



Nutritional and developmental responses of three mountain bunchgrasses to summer cattle and winter elk grazing
by William John Dragt

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Range Science
Montana State University
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Abstract:

Elk-Livestock Studies in Montana was established to study elk-livestock interactions through cooperative research programs of various state and federal agencies. The objectives of Elk-Livestock Studies were: 1) to determine the influence of various cattle management practices on elk and their habitats, 2) to evaluate alternative management practices, and 3) to develop beneficial guidelines for dual use of the available resource. This research project fell within objective one, and its objectives were: 1) to quantify the effects of summer cattle grazing at various phenological stages on the winter nutritional values of three mountain bunchgrasses, and 2) to quantify the effects of winter elk grazing on the growth and development in the following spring of the same three species. Rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) were the species studied. The study was conducted on the South Crow elk winter range in the Elkhorn Mountains of Montana.

For objective one a random experimental design of one factor with three levels and nine treatments was used. The grass species were the factor levels and the treatments consisted of the phenological stage when grazing had occurred plus an ungrazed stage. Winter chemical constituent values were the dependent variables. For objective two a randomized block design having one factor with three levels and two treatments in five blocks was used. Sites, species, grazing, and standing dead were the blocks, factor and two treatments, respectively. The dependent variables were plant height and phenological stage on six spring sampling dates.

None of the summer grazing treatments affected rough fescue or bluebunch wheatgrass winter nutritional values, and grazed plants were similar to ungrazed plants. Some phenological stages of summer grazing were reflected in Idaho fescue winter chemical constituent values, but no management significance could be attached to the differences. Winter grazing did not affect spring leaf lengths in rough fescue or bluebunch wheatgrass, and only occasionally affected Idaho fescue spring growth. The presence of standing dead in the spring resulted in longer Idaho fescue leaves in the next spring. Neither rough fescue nor bluebunch wheatgrass spring leaf lengths were affected by the presence of overwintering residual material. These results were discussed from the perspective of the winter physiological activity of each species of grass..

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ABSTRACT

Elk-Livestock Studies in Montana was established to study elk-livestock interactions through cooperative research programs of various state and federal agencies. The objectives of Elk-Livestock Studies were: 1) to determine the influence of various cattle management practices on elk and their habitats, 2) to evaluate alternative management practices, and 3) to develop beneficial guidelines for dual use of the available resource. This research project fell within objective one, and its objectives were: 1) to quantify the effects of summer cattle grazing at various phenological stages on the winter nutritional values of three mountain bunchgrasses, and 2) to quantify the effects of winter elk grazing on the growth and development in the following spring of the same three species. Rough fescue (Festuca scabrella), Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum) were the species studied. The study was conducted on the South Crow elk winter range in the Elkhorn Mountains of Montana.

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None of the summer grazing treatments affected rough fescue or bluebunch wheatgrass winter nutritional values, and grazed plants were similar to ungrazed plants. Some phenological stages of summer grazing were reflected in Idaho fescue winter chemical constituent values, but no management significance could be attached to the differences. Winter grazing did not affect spring leaf lengths in rough fescue or bluebunch wheatgrass, and only occasionally affected Idaho fescue spring growth. The presence of standing dead in the spring resulted in longer Idaho fescue leaves in the next spring. Neither rough fescue nor bluebunch wheatgrass spring leaf lengths were affected by the presence of overwintering residual material. These results were discussed from the perspective of the winter physiological activity of each species of grass.

INTRODUCTION

Management and research groups have spent much effort investigating the various aspects and relationships of land, livestock and elk management. One current program is "Elk-Livestock Studies in Montana", an interagency effort to study elk-livestock interactions. "Elk-Livestock Studies" was initiated in 1982 to: 1) determine the influence of various cattle management practices on elk and their habitat, 2) to evaluate alternative management practices and 3) to develop beneficial guidelines for dual use of the available resource. In addition to Montana State University, the Intermountain Forest and Range Experiment Station in Missoula, MT, the Montana Department of Fish, Wildlife and Parks and the University of Montana are also involved in the program.

This project fell within the first objective of "Elk-Livestock Studies". Its objectives were: 1) to quantify the effects of summer cattle grazing at various phenological stages on the resulting winter nutritional values of three mountain bunchgrasses, and 2) to quantify the effects of elk winter grazing on growth and development of the same grasses in the following spring.

Two decisions were made which had important influences on the project. First, it was decided that this project would describe one annual cycle of growth and utilization from an individual plant perspective. As a result fieldwork was designed to minimize the impact of the project. Some effects of this decision were the use of line transects instead of cages and animals for defoliation

treatments. This approach resulted in reduced treatment control and sacrifice of experimental design integrity. Some treatment combinations were missing or had small sample sizes. The statistical analysis was less rigorous than could have been achieved from a more controlled experiment.

The other important decision was the selection of key species. Rough fescue (Festuca scabrella Torr.), Idaho fescue (Festuca idahoensis Elmer.) and bluebunch wheatgrass (Agropyron spicatum (Pursh) Scribn. and Smith) were chosen, because they are both important habitat components and major constituents of winter elk diets in Montana. Of the three species Idaho fescue was the most abundant and rough fescue the least. Sites with both rough fescue and bluebunch wheatgrass appeared to be ecotones between patches of rough fescue and the generally occurring bluebunch wheatgrass. Selection of these key species reduced the potential sampling sites from the entire available area to specific sites where all three species occurred.

LITERATURE REVIEW

Elk diet selection studies from the mountainous regions of Montana are presented to support the choice of rough fescue, Idaho fescue and bluebunch wheatgrass as the studied species. Grass carbohydrate allocation strategies and growth responses to grazing are summarized. Phenological development, grazing responses and nutrient concentration patterns for rough fescue and bluebunch wheatgrass are presented. Only seasonal progression of nutrient concentrations are presented for Idaho fescue. The literature on bluebunch wheatgrass was much more extensive and complete than for either fescue.

ELK DIETS

Elk food habit studies in the Rocky Mountain region have been extensively reviewed by Kufeld (1973). From these studies it could be concluded that elk selected the greenest forage available. During the seasons of plant dormancy their diets were composed predominantly of graminoids. This general pattern has also been observed in Montana studies (table 1). Additionally, in Montana, a large proportion of the species selected were the dominant available bunchgrasses. In the Elkhorn Mountains of central Montana up to 62% of elk winter diets were composed of Idaho fescue, rough fescue and bluebunch wheatgrass, the most abundant and available bunchgrasses on the winter range (DeSimone et al. 1984). Other studies from Montana also reported that rough fescue, Idaho fescue and bluebunch wheatgrass were important elk winter diet components (table 1).

Table 1. Rough fescue (Fesc), Idaho fescue (Feid) and bluebunch wheatgrass (Agsp) in seasonal elk diets in Montana, selected studies.

