecundum* and *A. trachycaulum*

[3] Mostly *Astragalus agrestus*, *A. flexuosus*, and *A. striatus*

[4] Mostly *Viola adunca*

[5] Mostly Aster *laevis* var. *geyeri*

[6] Mostly *Erigeron caespitosus*

Appendix 4. Mean frequency (%) and mean canopy coverage (%) of species in the *Festuca-Stipa* community in the spring, 1970 burn during the 1970 (year 1) and the 1971 (year 2) growing seasons.

Species	Frequency				Canopy Coverage			
	Unburned (n=30)		Spring Burned (n=34)		Unburned (n=30)		Spring Burned (n=34)	
	1970	1971	1970	1971	1970	1971	1970	1971
Helictotrichon hookeri	27	20	21	9	3	1	2	1
Festuca scabrella	100	100	100	100	92	85	36	59
Carex spp.	100	100	100	100	68	55	65	72
Stipa spartea var. curtiseta	100	100	100	100	87	90	87	90
Aster spp.	27	37	80	91	2	5	16	20
Comandra pallida	43	63	68	62	2	7	5	9
Anemone patens var. wolfgangiana	7	30	32	35	#	3	2	5
Achillea millefolium	10	10	26	32	1	3	3	6
Antennaria nitida	7	7	21	12	1	2	5	7
Agropyron spp.[1]	53	70	35	32	18	26	8	10
Elaeagnus commutata	83	93	29	38	20	29	5	6
Rosa arkansana	50	57	53	50	6	11	9	10
Solidago spp.[2]	13	30	3	24	#	5	#	2
Agrostis scabra	3	17	3	15	#	1	#	1
Astragalus spp.[3]	23	27	15	15	4	8	2	2
Viola spp.[4]	17	20	38	24	1	2	3	3
Artemisia ludoviciana var. gnaphloides	3	3	26	29	#	#	2	4
Sisyrichium montanum	3	13	0	26	#	1	0	2
Thermopsis rhombifolia	3	0	35	35	#	0	2	5
Geum triflorum	0	10	9	12	0	#	2	4
Galium boreale	0	7	0	3	0	#	0	#
Campanula rotundifolia	7	0	6	0	#	0	#	0
Axyris amaranthoides	3	0	0	3	#	0	0	#
Symphoricarpos occidentalis	13	17	0	0	2	4	0	0
Androsace septentrionalis	3	17	0	0	#	2	0	0

Appendix 4. (cont.)

Species	Frequency				Canopy Coverage			
	Unburned		Spring Burned		Unburned		Spring Burned	
	1970	1971	1970	1971	1970	1971	1970	1971
Phlox hoodii	0	7	0	0	0	2	0	0
Amelanchier alnifolia	0	#	0	0	0	#	0	0
Thalictrum venulosum	0	7	0	0	0	#	0	0
Poa spp.	17	17	0	0	2	2	0	0
Potentilla spp.[5]	3	3	0	0	#	#	0	0
Populus tremuloides	0	0	3	3	0	0	#	#
Koeleria cristata	10	0	15	3	#	0	#	#
Selaginella densa	17	0	0	0	6	0	0	0
Bromus gracilis	0	0	12	0	0	0	1	0
Bromus anomalus	0	0	3	0	0	0	#	0
Bromus ciliatus	0	0	6	0	0	0	#	0
Fragaria virginiana var. glauca	0	0	3	0	0	0	#	0
Festuca saximontana	0	0	0	3	0	0	0	#

[#] Mean canopy coverage was 0.5 per cent or less

[1] Mostly Agropyron subsecundum and A. trachycaulum

[2] Mostly Solidago decumbens

[3] Mostly Astragalus agrestis, A. flexuosus and A. striatus

[4] Mostly Viola adunca

[5] Mostly Potentilla gracilis

Appendix 5. Mean frequency (%) and mean canopy coverage (%) of species in the Symphoricarpos community in spring, 1971 burn.

