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Effect of Burning and Mowing on *Festuca hallii* (Vasey) Piper (*Festuca scabrella* Torr.)

University — Université

UNIVERSITY OF ALBERTA

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

M. Sc.

Year this degree conferred — Année d'obtention de ce grade

1980

Name of Supervisor — Nom du directeur de thèse

DR. A. W. BAILEY

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[illegible]

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"Effect of Burning and Mowing on <u>Festuca hallii</u> (Vasey) Piper (<u>Festuca scabrella</u> Torr.)"

by

 Heather M. M. Sinton

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

IN

Range Management

Plant Science

EDMONTON, ALBERTA

1980

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Effect of Burning and Mowing on Festuca hallii (Vasey) Piper (Festuca scabrella Torr.)" submitted by H. M. Sinton in partial fulfilment of the requirements for the degree of Master of Science in Range Management.

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Supervisor

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Date ....October 16, 1980.........

ABSTRACT

A study was conducted in the east-central Alberta aspen parkland to determine the effects of burning and mowing on Festuca hallii (Vasey) Piper at different stages of its growth. Two- by three-metre plots of an undisturbed, nearly pure F. hallii grassland were subjected to three treatments: burning, mowing with herbage removal and no disturbance (control). A split-plot design was used with eight replications. Treatments were administered on five dates in 1978: April 8, April 27, June 1, July 31 and October 18.

Herbage yields of F. hallii were reduced in the first growing season following burning or mowing at any date. The two treatments produced similar responses. Reduced yields were a function of shorter leaf and sheath lengths. Increased light intensity brought about by litter and herbage removal was thought to be the major cause of this response. The number of tillers bearing three and four leaves increased in the first growing season following treatment. Total tiller density and density of one-leaved tillers increased in the first year following the July and October treatments; and in the second year for the remaining three treatment dates. New tillers were formed predominantly in the fall, and to a lesser extent in the spring.

In 1979, herbage yields increased on untreated areas by 16 to 29% over 1978 yields. In the second year, plots treated on April 8 produced yields exceeding those of controls by 10 to 13%. Yields on plots treated on April 27

were 8% lower than control yields, while yields on plots treated on June 1 were 18% lower than yields on control plots. The recovery of productivity was partially attributed to recovering leaf and sheath lengths.

Growth rates on all treated plots were lower than those on control plots during a monitored two week period in June, 1979. Basal area of live *F. hallii* remained unaffected by treatment, with the exception of burning in October. Production of *F. hallii* inflorescences was not influenced in the first growing season following any treatment. In the second year, density of inflorescences on treated plots increased four- to seven-fold over controls.

Daytime soil temperatures during the growing season were consistently higher on denuded plots than on controls, one and two years after treatment. Temperatures on burned plots were 1 to 2°C higher than on mowed plots. This effect largely disappeared in the second year.

Burning produced the same morphological effects on *F. hallii* as mowing in this study. It was, therefore, concluded that the short-term effects of burning in undisturbed *F. hallii* grassland were related primarily to herbage and litter removal rather than to the direct effect of heat from the fire or the indirect effect of fertilization by ash.

ACKNOWLEDGEMENTS

I would like to thank Terry Gerling, my husband, for his patience, encouragement and assistance during the course of this study. His help during the data collection of 1979 was invaluable. He also gave of his time and skill in the production of the graphs in this manuscript.

I am grateful to Bill Trabysh, Calvin Duane, Dr. A. W. Bailey, Mary-Jane Davies, Lorne Cole, and Dennis Holowaychuk for their assistance in setting up the experiment and administering the treatments. Special thanks goes to Calvin Duane who spent many hours in the sun and rain, helping me to collect the 1978 data. I would also like to extend special thanks to Sydney Hamilton and Lynne Robertson, who contributed their typing skills at times which were not always convenient to themselves. I am grateful too for the assistance of Brian Pinchbeck. He was never too busy to lend a hand in unravelling a new mystery in computer programming.

I thank my supervisor, Dr. A. W. Bailey, for his direction and moral support. His encouragement during periods of "rough sailing" was much appreciated. I also thank Dr. W. VandenBorn and Dr. P. Woodard for their advice and their participation as committee members. Lastly, I would like to extend thanks to Dr. A. Clark who took the time to read this thesis and to participate in the defense examination. Her comments and suggestions were most helpful.

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1. INTRODUCTION

Festuca hallii (Vasey) Piper[1], is the dominant native grass on rangelands of east-central Alberta (Figure 1). It was grouped until recently with Festuca doreana Loom. of southwestern Alberta, forming what was known as the Festuca scabrella Torr. association. F. hallii grasslands are becoming restricted to small areas because of the expansion of Populus tremuloides Michx. forests. If F. hallii rangelands are to be preserved, this tree encroachment has to be curtailed. Various control measures have been implemented, including: use of herbicides, mechanical removal of trees, burning and grazing of young stems. There has been renewed interest in the use of fire as a management tool in recent years. It has the advantages of being economical and quick. It also has potential as a means of sanitation and fertilization. Since the objective of P. tremuloides control also involves the preservation of F. hallii grassland, it is essential to know how burning affects this forage.

An experiment was designed to test the response of F. hallii to burning at different stages of development. A mowing treatment with herbage removal was also included in the study to separate the heat effects of the fire from the effects of defoliation. The development of a rationale for the study involved an understanding of the factors which influence the location of F. hallii and its survival. The

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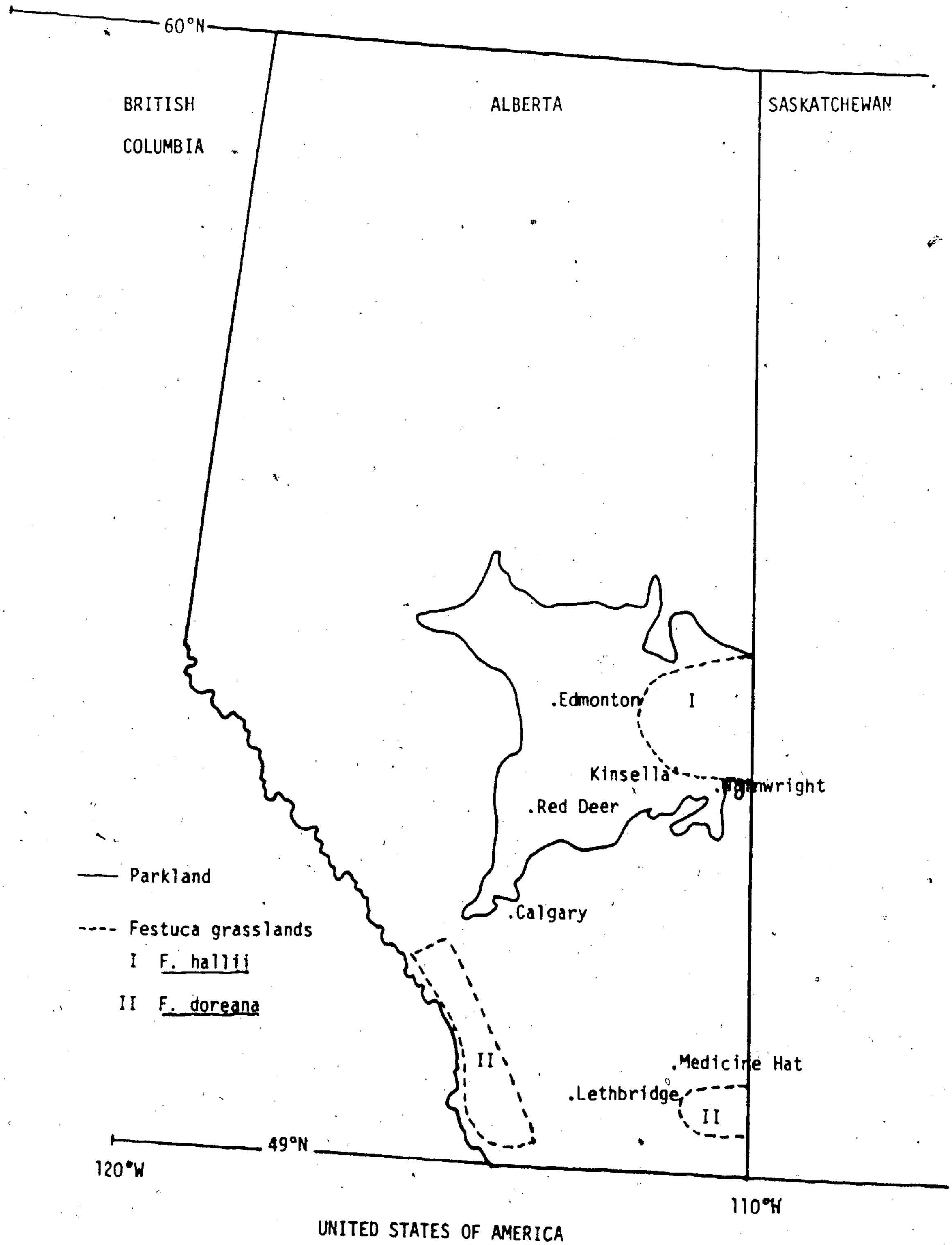
[1]Vascular plant nomenclature follows Looman and Best (1979)

Figure 1: Location of study area in relation to area of best development of Festuca hallii [Vasey] Piper and Festuca doreana Loom.



Adapted from Johnston, A. and Cosby, H.F. (1966) and Looman, J. (1969).

growth of the plant is directy affected by the physical and chemical condition in its micro-environment. This is determined by the interaction of factors including: daylength and light intensity; air and soil temperature ; soil moisture and nutrient supplies. These factors are themselves influenced by broader environmental variables such as: climate, topography and soil type . The capability of F. hallii to survive a change in its environment would be determined by its genetic composition, its stage of development at the time of disturbance and its history of use. Since it is not possible to control many variables in a field experiment, site uniformity in topography, soil type and species composition were considered to be very important (Figure 2). An undisturbed stand of F. hallii was chosen to avoid conflict with influences of past use. It could be assumed, therefore, that any homogeneous disturbance to this grassland would cause uniform changes in the micro-environment of the plant. Mowing fitted this description better than burning since the outcome of the latter is dependent upon a complex of fuel, soil and weather conditions. Because of this source of variability, detailed records of fuel and weather variables were kept at the time of each treatment.

The study was concentrated on measurements of plant response to treatment rather than on measurement of the changes in the micro-environment which caused the response. It was thought that this would provide basic information

Figure 2: Experimental site before treatment (April, 1978).
Foreground: Festuca hallii (Vasey)Piper
Background: Populus tremuloides Michx. forest

which could, if desired, be extended at a later date. Since tillers act independently of each other, they were considered to be the functional units of the plant. Many measurements were, therefore, made on a per tiller basis. Other more general measurements, such as herbage yield, were used to obtain an overall representation of what was happening to the stand.

The major objectives of this study can be outlined as follows:

1. to examine the effects of burning and mowing on F. hallii at different stages in the annual growth of the plant.

2. to differentiate between the effect of herbage and litter removal and the other direct effects of fire (heat and nutrient redistribution).

These objectives were realized by comparing specific measurements of plant response among treatment dates and treatments. The following parameters of the plant vigour and vitality following treatment were used for comparison:

a. tiller density,

b. leaf and sheath length,

c. rate of tiller growth,

d. basal cover,

e. herbage yield,

f. litter production,

g. density of inflorescences.

2. DESCRIPTION OF THE STUDY AREA

Experimental plots were located on the University of Alberta Ranch, 154 km south-east of Edmonton, Alberta. Specifically, they were on the north-west quarter of section 33, township 46, range 11, west of the fourth meridian.

The ranch lies on part of the Viking moraine, which was formed during the recession of Keewatin glaciation almost 15,000 years ago. The till of the hummocky disintegration morraine contains a high percentage of medium and coarse sand. As a result, the soils developed from this parent material are of a medium loam texture. Chernozemic soils occur under the grasslands and Gleysolic soils are found in the depressions of moderate to strongly rolling topography. This is referred to locally as "Knob and Kettle" topography. Dark Brown Chernozems are found on hilltops and these grade into Black Chernozems at the mid-slope position.

The alkaline condition of many of the sloughs in the area can be attributed to the brackish water origin of the underlying bedrock. Wyatt et al. (1944) classified this bedrock in the pale beds division. It consists of sandstones interbedded with greenish shales and thin coal seams. Saline sloughs tend to be located in the lowest topographic positions, indicating that they are terminal drainage basins for the numerous less brackish sloughs found at higher elevations.

Trewartha (1968) classified the climate of the area as humid microthermal with cool summers (Dfb). According to

Wonders (1969), the University Ranch would lie within the dry subhumid zone of Alberta with an average potential evapotranspiration of 51.0 - 56.0 cm of water and an average actual evapotranspiration of 35.5 - 40.5 cm. Average annual precipitation for the area is 38 cm per year; about 67 per cent of this falls during the growing season from May to September and 50 per cent during June, July and August. Precipitation patterns for 1977-79 are presented in Table 1. The coldest month is January, the mean monthly minimum temperature being -23°C, and the mean monthly maximum being -13°C. July is the warmest month, maximums averaging 19°C and minimums 8°C. Mean maximum, minimum, and mean monthly temperatures for 1977-79 are presented in Table 2. Prevailing winds are from the west and northwest (Wyatt et al. 1944).

The vegetation in the study area is aspen parkland as described by Moss (1955). Clones of *Populus tremuloides* are predominant with small areas of grassland, characterized by the *Festuca scabrella* association (Moss and Campbell 1947). *Populus tremuloides* has been calculated to be invading the grasslands at a rate of 7.6 m/km/year (Scheffler 1976).

Ungrazed upper slopes in the grassland are dominated by *Stipa spartea* var. *curtiseta* Hitchc. Subdominants in this community include: *Artemisia ludoviciana* Nutt. *Rosa arkansana* Porter and *Aster* spp. Grazing of slopes and hilltops results in a shift toward vegetation more adapted to dry edaphic conditions (Johnston 1962). The dominant

Table 1: Monthly precipitation (mm) recorded at Kinsella, Alberta 1977-1979.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Ppt. for Growing Season Apr-Sep	Total Yearly Ppt.
1977	27.9	1.3	1.0	17.8	129.0	23.9	65.0	30.5	51.8	5.1	2.5	30.5	318.0	386.3
1978	40.6	12.7	2.5	30.5	78.7	52.3	45.7	79.7	83.8	33.0	20.3	27.9	370.7	507.7
1979	10.6	28.3	13.6	42.6	11.0	46.5	120.3	34.7	55.0	4.2	3.7	9.5	310.1	380.0

Table 2: Mean maximum, mean minimum and mean monthly temperatures(°C), for the growing season (April-September) at Kinsella, Alberta

Year	April			May			June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1977	14.5	2.6	8.5	16.0	7.1	11.6	20.2	10.3	15.2	20.0	11.3	15.6	19.2	8.0	13.6	13.3	5.6	9.5
1978	7.7	0.2	3.9	15.8	6.6	11.2	21.4	11.3	16.4	23.0	12.2	17.6	24.8	8.8	16.8	16.1	5.8	10.9
1979	4.0	-3.5	0.2	14.4	4.4	9.4	20.1	9.9	15.0	23.1	12.8	17.9	22.3	10.4	16.4	17.9	6.9	12.4
Long-term means (1962-1979):	8.0	-0.5	3.9	15.8	5.9	10.8	20.0	10.9	15.4	22.5	13.3	17.9	21.4	10.5	16.0	16.6	6.3	11.6

plant species would then include: *Bouteloua gracilis* (HBK) Lag., *Carex heliofila* Mack./*C. filifolia* Nutt. and *Artemisia frigida* Willd. Subdominants in this community would include: *Agropyron dasystachyum* (Hook.) Scribn., *Koeleria cristata* (L.) Pers. and *Anemone patens* L.

The wettest soil profiles in the grassland favour the growth of *Agropyron subsecundum* (Link) Hitchc. This species is most common in lower slope positions where water discharge is evident. Conditions are often moist enough that shrubs are present: *Symphoricarpos occidentalis* Hook. is the most prevalent.

3. LITERATURE REVIEW

3.1 Festuca scabrella Torr.

3.1.1 History of the Association

Moss (1932) was the first to describe Festuca scabrella as one of the chief dominants in the grassland of central Alberta. Prior to this, Macoun (1882) mentioned "Northern Buffalo grass" (Stipa spartea var. curtiseta) as the dominant grass of the region. Clements and Clements (1939) mentioned F. scabrella as an important grass in what they called the 'submontane' type of mixed prairie, found in Central Alberta and Saskatchewan. In his 1944 paper, Moss recognized a Festuca - Danthonia association for a limited area in south-west Alberta. Fescue grasslands in Saskatchewan were studied by Coupland and Brayshaw (1953). They proposed the "Festuca scabrella association" as the 7th North American grassland formation. In 1947, Tisdale described an 'Agropyron - Festuca zone' in the southern interior of British Columbia, occurring at altitudes of over 860 m. Bird (1961) mentioned the occurrence of small areas of fescue prairie in Saskatchewan but did not include it in the grassland types of Manitoba.

Looman (1969) examined the Fescue Grasslands of Western Canada and classified the association according to the Zurich-Montpellier method. Wroe (1971) suggested that the late recognition of the Fescue Grassland may have paralleled its recent development.

3.1.2 Identification

Festuca scabrella owes its name to the scabrous nature of the ventral surface and margins of its leaves. Moss (1959) described the species as follows:

> "densely tufted, often as large tussocks, (30-60 cm in diameter) these enlarging by short rhizomes; culms coarse, 3-9 dm high; basal leaves firm, scabrous, involute, erect; old basal sheaths long persistent, their blades early disarticulating, panicle 5-15 cm long, the branches appressed or ascending, the spikelets toward the tips; spikelets elliptic or ovate; glumes scarious, lustrous, somewhat unequal, 5-9 mm long, lemmas firm, 7-10 mm long, scabrous, 5-nerved, the midnerve forming a keel upwards; closely related to *F. altiaca* Trin. and often classified with it."

Hitchcock et al. (1969) described the spikelets of *Festuca scabrella* as being 4 to 6 flowered. They also mentioned a variety, *F. scabrella var. major* Vasey, on which the culms are, on the average, taller; the panicle larger and more spreading and the lemmas more strongly nerved. This variety has been found on hills and in dry woods in Michigan, and west from Montana to Washington.

Johnston and Cosby (1966) reported that their observations indicated many deviations from the published taxonomic features of rough fescue, especially the rhizomatous character. They suggested that under drier edaphic conditions, F. scabrella tended to assume a bunch habit, while in moister situations and on favorable soils, the rhizomatous form was favored. It is the latter form of F. scabrella which is found in the study area at Kinsella, Alberta.

Bowden (1960) found that the chromosome numbers in F. scabrella varied. Collections made in southern Alberta were found to be octaploid (2n=56). These specimens were designated by Bowden (1960) as F. scabrella var. major. Other collections, some of which were taken from northern Quebec, were found to be tetraploid (2n=28).

Looman and Best (1979) only mentioned F. scabrella as a sub-species of F. altaica, which was northern rough fescue. F. scabrella, as defined by Moss (1959) was stratified in Looman and Best (1979) into two species, F. hallii and F. doreana.

F. hallii was described by Looman and Best (1979) as a tufted grass having fibrous roots and often bearing rhizomes. The culms were 20-60 cm high and glabrous, as are the leaf sheaths. The blades were 1-1.5 mm wide and involute; gray-green in colour and sparsely short pubescent. The inflorescences were 6-15 cm long and are open to contracted at flowering. The spikelets had 2-3 florets and the third floret was infertile. Glumes were membranous and often diffused with purple. The lemmas were 7-8 mm long and were 5 nerved. They were scabrous, especially on the margins and often diffused with purple. This species was distributed through the parkland prairie and Cypress Hills, as well as in the Wood Mountain area (Looman and Best 1979).

F. doreana formed large tussocks and had a fibrous root system, but no rhizomes (Looman and Best 1979). The culms were 40-120 cm high, stout and glabrous. The blades were 2-4 mm wide; 7 nerved and sparsely short pubescent. They could be flat or involute. The inflorescences were open to somewhat contracted at anthesis. Spikelets were 11-16 mm long and 3-6 flowered. The glumes were 3 nerved and the lemmas were 5 nerved. The latter were glabrous to scabrous, and occasionally diffused with purple. *F. doreana* is found in the southern Rocky mountains and foothills (Looman and Best 1979). A synonym for the species has been *F. scabrella* var. *major* Vasey.

The species found on the University of Alberta ranch, Kinsella, Alberta fits the description for *F. hallii* in all respects except one. The leaf blades were scabrous rather than sparsely short pubescent. Looman[2] confirmed the identification as *F. hallii*.

3.1.3 Range of *Festuca scabrella*

F. scabrella has been found in eastern areas where the climate is cold-temperate and sub-humid; in central areas where the climate is semi-arid and in the west where the climate is cold temperate and sub-humid (Looman 1969). Temperatures range from -40 to +40°C; the frost-free period

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[2] Looman, J. 1980. Personal communication.

from less than 90 days to 200 days; precipitation from 46-76 cm and evaporation from 38-51 cm annually (Looman 1969). This resulted in a precipitation to evaporation ratio of 0.9 to 1.2. Festuca scabrella has been found at altitudes ranging from 700 m in Manitoba to 1950 m in the Rocky Mountains and in Southern British Columbia (Looman 1969).

According to Johnston (1958), Festuca scabrella followed a distribution pattern similar to a number of arctic-alpine species. The southward and eastward movement of the species range was believed to have occurred during the last glaciation. Generally, the species has been found on Dark Brown and Black Chernozemic soils, which have a pH range of 6.6 to 7.3 and a cation exchange capacity (C.E.C.) range of 18.7-27.0 meq/100 g (50-60 percent saturated by Ca^{++}). Total potassium was high, but nitrogen and phosphorus were low, averaging 5.5 and 13 ppm respectively. Soil texture varied from fine sandy loam to clay loam over glacial till (Looman 1969).

3.1.4 Dominance Groups

In undisturbed areas, F. scabrella forms an almost pure stand. Looman (1969) reported that rough fescue averaged 25% of total density on such sites. Wroe (1971) found that F. scabrella in south-central Alberta had a canopy cover of 94.4% and represented nearly 75% of the herbage growth by weight on undisturbed hilly rangeland. Dominance groups, in which the second species averaged about 12 to 15% of the total density were common, according to Looman (1969). These combinations were a result of varying climatic and edaphic factors. Looman (1969) stated that they could be regarded as indicators of a temperature moisture gradient, existing geographically as well as locally or topographically.