SPECIES			SEASON	LOCATION	TECHNIQUE	CITATION
FESC	FEID	AGSP				
% OF DIET						
48	10	6	WINTER	ELKHORNS MT	MICROHISTOLOGICAL	DESIMONE ET AL. 1984
1	27	21	WINTER	ELKHORNS MT	FEEDING SITE EXAM	GORDON 1968
48	49	8	SPRING			
5	55	5	SPRING	ELKHORNS MT	FEEDING SITE EXAM	STEVENS 1965
39	24		APRIL	SUN RIVER MT	FEEDING SITE EXAM	KNIGHT 1961
1	6		MAY			
88% GRASS ¹	2	3	SPRING	LITTLE BELTS MT	FEEDING SITE EXAM	KIRSCH 1963
84% GRASS			WINTER		RUMEN ANALYSIS	
			SPRING			
100% GRASS-LIKE ²			WINTER	NAT'L BISON RANGE MT	RUMEN ANALYSIS	MORRIS & SCHWARTZ 1957
100% GRASS-LIKE			SPRING			
4	3	48	WINTER	SUN RIVER MT	FEEDING SITE EXAM	CASAGRANDA & JANSON 1957
13	16	13	WINTER	SUN RIVER CANYON MT	FEEDING SITE EXAM	SCHALLENBERGER 1966
	71	5	WINTER	GRAVELLY MTNS MT	FEEDING SITE EXAM	EUSTACE 1967
	31	37	WINTER		CLIPPING	
90% GRASS ¹			WINTER	GRAVELLY MTNS MT	RUMEN ANALYSIS	ROUSE 1957
90% GRASS			SPRING			
67% GRASS ¹	18	35	WINTER	GALLATIN CANYON MT	FEEDING SITE EXAM	CONSTAN 1967
			MARCH			
31 ³		25	WINTER	ROCKY MTN FRONT MT	MICROHISTOLOGICAL	KASWORM ET AL. 1984
20		21	SPRING			
43	27	11	SPRING	SUN RIVER MT	FEEDING SITE EXAM	KNIGHT 1970

¹GRASSES IN THE DIET WERE NOT DIVIDED BY SPECIES, BUT THE KEY SPECIES WERE THE DOMINANT GRASSES ON THE STUDY AREA.

²GRAMINOIDS IN THE DIET WERE NOT DIVIDED BY SPECIES, BUT THE KEY SPECIES WERE THE DOMINANT GRASSES ON THE STUDY AREA.

³ALL FESTUCA IN THE STUDY COMBINED.

CARBOHYDRATE ALLOCATION STRATEGIES

Carbohydrate allocation patterns on a seasonal basis and in response to defoliation and grazing treatments have been reviewed by Trlica (1977), White (1973) and Cook (1966). Some generalizations supported by all three authors included: 1) although it was seldom emphasized total plant soluble carbohydrates increased with maturity, 2) carbohydrate allocation patterns varied with phenological development and environmental conditions, and 3) the level of soluble carbohydrates located in a particular tissue at any given time was also a function of concurrent plant physiological activities and biotic and abiotic environmental influences.

Grazing, a biotic environmental influence, has modified the carbohydrate allocation pattern of all species studied to date. Studies using more sophisticated techniques have demonstrated that individual species responded differently to grazing (e.g. Caldwell et al. 1981). However some interspecific generalizations were apparent. If grazing ended before the initial growth period ended, injury from defoliation was reduced. Fall regrowth was much more important to plants grazed through the entire initial growth period than to plants grazed early in the initial growth period or ungrazed (McLean and Wikeem 1985a,b). Graminoids that were entirely dormant during the winter were more dependent on carbohydrate reserves for spring growth initiation than those with photosynthetically active overwintering leaves (Robertson and Woolhouse 1984b). Graminoids that depended on overwintering photosynthetically active leaves to fuel initial spring growth required some intact leaves in the spring (Robertson and

Woolhouse 1984b). There may also be additional carbohydrate allocation patterns not yet elucidated.

AGROPYRON SPICATUM

Quinton et al. (1982) studied bluebunch wheatgrass vegetative and reproductive growth in the absence of grazing from 1971 to 1973 in interior British Columbia. Vegetative growth initiation was determined by extrapolation of yield and leaf growth curves to zero. Growth initiation, estimated from yield curves, occurred from mid-March to May. Soil temperatures at 10 cm were 6°C and average air temperatures within 1°C. Soil moisture at 28 and 75 cm had been recharged by spring snow melt. Leaf growth estimates of growth initiation were earlier. Soil temperatures were still near 0°C at 10 cm and snow melt less than one week earlier. A 6°C soil temperature at growth initiation was supported by others (Harris 1967 and Anderson and McNaughton 1973).

Vegetative growth in British Columbia lasted two months with culms reaching a maximum height of 19 cm. Average culm length reached 38.2 cm in Washington (Rickard et al. 1975) and 16.4 cm at Dubois, ID (Blaisdell 1958). Leaf growth ceased in early summer. Associated soil moisture levels were variable, and air temperatures were still cooler than optimum growth temperatures (DePuit and Caldwell 1975).

Fall growth in British Columbia occurred only in the year with both the wettest and warmest September and October. Precipitation and temperature were 135% and 120% of average, respectively. Phenological development patterns from several areas are reported in table 2.

Table 2. The progression of bluebunch wheatgrass phenological development in the Northern Rockies.

PHENOLOGICAL STAGE	DATE			
snow free		Ap 1	Mr 30	
growth initiation	mid-Ap	Ap 11	Ap 4	late Ap
boot	Jn 1	Ma 16	Ma 22	Ma - early Jn
early head	early Jn	Ma 28		
full head	mid-Jn	Jn 6	Jn 14	
early flower	mid-late Jn			
full flower	late Jn-mid-Jl	Jn 18	Jn 25	
seed ripe	late Jl	Jn 28	Jl 19	
seed shatter	late Jl-early Ag	Jl 21	Jl 24	late Jl
growth cessation	early Jn-mid-Jl	Jn 7	Jl 8	late Jl
fall growth	last half Oc			Jl & Ag - Oc
Years	1971-73	1937-40	1941-47	
Location	Kamloops, B.C.	Dubois, ID	Dubois, ID	Missoula, MT
Citation	Quinton et al. 1982	Blaisdell et al. 1952	Blaisdell 1958	Daer and Willard 1981

Climatic patterns modified the rate of phenological progression (Quinton et al. 1982). Where low spring temperatures were limiting, early phenological stages were compressed in time. Where summer drought was limiting, later phenological stages were shorter. Blaisdell and Pechanec (1949) reported that clipping during spring growth did not affect the time or rate of phenological development. Spike numbers were not well correlated with tiller number or basal area of plants.

Several studies analyzing bluebunch wheatgrass chemical constituents have established seasonal variation in components associated with forage quality. Stoddart (1946) reported that total carbohydrates increased as vegetation matured. Nonstructural carbohydrates, presumably available for plant utilization or storage, increased in the spring (Caldwell et al. 1981). Daer and Willard (1981) found that minimum total nonstructural carbohydrates (TNC) levels corresponded to initial growth and early boot stages and that the maximum TNC occurred at the late boot stage. "Other carbohydrates" (total carbohydrates - cellulose) reached maximum concentrations in the fall and minimum levels in late winter (Stoddart 1946). Cellulose content ranged from 24% in early spring to 31% in late spring, 33% in late summer and 43% in late winter. Lignin increased from 4% in early spring growth to 14% in fall and 18% in late winter. Protein concentration declined from 26% in new spring growth to 13% when heads were emerging and 3% in the fall. Fall through spring nutrient contents are reported in table 3.