Species	Frequency		Canopy Coverage	
	Unburned (n=125)	Burned (n=125)	Unburned (n=125)	Burned (n=125)
Rosa spp.[1]	14	15	2	2
Viola spp.[2]	12	9	1	1
Epilobium angustifolium	5	3	1	1
Symphoricarpos occidentalis	99	100	87	78
Carex spp.	38	7	5	#*
Elaeagnus commutata	18	1	5	#
Cerastium arvense	7	2	1	#
Agropyron spp.[3]	18	0	2	0
Thalictrum venulosum	2	0	#	0
Bromus ciliatus	2	0	#	0
Lappula redowski	4	0	#	0
Prunus virginiana	2	0	#	0
Poa spp.	1	0	#	0
Ribes sp.	1	6	#	1
Polygonum convolvulus	1	7	#	1
Galium boreale	7	22	#	4*
Vicia americana	5	47	1	15*
Rubus strigosus	0	82	0	32*
Stachys palustris var. pilosa	0	72	0	18*
Lathyrus spp.[4]	0	12	0	2
Chenopodium album	0	6	0	1
Potentilla spp.[5]	0	1	0	#
Taraxacum officinale	0	2	0	#
Populus tremuloides	0	2	0	#

*Mean percent canopy coverage was significantly different at the 0.05 level

#Mean canopy coverage was 0.5 per cent or less

[1] Includes Rosa woodsii and R. acicularis

[2] Mostly Viola adunca

[3] Mostly Agropyron subsecundum and A. trochycaulum

[4] Includes Lathyrus ochroleucus and L. venosus var. intonsus

[5] Mostly Potentilla gracilis

Appendix 6. Mean frequency (%) and mean canopy coverage (%) in the *Symphoricarpos* community in the spring, 1970 burn between the 1970 (year 1) and the 1971 (year 2) growing seasons.

Species	Frequency				Canopy Coverage			
	Unburned		Spring Burned		Unburned		Spring Burned	
	1970 (n=23)	1971 (n=23)	1970 (n=28)	1971 (n=28)	1970 (n=23)	1971 (n=23)	1970 (n=28)	1971 (n=28)
Symphoricarpos occidentalis	100	100	100	100	92	89	94	88
Cerastium arvense	4	0	25	11	1	0	5	2
Aster spp.[1]	4	0	25	7	#	0	4	1
Carex spp.	30	52	54	50	7	12	14	25
Rubus strigosus	48	67	61	75	7	23	15	22
Ribes	4	9	7	11	#	1	4	5
Galium boreale	0	22	29	32	0	2	8	9
Calamagrostis neglecta	17	4	32	25	5	1	12	16
Bromus ciliatus	9	9	7	7	1	#	2	4
Cirsium undulatum	4	4	4	4	1	#	1	3
Muhlenbergia cuspidata	4	0	7	7	1	0	1	4
Agropyron spp.[2]	36	44	18	18	6	6	4	5
Viola spp.[3]	9	4	11	21	1	1	1	2
Rosa spp.[4]	4	4	4	4	1	1	1	1
Artemisia ludoviciana var. gnaphloides	0	0	29	43	0	0	9	11
Festuca scabrella	0	0	7	7	0	0	4	4
Stipa spartea var. curtiseta	0	0	7	7	0	0	4	4
Lappula redowski	0	0	7	18	0	0	1	2
Thalictrum venulosum	0	0	4	11	0	0	1	2
Achillea millefolium	0	0	7	7	0	0	#	#
Solidago	0	0	4	4	0	0	#	#
Chenopodium album	0	0	57	11	0	0	8	#
Thlaspi arvense	0	0	11	0	0	0	4	0
Polygonum convolvulus	0	0	18	0	0	0	2	0

Appendix 6. (cont.)

Species	Frequency				Canopy Coverage			
	Unburned		Spring Burned		Unburned		Spring Burned	
	1970 (n=23)	1971 (n=23)	1970 (n=28)	1971 (n=28)	1970 (n=23)	1971 (n=23)	1970 (n=28)	1971 (n=28)
Crucifera	0	0	0	18	0	0	0	2
Fragaria virginiana var. glauca	0	0	0	4	0	0	0	1
Vicia americana	0	0	0	4	0	0	0	#
Poa spp.	0	4	0	4	0	#	0	#
Gaillardia aristata	17	0	0	0	3	0	0	0

#Mean canopy coverage was 0.5 per cent or less

[1]Mostly _Aster_ _laevis_ var. _geyeri_

[2]Mostly _Agropyron_ _subsecundum_ and _A_. _trachycaulum_

[3]Mostly _Viola_ _adunca_

[4]Includes _Rosa_ _woodsii_ and _R_. _acicularis_

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