3.1.4.1 Festuca scabrella Torr.-Danthonia parryi Scribn. Association

This association predominates in the southern foothills of the Rocky Mountains in Alberta. This area is the warmest and driest of the Fescue Grasslands found in Canada, and also the richest in associated species. Moss and Campbell (1947) listed 20 grasses, 3 sedges, 10 shrubs, 115 forbs and a few mosses and lichens for the area. They attributed this diversity to the close proximity of other vegetation types, and to migration from western and southern areas. The absence of many of the species north and east of the foothills region is likely an effect of glaciation, with insufficient time having elapsed to accomplish their reintroduction. It should be noted that this association only exists on light and moderately grazed uplands. Pure stands of rough fescue are found on ungrazed uplands. Festuca scabrella and Danthonia parryi are co-dominants. Moss and Campbell (1947) listed Festuca idahoensis Elmer, Stipa columbiana Macoun, Agropyron spicatum (Pursh)Scribn. and Smith, Potentilla fruticosa L., Achillea millefolium L. and Salix spp. as the subordinate species in this association. From personal observation, I would say that Festuca idahoensis and Bromus inermis appear to be the major sub-dominants at the present time. At higher elevations, this association is restricted to warm slopes or stony soils. On other soils and aspects, it is replaced by the Festuca scabrella - Danthonia intermedia association. Danthonia intermedia had great ecological versatility and probably the species was composed of ecotypes (Koterba and Habeck 1971). Major associates included: Agropyron subsecundum, Helictotrichon hookeri (Scribn.) Henr., Stipa spartea var. curtiseta and Carex spp.; Potentilla fruticosa L. and Salix spp. were the dominant shrubs.

3.1.4.2 Festuca scabrella -Stipa spartea var.curtiseta Association

Coupland and Brayshaw (1953) named this as the dominant association in the parkland region. Festuca hallii is very much the dominant grass on mesic undisturbed sites. From personal observation, I would say that Stipa is only one of many subdominants on these sites, others being: Agropyron subsecundum, Solidago spp., Cerastium spp., Agropyron dasystachyum and upland Carex spp. Stipa spartea var. curtiseta dominates on more xeric sites, along with Agropyron spp. and Bouteloua gracilis. Potentilla fruticosa is absent from the parkland. Shrubs taking its place include: Elaeagnus commutata Bernh.and Symphoricarpos occidentalis. Populus tremuloides and Salix spp. are also common. Coupland and Brayshaw (1953) stated that the _Festuca_ - _Stipa_ association of the parklands was preclimax to _Populus_ forest.

3.1.4.3 _Festuca scabrella_ -_Stipa richardsonii_ Association

This association is found in the Rocky Mountain foothills of Alberta, in the Banff - Jasper area. Stringer (1973) listed the subordinate species as: _Stipa columbiana_, _Poa alpina_ L., _Antenaria umbrinella_ Rydb., _Astragalus alpinus_ L., _Delphinium glaucum_ S. Wats. and _Calamagrostis inexpansa_ A. Gray. He also stated that this area was dominated by grassland until about 50 years ago. At that time fire protection was introduced and aspen, followed by spruce, has invaded the region.

3.1.4.4 _Festuca scabrella_ - _Agropyron spicatum_ var. _inermis_ Association

Van Ryswyk (1966) reported this association in the Fraser plateau area of British Columbia. It is found at altitudes of 490 - 825 m, under a mild form of continental climate (frost-free period 144-204 days; P:E ratio 1.7-1.9). Species commonly found as associates here include: _Zygadenus venosus_ S. Wats., _Rosa woodsii_ Lindl., _Stipa columbiana_, _Koeleria cristata_, _Geranium viscosissimum_ Fisch and Mey, _Juncus balticus_ Willd., _Delphinium bicolor_ Nutt. and _Poa pratensis_ L.

3.1.4.5 Festuca scabrella - Agropyron subsecundum and Festuca scabrella - Andropogon scoparius Michx. Associations

These associations were found in Manitoba and Wood Mountain, Saskatchewan respectively (Looman 1969). The Festuca scabrella - Agropyron subsecundum combination is also found occasionally in the lower foothills of the Rocky mountains, the Cypress Hills and the parklands. Lynch (1955) reported that Stipa spartea Trin. and Andropogon gerardi Vitman. are subdominants in the Manitoba association. In the Wood Mountain area, Danthonia intermedia, Andropogon scoparius and Lilium philadelphicum L. were found as associates (Looman 1963).

3.1.4.6 Festuca scabrella as a Sub-dominant Species

Toward the southern limits of its range in west-central and southwestern Montana, Festuca scabrella has generally been found only on higher mountain slopes (Stickney 1960). In northwestern Montana, it has often been found on river valley bottomlands (Koterba and Habeck 1971). More often, however, Festuca scabrella has occurred in communities as a sub-dominant. The eastern Washington - northern Idaho grasslands, for example, are dominated by Agropyron spicatum and Festuca idahoensis (Daubenmire 1943, 1970; Tisdale 1947). The compositional shift northward to dominance by Festuca scabrella has been attributed to increasing amounts of available moisture (Tisdale 1947). This can be a result of increased precipitation or a decrease in the percent occurrence of sandy loam soils. Redmann (1975) stated that cool-season species on fine-textured soils have the competitive advantage on these sites. The moisture conditions on fine-textured soils are most favourable early in the season and become unfavourable sooner than in the sandy sites.

3.1.5 Phenology

Johnston and MacDonald (1967) reported that F. scabrella (F. doreana) in southwestern Alberta started growth early in May, when the soil temperature at a 20 cm depth was 2°C. In 1978, I observed the rhizomatous F. hallii in the parklands to have new green growth under the snow on March 31, 1978 and a new growth of 6.5 cm was measured on April 8.

Heading of F.doreana occurred in late June when the soil temperature reaches about 12.7°C; under a daylength of about 16 hours (Johnston and MacDonald 1967). Festuca hallii in the parklands headed in early to mid June. Anthesis occurred in mid to late June. Seeds of Festuca doreana in southwestern Alberta had matured by early August. In the parklands, this happened about two weeks earlier. Plants enter winter dormancy in early October in southwestern Alberta (Johnston and MacDonald 1967). New green growth of 6.7 cm was observed on F. hallii tillers on October 8, 1978 at Kinsella, Alberta. Evans et al. (1964) reported that fescuoid species grew actively at temperatures of 15°C and below.

Reproduction of Festuca hallii in the parklands is maintained for the most part by growth of rhizomes. Festuca doreana of southwestern Alberta has only a limited ability to produce lateral tillers from axillary meristems. It, therefore, depends upon sexual reproduction to a greater extent. Johnston and MacDonald (1967) reported Festuca doreana as an erratic seed-setter, several years elapsing without any appreciable seed-set in many areas. They found that initiation of floral primordia took place in late August to early September, but were unable to determine the cause of initiation. Moss (1947) noted that the generally good heading of this species in west and central Alberta in 1947 followed a winter of exceptionally heavy snowfall. Seed-set was much better in 1979 than in 1978 at Kinsella. Precipitation in the late summer and fall of 1978 was above average (Table 1). Vegetative growing points remained at or near ground level throughout the year in F. doreana. Johnston and MacDonald (1967) claimed that the compact clumps protect the perennating buds from fire.

3.1.6 Establishment of Festuca scabrella

F. scabrella (F. doreana) has been shown to germinate readily. At a temperature of 18°C, 80% germination was achieved in five days (Johnston 1961). In his experiments, Johnston found that germination was inhibited by a wet-cold treatment, similar to conditions imposed during a typical spring. The least vigorous seedlings were those subjected to the greatest degree of competition. The highest dry matter yields were obtained from shallow seeding and the largest plants were those grown on top of a five cm layer of litter. However, the percent survival of emerged seedlings was best at shallow litter depths. After establishment, the effects of litter were beneficial; nitrogen was supplied by the decomposing plant material. Seedlings were also inhibited by a solution prepared from partially decomposed litter. This meant that seeds broadcast and covered by litter had a low survival rate. Carry-over of seed from year to year was negligible as a result.

Festuca doreana stands were slow to develop, the establishment period being three to four years in comparison to one to two years for cultivated grasses (Johnston and MacDonald 1967). However, winter-kill was quite low in undisturbed plants of rough fescue. Seed was difficult to obtain, because of irregular floral initiation and seed-set. Johnston and MacDonald (1967) found that environmental conditions that result from spaced plantings and cultivation of nurseries appeared to favour initiation of floral primordia. As yet, commercial seed production does not appear to be economically feasible.

3.1.7 Productivity and Quality of F. scabrella

Festuca scabrella (F. doreana) has been recognized as one of the more productive native grasses. However, Wilson and Johnston (1969) recommended reseeding of pastures to domestic grasses, because of better seedling growth and their greater herbage production. They found that tall fescue, Festuca arundinacea could produce up to 17 times as much dry matter as Festuca doreana, under optimum growing conditions. Tall fescue had a greater leaf area ratio because its leaves were wider and longer and less inclined to roll.

Some work has been done on fertilization of fescue grasslands. The emphasis has been on improving the quality of the species. F. scabrella has been shown to be very palatable to both livestock and big game throughout the seasons (Hodgkinson and Young 1973). Johnston and Bezeau (1962) found that samples of F. doreana taken from southwestern Alberta had an average protein content of 10% in the heading stage. Phosphorus content was approximately 14% during the same stage. Protein and phosphorus levels declined to 5% and 8% respectively, when the forage reached the cured stage. Curing normally occurred during late July, but can be earlier or later depending on the season (Pigden 1953). F. scabrella was one of several grasses that retained a relatively high nutritive value late in the growing season. In addition, its physical form was preserved; stems and leaves did not decompose until eight to ten months after cessation of growth (Pigden 1953). Pigden (1953) found that a very high proportion of stem material in two cultivated grasses, smooth brome and crested wheatgrass, was heavily lignified structural material at the cured stage. Conversely, F. scabrella was found to have a high proportion of non-lignified mesophyll tissue in its leaves at the same stage. Therefore, it is probable that the native grass is more easily digested than the cultivated species in the cured stage.

The National Research Council (1970) indicated that beef cattle require 20% phosphorus in a ration. Bezeau et al. (1966) found that this level was achieved when phosphorus was applied at a rate of about 150 kg/ha. The residual effect two years after treatment was still nutritionally adequate. They also found that the formation of silica uroliths in cattle could be prevented if the silica content of Festuca doreana was kept below 2%. This was accomplished by applying about 150 kg/ha of nitrogen per year to keep the protein content of F. doreana above 16%. Without fertilization, such a high protein content could only be expected in 50% of cases at the leaf stage (Johnston and Bezeau 1962).

3.1.8 Response of F. scabrella to Disturbance

3.1.8.1 Grazing

Buffalo used to graze F. doreana during the winter (Johnston and MacDonald 1967). This did not kill the plants or reduce their summer vigour. With the introduction of cattle, it was found that F. doreana tended to decrease in a stand as summer grazing intensity increased. Johnston and

MacDonald (1967) suggested that _F. doreana_ could be eliminated from a stand with only two or three years of continuous heavy summer grazing.

In a study conducted in southwestern Alberta, Peake and Johnston (1966) determined that at the end of ten years, vegetation on heavily grazed fields could only support grazing for two and one half to three months, while moderately grazed fields could be grazed for six months. Gains per head of domestic cattle were greatest under light or moderate grazing but highest production per acre was obtained by the heaviest grazing treatment (three acres per animal unit). Soil colour in the Ah horizon was found to change from black under light grazing, to very dark gray under moderate grazing to dark grayish brown under heavy grazing to very dark brown under heavy grazing (Johnston et al. 1971). Soil moisture was reduced in the heavily grazed field and mean monthly soil temperature was higher in summer and colder in winter than in the lightly grazed field. Johnston (1962) and Peake and Johnston (1966) stated that a drier microclimate was created under heavy grazing. This was unsuitable for the growth of _F. doreana_, causing a decline in its production. Decrease of _F. doreana_ on heavily grazed pastures could be explained on the basis of an erect growth habit and of the ease with which close grazing can remove most of the photosynthetic tissue (Johnston and MacDonald 1967). However, a large proportion of the shoot apices of _F. doreana_ remained vegetative throughout the year and hence, below the height of accessibility to grazing animals. As grazing pressure increased, the percent of forbs and shrubs increased; 31 species were present in heavily grazed sites as compared to 19 species in ungrazed areas (Johnston 1961b). Stocking rates should be adjusted accordingly. There has been limited research on the effects of grazing on Festuca hallii. Bailey et al. (1980) indicated that heavy summer grazing reduced forage yield significantly in east central Alberta. Changes in basal cover and species composition due to grazing have not yet been investigated in the parklands.

3.1.8 [illegible]

[illegible] mowing practice in Alberta has been to take a crop of [illegible] in alternate years. Moss and Campbell (1947) maintai[illegible] that, as a result, F. scabrella had become much smaller [illegible] stature and in diameter of tussock. Willms (1980)[3] [illegible]ound that mowing of F. hallii in May, for three consecutive years, significantly reduced tiller density. Bailey et al. (1980) found that a cultivated community (alfalfa, creeping red fescue and smooth brome) produced 62% more forage than a rough fescue community in east central Alberta. Dry matter produced with two harvests was 19% greater in the cultivated community and 65% greater in the F. hallii community.

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[3] Willms. [illegible] 1980. Personal communication.

3.1.8.3 Burning

Bailey and Anderson (1978) found that the *Festuca - Stipa* grassland community in east-central Alberta was well-adapted to surviving a single prescribed burn. Canopy coverage was reduced more by spring burning than by fall burning. Production of seed heads was unaffected by a fall prescribed burn but was reduced following spring burning. Anderson and Bailey (1980) found that repeated annual burning reduced average leaf length and the number of inflorescences per square metre. Canopy cover and grass production were reduced by 50%.

3.1.9 Successional Status

The successional status of the fescue grassland has been the subject of some debate in past years. Moss and Campbell (1947) considered the *F. scabrella* community to be a climax grassland community. Coupland and Brayshaw (1953) called the *F. scabrella* association within the aspen parkland a post-climax community. It has also been called a pre-climax community to coniferous forest by Looman (1963) and van Ryswyk (1966). Forest invasion of grasslands has been occurring in Alberta as a natural consequence of prevailing climate (Moss and Campbell 1947). The rate of spread before settlement was controlled by wildfires and fires set by Indians (Nelson and England 1971). The influence of bison and other grazing animals on this range is subject to speculation. Moss and Campbell (1947) maintained that the _F. scabrella_ climax was realized during the time when buffalo were transient members of the same biotic community. Larson (1940) believed that buffalo had much the same effect on plains grassland as domestic cattle have now. However, their effect on the Fescue Grasslands of southwestern Alberta would not have been as great, since they grazed there only when the plants were dormant. Also, it should be remembered that they were not confined as cattle are now.

The pattern of succession in the Fescue Grassland has involved, first, an increase in broad-leaved plants such as aster, rose, yarrow and horsemint (Johnston 1970). Following this, there has been establishment of larger shrubs: _Symphoricarpos occidentalis_, _Elaeagnus_ spp., and sometimes _Potentilla fruticosa_ on mesic sites and _Salix_ spp., on more moist sites. These have tended to reduce the cover of herbaceous species, which were not very shade tolerant. Aspen seedlings can establish when conditions are such that the seed will be kept moist for about two weeks (Moss 1938). Maintenance of such conditions for this length of time would be relatively rare in the parkland. Vegetative reproduction by means of suckers is common where established aspen clones exist. The shrub species are eliminated after aspen grows to a height where shading becomes important.

Grazing has retarded the development of shrubs and aspen, the degree of control depending upon grazing intensity, browsing habits of the animals and the local environmental conditions (Moss and Campbell 1947). Not all shrubs can be controlled in this way.

Prescribed burning of Fescue Grasslands can be used in the control of brush invasion. This technique, however, has to be combined with heavy grazing or herbicide treatment to control resuckering (Bailey 1978).

3.2 Fire

3.2.1 Effects of Fire on Plant Growth

Prescribed burning is a range management practice which is being successfully implemented on many rangelands. It has been used to increase availability and utilization of forage, to increase herbage yield, to control undesirable plant species and to improve wildlife habitats (Wright 1974). Before developing a scheme for prescribed burning in a particular region, it is important to understand how fire affects the plant species involved.

One of the major effects of fire on plant growth has been the removal of top growth and litter, which favours plant yields by raising soil temperatures (Kucera and Ehrenreich 1962). Sharrow and Wright (1977) found that the rate of nitrogen mineralization was increased, but stimulated plant growth caused reductions in both the nitrate and moisture content of the soil. Addition of ash may not enhance production until several seasons after the burn, if at all. Lloyd (1971), however, demonstrated that nutrients in deposited ash were readily released and became available for uptake by plants. Precocity of new shoots on fresh burns has also been related to increased soil temperatures, as has the increase in per cent germination (Daubenmire 1968).

Mulch depth has been reduced by burning (Dix and Butler 1954) although soil organic matter could increase (Anderson and Bailey 1980). Soil pH is also generally higher after burning (Owensby and Wyrill 1973). Generally, burning has been beneficial in areas where litter accumulation was great and soil moisture adequate (Launchbaugh 1973). Decreased light penetration and lower soil temperatures due to the presence of large amounts of litter can prevent further plant growth. Allelopathic effects may also be involved, as leachates from the litter seep into the soil. In dry years, soil moisture has been the limiting plant growth factor and burning had no beneficial effects (Sharrow and Wright 1977; de Jong and MacDonald 1975). Since wildfires are most prevalent during the driest part of the year, their effects tend to be more devastating to plant growth than those of prescribed burns.

New growth on burned areas has usually contained increased amounts of protein and minerals as well as moisture (Daubenmire 1968). The latter condition can be detrimental to the precocious young plants in areas where danger from frost is high. The content of indigestible material has often been reduced, thereby increasing palatability.

The most varied effects of fire relate to the subsequent production, vigour, density and reproductive capability of the plant species involved. These can either decrease or increase depending upon conditions at the time of the fire and individual species differences. Size of leaves has often been reduced but could be accompanied by an increase in the number of tillers (Daubenmire 1968; Hulbert 1969). Effect of fire on production has usually been consistent within a particular geographic region. Season of burning and litter accumulation have also played their part. Fire has increased basal area without having much effect on production. Stimulation of flowering activity has often been observed (Daubenmire 1968; Anderson 1972) but has usually been short-lived.

Clipping or mowing has produced changes similar to those created by fire (Hulbert 1969). A combination of burning and clipping treatments have been used to separate the effects of fire (heat, litter removal and nutrient redistribution) (Daubenmire 1968).

3.2.2 Factors Influencing Fire Damage to Plants

There are many factors which can influence the extent of fire damage to plants. Those related to the fire itself include: the type of fire, its temperature and its duration. Backfires generally have caused more damage than headfires in grasslands because of their proximity to the perennating buds (Daubenmire 1968). Backfires tend to be of greater duration but are not as hot. Therefore, there is a greater chance for a backfire to burn deeply into plant crowns. Previous work by Anderson (1972) in the Festuca - Stipa association of the parklands indicated that maximum temperatures for headfires were reached at an average elevation of 15 cm while backfire maxima took effect at an average of 5 cm above ground.

Environmental influences at the time of the fire have also been shown to be important. The prevailing weather conditions, including air temperature, wind speed and humidity will affect the intensity of the burn. A drier climate will sometimes promote greater damage by fire (Daubenmire 1968). It has also been established that the greater the degree of erosion in the habitat, the greater the observable damage after fire (Robocker and Miller 1955). The time of day at which burning is carried out can modify results, the fuel becoming drier as the relative humidity drops to a minimum by mid-afternoon. More rapid but less complete burns could be expected on areas with stronger topographic relief (Lloyd 1972).

An inverse relationship exists between the level of soil moisture and the extent of fire damage to plants. Efforts should be made to burn when the soil surface is wet and the dead plant material or litter barely dry (Owensby and Wyrill 1973). This has given maximum protection to plant crowns.

The amount of litter which has accumulated before burning will affect the duration of the fire and increase fuel continuity. The type and amount of fuel, its flammability, its initial temperature and moisture content can affect the damage inflicted by a fire. It has been shown that the greater the amount of fuel, the greater the injury to plants (Conrad and Poulton 1966). Flammability is related to fuel types, finer textured fuels being more combustible than coarse-textured fuels. Brown (1969) found that flammability of cheatgrass depended largely on physical properties such as weight and porosity as well as moisture content. Mutch and Philpot (1970) reported that heat content was lower in Taeniatherum asperum (Sim.) Nevski than Bromus tectorum due to a higher content of inert ash. High silica content might actually have helped to make Taeniatherum asperum a fire hazard (Mutch and Philpot 1970).

Daubenmire (1968) stressed the importance of plant characteristics as determinants of fire damage. The phenologic condition of the plant is of considerable significance (Daubenmire 1968; Bailey and Anderson 1978). Removal of foliage, whether by clipping or burning, can severely injure a plant if done at a time when carbohydrate reserves are at a low level or elevated perennating buds are damaged. In perennial grasses, the lowest level of carbohydrate reserves is reached before the photosynthetic capacity of the new foliage is sufficient to both sustain growth and start the rebuilding of reserves. Those grasses which remain dormant until later in the spring (i.e. warm season grasses) usually escape injury during spring burning. It would seem expedient, therefore, to burn cool-season grasses as early in the spring as conditions permit.

Resistance of some species to fire over others can also be related to morphological differences. Some grass species possess protective sheaths which maintain a high moisture content level. These sheaths can act as barriers to radiation and reduce heat injury to buds. Compact arrangement of tillers can also serve to alleviate fire damage. Conrad and Poulton (1966) found Festuca idahoensis to be much more severely damaged than Agropyron spicatum, the reason being that the buds of the former are closely spaced and above ground, while those of the latter are widely spaced and below ground. Johnston and MacDonald (1967) claimed that the compact clumps of F. doreana protected the perennating buds from damage by fire. Wright (1971) found the low quantity of dead plant material per unit basal area in squirreltail caused a quick hot flame with a minimum of heat penetration to growing points. He reported that the more dense plant material of needle and thread burns more slowly and for a longer time period, with resultant damage to growing points.

4. METHODS

4.1 Experimental Design

The design for this study was a fixed model split-plot, with eight replicates, five treatment dates and three treatments (Figure 3) The five treatment dates were randomly assigned within each replicate to main-plots measuring 4 m x 9 m. These were split into three subplots, which were subjected to three treatments: burning, mowing and no disturbance (control). Each subplot measured 2 m x 3 m. A walk-way, 1.5 m wide, was left around each subplot.