Table 3. Nutritional profiles of bluebunch wheatgrass from fall dormancy through spring growth.

STAGE OR SEASON	TOTAL ¹ CRUDE			CRUDE				CITATION
	CH ₂ O %	FIBER %	NFE %	CELLULOSE %	LIGNIN %	PROTEIN %	ASH %	
MATURE		37.8	49.4			5.0	5.2	KNIGHT ET AL. 1908
FALL		35.1	46.7			3.2	12.5	MCCREARY 1927
NOV		31.2	46.4			3.4	7.9	MCCREARY 1931
JAN		29.5	44.2			5.0	10.9	"
APR		28.5	43.7			4.2	13.4	"
OCT		30.7	48.4			3.0	8.2	"
POST SEED SHATTER		33.4	39.6			2.9	10.1	MCCALL 1940
NEW GROWTH		20.6	36.6			25.5		BLAISDELL ET AL. 1952
MATURE FOLIAGE		30.2	44.1			7.8		"
NOV		33.9	43.5			3.7		"
NEW GROWTH (4/20)	62.5			24.2	4.0	26.2	8.6	STODDART 1946
DRY MATURE (9/15)	86.6			32.9	12.9	2.9	7.5	"
OLD GROWTH (4/1)	88.6			43.2	17.7	2.5	6.5	"
NEW GROWTH (4/15)	63.8			24.8	5.6	23.4	9.0	"
DRY MATURE (9/15)	83.3			31.8	14.5	4.6	8.9	"

¹TOTAL CARBOHYDRATES

Herbage removal affected bluebunch wheatgrass nutrient content in the same summer. Stoddart (1946) reported that one midspring clipping resulted in the best overall forage quality as reflected by higher protein and lower lignin contents. Subsequent clippings at one- or two-week intervals resulted in slight forage value declines, but all clipping treatments had higher forage values than unclipped control plants. Caldwell et al. (1981) reported that protein concentrations in regrowth leaves were similar to those of unclipped leaves one month earlier. Bolton and Brown (1980) associated higher nitrogen (N) concentrations with higher photosynthetic activity. Caldwell et al. (1981) measured higher photosynthetic activity in regrowth tissue compared to unclipped photosynthetic tissue. Nitrogen incorporated into regrowth was new assimilate, because root and crown N pools did not decline (Caldwell et al. 1981).

Total nonstructural carbohydrate pools in bluebunch wheatgrass, which were concentrated in stems and sheaths in intact plants, were diminished by clipping and remained low in regrowth compared to unclipped plants (Caldwell et al. 1981). "Other carbohydrates" also declined in clipped plants (Stoddart 1946). Carbohydrate pools in the roots declined rapidly with growth initiation, increased slightly during the active growth period, and were completely replenished following active vegetative growth (Daer and Willard 1981, McCarty and Price 1942 and McIlvaine 1942). Removal of photosynthetic tissue disrupted this pattern of allocation to the roots, reducing reserves available for growth initiation the following spring (Blaisdell and Pechanec 1949).

Bluebunch wheatgrass foliage removal by burning, grazing or clipping in any season reduced production in at least the following year (Stoddart 1946, Blaisdell and Pechanec 1949, Mueggler 1972, Sauer 1978, Wilms et al. 1980 and McLean and Wikeem 1985a). The clipped tillers rarely produced new tillers (Caldwell et al. 1981). Severest damage resulted from both spring and fall clippings (Stoddart 1946). A single clipping treatment during the most metabolically demanding growth periods, active reproductive stages or carbohydrate reserve replenishment periods, all reduced yield in the following year (McCarty and Price 1942, McIlvaine 1942, Blaisdell and Pechanec 1949 and Wilson et al 1966). If clipping killed a tiller it usually died immediately or with the onset of drought (Caldwell et al. 1981). When competition from surrounding vegetation was reduced, extreme clipping during critical growth stages was much less detrimental (Mueggler 1972).

The key factor mitigating defoliation damage appeared to be the time and amount of leaf growth remaining following defoliation (McLean and Wikeem 1985a). Plants defoliated early in the spring with several weeks of leaf growth following defoliation had higher survivability and vigor than plants defoliated near or past the end of the leaf growth period (McLean and Wikeem 1985a, Stoddart 1946 and Blaisdell and Pechanec 1949).

The effects of clipping fall regrowth were more variable and difficult to explain. Blaisdell and Pechanec (1949) reported that fall regrowth was very important to production in the next year. Clipped plants with regrowth yielded, in the next growing season, 270%

of plants with no regrowth. Plants with regrowth also produced 2.5 times as many flower stalks as plants without regrowth. McLean and Wikeem (1985a) reported that clipping plants with 5.1 g/plant of fall regrowth resulted in significantly higher percent kill in the following year than clipping plants with 2.7 or 1.6 g of fall regrowth, suggesting that some threshold level of fall regrowth production was required to have an impact.

Clipping bluebunch wheatgrass standing dead in January reduced production in the following spring, leaf and culm yield declined 28%, leaf length decreased 25% and loss of standing dead decreased 21%. Factors associated with reproduction were not significantly affected (Sauer 1978).

The caespitose growth form provides microsite modifications (Sauer 1978, Chapin et al. 1979, Caldwell et al. 1981 and Smith et al. 1983). By removing standing dead material some beneficial effects of the caespitose growth form were lost. Sauer (1978) hypothesized that freer air circulation increased moisture stress, causing stomate closure, reducing CO_2 uptake and consequently production. Sauer (1978) also suggested photoinhibition of photosynthesis. However, bluebunch wheatgrass leaf display patterns and culm densities exposed most leaves to direct solar radiation in intact bunches (Caldwell et al. 1981). Bluebunch wheatgrass leaves had a relatively high photosynthetic rate per area (Caldwell et al. 1981). Competition from surrounding vegetation may have contributed to decreased production (Mueggler 1972). Other researchers (Blaisdell and Pechanec 1949 and

Wilson et al. 1966) have reported that overwintering fall regrowth became the first carbohydrate source in the spring, because carbohydrate reserves declined shortly after rather than concurrently with growth initiation (Caldwell et al. 1981). Absence of fall regrowth for earliest spring photosynthetic activity may also inhibit spring production. Fall regrowth has also been reported as a major source of new tillers (Daer and Willard 1981).

All of these studies used treatments which removed all tillers. Bluebunch wheatgrass responses to selective herbivory would be similar, but less severe, than those presented above. Some leaves would remain ungrazed and could continue photosynthetic activity. Stems and sheaths comprised major pools of nonstructural carbohydrates which could apparently contribute to regrowth production (Caldwell et al. 1981). Bluebunch wheatgrass stem and sheath photosynthesis was as productive and efficient as leaf photosynthesis (Caldwell et al. 1981). Therefore selective grazing of leaves would not eliminate all photosynthetically active tissue.

FESTUCA SCABRELLA

Rough fescue growth and phenological development were studied at two sites near Kamloops, British Columbia (Stout et al. 1981) and at Stavely and Lethbridge, Alberta (Johnston and McDonald 1967). Growth and phenological development varied between years and sites. Environmental factors seemed to control initiation of growth, but phenotypic adaptation resulted in different rates of phenological progress at different sites. For the three years studied in B.C.

(Stout et al. 1981) there were no more than three weeks variation in the timing of any phenological stage.

Stout et al. (1981) calculated from yield curves that growth initiated in mid-April with soil temperatures of 2-3°C at 10 cm. Johnston and McDonald (1967) reported new growth in early May with 20 cm soil temperatures of 2°C and calculated that leaf growth had been initiated two weeks earlier. Culm growth began six weeks after growth initiation. Growth initiation was correlated with soil temperature but not air temperature. Concurrent soil moisture had been completely recharged by snow melt (Bailey and Anderson 1978).

Cessation of vegetative growth was keyed to soil moisture (Stout et al. 1981) and modified by air temperature influences on plant water relations. Plant weight gain continued following leaf growth cessation, because photosynthesis could continue at vapor pressure levels which inhibited cell expansion (Hsiao 1973). Concurrent soil temperatures were not warm enough to inhibit growth (Smoliak and Johnston 1968). In Alberta foliage had entered winter dormancy by early October (Johnston and McDonald 1967). Patterns of phenological development from British Columbia and Alberta are reported in table 4.

Johnston and McDonald (1967) reported that rough fescue reproductive culm production ranged from 6.7 to 121.7 culms per plant. Seed production was erratic and difficult to relate to specific environmental cues (Johnston and McDonald 1967 and Stout et al. 1981). Abundant flower production years have included 1952, 1964, 1966 (Johnston and McDonald 1967) and 1972 (Stout et al. 1981). Floral primordia were initiated in the fall with seed production in the

Table 4. The progression of rough fescue phenological development in Alberta and British Columbia.

PHENOLOGICAL STAGE	DATE							
boot	Ma 27	-	Ma 1	Ma 12	Ma 10	Ap 30		
early head	Jn 3	Ma 18	Ma 8	Ma 19	Ma 17	Ma 7	late Jn	
full head	Jn 10	Ma 25	Ma 30	Ma 22	Ma 24	Ma 14	mid Jl	
early flower	Jn 17	Jn 1	Ma 30	Jn 2	Ma 31	Ma 28		
full flower	Jn 24	Jn 15	Jn 6	Jn 9	Jn 7	Jn 5		
end of flower	Jl 1	Jn 22	Jn 13	Jn 23	Jn 14	Jn 12		
seed in milk	-	-	Jn 29	Jn 30	-	Jn 19		
seed in dough	-	Jl 11	-	Jl 7	Jl 5	Jn 26		
seed ripe	Jl 22	-	Jl 5	Jl 14	-	Jl 3	early Au	
seed shatter	-	Jl 24	Jl 5	-	Jl 17	Jl 3		
growth cessation	Jn 17	Jl 7	Jn 13	Jn 23	Jn 28	Ma 28		
fall growth	Se 3	none	Oc 16	Se 15	none	Oc 3		
Years	1971	1972	1973	1971	1972	1973	1964 -1966	
Location	Hamilton, B.C.			East Mara, B.C.			Lethbrige, Al.	
Elevation	1158 m			854 m				
Citations	Stout et al. 1981			Stout et al. 1981			Johnston and McDonald 1967	

following summer (Johnston and McDonald 1967), a trait shared with some other northern grasses including Idaho fescue (Hodgson in Johnston and McDonald 1967). Within this time span a variety of potentially influential environmental events could occur. Initiated primordia were cold tolerant (Johnston and McDonald 1967). Of 3,780 primordia examined from 1963 through 1967, only one percent suffered frost killing. Minimum temperatures during this period were -40°C air temperature and -11 and -9°C soil temperatures at 10 and 20 cm depths, respectively. Still only about 35% of initiated floral primordia successfully developed into seedheads, and spring management did not appear to affect seedhead production. Seed germination ranged from 86 to 97% (Johnston and McDonald 1967).

Rough fescue had characteristics which were indicative of both grazing tolerance and susceptibility (Johnston and McDonald 1967). Meristems of vegetative culms were not elevated, and the range of reproductive to vegetative culm ratios, 0.299 to 0.001, was relatively low even in years of high seed production. Grazing susceptible traits included the erect caespitose growth form which made a high proportion of photosynthetic tissue available to herbivory. Tillering in rough fescue was neither vigorous nor stimulated by the removal of culms or elevated meristems. Under grazing management, such as rest-rotation and deferred grazing methods with moderate utilization, rough fescue has recovered and maintained itself (Anderson and Franzen 1983).

Rough fescue was damaged by consecutive years of heavy summer grazing (Johnston and McDonald 1967). But protection from even light grazing, 15% to 25% utilization for 12 years, increased the presence

of rough fescue in an exclosure (Johnston 1961). Spring burning produced varying results (Bailey and Anderson 1978). Burning with 10 cm of new growth resulted in reduced, but recovering canopy coverage for at least three years (39% of unburned in year one, 69% in year two and 90% in year three). When burned with 4 cm of new growth, canopy coverage declined less and production was not affected. Floral primordia were unaffected by burning until they had been elevated above the root crown in the spring, when seedhead density was greatly reduced (3% of unburned one year post burn) (Bailey and Anderson 1978).

Based on anecdotal evidence some rough fescue populations have had a long history of heavy winter grazing (Johnston and McDonald 1967). In areas of the northern Great Plains where Fescue grassland is the dominant vegetation type, such as the Cypress Hills in southeastern Alberta, buffalo summered on the open plains and wintered in the hills. In such areas rough fescue was subjected to severe winter grazing every year, but rested the remainder of the year.

Chemical analyses have found that, except for protein, nutritional components of rough fescue were relatively stable through the year (Johnston and Bezeau 1962 and Bezeau and Johnston 1962). Protein decreased from 13.7% in early vegetative growth to 4.7% in the fall and 4.2% by the end of winter. Overwinter protein decline was more variable than in other seasons. Crude fiber and cellulose increased through the growing season from 29.9 to 33.4% and 33.2 to 38.4%, respectively. Overwinter crude fiber increased to 34.8% and cellulose to 39.5%. In vitro dry matter disappearance dropped from

48.5% in early spring to 32.1% by fall and 24.0% at the end of winter. Rough fescue nutrient contents from dormancy through spring are reported in table 5.

FESTUCA IDAHOENSIS

For Idaho fescue only the seasonal progression of diet quality will be discussed. Growth and phenological development and grazing effects are not presented because this information was not found. McCall (1940) reported that the typical fall decline in grass nutritional values was less pronounced in Idaho fescue than in other bunchgrasses studied. In particular crude protein (CP) dropped to 4.6% in Idaho fescue and 2.9% in bluebunch wheatgrass while crude fiber increased to 27.2% in Idaho fescue and 33.4% in bluebunch wheatgrass. In digestion trials using lambs on mature forages, Idaho fescue had higher total digestible nutrients and positive crude protein digestion coefficients (% dietary CP - % fecal CP). Bluebunch wheatgrass had lower total digestible nutrients and negative crude protein digestion coefficients. Idaho fescue was more nutritious than bluebunch wheatgrass.