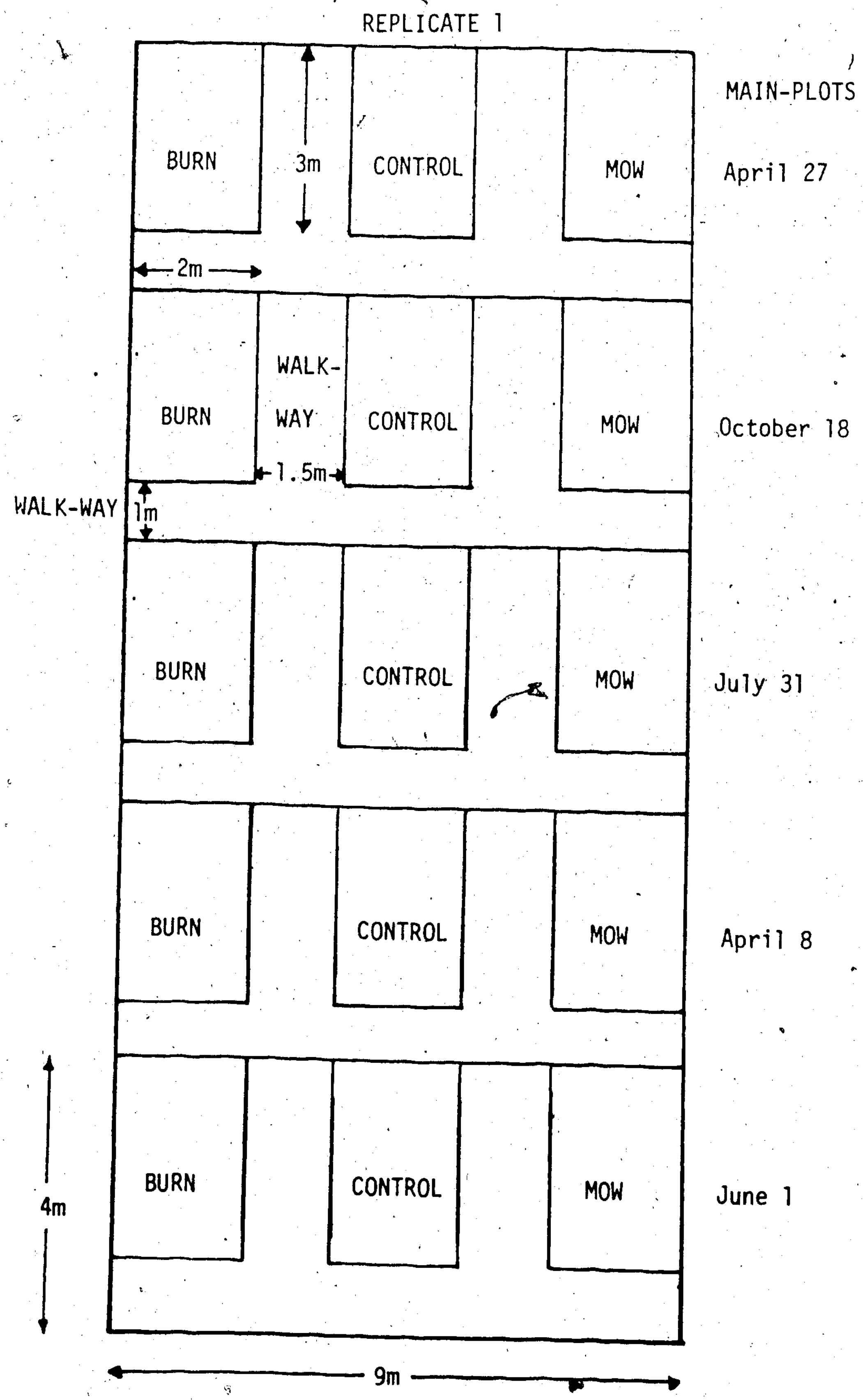
4.2 Treatment and Sampling Procedures at the Time of Each Trial

Treatments were administered on five dates in 1978: April 8, April 27, June 1, July 31 and October 18. The procedures used during each trial are outlined below.

4.2.1 Fuel Moisture

Samples were collected before and after burning from two 50 cm x 100 cm plot frames placed immediately adjacent to the sub-plots selected for burning. The litter, or fallen dead plant material was removed first, and placed in an airtight labelled plastic bag to retain its moisture. The standing fuel, that is, live or dead plant material which had not fallen, was clipped using electric sheep shears. Electricity was obtained from a portable, gasoline powered

Figure 3: Experimental design.



generator. The clipped standing fuel was also placed in plastic bags. Any remaining litter was then collected and added to the appropriate container. Later in the day the bags were weighed and the 'wet weight' minus the weight of the bag recorded. Fuel samples were then transferred to paper bags and placed in a drying oven at 50°C. These were weighed three days later and the 'dry weight' minus the weight of the bag recorded. Moisture levels for each fuel type were then calculated. Fuel remaining after burning was collected in paper bags, dried and weighed.

4.2.2 Soil Moisture

Soil samples were obtained on each trial date by lifting the sod beside the sub-plots selected for burning. Two samples were collected at a depth of three to eight cm, from each replicate and placed in air-tight metal containers. The containers were then placed in plastic bags to further prevent loss of moisture and then frozen. The samples were later thawed and their wet weight determined. They were then oven-dried at 105°C. After 24 hours, each sample was re-weighed and the dry weight recorded.

4.2.3 Soil Temperature

Soil temperatures were recorded immediately before treatment using dial thermometers with bimetallic elements. These were randomly located within each subplot at a depth of 5 cm. Three readings were taken in each burned, mowed and control plot at the time of a trial. On April 8, 1978, the ground was still frozen and penetration of the thermometer was limited to 1 or 2 cm.

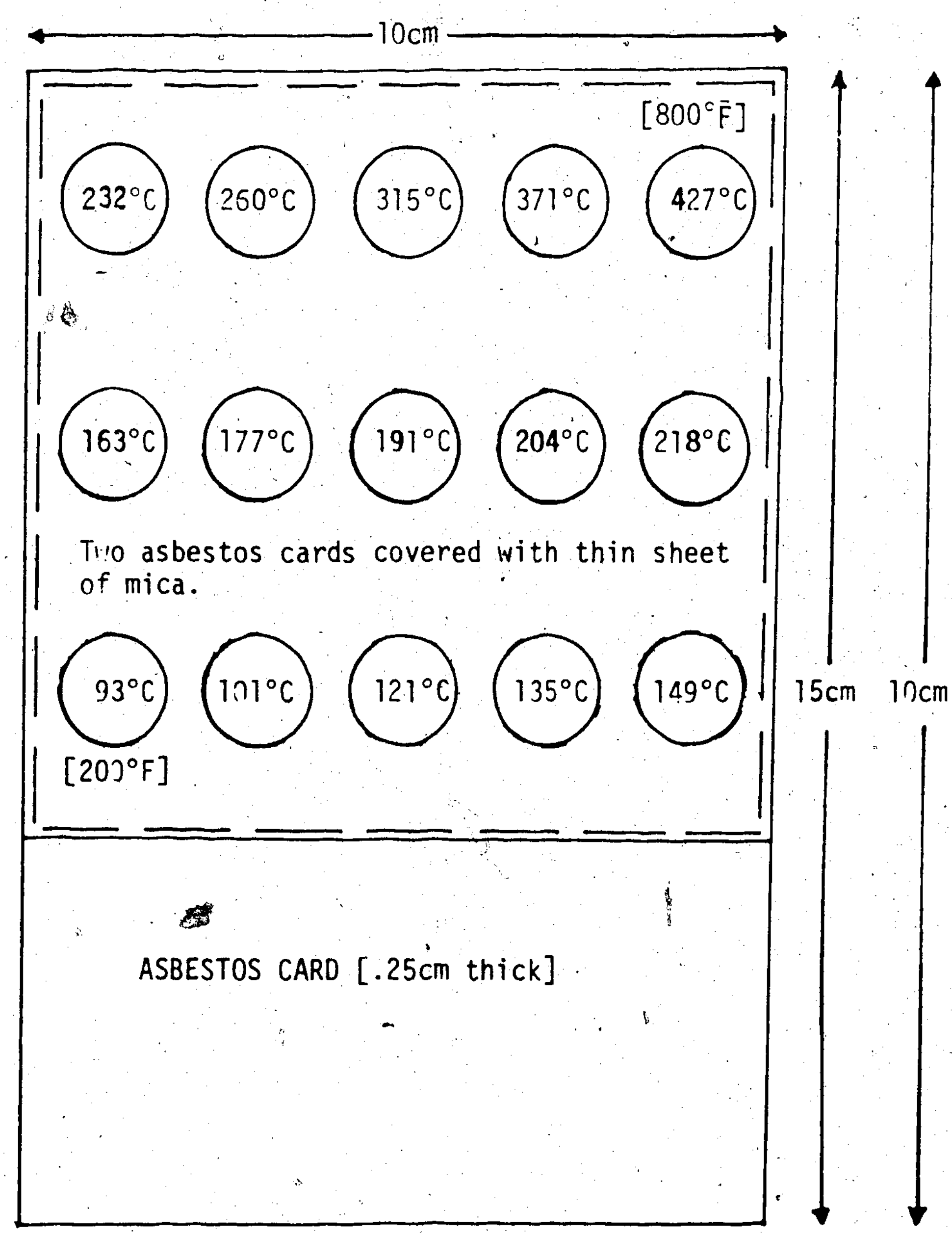
4.2.4 Fire Weather Records

At each treatment date, the weather conditions recorded before and after burning were: air temperature, relative humidity, wind speed and wind direction (Table 3). Air temperature and relative humidity were recorded with a sling psychrometer; wind speed with an anemometer. In addition, the total precipitation during the week previous to each treatment; the amount of the most recent precipitation, and the number of days since its occurrence were recorded. This information was obtained from a weather station maintained at the University of Alberta ranch headquarters, 1 km southeast of the study site.

4.2.5 Measurement of Fire Temperature

Asbestos cards, one measuring 15 cm long by 10 cm wide by 0.25 cm thick and one measuring 10 cm by 10 cm by 0.25 cm thick were prepared (Figure 4). Two cards were used to construct one device used to measure fire temperature. The smaller of the two cards contained holes punched in three rows. The other card was placed behind the first for support. Temperature pellets, each designed to melt at a specific temperature, were aligned on the punched asbestos card. The pellets were intended to melt at the specific

Figure 4: Measurement of fire temperature.

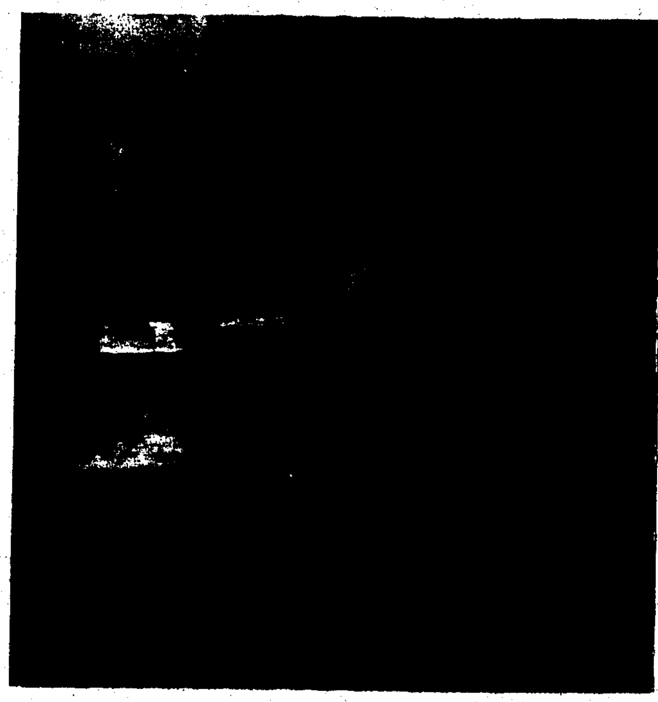


temperatures [illegible] 101, 121, 135, 149, 163, 177, 191, 204, 218, 2[illegible], 260, [illegible], 371 and 427°C. The pellets were then covered by a [illegible] cm by 10 cm by 0.02 cm thick sheet of mica. The three sections were stapled together, and two of the completed cards placed in each subplot chosen for burning. It had been found in previous research (Bailey and Anderson 1980) that temperature maxima during fires in this grassland type occurred between heights of 5 and 15 cm. The asbestos cards were supported such that the temperature pellets were within this 10 cm range. Since headfires were used, the cards were placed such that the side covered by mica faced the direction from which the wind was blowing. Following the fire, temperature maxima were determined by examining the pellets for signs of melting using a binocular microscope (20x).

4.2.6 Burning Technique and Mowing Procedures

Each plot selected for burning on a particular trial date was surrounded on three sides by horizontal sheets of plywood (Figure 5). The grass beneath the plywood was soaked with water as were the sheets themselves. A tractor-pulled water tank with an attached spray-gun was kept nearby for this purpose and as a safety precaution. A headfire was lighted with a propane torch along the unprotected edge of the sub-plot. The flames generally died out when encountering the wet grass on the opposite side of the plot, however, particular care had to be taken to leave

Figure 5: Burning technique (July, 1978).



no smouldering patches. This method proved to be effective except under very windy conditions when gusting caused the flames to cross the fireguard.

A small harvester was used for mowing. The clipped material taken up by the harvester was dried and weighed. A tractor-drawn rotary lawnmower was employed to reduce stubble height to a level comparable to that on burned subplots. Stubble height was then measured and recorded on the burned and mowed sub-plots. Six measurements of stubble height were taken on each subplot. Care was taken to position the base of the ruler as close to the mineral soil surface as possible.

4.2.7 Stage of Growth

A sod was dug up from each control subplot at the time of treatment. These samples were frozen and later examined. An attempt was made to characterize the stage and type of growth exhibited by *F. hallii* at the time of each treatment. The measurements taken included: density of bunches; basal area per bunch; the number of live, recent dead and old dead tillers per bunch and the length of old and new green growth. Basal area was measured with calipers. Two measurements were made, one at a right angle to the other. Separate estimates of basal area were calculated from the two measurements and then averaged. Recent dead tillers were those which were completely yellow, while old dead tillers had a gray or dark brown appearance. Old green growth was defined as those tillers which exhibited the beginnings of senescence at the leaf tips, or those which were completely green and longer than 10 cm. New green growth showed no signs of yellowing at the leaf tips and measured less than 10 cm. The 10 cm measurement was chosen arbitrarily. This condition classification was similar to that used by Coupland and Abouguendia (1974).

4.3 Sampling Procedures after Treatment

4.3.1 Herbage and Litter Production

The plant material within three 39 x 64 cm plot frames was harvested at ground level in August, 1978 and August, 1979, in each of the burned, mowed and control subplots. In both years, control yields were estimates of annual herbage production. Achievement of a true estimate of *F. hallii* yield necessitated the sorting of samples before drying. The samples were then oven-dried at 50°C and weighed.

Both standing and humic litter, as defined by Dyksterhuis and Schmutz (1947) were collected but not separated. Standing litter was removed before clipping while humic litter was collected after harvesting. These samples were also oven-dried at 50°C and weighed.

4.3.2 Tiller Density, Leaf and Sheath Lengths and Rate of Growth

Tiller density was determined for *F. hallii* by harvesting the contents of four 10 cm x 10 cm plot frames, at the end of July in both 1978 and 1979. The samples were frozen and examined at a later date. The tillers in each sample were separated into the following categories: green one, two, three or four-leaved and dead tillers. The number of tillers in each category were recorded for each sample. The length of the leaf and sheath of the longest tiller was recorded in each of the categories, as described above.

The growth rate of *F. hallii* was monitored on five tagged bunches over a nine day period in June, 1979. Numbered aluminum chicken leg bands were used to mark the bunches (Figure 6). Initial measurements were taken on the longest tiller in each of five tagged bunches in each subplot on June 18, 1979. The second measurement on the same bunches was made on June 26, 1979.

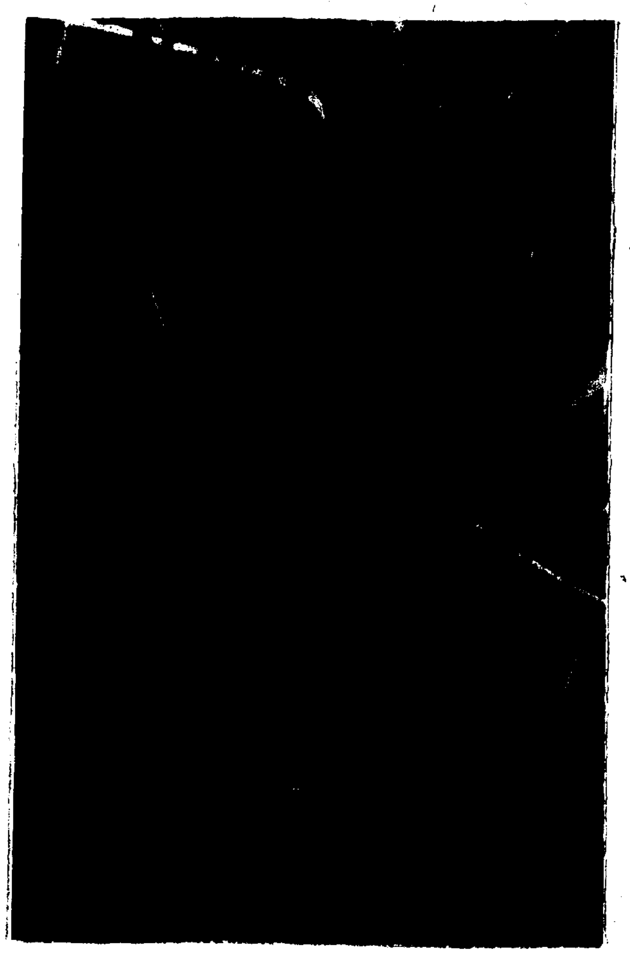
4.3.3 Basal Area

The vertical point method for estimation of basal area was used following Johnston (1956). A point frame with ten holes spaced 2.54 cm apart was used to sample basal cover in June, 1979. Fifty points were sampled in each sub-plot, making a total of 400 points for each treatment within each trial. Only actual hits were recorded.

4.3.4 Inflorescence Production

Numbers of *F. hallii* and *S. spartea* var. *curtiseta*

Figure 6: Festuca hallii bunch tagged with a chicken leg-band.



inflorescences in three 39 x 64 cm plot frames per subplot were recorded during July of 1979.

4.3.5 Soil Temperatures

Soil temperature was recorded at 3, 6 and 9 cm depths on July 24, 1978 and on July 3, 1979. Dial thermometers with bimetallic elements were used and temperatures were recorded between 1300 and 1500 hours.

4.3.6 Data Analysis

Split plot analysis of variance was used to determine the significance of treatment date and treatment on: herbage yield, litter production, tiller density, leaf and sheath lengths, growth rate of tillers, basal area, density of inflorescences and soil temperature. The computing program used assumed that the split plot was a fixed model, which meant the subplot error term was used to calculate the subplot F value even if the interactions were significant. This followed the procedure outlined by Cochran and Cox (1957). In addition, if the main-plot (treatment date) error variance was less than the subplot (treatment) error variance, then the error terms were pooled. The pooled error variance was then used to calculate all F values. Treatment means are presented in Appendix A when the exact values do not appear in the text. Where possible, standard errors have been provided. Otherwise, means have been compared using Duncan's multiple range test. The latter procedure is not strictly acceptable for a split-plot design, but does provide some visual method of comparison otherwise unavailable. Analysis of variance tables appear in Appendix B.

5. RESULTS AND DISCUSSION

5.1 Factors Affecting Fire Behavior and Plant Response

The prevailing weather conditions before and during prescribed burning treatments are given in Table 3. Burning was conducted in the late afternoon when relative humidity reached its low for the day and air temperatures were still near their maximum. This Festuca grassland can be burned under more humid conditions than the 25% to 40% relative humidity experienced during our burning treatments. Bailey and Anderson (1978) reported successful burning under a relative humidity of 47%. Bailey (1978) burned these grasslands when the relative humidity was as high as 65%. Successful burning when the humidity is high would be possible on rangeland when litter cover is minimal and air circulation, therefore, good. In the present study, litter accumulation was heavy (Table 4) and ventilation was poor. Because of this, wind speed was important. For example, the high wind speed on April 8 tended to compensate for the high fuel moisture levels in the fuel and the low ambient temperature (9°C). Gusts of wind, which reached speeds of 22 km/hr during the July 31 burn presented problems of control. Also on this date, the litter smouldered long after flaming combustion had ceased.

The total quantity of fuel (standing fuel plus litter) on each treatment date was comparable (Table 4). The high weight values for standing fuel for the first two treatment

Table 3: Weather conditions before and during prescribed burning treatments

Treatment Date	Precipitation (mm) within previous week	No. days from last precipitation	Amount of last precipitation (mm)	Time of burn	Air temperature at time of burning (°C)	Relative humidity (%) at time of burning	Wind speed (km/hr)	Speed of gusts (km/hr)	Wind direction
April 8, 1978	8	2	2	1530	9	38	8	14	north-west
April 27, 1978	3	3	3	1600	24	25	6	16	south-east
June 1, 1978	24	2	8	1530	21	35	5	8	north-west
July 31, 1978	7	2	3	1730	26	33	6	22	north-west
October 18, 1978	5	5	5	1635	18	34	6	11	west

Table 4. Mean fuel weights (kg/ha), fire temperature (°C), and fuel consumed (%) on five treatment dates.

Treatment Date (1978)	Standing fuel (kg/ha)	Litter (kg/ha)	Fire temp. (°C)	Fuel consumed (%)
April 8	5883±201	5661±212	225±6	43±4
April 27	4479± 96	4884±145	261±5	64±2
June 1	4535±125	5845±187	224±6	51±2
July 31	2756± 45	7166±214	257±9	71±2
October 18	2128± 82	9170±315	234±1	74±2

Table 5. Mean moisture content (%) of fuel and soil (0-5 cm) on five treatment dates.

Treatment Date (1978)	Percent moisture		
	Standing fuel	Litter	Soil
April 8	37.9±1.9	62.4±1.2	42.5±0.9
April 27	9.9±0.2	28.9±0.7	33.7±0.8
June 1	33.3±0.4	32.6±1.3	22.7±0.7
July 31	49.5±0.3	9.6±0.6	16.2±0.6
October 18	33.4±0.3	25.1±1.1	26.4±0.6

dates were the result of sampling procedures. Most of the standing fuel on these two dates consisted of the previous year's growth since green-up was only beginning.

Fuel moisture levels varied considerably from one treatment date to the next, depending primarily on precipitation patterns (Table 5). This affected the quantity of fuel consumed (Table 4). Stubble height (Table 6) reflected some of the differences in the fuel moisture levels, particularly on April 8 when moisture levels in the litter were highest. High moisture on this date was a result of snowmelt rather than precipitation. Correlations indicated that stubble height was more closely related to moisture levels in the litter than to those in the standing fuel (Table 7). Fire temperature was more closely correlated with fuel and soil moisture than with any weather variable. The quantity of fuel remaining after burning was related to relative humidity and air temperature in addition to fuel moisture.

The stage of growth of _F. hallii_ at the time of each treatment is presented in Table 8. This perennial grass appeared to begin growth before snowmelt in 1978. New shoots measuring 3 cm were found under a cover of snow on March 31. However, it was not clear whether this growth had survived from the previous autumn or if it had a more recent initiation. There was a considerable amount of longer growth which had died back with frost action, leaving a few centimetres of green stem and leaf at the base of the

Table 6. Mean stubble height (cm) on burned and mowed subplots on five treatment dates.

Treatment Date	Stubble height (cm) Burned subplots	Mowed subplots
April 8, 1978	6.4±1.2	6.6±0.3
April 27, 1978	3.2±0.6	2.7±0.2
June 1, 1978	3.4±0.2	2.9±0.1
July 31, 1978	2.5±0.1	3.0±0.2
October 18, 1978	2.9±0.2	3.0±0.1
Grand means	3.7±0.8	3.6±0.8

Table 7: Correlations among variables affecting fire behavior and plant response.