McCall (1939) determined biweekly chemical constituents of Idaho fescue over a four year period (table 6). Crude fiber rose slightly as Idaho fescue matured from "new growth" to "maturing" stages, changed little in the "fall" and rose again through the "winter." Only "new growth" and "winter" crude fiber levels were significantly different. Nitrogen free extract (NFE) in "winter" and "new growth" were significantly lower than in "maturing" and "fall" stages. Crude

Table 5. Nutritional profiles of rough fescue from fall dormancy through spring growth.

Stage or Season	Total ¹ CH ₂ O	Crude Fiber %	NFE %	Cellulose %	Crude Protein %	Ash %	IVDMD %	Citation
leaf		29.9		33.2	13.7	6.9	48.5	Johnston & Bezeau 1962
cured		33.4		38.4	4.7	8.5	32.1	and
weathered		34.8		39.5	4.2	8.6	24.0	Bezeau & Johnston 1962
seed shed (9/15) ¹		36.0			4.2	10.2		McLean & Tisdale 1960
weathered (11/25)	82.6	42.5	46.6		2.1	12.3		"
leaf (6/16)		30.3			12.0	10.1		Clarke & Tisdale 1945
partly cured (8/10)		37.2			5.4	9.8		"

¹Total carbohydrates

Table 6. Four-year averages of semimonthly analyses of Idaho fescue (dry matter basis) (McCall 1939).

<u>Period</u>	Ash %	Crude Protein %	<u>Carbohydrates</u>	
			Crude Fiber %	N-free extract %
Mature:				
First part of Ja	16.2	4.7	32.6	43.6
Last part of Ja	16.4	4.7	32.7	43.2
First part of Fb	15.3	4.8	33.6	44.1
Last part of Fb	16.6	4.9	32.8	43.0
First part of Mr	18.8	5.1	31.1	42.3
Last part of Mr	18.5	5.0	31.9	42.4
First part of Ap	18.6	5.1	30.8	42.5
New growth:				
First part of Mr	10.0	17.4	26.0	42.4
Last part of Mr	9.9	19.0	24.1	43.0
First part of Ap	10.4	18.9	25.1	42.0
Middle part of Ap	11.1	16.2	24.0	44.8
Last of Ap-first of Ma	13.2	13.8	28.3	41.2
Middle part of Ma	12.9	11.1	28.2	44.3
Last part of Ma	12.1	9.2	30.2	45.2
First part of Jn	13.1	7.8	31.2	44.5
Last part of Jn	13.2	6.5	30.3	46.7
First part of Jl	14.0	5.0	31.6	46.3
Last part of Jl	13.7	4.6	31.4	46.8
First part of Au	13.7	4.1	31.2	47.7
Last part of Au	14.3	4.1	30.9	47.1
First of Sp	14.6	3.9	29.0	48.7
Middle part of Sp	13.6	3.7	30.5	48.9
Last of Sp-first of Oc	15.4	4.2	30.7	46.2
Middle part of Oc	17.0	4.6	29.0	45.9
Last part of Oc	16.4	4.7	30.3	45.0
Middle part of Nv	16.3	4.4	31.6	44.4
Last of Nv-first of Dc	14.8	4.2	32.9	45.2
Middle part of Dc	15.5	4.4	32.7	44.4
Last part of Dc	17.8	4.6	30.9	43.8

protein declined from "new growth" to "maturing" stages then remained stable through the "fall" and "winter". "New growth" crude protein was significantly higher than the other three stages which were not significantly different from each other. Ash rose steadily from "new growth" through the year. Seasonal chemical constituents of Idaho fescue from several studies are summarized in table 7.

Table 7. Nutritional profiles of Idaho fescue from fall dormancy through spring growth.

Stage or Season	Crude Fiber %	NFE %	Cellulose %	Crude Protein %	Ash %	IVDMD %	Citation
new growth	26.0	42.4		17.4	10.0		McCall 1939
fall	30.9	45.3		4.4	16.0		"
winter	32.4	43.3		4.8	16.8		"
post seed shatter	27.2	38.7		4.6	14.6		McCall 1940
seed ripe	32.7		35.0	7.6	7.5	27.0	Johnston & Bezeau 1962
cured	31.9		35.9	4.9	10.6	18.8	and
late winter	33.4		38.8	4.5	9.0	14.6	Bezeau & Johnston 1962

STUDY AREA

The field work for this project was conducted in Muddy Lake and Jenkin's Gulch drainages, tributaries of Crow Creek located on the southeastern end of the Elkhorn Mountains on the Muddy Lake and Middle pastures of the South Crow cattle allotment on the Helena National Forest, Montana (fig. 1 to 3).

SITE DESCRIPTION

The climate in the region is modified continental with large annual and daily temperature variations (DeSimone et al. 1984). Elevation and precipitation range from 1464 m to 2100 m and 51 cm to 76 cm, respectively. The general vegetation aspect on the study area is a rolling grassland with steep conifer draws and broader cottonwood bottoms. Slopes and ridge tops have stony, loamy soils. The vegetation on the upland sites is dominated by bunchgrasses. Idaho fescue is ubiquitous. Rough fescue occurs on the slightly moister sites and bluebunch wheatgrass on most other sites.

Each transect was located on a site where all three species occurred. There were five sites called South Crow I (SCI) and II (SCII), Jenkin's Gulch I (JGI) and II (JGII) and Muddy Lake (ML). The elevation, aspect and slope of each site are reported in table 8. Based on observations during fieldwork, the Jenkin's Gulch sites were cooler and moister and the South Crow sites were warmer and drier than the others.

Approximately 200 elk have wintered in the study area since the 1960's (DeSimone et al. 1984). Generally winter range is used from

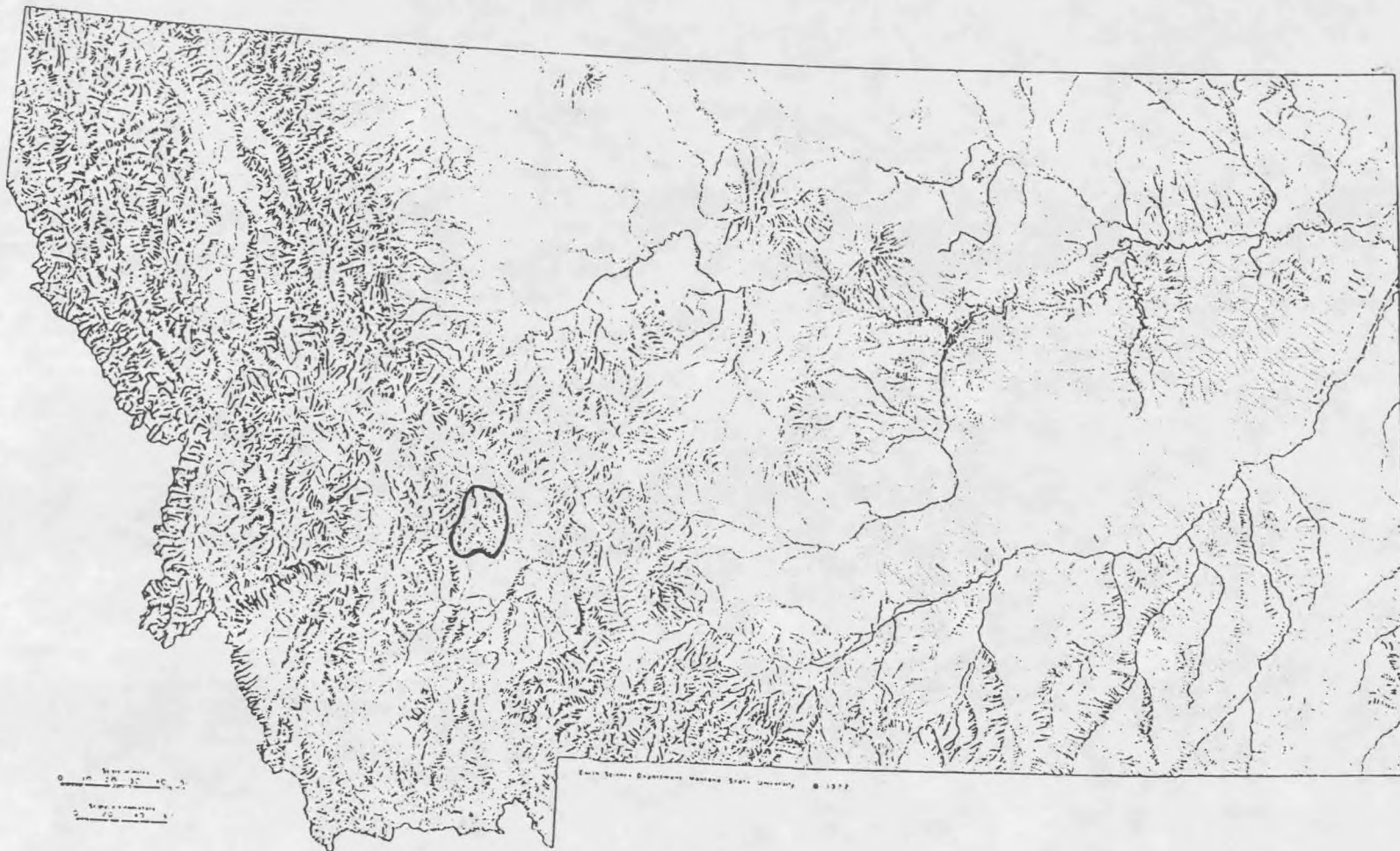


Figure 1. The location of the Elkhorn Mountains in Montana.

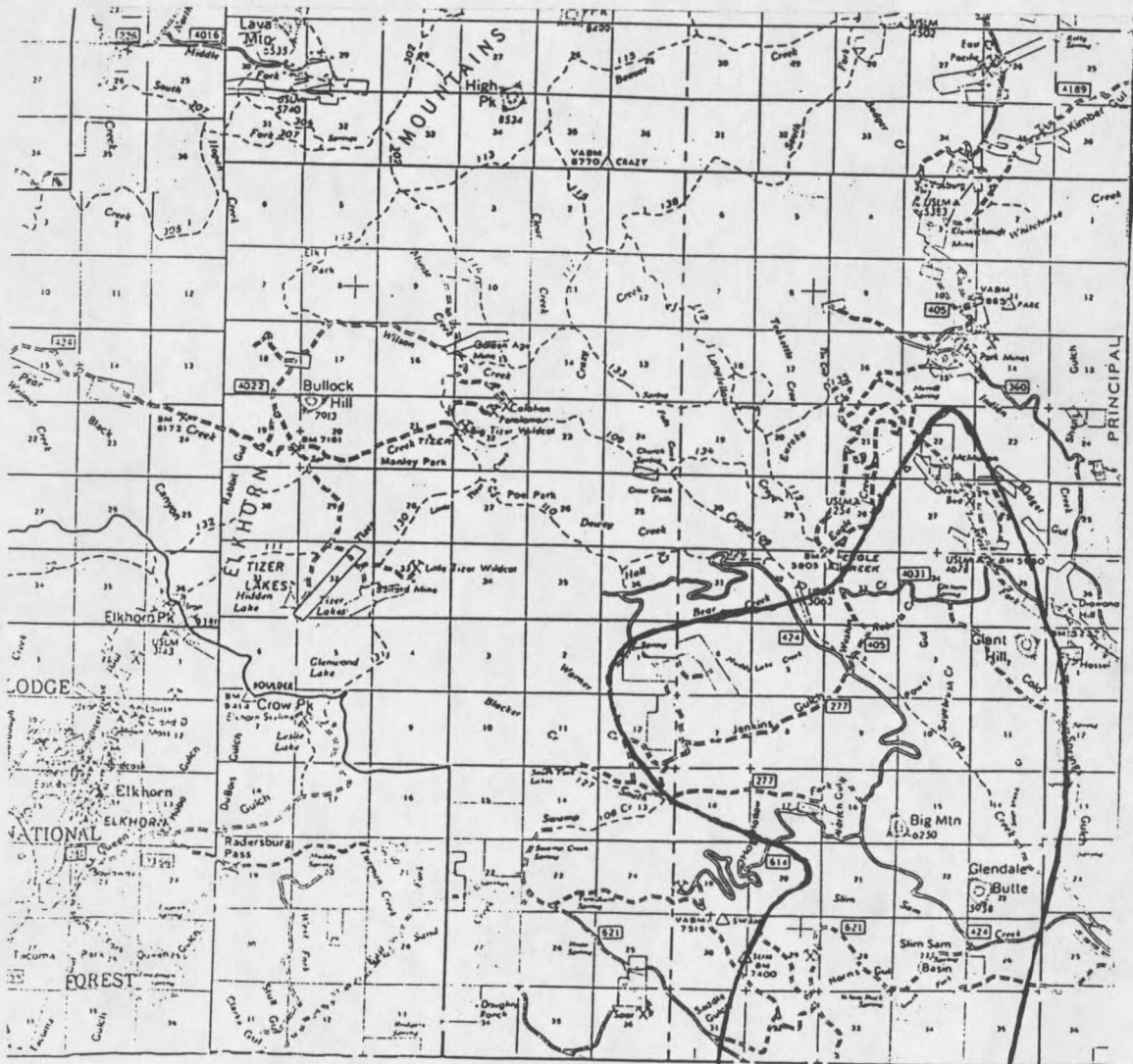
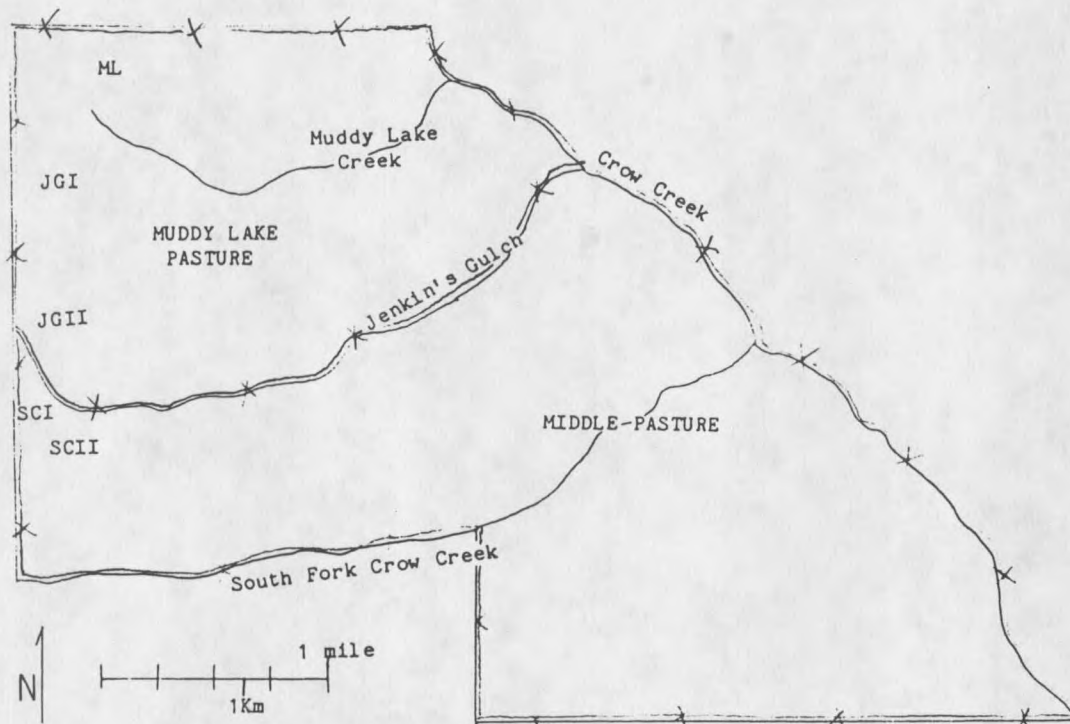