	St-moist	Lit-moist	So-moist	So-temp	Pptwk	Amt-ppt	Day-ppt	Rh	Air-temp	Gust	Slope	Ftemp	Rfuel	Stubht
St-moist	1.00													
Lit-moist	0.66 P=0.00	1.00												
So-moist	0.14 P=0.12	0.64 P=0.00	1.00											
So-temp	0.07 P=0.27	-0.58 P=0.00	-0.84 P=0.00	1.00										
Ppt-wk	0.57 P=0.00	-0.09 P=0.23	-0.61 P=0.00	0.79 P=0.00	1.00									
Amt-ppt	0.27 P=0.01	-0.44 P=0.00	-0.80 P=0.00	0.95 P=0.00	0.92 P=0.00	1.00								
Day-ppt	-0.87 P=0.00	-0.54 P=0.00	0.06 P=0.32	-0.22 P=0.03	-0.75 P=0.00	-0.43 P=0.00	1.00							
Rh	0.87 P=0.00	0.69 P=0.00	0.13 P=0.13	0.01 P=0.48	0.52 P=0.00	0.23 P=0.03	-0.98 P=0.00	1.00						
Air-temp	-0.65 P=0.00	-0.92 P=0.00	-0.62 P=0.00	0.58 P=0.00	0.02 P=0.44	0.41 P=0.00	0.64 P=0.00	-0.80 P=0.00	1.00					
Gust	-0.48 P=0.00	0.21 P=0.04	0.69 P=0.00	-0.86 P=0.00	-0.99 P=0.00	-0.97 P=0.00	0.65 P=0.00	-0.47 P=0.00	-0.16 P=0.10	1.00				
Slope	-0.06 P=0.31	-0.26 P=0.02	-0.08 P=0.25	0.05 P=0.33	0.02 P=0.42	0.11 P=0.19	0.12 P=0.15	-0.16 P=0.09	0.21 P=0.04	-0.05 P=0.33	1.00			
Ftemp	-0.47 P=0.00	-0.45 P=0.00	-0.47 P=0.00	0.16 P=0.09	-0.02 P=0.42	0.12 P=0.16	0.25 P=0.02	-0.30 P=0.01	0.36 P=0.00	-0.03 P=0.41	0.12 P=0.16	1.00		
Rfuel	0.48 P=0.00	0.51 P=0.00	0.27 P=0.01	-0.25 P=0.02	0.10 P=0.19	-0.14 P=0.13	-0.47 P=0.00	0.54 P=0.00	-0.59 P=0.00	-0.02 P=0.43	-0.12 P=0.16	-0.41 P=0.00	1.00	
Stubht	0.64 P=0.00	0.86 P=0.00	0.56 P=0.00	-0.53 P=0.00	-0.00 P=0.49	-0.36 P=0.01	-0.60 P=0.00	0.74 P=0.00	-0.92 P=0.00	0.13 P=0.19	-0.17 P=0.19	-0.42 P=0.00	0.59 P=0.00	1.00

Key for Table 7

St-moist:	Percent moisture in standing fuel before burning.
Lit-moist:	Percent moisture in litter before burning.
So-moist:	Percent moisture in soil (0-5 cm) before burning.
So-temp:	Soil temperature (°C) before treatment.
Ppt-wk:	Total precipitation (cm) during the week before treatment.
Amt-ppt:	Amount (cm) of last precipitation before treatment.
Day-ppt:	Number of days since last precipitation (before treatment).
Rh:	Relative humidity at the time of burning.
Air-temp:	Air temperature (°C) at the time of burning.
Gust:	Speed (km/h) of wind gusts during burning.
Slope:	Slope of each subplot.
Ftemp:	Fire temperature (°C).
Rfuel:	Fuel remaining (%) after burning.
Stubht:	Stubble height (cm) on treated subplots.

Table 8: Condition classification of <u>Festuca hallii</u> tillers on five treatment dates in 1978.

Treatment Date	Condition Classes							
	No. of new tillers (m^{-2})	Length of new tillers (cm)	No. of old green tillers (m^{-2})	Length of old green tillers (cm)	No. of recent dead tillers (m^{-2})	No. of old dead tillers (m^{-2})	Diameter of bunches (cm)	No. of bunches (m^{-2})
April 8, 1978 (n = 403)	387± 69[1]	6.5±0.3	3945±381	9.0±0.2	4205±1115	1947±660	0.35±0.02	2118±181
April 27, 1978 (n = 575)	881±131	5.9±1.1	3142±390	7.8±0.4	3340± 622	1706±249	0.37±0.04	1773±142
June 1, 1978 (n = 388)	-	-	3206±428	12.2±0.8	2673± 485	1508±469	0.38±0.03	1695±225
July 31, 1978 (n = 334)	-	-	5024±567	33.0±1.4	1748± 287	1850±511	0.40±0.04	1912±186
Oct. 18, 1978 (n = 290)	1106±195	6.7±0.4	4295±607	11.7±2.4	2181± 262	751±122	0.55±0.06	1267±194

[1] Standard error

n=number of bunches on sample sod

New tillers: those which were green to leaf tips and measured less than 10 cm.

Old green tillers: those which had yellowed leaf tips or those which were green and measured greater than 10 cm.

Recent dead tillers: those which were completely yellow in appearance.

Old dead tillers: those which were gray or dark brown in appearance.

tillers. New leaves emerged both from new tillers and from the bases of the old tillers. The mean length of both new and old green tillers appeared to decline between April 8 and April 27. With the protective covering of snow gone, it was likely that frost action during this period caused browning of the leaf tips. The one-leaved tillers went on to produce at least one more leaf before the inflorescence was elevated in early June. Two-leaved tillers were characteristic of the species. Leaves reached an average length of 33 cm before senescence. Some exceptional tillers produced three and four leaves. Leaves on such tillers were always shorter than those on two-leaved tillers. In 1978 and 1979, inflorescences were in the anthesis developmental stage by mid- to late June. Seed set was complete by mid-July. Leaf production on tillers ceased after seed set. However, more new tillers were initiated in the fall than at any other time during the year (Table 8). The exact period for this proliferation of fall tillers is unknown. It is likely, however, that tiller initiation commences with the onset of cooler weather. Chilcote et al. (1973) were of the opinion that higher day-time and lower night-time soil temperatures in the fall and early winter caused initiation of vegetative tillers in grasses. The size of bunches remained essentially the same. Increased diameters observed on October 18 were a result of samples including fewer but larger bunches.

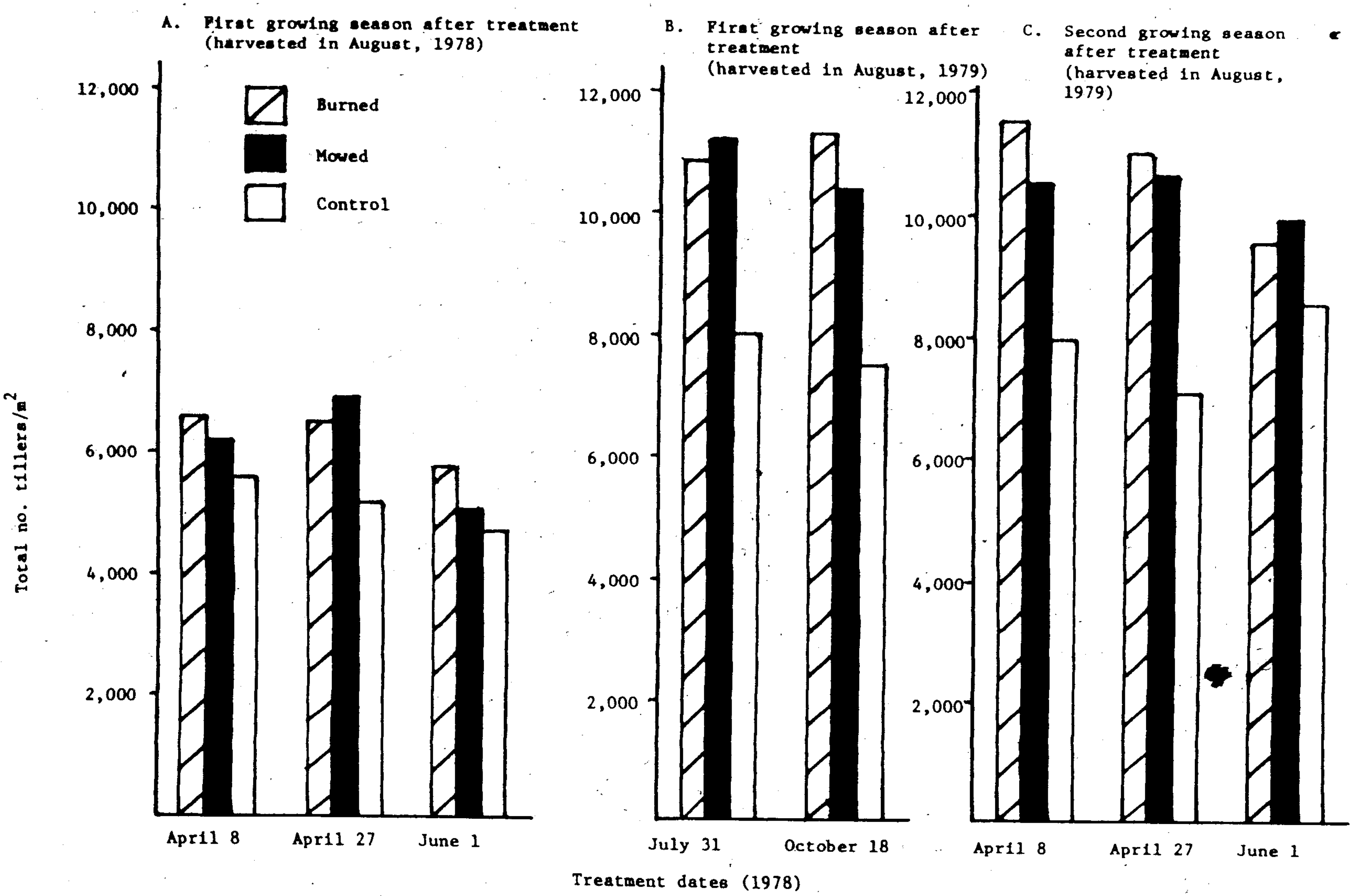
This study did not determine the longevity of individual tillers. Some survived at least one winter, since new leaves were observed growing within the dead sheaths of the previous year's growth. The number of recent dead tillers decreased as the growing season progressed, increasing again in the fall. The fact that a large number of recent dead tillers were found in late spring and summer did not mean that they were dying continously. It meant that dead tissue in this species persisted for a long period of time. A whole year could pass, for example, before recent dead tillers decomposed sufficiently to be classified as old dead tillers. Leaves on tillers initiated in the spring were observed to live until early August, when die-back began to occur.

5.2 Tiller Density

The total number of live *F. hallii* tillers was observed to increase following either burning or mowing on any of the treatment dates (Figure 7). Tillering was more prolific in 1979 than in 1978 probably because of greater precipitation in the fall of 1978; 197 mm as compared to 87 mm. On untreated areas, tiller density increased by an average of 54% over 1978. If the July and October treatment means were adjusted for this 54% increase, magnitude of the response could be considered similar to that of the June 1 treatments in the first growing season.

Differences among treatment dates existed for tiller initiation in 1978 but not in 1979 (Appendix B). This could

Figure 7. Total number of live *Festuca hallii* tillers/m^2



indicate that in 1978 progressively fewer tillers were initiated as the growing season advanced, reaching a low point perhaps when temperatures were highest. The uniformity of response during 1979 may mean that a threshold was involved, and once crossed, produced the same result.

An increase in the number of three- and four-leaved tillers was observed during the first growing season following either burning or mowing. This fact provided the rationale for separating tillers into categories based on the number of leaves they carried. Examination of means for the one-leaved tiller category indicated that there was little tiller initiation on spring-treated subplots preceding the August 1978 harvest (Figure 8). Initiation of tillers on untreated subplots preceding the August, 1979 harvest was 1.7 times greater than in 1978. Precipitation records show that rainfall in July 1979 was 2.6 times that which fell in July 1978 (Table 1). This may account for the observed results. Burned and mowed areas exhibited substantial gains in one-leaved tiller density over controls during the 1979 growing season.

It could have been expected that a similar pattern would be found for two-leaved tillers. Certainly differences between treatments were not found in the first year following treatment (Figure 9). This seemed logical since insufficient time had passed for the initiation and growth of new tillers on treated areas. However, it was somewhat surprising that treated areas did not respond in 1979 by

Figure 8. Number of one-leaved *Festuca hallii* tillers/m^2

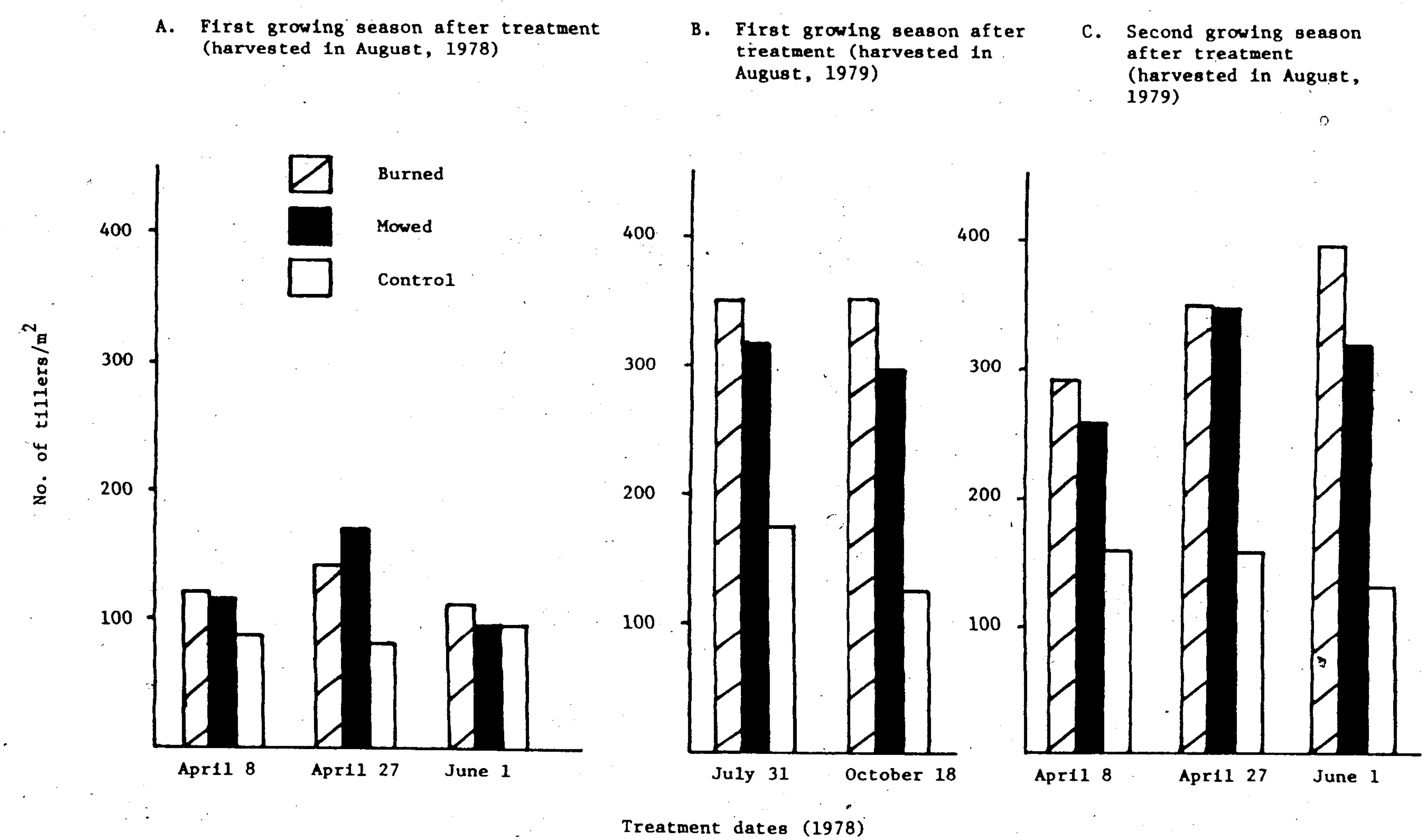
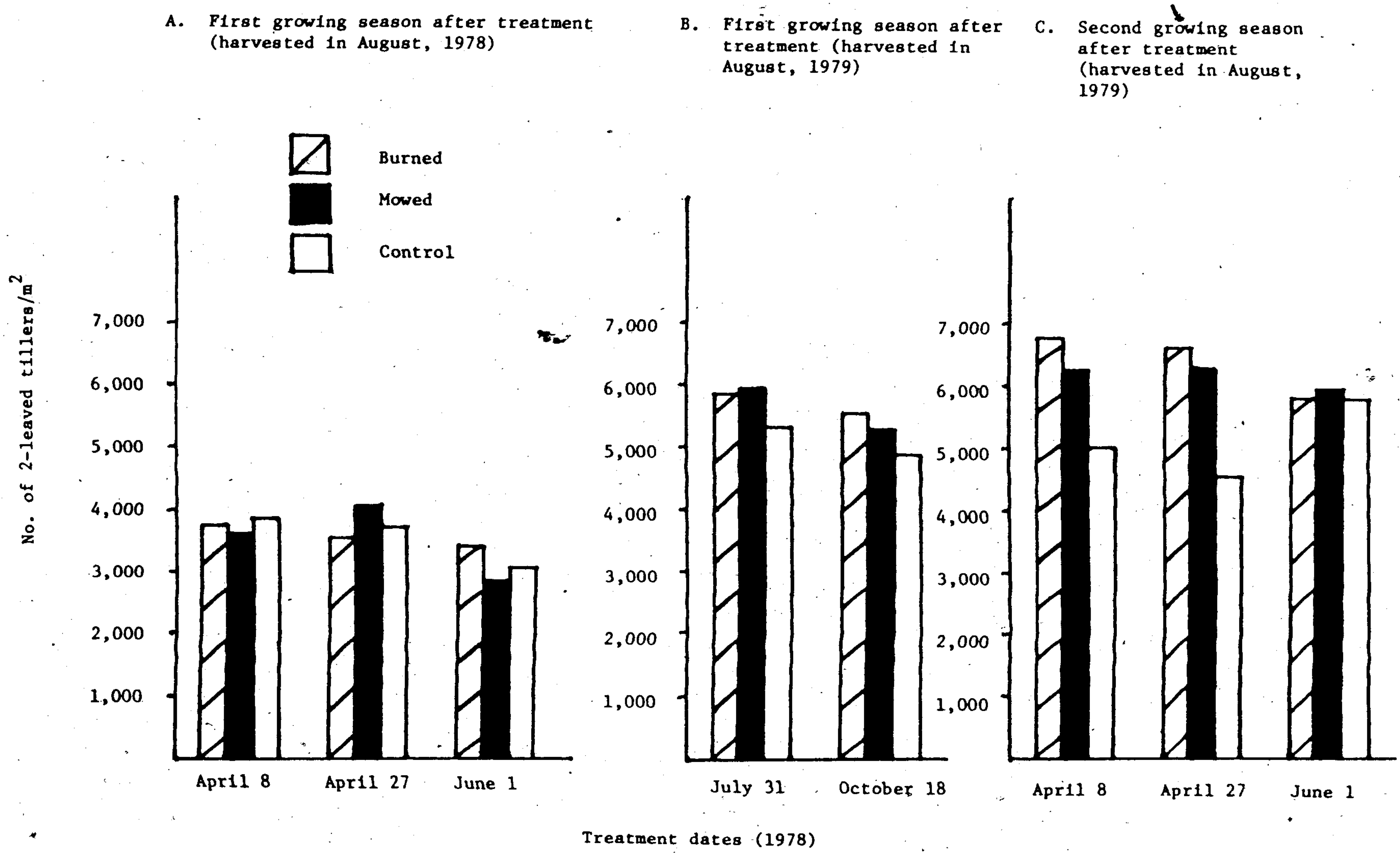


Figure 9. Number of two-leaved *Festuca hallii* tillers/m^2



producing significantly more two-leaved tillers. A trend toward this was noted with the April 8 and April 27 treatments. It may be that the response of the plant was delayed. In this case, the increased number of one-leaved tillers observed in 1979 might have swelled the two-leaved category in 1980.

Figures 10 and 11 help to further explain the response of F. hallii to defoliation. Following treatment, the plants first reacted by producing more leaves rather than more tillers. During the second growing season following treatment, the plant's energies were channelled into production of new tillers. Langer (1963) found that leaf production was favoured over tillering in some species when the temperature was increased. With shading removed, air temperatures would certainly be higher near the crowns of plants on treated areas.