Figure 2. The Elkhorn Mountains showing the Crow Creek winter range.



LEGEND

Allotment boundry and division fences 

Site Names

ML Muddy Lake
 JGI Jenkin's Gulch I
 JGII Jenkin's Gulch II
 SCI South Crow I
 SCII South Crow II

Figure 3. Drawing of the Muddy Lake and Middle pastures of the South Crow allotment showing the study site locations.

Table 8. Sampling site descriptions on the South Crow winter range.

<u>SITE</u>	<u>TRANSECTS</u> number	<u>ELEVATION</u> meters	<u>ASPECT</u>	<u>SLOPE</u> %
Muddy Lake	5	2048	SSW	5
Jenkin's Gulch I	6	2073	W	6
Jenkin's Gulch II	3	1987	SW	18
South Crow I	5	1926	SSE	24
South Crow II	5	1939	SW	12

the close of hunting season until the summer ranges are snow-free, usually December to June. The South Crow winter range is not a typical elk winter range for several reasons. The elk population is one of the densest and most productive in Montana (DeSimone personal communication). During all seasons 95% of the elk are on Forest Service land, thus avoiding conflicts with surrounding land owners. Typically 80% of the elk in the western U.S. winter on private land (DeSimone et al. 1984). Also the South Crow winter range is not in the Forest Service timber base. So during the winter elk winter range is the primary use of the area.

South Crow allotment has had a three pasture deferred rotation grazing system since 1970. There are 2517 AUM's allocated to 604 cows with calves (USDA 1970). In 1983 the grazing season ran from June 10 to October 15. The Middle pasture was grazed from June 10 into October and the Muddy Lake pasture from August 10 into October. The combination of high quality range, well managed livestock and a

healthy elk population made this study site an example of a desirable situation.

SITE SELECTION

The Crow Creek drainage was selected because two previous MSU master's projects (Stevens 1965 and Gordon 1968) have studied elk-livestock interactions in this area and reported habitat descriptions, seasonal habitat use and dietary information. Additionally current elk winter location data were made available by the Elkhorn Mountains Wildlife Monitoring Program (EMWMP). The Middle and Muddy Lake pastures were selected, partially, to facilitate coordination with EMWMP studies on the same area.

METHODS

TRANSECTS

When setting up the fieldwork a primary consideration was the implementation of procedures which would minimize the project's effects on the plants, animals and sites involved. A study of crested wheatgrass defoliation patterns (Norton and Johnson 1981) reported that very little regrazing of individual plants occurred in an extensive pasture situation. Based on this and supporting evidence within this article, it was decided that protection of individual plants from excessive utilization would not be a problem and permanent transects were selected. Gammon and Roberts (1978) used transects to study defoliation patterns of individual plants on southern African veld, and reported that two weeks between transect readings allowed identification of grazing effects and phenological development and so two weeks between transect readings was adopted in the current project. The first set of plant height readings was subjected to Stein's two-stage test for sample size adequacy (Steel and Torrie 1960), and it was determined that 15 transects adequately sampled the variation in leaf length for each species. Twenty-five transects were established to allow for unforeseen problems.

The 25 transects were in five groups with five transects per group. Each transect was subjectively located to include rough fescue, Idaho fescue and bluebunch wheatgrass plants and evidence of winter elk use and summer cattle use. A transect was a permanent 10 m line marked by fixed end points. When a transect was read a meter

tape was stretched tightly between the stakes always in the same direction. Canopy line intercept for each bunch of each key species was recorded. Each bunch was assumed to be an individual plant. This procedure allowed identification of individual plants through time without disturbing plants or modifying site characteristics.

Transects were read biweekly from April through October, 1983. Height of the longest vegetative leaf, phenological stage and utilization were recorded. Fescue leaf lengths were measured by holding the leaves straight up and measuring the longest. Bluebunch wheatgrass had elongated vegetative culms, so leaf length was the height of the highest point of the highest leaf on the culm. Eight phenological stages were identified, (1) vegetative, (2) boot (swelling visible in sheath to seedhead 50% out of the sheath), (3) emerging seedheads (seedheads greater than 50% out of the sheath to fully emerged, but not filling), (4) anthesis (any visible anthers regardless of condition), (5) mature flowers (from seedheads filling to fully developed), (6) seed shatter (any indication of disarticulation), (7) mature foliage (seedheads completely empty and leaves duller green through brown) and (8) fall regrowth (any greening of leaves). Mature foliage was the overwintering stage. At the outset it was hoped that some acceptable key to and/or definitions of phenological stages would be found; none were. The stages identified in this project were selected out of ease of field identification.

Fieldwork was continued from January through early July, 1984. During this winter, primarily in March, plants with known utilization

histories from the previous summer were collected for chemical analysis. These samples were stored at $\sim 50^{\circ}\text{C}$ and low humidity until analyzed. Clipping removed a plant from the sample population. Also during March the transects were read to determine winter leaf loss which was measured in two ways, winter grazing and the presence of standing dead at the beginning of new spring growth. On some or all of the following dates, depending on snow cover, the transects were read: April 19, May 10, May 18, June 10, June 18 and June 25. Height of the longest vegetative leaf and phenological stage were recorded using the same techniques and deliniations previously described.