The phenomenon of increased tillering in grasses after defoliation has been observed by various authors in different regions (Hulbert 1969; Chilcote et al. 1973; Willms 1979). Many explanations have been forwarded, including: high air and soil temperatures; high light intensity; increased supplies of nitrogen, phosphorus and potassium; increased cation exchange capacity of the soil and removal of apical dominance. Several of these were not likely considerations in the present study. Removal of apical dominance, for example, was not likely to have occurred. F. hallii vegetative stem apices remained at or

Figure 10. Number of three-leaved *Festuca hallii* tillers/m^2

A. First growing season after treatment (harvested in August, 1978)

B. First growing season after treatment (harvested in August, 1979)

C. Second growing season after treatment (harvested in August, 1979)

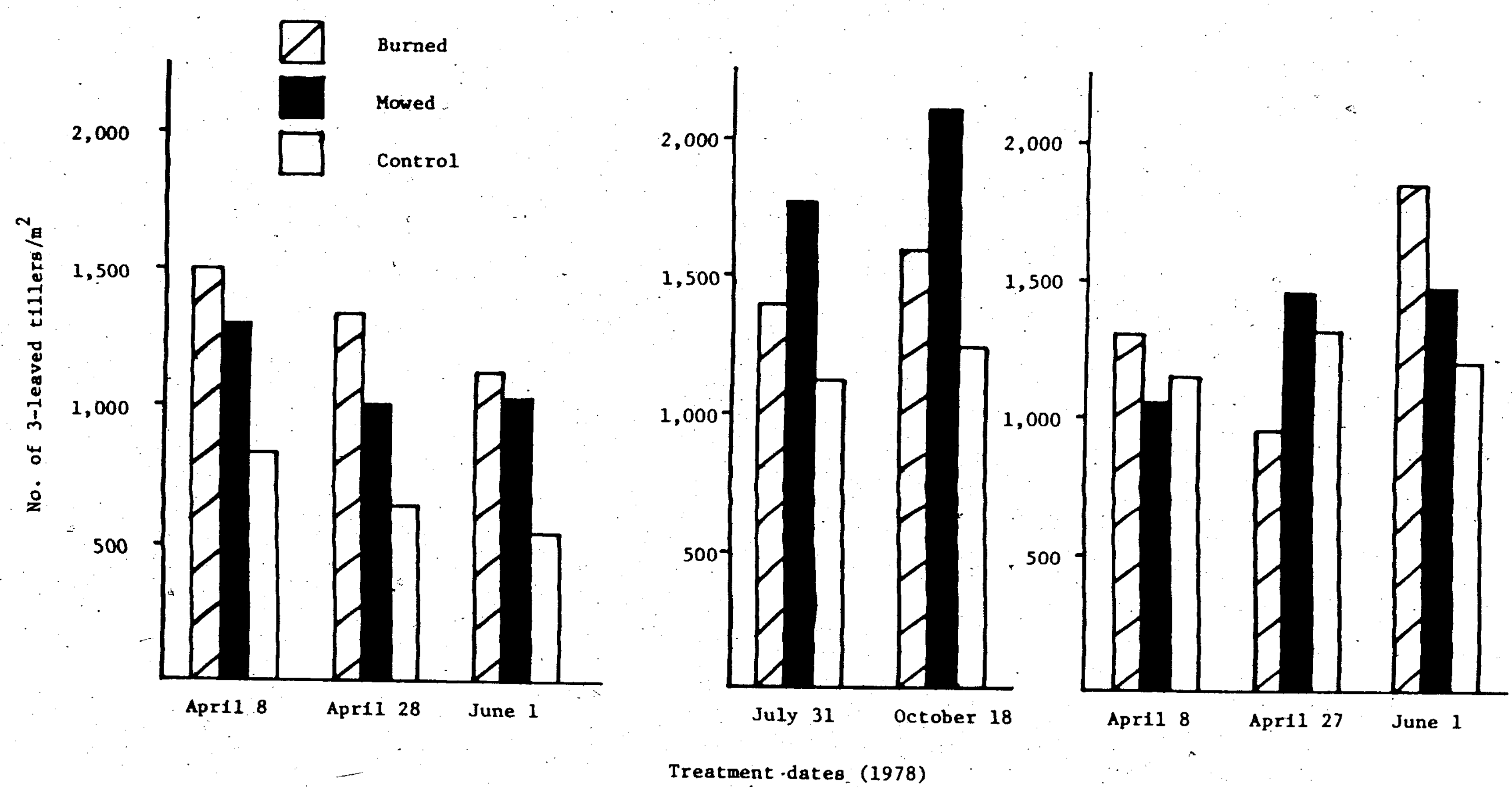
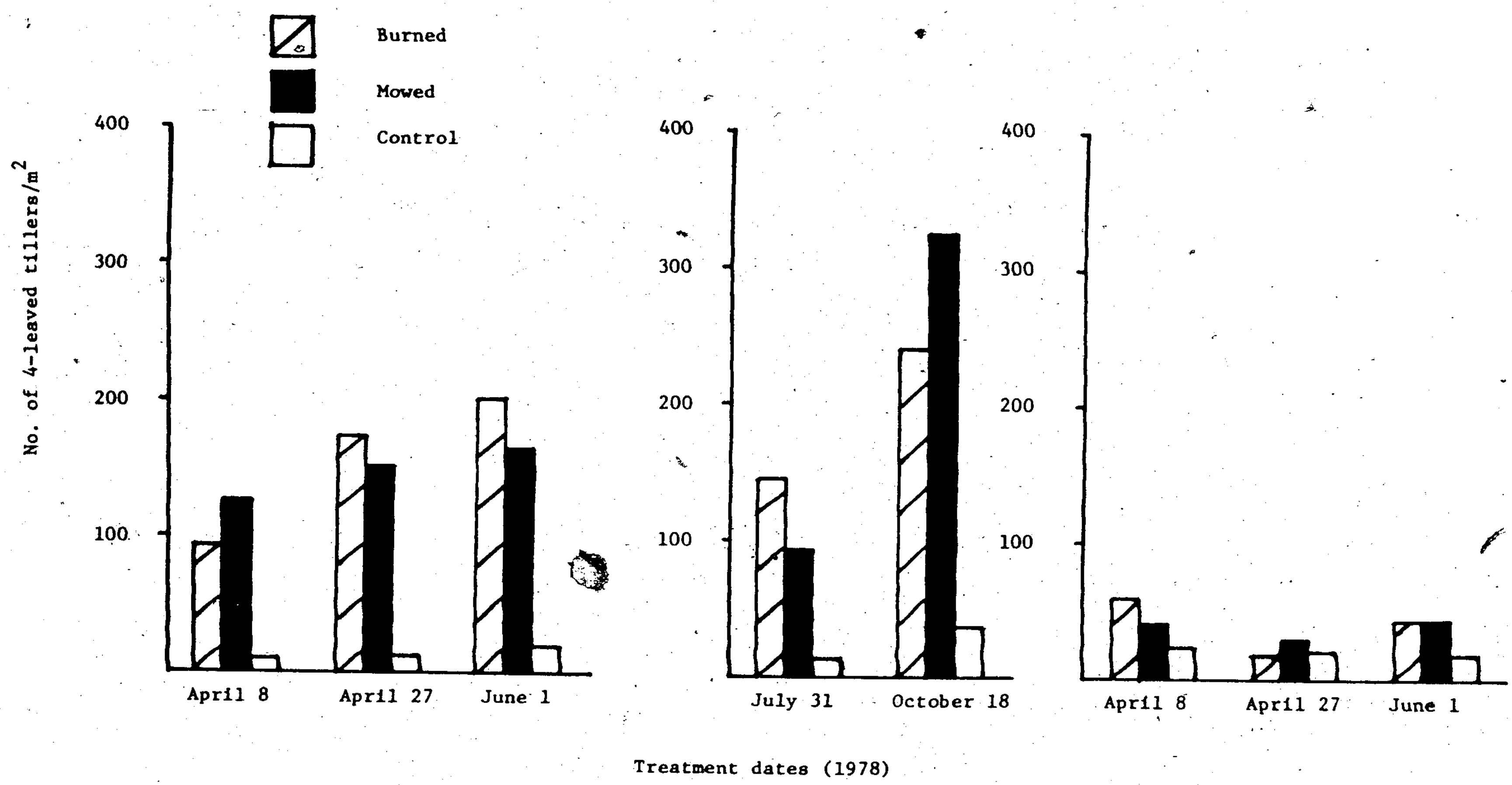


Figure 11. Number of four-leaved Festuca hallii tillers/m^2

A. First growing season after treatment (harvested in August, 1978)

B. First growing season after treatment (harvested in August, 1979)

C. Second growing season after treatment (harvested in August, 1979)



below ground level, like those of its relative, F. doreana (Johnston and MacDonald 1967). A few apical meristems were measured. These ranged in length from 2.4 mm to 9.1 mm, with a mean length of 4.7 mm. There did not appear to be any seasonal variations in length. Since the stem bases were located 1.5 to 2.0 cm below the soil surface, the apices would not have been affected by either burning or mowing. Youngner (1972) stated that defoliation of grasses in closed stands under field conditions could have resulted in stimulation of tillering even though stem apices remained intact. It can be assumed, therefore, that stimulation of tillering in the present study was the result of a factor other than removal of growing points.

Levels of soil nutrients were not measured in this experiment. However, the lack of uniform variation in tiller density between burned and mowed treatments seemed to indicate no major change in fertility on burned areas. Anderson and Bailey (1980) did find an increase in total phosphorus in the A horizon of an annually burned F. hallii grassland. Their sampling was conducted in October, therefore, it could assumed that levels total phosphorus would be stable; cessation of plant growth occurring before this time. They also discovered that the organic matter in the 0-5 cm depth was greater on burned areas. They concluded that the nitrogen-supplying power of the soil was enhanced. It is possible that increased fertility on burned areas would only become evident at a later date. Minor gains in productivity and vigour observed on burned subplots in the current investigation could just as easily be attributed to differences in soil temperature.

Since the major differences in tiller density existed between treated subplots and controls, it would be safe to assume that the simple removal of living and dead plant tissue was the indirect cause. The direct causes of stimulation could then be any of a number of changes in the physical micro-environment of the plant.

A change in soil moisture can be eliminated as a factor since drought depresses tillering (Youngner 1972). Soil moisture levels were shown to decline on defoliated areas due to increased evaporation from the soil surface (Old 1969).

In this study, increased soil exposure resulted in higher soil temperatures during the day (Figures 12 to 14). Chilcote et al. (1973) found that higher temperatures during the day favoured growth of tillers and increased the potential for secondary tillering. High soil temperatures also promoted root growth which aided in the establishment and survival of new tillers. Differences in soil temperature on treated and untreated areas were most pronounced during the first growing season. Temperatures differed from controls at all three depths; burned treatments consistently recording higher temperatures than mowed areas. Soil temperatures were several degrees higher than air temperature at the 3 cm depth during the first growing

Figure 12. Soil temperature (°C) at 3 cm.

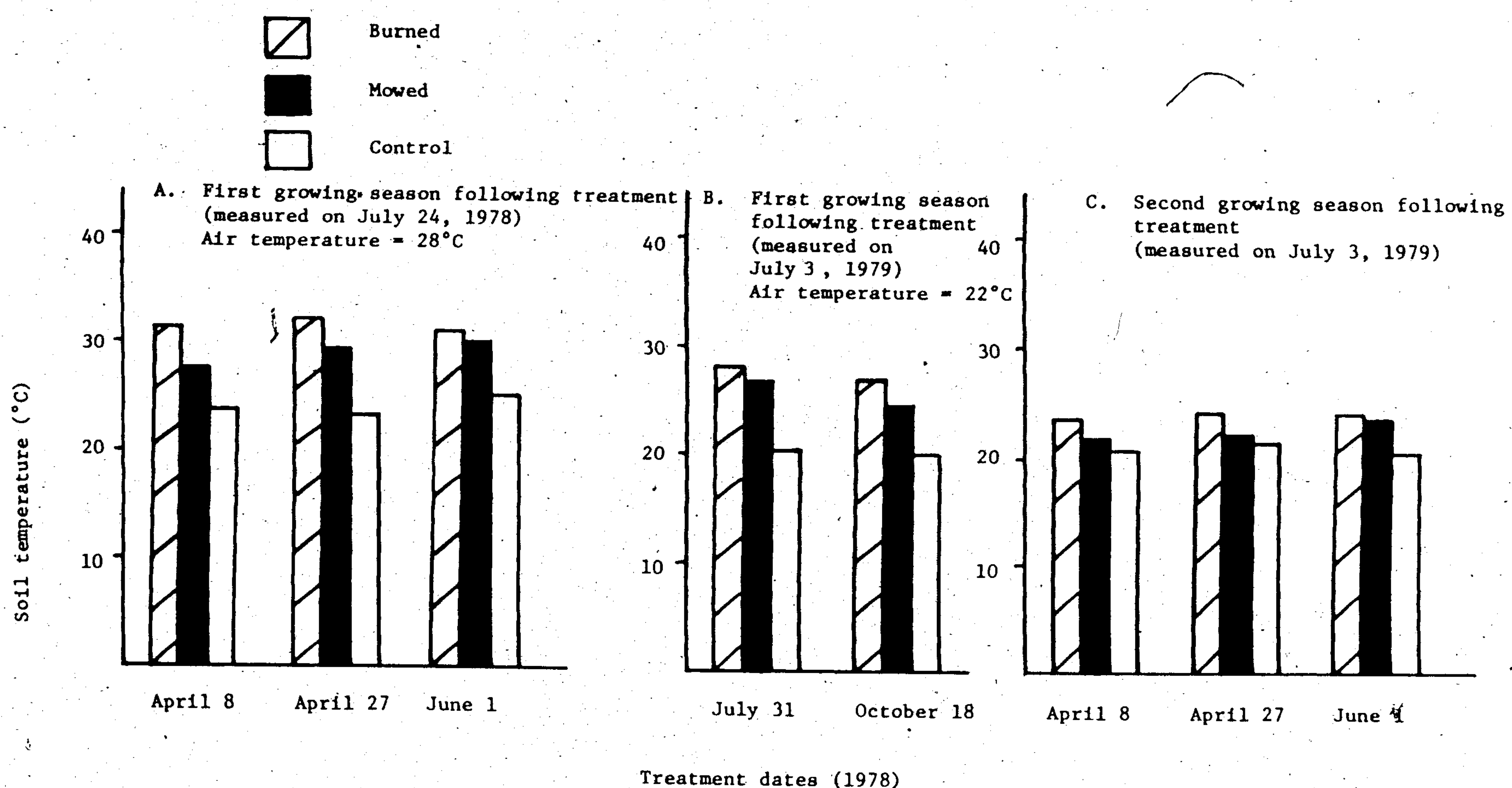


Figure 13. Soil temperature at 6 cm.

A. First growing season following treatment (measured on July 24, 1978)

B. First growing season following treatment (measured on July 3, 1979)

C. Second growing season following treatment (measured on July 3, 1979)

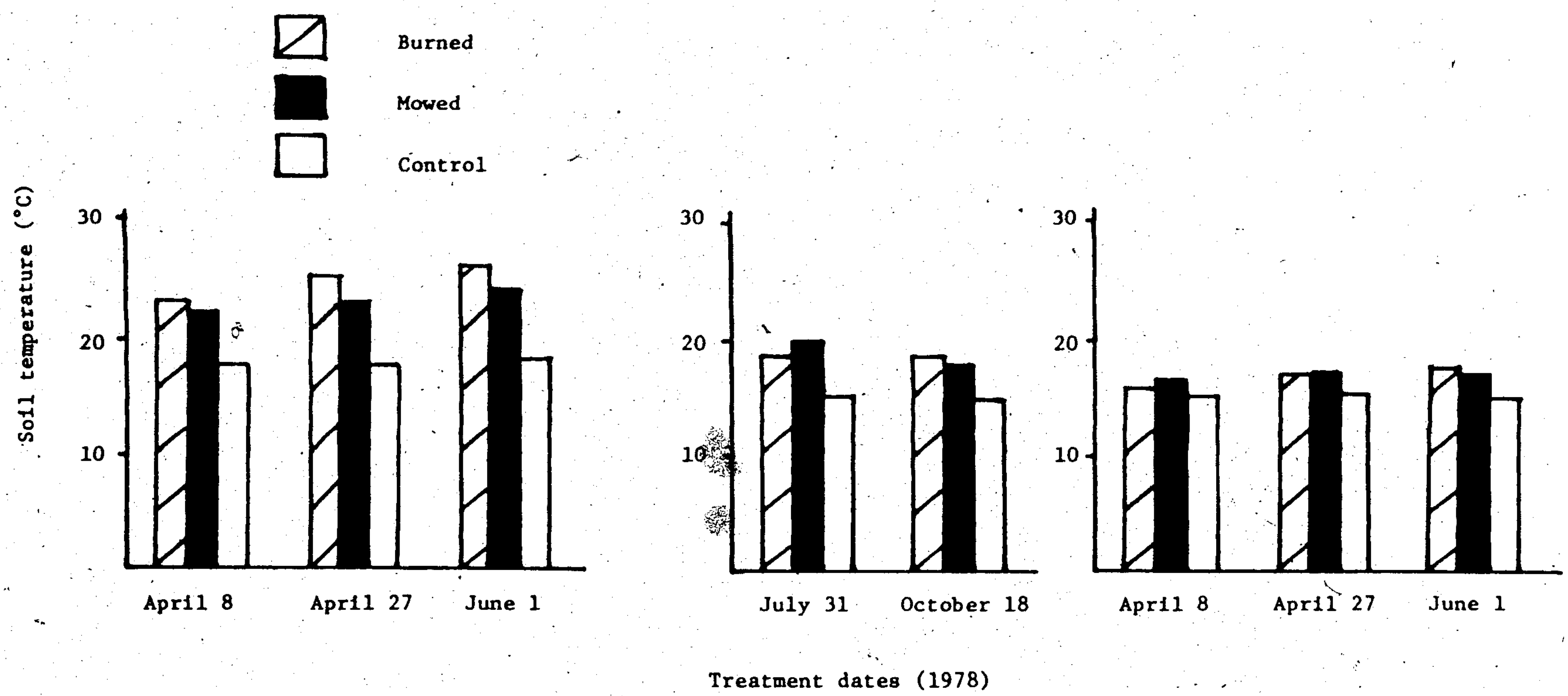
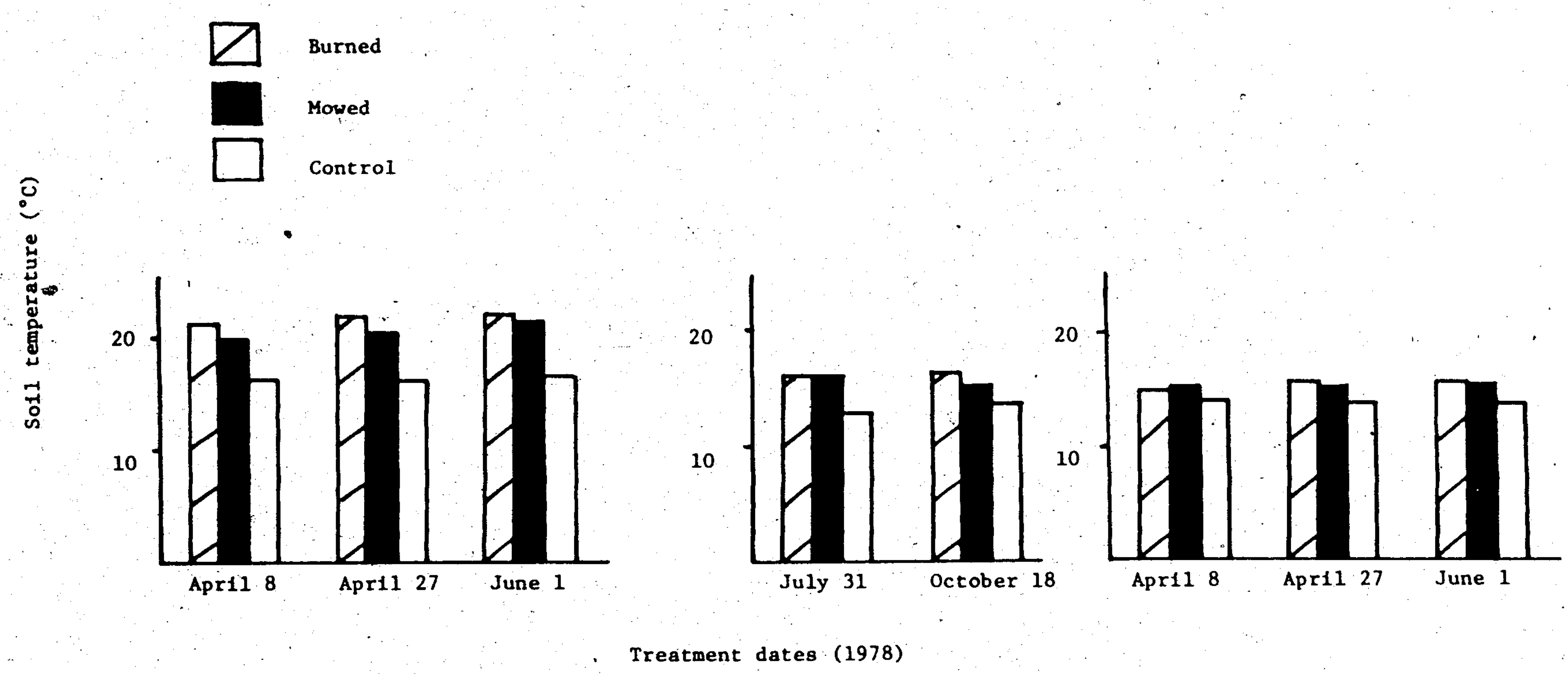


Figure 14. Soil temperature at 9 cm.

A. First growing season following treatment (measured on July 24, 1978)

B. First growing season following treatment (measured on July 3, 1979)

C. Second growing season following treatment (measured July 3, 1979)

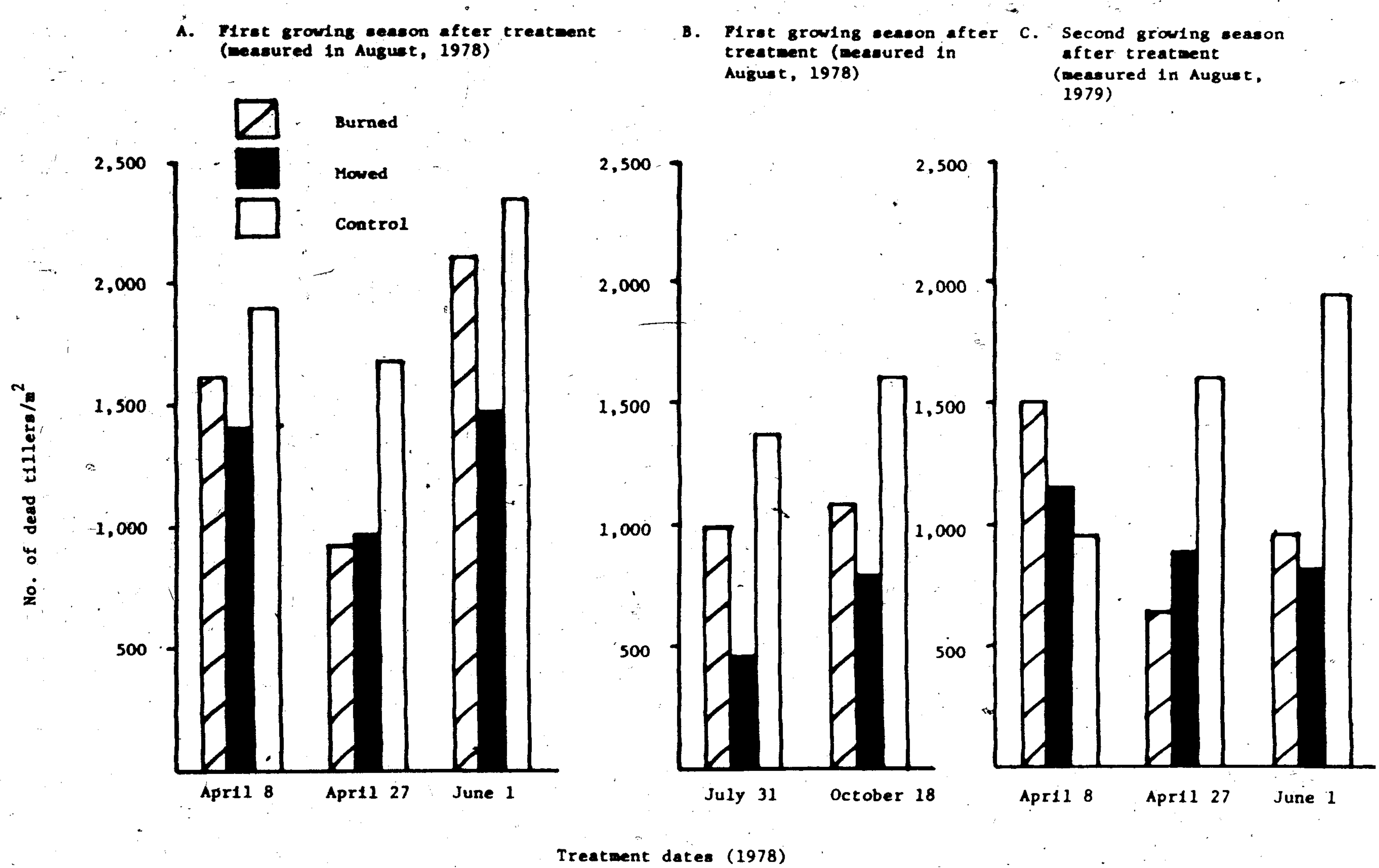


season. This effect was much less pronounced in the second year. Since the ash cover persisted well into the second growing season, it could be concluded that the smaller differences were a result of shading by new growth. Increased soil temperatures on mowed areas over controls were causedapparently by lower reflectance of radiation (Peet et al. 1975). The large quantities of litter in the control subplots reflected a great deal more radiation in the visible and infrared ranges. Once green growth appeared, the effect was lessened, but only completely eliminated when the ground became completely shaded again. The additional increment of temperature observed on burned subplots was attributed to the layer of black ash on the soil surface. This temperature difference was sufficient to cause some disparity in plant response between burned and mowed treatments.

Langer (1963) recognized that the ability of grasses to produce tillers was very sensitive to changes in light energy. Without exception, high light intensity was found to favour tillering. Therefore, it is most likely that the indirect cause of more prolific tillering on defoliated areas was the increased solar energy reaching the plant crown (both light and heat).

The density of dead tillers was highly variable on control subplots (Figure 15). It was observed that the greatest number of dead tillers were found under the most dense mats of litter. Neither type of defoliation resulted

Figure 15. Number of dead *Festuca hallii* tillers/m^2



in more dead tillers than were found on control subplots. The density of dead tillers decreased on treated subplots during the second growing season. This might be expected if no tiller death occurred over the winter months, and the previous year's dead top growth continued to decompose. The amount of dead material was dependent on the intensity of burning. The persistence of a greater number of dead tillers on subplots burned on April 8 was related to the greater fuel moisture levels on that date. Since the litter did not burn well, the lower portions of both live and dead tillers remained unaffected. Variation between burned and mowed treatments following the June 1 and July 31 treatment dates was a result of differences in plant maturity. Many tillers which started growth in April or May were killed by burning but were not completely consumed by the fire because of high moisture levels. However, on mowed subplots there was no discrimination between green and dead tillers; all were cut by the mower.

5.3 Tiller Length and Rate of Growth

Leaf and sheath lengths in all tiller categories were reduced following burning and mowing treatments. Means for the largest group, the two-leaved tillers, are presented in Figures 16 and 17. Means for the remaining tiller categories can be found in Appendix A. The two treatments caused similar reductions in length. Leaf lengths were an average of 23% greater on untreated areas in 1979 than in 1978.

Figure 16. Leaf length of Festuca hallii two-leaved tillers.

A. First growing season following treatment (measured in August, 1978)

B. First growing season following treatment (measured in August, 1979)

C. Second growing season following treatment (measured in August, 1979)

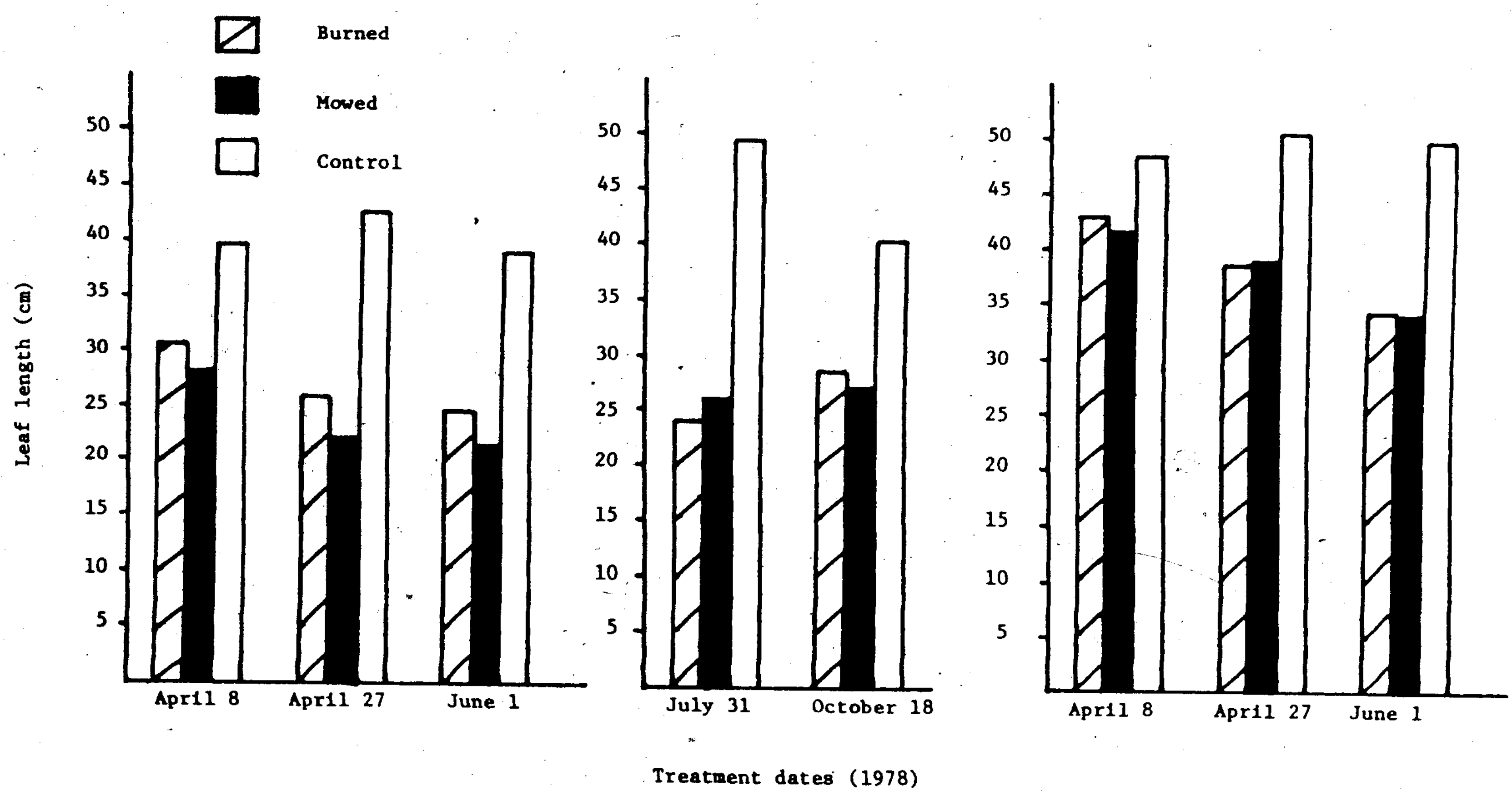
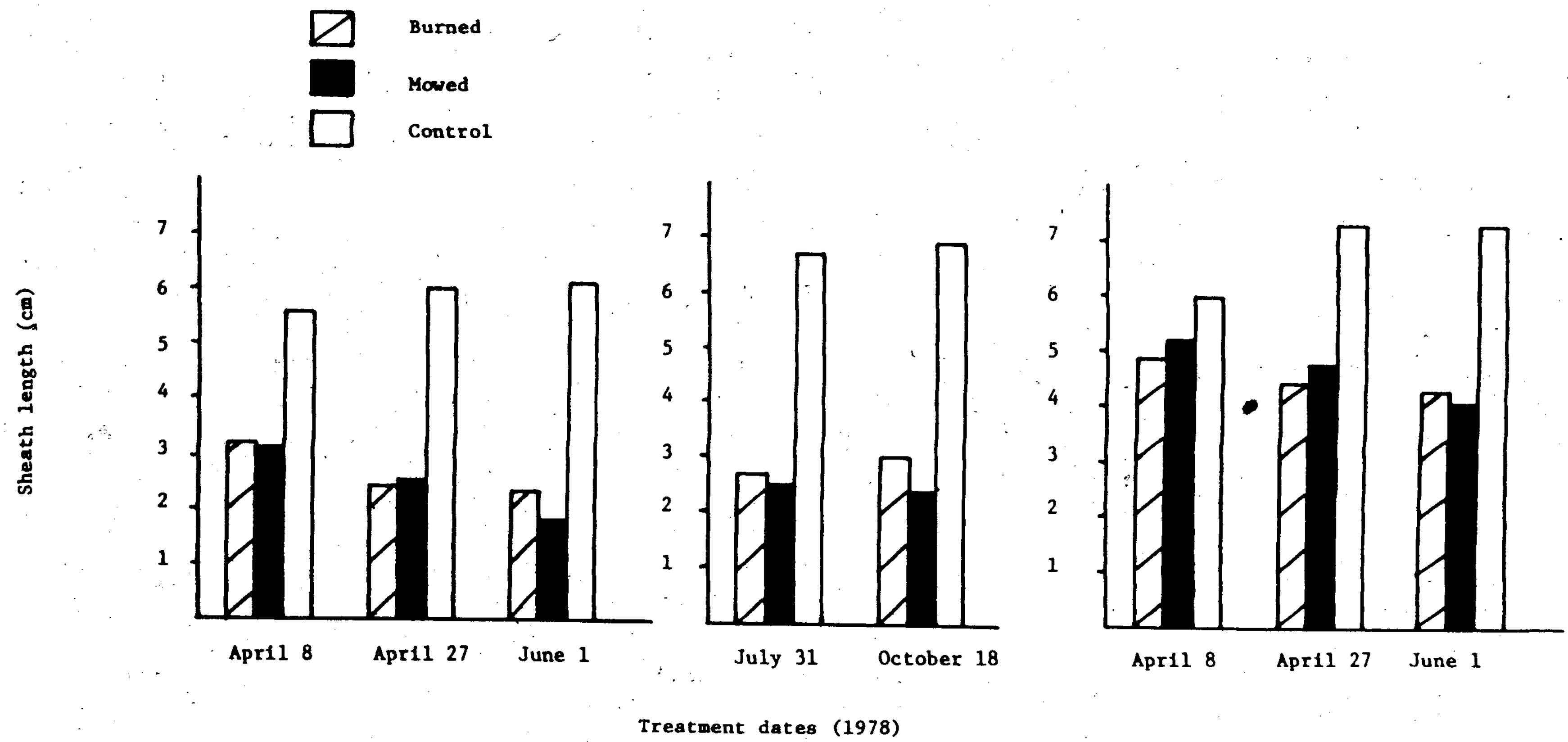


Figure 17. Sheath Length (cm) of Festuca hallii two-leaved tillers

A. First growing season following treatment (measured in August, 1978)

B. First growing season following treatment (measured in August, 1979)

C. Second growing season following treatment (measured in August, 1979)



Sheath lengths were 20% greater. This could be related to the higher than average precipitation during July of 1979 (Table 1). Adjustments made to the July and October treatment means indicated that leaves on these subplots were shorter during the first growing season than those on spring-treated areas. Leaves approached pre-treatment lengths only on the April 8 treated subplots during the second growing season. After adjustments, sheath lengths on the July and October defoliated subplots approximated those on the June treatments during the first growing season. As with leaf lengths, only sheaths on April 8 treated subplots came close to pre-treatment lengths during the second growing season. It was apparent that leaves and sheaths of F. hallii would take at least three growing seasons to recover to pre-treatment lengths when defoliated in this manner at any time during the growing season.

Immediate reductions in leaf and sheath length after disturbance, such as those seen in this study, are probably a response of the plant to the removal of shading. Reductions in tiller length have been common responses of grasses to disturbance (Daubenmire 1968). Chilcote et al. (1973) reported that grasses growing under a better light environment resulted in reduced top growth. With excessive leaf and sheath growth suppressed, food storage in stem bases increased and development of more tillers resulted. Anderson and Bailey (1980) found that repeated annual spring burning of F. hallii reduced leaf lengths by 50%. Shorter leaves and sheaths would signify that growth rates of the plants on defoliated areas were lower than on controls. This was found to be true of all plants monitored for an eight day period in June, 1979 (Table 9). Even plants treated on April 8, 1978 exhibited much slower rates of growth than those on untreated sites. It was unlikely, however, that these growth rates prevailed during the entire growing season. Just a few days before the sampling period, flowering of F. hallii began on treated subplots. At the time of anthesis, the growth rate of vegetative tillers has been shown to decline (McCarty and Price 1942). Since the plants in the controls did not flower until the end of the sampling period, it was expected that their growth rate would be higher. The difference in phenology between treated and untreated areas began in the spring, when growth on burned and mowed subplots started up to three weeks earlier. This effect has been attributed to warmer soils (Ehrenreich 1959).

The maximum rate of growth in a sward coincides with the time of nearly complete light interception (Brougham 1955). Greater defoliation results in a longer period of time before this p Because of its erect growth habit and narrow, involute leaves, F. hallii on defoliated subplots would have taken a relatively long period of time to achieve growth rates equal to or greater than those on untreated areas. It was expected that defoliated plants would eventually have reached a higher net assimilation rate. This

Table 9. Growth rate (cm) of Festuca hallii between June 18, 1979 and June 26, 1979.

Treatment	Treatment Dates (1978)				
	April 8	April 27	June 1	July 31	Oct 18
Burned	3.6bc	3.4bc	3.2bc	1.9c	2.5bc
Mowed	3.8b	3.3bc	2.9bc	1.9c	2.4bc
Control	6.7a	6.3a	6.0a	6.9a	6.9a

Means followed by the same letter (a-c) do not differ significantly ($P>0.05$).

was because most of the leaves would reach their optimum physiological age at the same time, resulting in maximum photosynthetic efficiency.

5.4 Herbage Yield and Litter Production

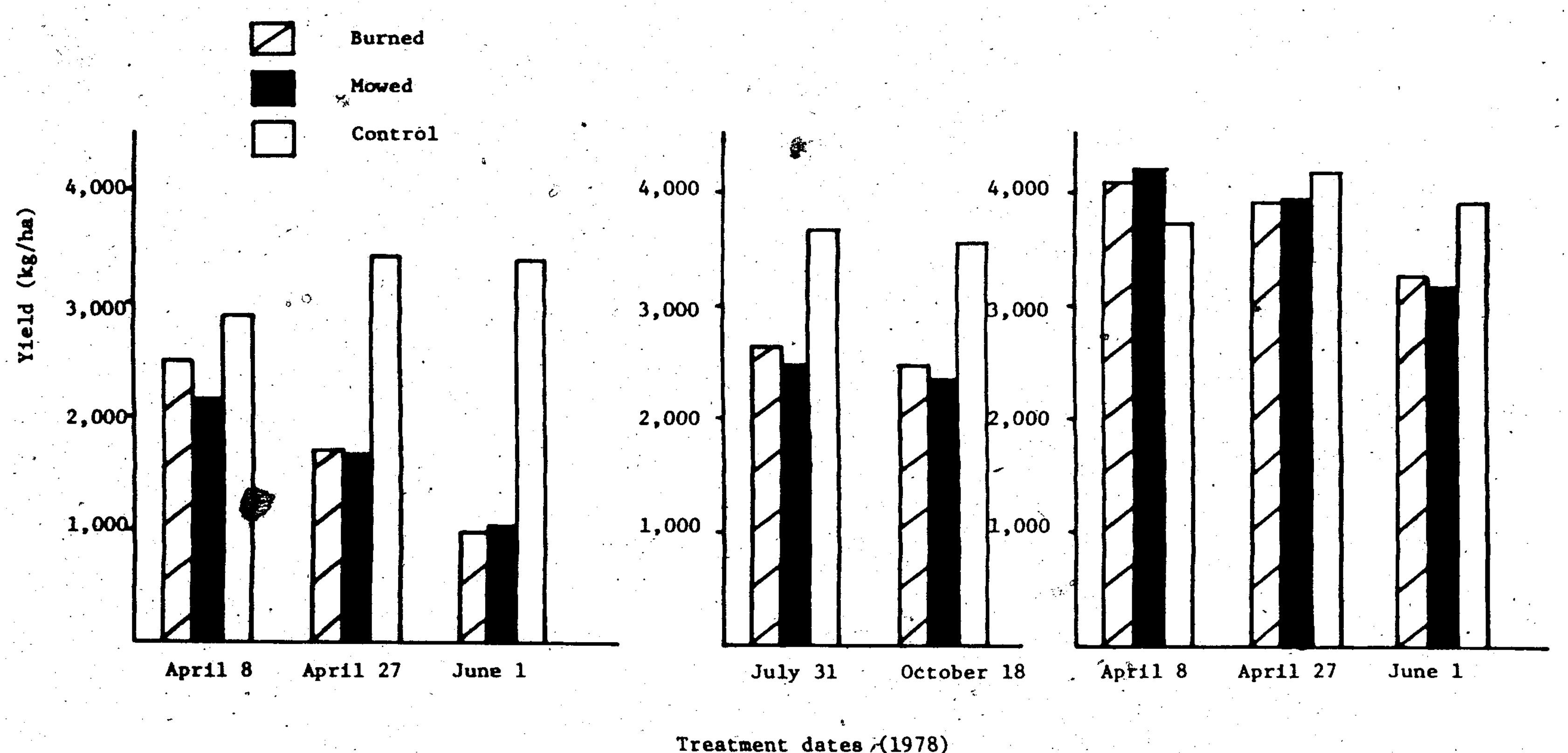
Burning and mowing at all treatment dates had similar effects on herbage yield for two growing seasons after treatment (Figure 18). The difference between April 27 and June 1 treatment yields and the equivalent on July 31 and October 18 may not be as great as it would first appear. To obtain an annual herbage yield figure for subplots treated prior to August, 1978, it would be necessary to add the weight of green growth present at the time of treatment to the August harvest value. This was most important for the June 1 treatments. The data was not collected in the present study. However, Bailey et al. (1980) reported a mean yield of 880 kg/ha on a Festuca-Stipa grassland on June 1 (1975-1977). If this value is added to the 1978 harvests from June 1 treated subplots, the result is similar to treatment on April 27. The differences in yield between early and late spring treatments observed in the second growing season could be attributed to the removal of shading closer to the time of fall tiller initiation. New tillers would be shortest on sub-plots where light intensity was greatest. Mowing on April 8 caused a greater reduction in yield than burning. The latter treatment resulted in incomplete removal of herbage because of high fuel moisture

Figure 18. Herbage yield (kg/ha) in the first and second growing seasons after treatment.

A. First growing season after spring treatments (harvested in August, 1978)

B. First growing season after spring treatments (harvested in August, 1979)

C. Second growing season after spring treatments (harvested in August, 1979)



levels, while mowing removed the plant material in a more uniform fashion. If reduced yields following defoliation were a response to elimination of shading, it was reasonable to expect mowing on April 8 to produce lower initial yields.

Forage yields on untreated plots were an average 22% higher in 1979 than in 1978. If this figure was subtracted from yields of the subplots treated on July 31 and October 18, the values acquired fell between yields obtained from April 8 and April 27 treated subplots.

Herbage yields were more closely related to stubble height than to any other variable pertaining to the time of treatment. Correlation coefficients were 0.50 in 1978 and 0.60 in 1979. Therefore, regrowth was more dependent on the height to which the plant was defoliated than on environmental conditions at the time of treatment. Yields were highly correlated with leaf lengths (0.81 in 1978 and 0.66 in 1979), but not with tiller density (0.26 and 1978 and 0.22 in 1979). This might have been due to the fact that leaf length showed a greater response to defoliation than tiller density did. Weight per tiller was not measured in this study, therefore, it was not possible to estimate yields, using this variable in combination with tiller density.

Litter was virtually eliminated from subplots burned on July 31 (Table 10). This reflected the extremely dry condition of this component of the fuel on that date. Generally, differences in the quantity of litter found in

Table 10. Litter (kg/ha) collected in August, 1979.

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	1188c	543cd	333cd	130d	368cd
Mowed	1133c	575cd	501cd	333cd	508cd
Control	4059b	4283b	4352b	4484b	5842a

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

the second season following the spring treatments approximated differences in productivity. The relatively larger mass of litter found on April 8 defoliated subplots can be attributed to the incomplete removal of herbage at the time of treatment. On the basis of collections made, it would have taken at least five growing seasons for the litter to reach pre-treatment levels. It has been shown that when the depth of litter is great, burning or mowing can stimulate production (Kucera and Ehrenreich 1962; Hulbert 1969; Old 1969). The litter in the grassland under study had been accumulating for 13 years. Since soil moisture was not limiting in this case, the removal of litter could be expected to stimulate production.

5.5 Basal Cover

The basal cover of live *F. hallii* remained virtually unaffected by any treatment (Table 11). This species occupied an estimated 18 to 23 percent of the total area in the grassland community. Mortality from either treatment was probably minimal, considering the fact that apical meristems were below ground level. Stubble height measurements indicated that fire approached ground level infrequently. The lower yields experienced after treatment were, therefore, a function of shorter tiller lengths rather than tiller mortality. This conclusion was supported by measurements of basal cover of dead *F. hallii* (Table 12). Treatment decreased the cover of dead tillers in most cases.

Table 11. Basal cover (%) in June, 1979 of live *Festuca hallii*.

Treatment	Treatment Dates (1978)				
	April 8	April 27	June 1	July 31	Oct 18
Burned	21.3ab	18.3ab	19.0ab	17.8ab	16.3b
Mowed	21.3ab	20.3ab	16.5b	19.5ab	19.8ab
Control	19.8ab	20.8ab	21.5ab	20.5ab	23.3a

Means followed by the same letter (a-b) do not differ significantly (P>0.05).

Table 12. Basal cover (%) in June, 1979 of dead *Festuca hallii*.

Treatment	Treatment Dates (1978)				
	April 8	April 27	June 1	July 31	Oct 18
Burned	5.5b	1.8e	2.8c-e	2.3de	3.0c-e
Mowed	3.0c-e	3.5b-e	3.3b-e	3.3b-e	4.8bc
Control	4.3b-d	4.5b-d	4.3b-d	8.0a	5.0bc

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

The greater coverage by dead stems on April 8 burned subplots during the second growing season was again due to the nature of the fire on that date; moisture levels preventing the combustion of much dead material.

Basal cover of burned F. hallii tillers and ash were affected by the intensity of the fires and the time elapsing between treatment and sampling dates (Table 13). For example, it was expected that more burned stems would have survived from the October 18 fire than from the July 31 fire. However, dry fuel conditions during the July treatment allowed more combustion of plant stems. Burned stems persisted in the stand for over a year. Those from the April 8 burn probably did not decompose more rapidly bur were counted instead as dead stems, since they suffered only minimal charring. The rate of decomposition has often been slow for several years following a fire because of a lack of compaction in the mulch (Dix 1960). More ash survived from the April 27 blaze than from the other two spring fires. This was not surprising since weather and fuel conditions on that date caused more complete combustion. Ash remaining on the subplots as a dark layer was important as it influenced soil temperatures and, therefore, subsequent plant growth.

Visual observations indicated that the basal cover of Carex filifolia and Androsace septentrionalis L. increased on burned and mowed subplots, while the cover of moss decreased. These plants are indicators of the drier micro-environment present following defoliation. Drier

Table 13. Basal cover (%) in June, 1979 of burned *Festuca hallii* and ash

Burned F. hallii

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	0.0e	2.8d	4.5c	8.3a	6.8b
Mowed	-	-	-	-	-
Control	-	-	-	-	-

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Ash(% basal cover)

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	2.3e	13.3c	7.0d	25.0b	27.5a
Mowed	-	-	-	-	-
Control	-	-	-	-	-

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

conditions have been attributed to increased exposure of the soil to evaporation (DeJong and MacDonald 1975; Redmann 1975). activity (Old 1969).

5.6 Inflorescence Production

Burning or mowing had no effect on production of F. hallii inflorescences during the first growing season. However, both types of defoliation resulted in increased flowering in the second growing season (Table 14). In addition, flowering stems were elevated earlier on treated subplots and came into anthesis prior to those on controls (Figure 19).

Stimulation of flowering after burning or mowing is a common phenomenon. Festuca species have been listed among those plants which have been stimulated (Daubenmire 1968). The fact that the stimulatory effect was delayed until the second growing season following spring treatments may have been because the floral induction process started late in the season. Floral initiation in a closely related species, Festuca doreana, took place in late August to early September (Johnston and MacDonald 1967). It was likely that F. hallii had a vernalization requirement for floral induction. Sachs (1972) found that the low temperature effect was perceived by the shoot apical meristems in many grasses. Since F. hallii apical meristems were below ground level and soil temperature on defoliated areas were affected to a depth of at least 9 cm, the induction process was

Table 14. Number of <u>Festuca hallii</u> inflorescences/m² in July, 1979

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	48.2b	65.7ab	60.8ab	2.3d	2.8d
Mowed	45.2bc	67.9ab	87.7a	3.1d	12.4d
Control	12.2cd	12.5cd	12.2cd	15.4cd	7.1d

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

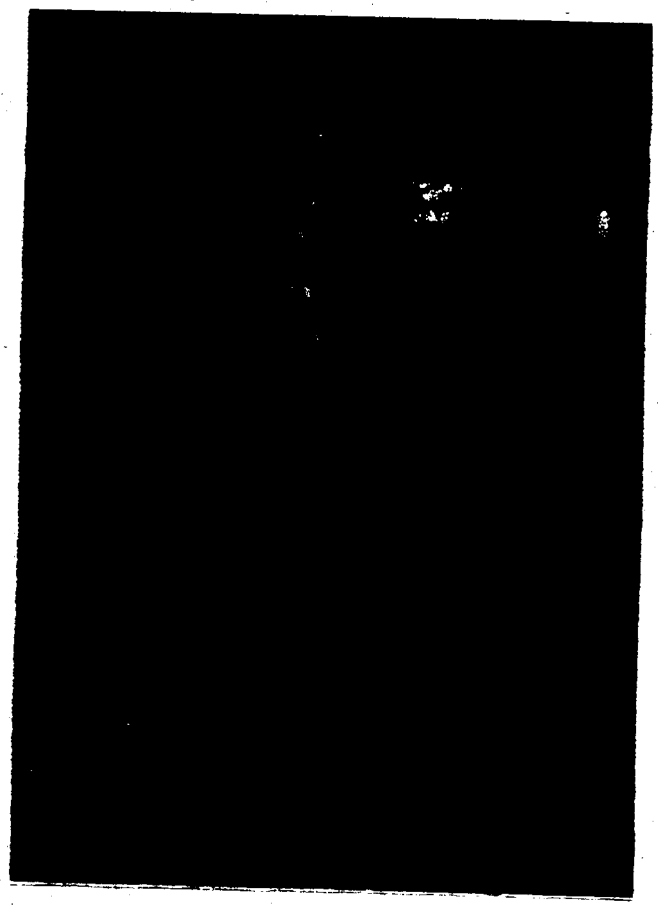
Table 15. Number of <u>Stipa spartea</u> var. <u>curtiseta</u> inflorescences/m²

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	15.0a-c	16.0a-c	23.3ab	13.0a-c	5.7bc
Mowed	28.8ab	28.7a	20.0a-c	25.6ab	4.7bc
Control	12.7a-c	9.1a-c	1.7c	5.0bc	1.0c

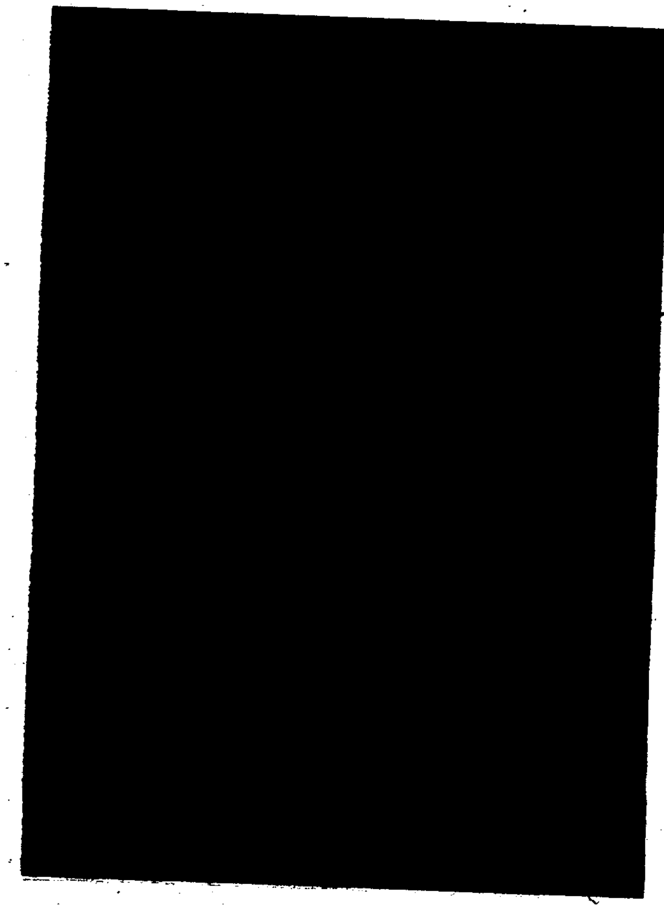
Means followed by the same letter (a-c) do not differ significantly (P>0.05).

Figure 19: *Festuca hallii* inflorescences photographed on June 18, 1979.

a. control subplot



b. burned subplot



probably influenced by lower soil temperatures at night. Variation in the density of inflorescences among treatment dates could have been related to the extent to which regrowth affected soil temperatures during the period of floral induction. For example, the most regrowth would have occurred on subplots treated on April 8, therefore, temperature extremes would not have been as pronounced. With the vernalization requirement only partially fulfilled, fewer inflorescences would have appeared the following summer. Similarly, the difference between inflorescence density on subplots burned and mowed on June 1 could be explained in terms of the quantities of plant material removed. Burning on that date did not eliminate as much material as mowing because of high fuel moisture and less favorable weather conditions. The remaining plant material on burned subplots could have acted as an insulating layer at night, keeping soil temperatures higher.

The apparent inability of plants treated at the end of July to produce increased numbers of inflorescences during the following growing season could mean that floral induction began before this date. Perhaps a more logical explanation was that the removal of top growth just before floral induction prevented the plant from accumulating enough carbohydrates to initiate the primordia.

The results obtained in the present study contradict those found by Bailey and Anderson (1978). They found that a single spring fire in 1970 did not affect production of F.

hallii seed heads for three years. A spring fire in 1971 reduced the density of inflorescences in the first year, while a fall fire in 1971 had no effect on production of seed heads. Precipitation records showed that rainfall in August and September of 1970 and 1971 was well below normal (Table 1). This might have inhibited floral induction, especially on burned areas which would already have a drier micro-environment.

The density of Stipa spartea var. curtiseta seed heads also increased following most treatments (Table 15). Statistical verification of this observation was difficult because of the frequent absence of Stipa from subplots. Bailey and Anderson (1978) also reported that a single spring fire in 1970 stimulated production of seed heads in this species for three growing seasons. However, burning the following spring had no effect on inflorescence density, while fall burning reduced the number of seed heads appearing the following year. Annual spring burning decreased the density of Stipa inflorescences in another study (Anderson and Bailey 1980). It was possible that annual burning reduced the vigor of this species and that insufficient non-structural carbohydrates were available for floral induction. The inconsistency of results indicated that sampling techniques did not take into account the fact that Stipa did not have a uniform distribution in this grassland. Measurements should have been made on a per bunch basis for minor grass species in this community, rather than by random location of a quadrat. The former method has been used successfully by Uresk et al. (1976).

6. CONCLUSIONS AND IMPLICATIONS FOR MANAGEMENT

F. hallii began growth in 1978 before snowmelt and continued growth until the last observation date, October 18. This suggests that if this type of grassland is to be grazed, it would be preferable to do so in the fall, when carbohydrate reserves have been established below ground. Grazing in the spring would be more detrimental to the plants' vigour since winter respiration would have brought carbohydrate stores to a low level. The results of the present study indicate that removal of the first flush of spring growth would also greatly retard the productivity of the sward.

The large accumulation of litter on this grassland would prevent effective utilization by grazing animals. Removal of litter would make the forage more accessible and more palatable (Bailey 1978). The present study has shown that litter and herbage removal by either burning or mowing lowers herbage yields in the first growing season, reduces leaf and sheath lengths and increases tiller density in *F. hallii*. Herbage production was not reduced following a prescribed burn conducted one week after snowmelt. Mowing on the same date, April 8, 1978, depressed production in the first year by 25%, which was a lower reduction than was found after mowing at any other date. Herbage production in the first growing season was probably depressed most (70%) following burning or mowing three weeks prior to anthesis (June 1, 1978). Burning or mowing five weeks after anthesis (July 31, 1978) or after most growth had died back (October

18, 1978) reduced yields in the first year by 30%. Yields recovered in the second year to pre-treatment levels on areas burned or mowed on April 8 or April 27. This study did not conclusively indicate whether spring or fall burning is better for this grassland. At first glance, it might appear that early spring burning should be favored. However, if conditions prior to and during burning had allowed more uniform combustion, reductions in yield similar to those on mowed areas (25%) might have been expected. This would have been similar to depressions in yield obtained after the July and October treatments. It is clear, however, that if spring burning is to be implemented, treatment should be carried out as soon after snowmelt as possible. If weather conditions tend to be more settled in the fall, it would be better to burn at that time.

Lowered production levels were largely a function of shorter leaf and sheath lengths. These were reduced least in the first year following treatment by burning or mowing on April 8, 1978 (30%), and most by treatment on July 31 (50%). Only tillers burned on April 8 regained pre-treatment leaf lengths by the second year, while sheath lengths were still shorter. This response was attributed to the removal of shading by herbage and litter. The shorter tillers growing after a prescribed burn on a previously undisturbed grassland would be better adapted to grazing. The grazing animal would then not be able to remove as great a percentage of photosynthetically active tissue. Therefore, a quicker recovery after grazing could be expected.

Tillering was shown by this study to occur predominantly in the fall and to a lesser extent in the early spring. The initial response of the <u>F. hallii</u> tiller to any spring treatment was the production of new leaves. This was followed by the initiation of a greater number of new tillers in the fall on treated subplots. Areas treated in June did not elicit the latter response. Defoliation, therefore, stimulated tillering in this species. This is another indication that <u>F. hallii</u> is likely to be well adapted to grazing, unlike its relative, <u>F. doreana</u>. The latter species is not rhizomatous and decreases rapidly under grazing.

The growth rate of <u>F. hallii</u> was lower on treated subplots during a ten day observation period in June, 1979. Growth rates were comparable among areas treated on different dates. That such reductions in growth rate occur following defoliation has to be taken into account when burning, mowing or grazing this grassland. The lower the height of defoliation the longer it will take the plants to regrow.

The basal area of live <u>F. hallii</u> was generally unaffected by burning or mowing. Mortality due to either type of litter and herbage removal was, therefore, virtually non-existent. This indicated that heat from the fires did not damage apical meristems. Fuel moisture levels were largely responsible for fires rarely burning to ground level. Apical meristems remained below ground level when vegetative, which also accounted for the absence of mortality following either defoliation treatment.

Production of _F. hallii_ inflorescences was unaffected in the first growing season following burning or mowing on any date in 1978. A four- to seven-fold increase in the production of seed heads was seen in the second growing season following spring treatment. Further investigation into the cause of this stimulation might be valuable. It would be useful to be able to produce _F. hallii_ seed, which could be used in the rejuvenation of overgrazed fescue rangelands in the area.

Daytime summer soil temperatures at 3, 6 and 9 cm were 1-6°C higher on all treated subplots in the first year following burning or mowing. Burned subplots had temperatures which were 1-2°C higher than mowed subplots. Increases over controls in the second year following spring treatment ranged between 1 and 2.5°C. Differences between burned and mowed subplots disappeared in the second year.

The morphological responses of _F. hallii_ on both burned and mowed subplots were similar. It can be concluded that the burning of this species can essentially be regarded as a type of defoliation treatment, since no evidence of differences due to heat damage or fertilization by ash could be found.

7. FUTURE RESEARCH

This study was designed to provide physiological and ecological information about an economically important forage species, <u>Festuca hallii</u>. A central finding was the compensatory decrease in tiller length with increase in tiller density, in response to defoliation. Tiller length, weight and density are components of forage yield. The apparent compensation between two of these yield components, particularly in response to defoliation, may suggest a potential limitation to herbage yield. This hypothesis should be examined more closely to determine ways of managing these yield components to optimize pasture performance.

The interaction between defoliation intensity and the phenologically-based capacity of the plant to regrow could be evaluated in a clipping study. Treatments could involve a range of clipping heights, imposed on plants at varying stages of development. Trends in tiller length, weight and density in response to these factorial treatments, could be interpreted to suggest minimal recovery times for yield and persistence. I interpreted the tendency for burned areas to produce more and longer tillers, as a response to soil temperature. An alternative explanation, that burning affected soil fertility, was beyond the scope of the present study, but could be explored by analyzing both soil and plant mineral nutrient status under burned, mowed and control treatments.

A third area of interest concerns the production of inflorescences. It has already been mentioned that commercial seed production for the reclamation of overgrazed or otherwise misused F. hallii rangeland would be advantageous. The present study showed that burning and mowing in the early part of the growing season stimulated the production of seed heads in the following year. Why does this happen? Perhaps this is a question best answered by a physiologist.

Once the behaviour of F. hallii in a relatively pure stand is understood, including aspects of intraspecific competition, then interspecific competition could be investigated. The reasons for the plant's existence as the dominant species on these rangelands could be explained. It might be possible, for example, that its persistent litter exerts an allelopathic, as well as physical barrier to the growth of other species. The interaction of the species with various cultivated and native legumes could be assessed, since the introduction of such plants would increase the quality of the forage and raise the level of available nitrogen in the soil.

With so little known about this forage, research could progress in many directions. The important thing is that the research into the physiology and ecology of this species continues, and the value of native rangelands is realized before they are all converted to cultivated pastures.

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9. APPENDIX A

Treatment Means with Duncan's Multiple Range Test

Table 1. Total number of <u>Festuca</u> <u>hallii</u> tillers/m^2 in 1978.

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	6599ab	6463ab	5747cd
Mowed	6200bc	6928a	5019f
Control	5572de	5172ef	4719f

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

Table 2. Total number of <u>Festuca</u> <u>hallii</u> tillers/m^2 in 1979.

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	11588a	11075a-c	9613a-e	10850a-c	11313a
Mowed	10525a-d	10738a-c	10025a-e	11200ab	10975a-c
Control	7975c-e	7125e	8575a-e	8013b-e	7500de

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Table 3. Number of one-leaved *Festuca hallii* tillers/m² in 1978.

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	1213ab	1413ab	1125ab
Mowed	1156ab	1703a	978b
Control	866bc	803b	981b

Means followed by the same letter (a-c) do not differ significantly (P>0.05).

Table 4. Number of one-leaved *Festuca hallii* tillers/m² in 1979.

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	3509a	3528a	2905a-c	3495a	3971a
Mowed	3183ab	2990a-c	2585a-d	3476a	3224a
Control	1760b-d	1265d	1579cd	1569cd	1321d

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

Table 5. Number of two-leaved <u>Festuca</u> <u>hallii</u> tillers/m² in 1978.

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	3775ab	3547ab	3397ab
Mowed	3619ab	4066a	2847b
Control	3859ab	3722ab	3172ab

Means followed by the same letter (a-b) do not differ significantly (P>0.05).

Table 6. Number of two-leaved <u>Festuca</u> <u>hallii</u> tillers/m² in 1979.

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	6780a	6624ab	5846ab	5875ab	5552ab
Mowed	6273ab	6303ab	5965ab	5916ab	5268ab
Control	5001ab	4578b	5806ab	5315ab	4926ab

Means followed by the same letter (a-b) do not differ significantly (P>0.05).

Table 7. Number of three-leaved *Festuca hallii* tillers/m² in 1978.

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	1519a	1331ab	1125b-d
Mowed	1300a-c	1009cd	1031cd
Control	838de	641e	547e

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Table 8. Number of three-leaved *Festuca hallii* tillers/m² in 1979.

Treatment	April 8	April 27	Treatment Dates (1978) June 1	July 31	Oct 18
Burned	1304b-d	956d	1856ab	1388b-d	1593a-d
Mowed	1058d	1456b-d	1[illegible]5b-d	1768a-c	2105a
Control	1148cd	1320b-d	1203cd	1119cd	1246b-d

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Table 9. Number of four-leaved *Festuca hallii* tillers/m^2 in 1978.

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	94c	172ab	200a
Mowed	125bc	150a-c	163a-c
Control	9d	6d	19d

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

Table 10. Number of four-leaved *Festuca hallii* tillers/m^2 in 1979.

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	58cd	18d	44d	144c	240b
Mowed	43d	29d	43d	93cd	326a
Control	23d	20d	20d	13d	36d

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

Table 11. Number of dead *Festuca hallii* tillers/m^2 in 1978.

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	1622a-c	919c	2100ab
Mowed	1403bc	956c	1469bc
Control	1888ab	1672a-c	2344a

Means followed by the same letter (a-c) do not differ significantly (P>0.05).

Table 12. Number of dead *Festuca hallii* tillers/m^2 in 1979.

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	1500a-d	649fg	965d-g	989d-g	1086c-f
Mowed	1150c-f	688fg	813e-g	453g	786fg
Control	951d-g	1623a-c	1953a	1365b-e	1721ab

Means followed by the same letter (a-g) do not differ significantly (P>0.05).

Table 13. Soil temperature (°C) at 3 cm.

July 24, 1978

Treatment	Treatment Dates		
	April 8	April 27	June 1
Burned	31.1ab	31.7a	31.0ab
Mowed	27.5c	29.3bc	30.0ab
Control	23.5d	23.3d	25.1d

Means followed by the same letter (a-d) do not differ significantly ($P > 0.05$).

July 3, 1979

Treatment	Treatment Dates				
	April 8	April 27	June 1	July 31	Oct 18
Burned	23.4c-e	23.7c-e	23.9cd	27.9a	26.7a
Mowed	21.4ef	21.9d-f	23.6c-e	26.5ab	24.4bc
Control	20.5f	21.3ef	20.3f	20.3f	20.0f

Means followed by the same letter (a-f) do not differ significantly ($P > 0.05$).

Table 14. Soil temperature (°C) at 6 cm.

July 14, 1978

Treatment	Treatment Dates April 8	April 27	June 1
Burned	22.8d	25.1b	26.1a
Mowed	21.8e	22.9d	23.8c
Control	17.5g	17.7fg	18.2f

Means followed by the same letter (a-g) do not differ significantly (P>0.05).

July 3, 1979

Treatment	Treatment Dates April 8	April 27	June 1	July 31	Oct 18
Burned	15.9d-g	16.8b-g	17.6b-d	18.5ab	18.3a-c
Mowed	16.6c-g	17.1b-f	17.3b-e	19.8a	17.7b-d
Control	15.3fg	15.4e-g	15.1g	15.2fg	15.0g

Means followed by the same letter (a-g) do not differ significantly (P>0.05).

Table 15. Soil temperature (°C) at 9 cm.

July 24, 1978

Treatment	Treatment Dates April 8	April 27	June 1
Burned	20.9ab	21.5a	21.6a
Mowed	19.5c	20.1c	20.9ab
Control	16.1d	15.9d	16.3d

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

July 3, 1979

Treatment	Treatment Dates April 8	April 27	June 1	July 31	Oct 18
Burned	14.8cd	15.5a-c	15.5a-c	16.3a	16.4a
Mowed	15.0c	15.2c	15.3b	16.3ab	15.4a-c
Control	13.8de	13.7e	13.6e	13.0e	13.5e

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Table 16. Leaf length of <u>Festuca hallii</u> in 1978 and 1979 for one-leaved tillers.

1978

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	23.2bc	17.7d	17.1d
Mowed	19.2cd	16.5d	14.4d
Control	26.3ab	29.4a	30.3a

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

1979

Treatment	April 8	April 27	Treatment Dates (1978) June 1	July 31	Oct 18
Burned	35.7a-c	32.4cd	28.4d	19.3e	21.9e
Mowed	34.5bc	32.2cd	28.5d	21.3e	20.7e
Control	40.4a	40.5a	41.2a	39.1ab	39.6ab

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Table 17. Leaf length of *Festuca hallii* in 1978 and 1979 for two-leaved tillers.

1978

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	30.5c	25.8de	24.7ef
Mowed	28.0cd	22.2fg	21.6g
Control	39.8b	42.5a	39.2b

Means followed by the same letter (a-g) do not differ significantly (P>0.05).

1979

Treatment	April 8	April 27	Treatment Dates (1978) June 1	July 31	Oct 18
Burned	43.0bc	38.9cd	34.4de	24.2f	28.6ef
Mowed	42.3c	38.9cd	34.2de	~~25~~.9f	27.2f
Control	48.4ab	50.7a	49.8a	49.0a	50.7a

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

Table 18. Leaf length of <u>Festuca hallii</u> in 1978 and 1979 for three-leaved tillers.

<u>1978</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	29.6d	23.5f	21.9g
Mowed	26.6e	20.6gh	19.8h
Control	37.2b	39.4a	35.8c

Means followed by the same letter (a-h) do not differ significantly (P>0.05).

<u>1979</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	39.4b	37.7bc	33.1b-d	22.9e	31.1cd
Mowed	39.3b	36.3bc	33.4b-d	23.9e	26.7de
Control	46.6a	48.9a	48.7a	46.0a	46.2a

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

Table 19. Leaf length of <u>Festuca hallii</u> in 1978 and 1979 for four-leaved tillers.

1978

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	18.9ef	19.2e	18.9ef
Mowed	22.7c	18.3f	16.0g
Control	23.8b	31.6a	21.3d

Means followed by the same letter (a-g) do not differ significantly (P>0.05).

1979

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	28.9d-g	28.4e-g	29.2d-f	18.9i	26.0f-h
Mowed	29.0d-g	34.8bc	28.6d-g	23.5g-i	21.9hi
Control	45.4a	39.2b	34.1b-d	39.1b	33.0c-e

Means followed by the same letter (a-i) do not differ significantly (P>0.05).

Table 20. Sheath length (cm) of _Festuca hallii_ in 1978 and 1979 for one-leaved tillers.

1978

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	1.9b	1.8b	1.0b
Mowed	1.7b	1.2b	1.0b
Control	3.3a	3.4a	3.9a

Means followed by the same letter (a-b) do not differ significantly (P>0.05).

1979

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	3.3cd	2.9d-f	2.8d-f	1.9fg	2.1e-g
Mowed	3.6b-d	3.1de	2.8d-f	1.7g	1.9fg
Control	4.5ab	5.3a	5.5a	4.2bc	4.6ab

Means followed by the same letter (a-g) do not differ significantly (P>0.05).

Table 21. Sheath length of <u>Festuca hallii</u> in 1978 and 1979 for two-leaved tillers.

<u>1978</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	3.2c	2.4d	2.3d
Mowed	3.1c	2.5d	1.8e
Control	5.6b	6.0a	6.1a

Means followed by the same letter (a-d) do not differ significantly (P>0.05).

<u>1979</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	4.9cd	4.4d	4.3de	2.7f	3.0ef
Mowed	5.2cd	4.8cd	4.1de	2.5f	2.4f
Control	6.0bc	7.3a	7.3a	6.7ab	6.9ab

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

Table 22. Sheath length of <u>Festuca hallii</u> in 1978 and 1979 for three-leaved tillers.

<u>1978</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	3.2c	2.4d	2.4d
Mowed	3.1c	2.3d	1.9e
Control	5.4b	5.4b	6.2a

Means followed by the same letter (a-e) do not differ significantly (P>0.05).

<u>1979</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	4.6c	4.0cd	4.2cd	2.7ef	3.1d-f
Mowed	4.6c	4.3c	3.8c-e	2.6f	2.7ef
Control	8.0b	6.6ab	7.2a	6.1b	7.0ab

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

Table 23: Sheath length (cm) of <u>Festuca hallii</u> in 1978 and 1979 for four-leaved tillers.

<u>1978</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1
Burned	2.7e	2.2g	2.3f
Mowed	3.1d	2.3f	1.8h
Control	4.5c	6.1a	5.5b

Means followed by the same letter (a-h) do not differ significantly (P>0.05).

<u>1979</u>

Treatment	Treatment Dates (1978) April 8	April 27	June 1	July 31	Oct 18
Burned	4.2cd	2.8f-h	4.0c-e	2.2h	3.1e-h
Mowed	3.5d-g	4.7c	4.1cd	2.4h	2.6gh
Control	6.9a	5.8b	4.4cd	4.8c	3.7d-f

Means followed by the same letter (a-h) do not differ significantly (P>0.05).

Table 24. Herbage yield of <u>Festuca</u> <u>hallii</u> (kg/ha) in 1978.

Treatment	Treatment Dates (1978)		
	April 8	April 27	June 1
Burned	2491cd	1702e	972f
Mowed	2153de	1663e	1026f
Control	2885bc	3427a	3386ab

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

Table 25. Herbage yield of <u>Festuca</u> <u>hallii</u> (kg/ha) in 1979.

Treatment	Treatment Dates				
	April 8	April 27	June 1	July 31	Oct 18
Burned	4105ab	3839a-c	3265cd	2644ef	2475f
Mowed	4213a	3842a-c	3183de	2461f	2353f
Control	3733a-d	4182a	3917ab	3675a-d	3566b-d

Means followed by the same letter (a-f) do not differ significantly (P>0.05).

10. APPENDIX B

Analysis of Variance Tables

TILLER DENSITY 1978

TOTAL NO. OF TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	2456.3264	350.9036	15.4329	0.0000
MAINPLOTS	2	1586.3125	793.1563	34.8835	0.0000
MAINPLOT ERROR	448	1962.9145	22.7373		
SUBPLOTS	2	1674.7292	837.3645	36.8277	0.0000
INTERACTION	4	525.8958	131.4740	5.7823	0.0002
SUBPLOT ERROR	448	8223.4102	22.7373		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

TILLER DENSITY 1978

NO. OF 1-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	312.2361	44.6051	1.0862	0.4217
MAINPLOTS	2	105.5156	52.7578	1.2847	0.3074
MAINPLOT ERROR	14	574.9149	41.0653		
SUBPLOTS	2	233.5833	116.7917	4.9802	0.0115
INTERACTION	4	170.6823	42.6706	1.8196	0.1430
SUBPLOT ERROR	42	984.9426	23.4510		

TILLER DENSITY 1978

NO. OF 2-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	1357.0208	193.8601	2.1952	0.0483
MAINPLOTS	2	627.9661	313.9829	3.5554	0.0352
MAINPLOT ERROR	56	957.4922	88.3117		
SUBPLOTS	2	7.6068	3.8034	0.0431	0.9579
INTERACTION	4	250.0130	62.5033	0.7078	0.5900
SUBPLOT ERROR	56	3987.9634	88.3117		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

TILLER DENSITY 1978

NO. OF 3-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	133.8889	19.1270	2.8111	0.0098
MAINPLOTS	2	128.1276	64.0638	9.4155	0.0002
MAINPLOT ERROR	112	204.7752	6.8041		
SUBPLOTS	2	527.6276	263.8137	38.7729	0.0000
INTERACTION	4	11.0495	2.7624	0.4060	0.8040
SUBPLOT ERROR	112	557.2813	6.8041		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

TILLER DENSITY 1978

NO. OF 4-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	10.7361	1.5337	4.0256	0.0004
MAINPLOTS	2	3.2240	1.6120	4.2310	0.0157
MAINPLOT ERROR	224	20.0399	0.3810		
SUBPLOTS	2	31.0469	15.5234	40.7449	0.0000
INTERACTION	4	2.2760	0.5690	1.4935	0.2050
SUBPLOT ERROR	224	65.3021	0.3810		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

TILLER DENSITY 1978

NO. OF DEAD TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	914.4405	130.6344	3.0576	0.0085
MAINPLOTS	2	752.1029	376.0513	8.8017	0.0005
MAINPLOT ERROR	56	550.4944	42.7250		
SUBPLOTS	2	583.0872	291.5435	6.8237	0.0022
INTERACTION	4	125.5169	31.3792	0.7344	0.5724
SUBPLOT ERROR	56	1842.1040	42.7250		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

TOTAL TILLER DENSITY 1979

TILLER DENSITY 1979

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	9164.2000	1309.1714	1.0805	0.4017
MAINPLOTS	4	716.2083	179.0521	0.1478	0.9625
MAINPLOT ERROR	28	33926.5917	1211.6638		
SUBPLOTS	2	23322.0250	11661.0117	25.0136	0.0000
INTERACTION	8	2772.8917	346.6113	0.7435	0.6529
SUBPLOT ERROR	70	32633.0820	466.1868		

DENSITY DATA 1979

NO. OF TILLERS WITH ONE LEAF

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	3115.3208	445.0457	1.5289	0.1983
MAINPLOTS	4	447.4453	111.8613	0.3843	0.8180
MAINPLOT ERROR	28	8150.3340	291.0833		
SUBPLOTS	2	8774.7437	4387.3711	59.4823	0.0000
INTERACTION	8	501.7641	62.7205	0.8503	0.5622
SUBPLOT ERROR	70	5163.1445	73.7592		

DENSITY DATA 1979

NO. OF TILLERS WITH TWO LEAVES

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	2777.1000	396.7285	0.8975	0.5219
MAINPLOTS	4	837.2917	209.3229	0.4736	0.7547
MAINPLOT ERROR	28	12376.3648	442.0129		
SUBPLOTS	2	2310.6500	1155.3250	5.4188	0.0065
INTERACTION	8	1319.3786	164.9223	0.7735	0.6271
SUBPLOT ERROR	70	14924.3633	213.2052		

DENSITY DATA 1979

NO. OF TILLERS WITH THREE LEAVES

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	452.0557	64.5794	1.7926	0.1284
MAINPLOTS	4	364.5651	91.1413	2.5299	0.0628
MAINPLOT ERROR	28	1008.7209	36.0257		
SUBPLOTS	2	269.2547	134.6273	4.9902	0.0094
INTERACTION	8	503.7691	62.9711	2.3341	0.0277
SUBPLOT ERROR	70	1888.4883	26.9784		

DENSITY DATA 1979

NO. OF TILLERS WITH FOUR LEAVES

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	5.8258	0.8323	1.2057	0.3069
MAINPLOTS	4	51.4107	12.8527	18.6207	0.0000
MAINPLOT ERROR	98	18.2800	0.6902		
SUBPLOTS	2	17.6765	8.8382	12.8046	0.0000
INTERACTION	8	25.6403	3.2050	4.6434	0.0001
SUBPLOT ERROR	98	49.3632	0.6902		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

DENSITY DATA 1979

NO. OF DEAD TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	536.9302	76.7043	3.2549	0.0027
MAINPLOTS	4	190.8302	47.7076	2.0244	0.0925
MAINPLOT ERROR	196	1100.3989	23.5658		
SUBPLOTS	2	1143.0797	571.5398	24.2530	0.0000
INTERACTION	8	780.7472	97.5934	4.1413	0.0001
SUBPLOT ERROR	196	3518.4890	23.5658		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

SOIL TEMPERATURE DATA 1978(3 CM)

JULY 24,1978 : TEMP1

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	111.1701	15.8814	5.2496	0.0000
MAINPLOTS	2	20.7604	10.3802	3.4312	0.0358
MAINPLOT ERROR	112	118.5174	3.0253		
SUBPLOTS	2	669.6771	334.8384	110.6806	0.0000
INTERACTION	4	22.8438	5.7109	1.8877	0.1175
SUBPLOT ERROR	112	220.3125	3.0253		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

SOIL TEMPERATURE DATA 1978(6 CM)

JULY 24,1978 : TEMP1

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	49.7778	7.1111	22.7601	0.0000
MAINPLOTS	2	49.7708	24.8854	79.6491	0.0000
MAINPLOT ERROR	448	26.9514	0.3124		
SUBPLOTS	2	604.3958	302.1978	967.2249	0.0000
INTERACTION	4	16.0833	4.0208	12.8692	0.0000
SUBPLOT ERROR	448	113.0208	0.3124		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

SOIL TEMPERATURE DATA 1978(9 CM)

JULY 24,1978 : TEMP1

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	54.2248	7.7464	12.6899	0.0000
MAINPLOTS	2	6.7630	3.3815	5.5395	0.0051
MAINPLOT ERROR	112	11.5148	0.6104		
SUBPLOTS	2	361.6797	180.8398	296.2466	0.0000
INTERACTION	4	3.2995	0.8249	1.3513	0.2555
SUBPLOT ERROR	112	56.8542	0.6104		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

SOIL TEMPERATURE 1979 (3 CM)

SOIL TEMPERATURE JULY 3/79

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	67.7690	9.6813	2.1073	0.0760
MAINPLOTS	4	152.3294	38.0824	8.2892	0.0002
MAINPLOT ERROR	28	128.6372	4.5942		
SUBPLOTS	2	443.3211	221.6605	56.6286	0.0000
INTERACTION	8	128.3456	16.0432	4.0986	0.0005
SUBPLOT ERROR	70	274.0000	3.9143		

SOIL TEMPERATURE 1979 (6 CM)

SOIL TEMPERATURE JULY 3/79

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	21.0924	3.0132	1.1867	0.3175
MAINPLOTS	4	46.9049	11.7262	4.6180	0.0019
MAINPLOT ERROR	98	47.5951	2.5392		
SUBPLOTS	2	150.3508	75.1754	29.6055	0.0000
INTERACTION	8	39.2326	4.9041	1.9313	0.0636
SUBPLOT ERROR	98	201.2500	2.5392		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

SOIL TEMPERATURE 1979 (9 CM)

SOIL TEMPERATURE JULY 3/79

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	18.9667	2.7095	3.2781	0.0036
MAINPLOTS	4	6.3854	1.5964	1.9313	0.1112
MAINPLOT ERROR	98	12.8146	0.8266		
SUBPLOTS	2	111.6812	55.8406	67.5585	0.0000
INTERACTION	8	17.9646	2.2456	2.7168	0.0095
SUBPLOT ERROR	98	68.1875	0.8266		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

LEAF LENGTH OF 1-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	278.6094	39.8013	1.7240	0.1826
MAINPLOTS	2	67.7852	33.8926	1.4681	0.2638
MAINPLOT ERROR	14	323.2144	23.0867		
SUBPLOTS	2	1894.9674	947.4836	42.6324	0.0000
INTERACTION	4	277.8929	69.4732	3.1260	0.0244
SUBPLOT ERROR	42	933.4297	22.2245		

1978

LEAF LENGTH OF 2-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	104.3542	14.9077	2.5815	0.0166
MAINPLOTS	2	223.1953	111.5977	19.3249	0.0000
MAINPLOT ERROR	112	183.1237	5.7748		
SUBPLOTS	2	3734.5443	1867.2720	323.3484	0.0000
INTERACTION	4	181.7394	45.4348	7.8678	0.0000
SUBPLOT ERROR	112	463.6538	5.7748		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

LEAF LENGTH OF 3-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	116.2630	16.6090	10.2595	0.0000
MAINPLOTS	2	346.2109	173.1055	106.9285	0.0000
MAINPLOT ERROR	448	179.3451	1.6189		
SUBPLOTS	2	3143.9167	1571.9583	971.0100	0.0000
INTERACTION	4	192.6903	48.1726	29.7565	0.0000
SUBPLOT ERROR	448	545.9180	1.6189		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

LEAF LENGTH OF 4-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	72.9362	10.4195	30.4346	0.0000
MAINPLOTS	2	237.5443	118.7721	346.9258	0.0000
MAINPLOT ERROR	1792	88.4133	0.3424		
SUBPLOTS	2	686.1432	343.0715	1002.0901	0.0000
INTERACTION	4	413.2227	103.3057	301.7493	0.0000
SUBPLOT ERROR	1792	525.0886	0.3424		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

SHEATH LENGTH OF 1-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	6.9294	0.9899	1.2108	0.3122
MAINPLOTS	2	1.2811	0.6405	0.7835	0.4617
MAINPLOT ERROR	56	10.8739	0.8175		
SUBPLOTS	2	70.5518	35.2759	43.1486	0.0000
INTERACTION	4	6.6843	1.6711	2.0440	0.1006
SUBPLOT ERROR	56	34.9086	0.8175		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

SHEATH LENGTH OF 2-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	4.6271	0.6610	6.8632	0.0000
MAINPLOTS	2	4.0971	2.0485	21.2698	0.0000
MAINPLOT ERROR	224	4.6468	0.0963		
SUBPLOTS	2	181.6361	90.8181	942.9546	0.0000
INTERACTION	4	8.3583	2.0896	21.6959	0.0000
SUBPLOT ERROR	224	16.9271	0.0963		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

SHEATH LENGTH OF 3-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	0.9456	0.1351	5.8898	0.0000
MAINPLOTS	2	3.5477	1.7738	77.3397	0.0000
MAINPLOT ERROR	896	3.7915	0.0229		
SUBPLOTS	2	155.0662	77.5331	3380.4485	0.0000
INTERACTION	4	9.8356	2.4589	107.2087	0.0000
SUBPLOT ERROR	896	16.7590	0.0229		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

1978

SHEATH LENGTH OF 4-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	3.3160	0.4737	54.8571	0.0000
MAINPLOTS	2	1.3109	0.6554	75.9009	0.0000
MAINPLOT ERROR	3584	7.5806	0.0086		
SUBPLOTS	2	139.8186	69.9093	8095.6484	0.0000
INTERACTION	4	16.9023	4.2256	489.3301	0.0000
SUBPLOT ERROR	3584	23.3688	0.0086		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

TILLER LENGTH 1979

LEAF LENGTH 1-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	116.7667	16.6809	0.4678	0.8494
MAINPLOTS	4	2005.7656	501.4414	14.0612	0.0000
MAINPLOT ERROR	28	998.5198	35.6614		
SUBPLOTS	2	4270.1125	2135.0562	104.2605	0.0000
INTERACTION	8	797.8846	99.7356	4.8704	0.0001
SUBPLOT ERROR	70	1433.4663	20.4781		

TILLER LENGTH 1979

LEAF LENGTH 2-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	45.2417	6.4631	0.2136	0.9793
MAINPLOTS	4	2256.8854	564.2212	18.6477	0.0000
MAINPLOT ERROR	28	847.1919	30.2569		
SUBPLOTS	2	6812.0750	3406.0374	163.5941	0.0000
INTERACTION	8	1272.0660	159.0082	7.6373	0.0000
SUBPLOT ERROR	70	1457.4045	20.8201		

TILLER LENGTH 1979

LEAF LENGTH 3-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	75.0083	10.7155	0.2794	0.9568
MAINPLOTS	4	1971.1719	492.7930	12.8510	0.0000
MAINPLOT ERROR	28	1073.7039	38.3466		
SUBPLOTS	2	5944.8375	2972.4187	95.8179	0.0000
INTERACTION	8	780.5219	97.5652	3.1451	0.0043
SUBPLOT ERROR	70	2171.5083	31.0215		

TILLER LENGTH 1979

LEAF LENGTH 4-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	117.6750	16.8107	0.5290	0.8050
MAINPLOTS	4	1262.8594	315.7148	9.9358	0.0000
MAINPLOT ERROR	28	889.7143	31.7755		
SUBPLOTS	2	3402.9500	1701.4749	99.6028	0.0000
INTERACTION	8	959.7307	119.9663	7.0227	0.0000
SUBPLOT ERROR	70	1195.7827	17.0826		

TILLER LENGT[illegible]

SHEA[illegible]ENGTH [illegible] TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	18.7921	2.6846	2.9603	0.0188
MAINPLOTS	4	30.8895	7.7224	8.5156	0.0001
MAINPLOT ERROR	28	25.3918	0.9069		
SUBPLOTS	2	129.8442	64.9221	82.7984	0.0000
INTERACTION	8	10.2287	1.2786	1.6306	0.1318
SUBPLOT ERROR	70	54.8869	0.7841		

TILLER LENGTH 1979

SHEATH LENGTH 2-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	14.8670	2.1239	1.5015	0.2074
MAINPLOTS	4	50.7139	12.6785	8.9632	0.0001
MAINPLOT ERROR	28	39.6062	1.4145		
SUBPLOTS	2	238.4846	119.2423	109.0279	0.0000
INTERACTION	8	39.3388	4.9174	4.4961	0.0002
SUBPLOT ERROR	70	76.5581	1.0937		

TILLER LENGTH 1979

SHEATH LENGTH 3-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	12.4845	1.7835	1.4773	0.2157
MAINPLOTS	4	33.3884	8.3471	6.9141	0.0005
MAINPLOT ERROR	28	33.8033	1.2073		
SUBPLOTS	2	226.8917	113.4459	130.2818	0.0000
INTERACTION	8	23.6281	2.9535	3.3918	0.0024
SUBPLOT ERROR	70	60.9541	0.8708		

TILLER LENGTH 1979

SHEATH LENGTH 4-LEAVED TILLERS

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	10.0204	1.4315	1.9041	0.1066
MAINPLOTS	4	57.7323	14.4331	19.1981	0.0000
MAINPLOT ERROR	28	21.0503	0.7518		
SUBPLOTS	2	84.2511	42.1255	72.7889	0.0000
INTERACTION	8	44.3974	5.5497	9.5893	0.0000
SUBPLOT ERROR	70	40.5115	0.5787		

GROWTH RATE 1979

GROWTH OF 10 DAYS (CM)

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	39.4758	5.6394	2.4025	0.0465
MAINPLOTS	4	18.3599	4.5900	1.9555	0.1289
MAINPLOT ERROR	28	65.7234	2.3473		
SUBPLOTS	2	358.5350	179.2675	99.4772	0.0000
INTERACTION	8	20.5985	2.5748	1.4288	0.2000
SUBPLOT ERROR	70	126.1468	1.8021		

BASAL COVER DATA 1979

%COVER LIVE FESCUE

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	801.4698	114.4957	5.0237	0.0001
MAINPLOTS	4	43.2031	10.8008	0.4739	0.7548
MAINPLOT ERROR	98	611.1969	22.7911		
SUBPLOTS	2	144.2031	72.1016	3.1636	0.0466
INTERACTION	8	222.7969	27.8496	1.2219	0.2943
SUBPLOT ERROR	98	1622.3333	22.7911		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

BASAL COVER DATA 1979

%COVER DEAD FESCUE

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	72.0001	10.2857	2.4057	0.0220
MAINPLOTS	4	30.1335	7.5334	1.7620	0.1380
MAINPLOT ERROR	196	267.9999	4.2755		
SUBPLOTS	2	101.2668	50.6334	11.8427	0.0000
INTERACTION	8	134.0665	16.7583	3.9196	0.0003
SUBPLOT ERROR	196	570.0000	4.2755		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

BASAL COVER DATA 1979

%COVER BURNT FESCUE

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	28.5001	4.0714	3.8000	0.0005
MAINPLOTS	4	113.1335	28.2834	26.3978	0.0000
MAINPLOT ERROR	392	120.9999	1.0714		
SUBPLOTS	2	528.0668	264.0332	246.4313	0.0000
INTERACTION	8	226.2665	28.2833	26.3978	0.0000
SUBPLOT ERROR	392	299.0000	1.0714		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

BASAL COVER DATA 1979

%COVER ASH

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	260.8000	37.2571	70.7169	0.0000
MAINPLOTS	4	1295.6667	323.9165	614.8179	0.0000
MAINPLOT ERROR	3136	376.8667	0.5268		
SUBPLOTS	2	6000.0000	3000.0000	5694.2227	0.0000
INTERACTION	8	2591.3333	323.9165	614.8179	0.0000
SUBPLOT ERROR	3136	1275.3333	0.5268		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

PRODUCTION DATA 1978

HERBAGE YIELD (GM)

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	2279.4028	325.6289	2.2775	0.0410
MAINPLOTS	2	3925.4792	1962.7395	13.7277	0.0000
MAINPLOT ERROR	56	1332.7964	142.9770		
SUBPLOTS	2	24518.9740	12259.4844	85.7444	0.0000
INTERACTION	4	5905.8345	1476.4585	10.3265	0.0000
SUBPLOT ERROR	56	6673.9180	142.9770		

MAINPLOT ERROR LESS THAN SUBPLOT ERROR - ERRORS POOLED

PRODUCTION DATA 1979

HERBAGE YIELD (GM)

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	3004.9167	429.2737	1.8681	0.1132
MAINPLOTS	4	19123.4167	4780.8516	20.8053	0.0000
MAINPLOT ERROR	28	6434.1120	229.7897		
SUBPLOTS	2	5600.8250	2800.4124	23.1975	0.0000
INTERACTION	8	5793.0708	724.1338	5.9984	0.0000
SUBPLOT ERROR	70	8450.4414	120.7206		

PRODUCTION DATA 1979

LITTER (GM)

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	9406.9375	1343.8481	2.9844	0.0180
MAINPLOTS	4	4031.7135	1007.9282	2.2384	0.0903
MAINPLOT ERROR	28	12607.9596	450.2842		
SUBPLOTS	2	272634.5266	136317.2500	352.7483	0.0000
INTERACTION	8	11175.5474	1396.9434	3.6149	0.0014
SUBPLOT ERROR	70	27051.0430	386.4434		

1979

NO. FESTUCA HEADS/.25 SQ.M.

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	1402.1928	200.3132	3.0491	0.0163
MAINPLOTS	4	2955.7413	738.9353	11.2478	0.0000
MAINPLOT ERROR	28	1839.4883	65.6960		
SUBPLOTS	2	1347.5909	673.7954	16.0136	0.0000
INTERACTION	8	1577.1365	197.1420	4.6853	0.0001
SUBPLOT ERROR	70	2945.3489	42.0764		

NO. STIPA HEADS/.25 SQM

SOURCE	DF	SS	MS	F	P
REPLICATIONS	7	552.6183	78.9455	3.3801	0.0097
MAINPLOTS	4	194.8851	48.7213	2.0860	0.1094
MAINPLOT ERROR	28	653.9643	23.3559		
SUBPLOTS	2	272.1880	136.0940	7.7865	0.0009
INTERACTION	8	110.8433	13.8554	0.7927	0.6107
SUBPLOT ERROR	70	1223.4695	17.4781		