CHEMICAL ANALYSIS

Twenty percent of the collected samples were analyzed using the following procedures: macro-Kjeldahl protein (PRO), dry matter (DM) and ash (ASH) following AOAC (1970), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) following Goering and VanSoest (1970) and in vitro organic matter disappearance (IVOMD) (Harris 1970). Additionally cellulose (CELL) and hemicellulose (HC) were calculated ($\text{CELL} = \text{ADF} - \text{ADL}$, $\text{HC} = \text{NDF} - \text{ADF}$) (Goering and VanSoest 1970). Twelve rough fescue, 10 Idaho fescue and 7 bluebunch wheatgrass values for each constituent were determined.

NEAR-INFRARED SPECTROSCOPY

The chemical analysis data were used to calibrate a TECHNICOR 400 INFRALYSER, a near-infrared (NIR) spectrophotometer, that then predicted the chemical constituents for the remaining 80% of the

samples. This NIR spectrophotometer had 19 filters with wavelengths from 1445 to 2348 nm, inclusive.

It was decided, during the course of the project, to use NIR prediction of chemical constituents for three reasons: 1) to save on the time and expense involved in laboratory analysis, 2) to begin a NIR data base for rangeland forages and 3) because samples were winter collections of usually grazed plants, the amount of material per sample was too small to permit complete chemical analysis. Also for these three reasons some of the usual NIR procedures (AACC 1962, Norris et al. 1976 and Shenk et al. 1981) were modified.

All samples were analyzed by NIR and the log values recorded in a file. The largest samples were chosen for the chemical analysis described above. Some samples were too small to allow analysis of all the chemical constituents. As a result, some samples were analyzed for only part of the constituents, some were analyzed for all constituents but not reread by NIR, and some were analyzed for all constituents plus reread by NIR. This means that sources of error associated size of samples and intrasample constituent correlations were not adequately dealt with.

Determination of filter coefficients and an intercept value for each constituent was done using the "All Possible Subsets Regression" program (Dixon 1981). The regression equations for each constituent are in Appendix A. All samples which were still large enough were rerun on the calibrated NIR machine to predict constituent values. Also the log values from the initial NIR readings for all samples were entered into a regression model along with the coefficients and

intercepts from the calibration procedure. The output was predicted chemical constituent values for all of the original samples, including those too small to rerun by NIR.

STATISTICAL ANALYSIS

BMDP (Dixon 1981) and MSUSTAT (Lund 1983) statistical packages were used to analyze the data. The specific programs used are referred to in context. For the remainder of this thesis significance means that $p \leq .05$.

For the statistical analysis this project was broken into a series of subprojects. This was necessary for two reasons: 1) No two factor/treatment combinations had equal sample size. 2) All treatments except those associated with lab results included unequal numbers of missing data. Using subprojects allowed the use of statistical packages for the analysis.

CHEMICAL CONSTITUENT DATA

For objective one, a random design with one factor and nine treatments was used. The factor was species with three levels. Treatments were the phenological stages when grazing had occurred in the previous summer, including no grazing. The dependent variables were the nine chemical constituents. There were unequal treatment numbers. The chemical constituent data was analyzed in four steps. The chemical constituent data for each species was described using the "Cluster Analysis of Variables" program (Dixon 1981). "Stepwise Discriminant Analysis" (Dixon 1981) was then performed on the chemical constituent results to determine if the phenological stage when

grazing had occurred was reflected in winter nutritional values. The calculations within this program were such that for a variable to be removed as a discriminating variable required an F-value of 4.0 which was about equal to $p=.05$. The values for each constituent were compared among species using "Multi-factor Analysis of Variance" (Lund 1983). For constituents with significant F-values the species means were separated using the Least Significant Difference technique.

TRANSECT DATA

The experimental design for the second objective was randomized block having one factor with three levels and two treatments in five blocks. Sites, species grazing and standing dead were the blocks, factor and two treatments, respectively. The dependent variables were plant height and phenological stage on six sampling dates. Initial analysis of plant height using analysis of variance, program 2V (Dixon 1981), found that on each date sites and species were always significantly different. Each site/species case was also analyzed on each date using analysis of variance, program 2V (Dixon 1981). This eliminated much of the missing data by causing the program to not recognize it. Grazing and standing dead were the treatments.

The phenological stage data was determined to be unsuitable for statistical analysis because two of the indexing keys predominated and the distribution of key values did not appear to be normal. The frequency of phenological stages for each site/species case and each treatment were graphed (Appendix B.)

RESULTS AND DISCUSSION

CHEMICAL CONSTITUENTS

The NIR predicted values of the chemical constituents are presented in tables 9 through 11. All values in this project were percent of total sample weight expressed on a dry matter basis. A large portion of what follows will be based on these analyses. The chemical constituent values were suitable for within-project analysis but must be used more cautiously in comparisons with other studies.

The use of NIR for predicting chemical constituents and forage quality parameters is increasingly accepted, so there is a growing body of literature (e.g. Brooks et al. 1984 and Park et al. 1983). General conclusions supported by this literature included the following: NIR predictions of constituents that could be associated with some limited number of specific chemical bonds (i.e. PRO) were more accurate than of constituents which included behavioral factors plus a wide range of chemical bonds (i.e. IVOMD). NIR predicted values tended to be higher than wet chemistry values. The larger the sample size the more accurate was the prediction. If the entire range of constituent values was included in the calibration, sample results were more accurate than if outlying constituent values had to be predicted. Ash has been poorly predicted by the Infralyser 400, because it does not recognize phosphorus. All of these problems and constraints more or less affected the NIR predicted constituent values in this project.

Table 9. All NIR predicted winter chemical constituent values for bluebunch wheatgrass and the phenological stage when grazing had occurred during the previous summer.

<u>CHEMICAL CONSTITUENTS¹</u>									
<u>STAGE²</u>	NDF %	ADF %	ADL %	CELL %	HC %	PRO %	DM %	ASH %	IVOMD %
1	81.4 ³	51.7	4.8	39.3	27.9	5.9	96.8	8.5	19.0
1	80.5	48.6	3.7	38.1	27.5	5.1	96.3	8.9	31.6
1	76.2	50.6	4.4	42.0	26.7	4.4	97.2	7.5	58.1
2	79.7	51.7	4.3	41.8	25.7	4.1	95.9	8.0	69.5
2	77.8	54.8	6.0	45.3	24.8	3.0	98.3	6.0	41.2
3	79.2	54.4	4.9	42.7	24.6	4.9	95.8	8.0	59.5
3	89.0	63.3	6.9	49.3	26.8	2.3	95.3	7.0	105.5
3	82.0	54.3	6.1	43.2	28.3	3.6	98.5	7.2	27.9
4	74.8	55.1	5.8	42.1	24.9	4.3	97.1	7.4	19.1
6	87.8	54.9	7.0	45.5	32.9	1.9	99.9	6.7	43.8
6	75.6	52.6	4.6	39.6	24.4	6.1	96.2	8.3	16.0
7	80.1	57.4	5.5	45.1	24.0	4.4	95.4	7.8	69.0
7	85.4	52.8	5.6	44.7	31.5	1.7	98.0	7.3	70.7
7	78.3	52.8	5.9	43.1	28.4	3.5	98.7	7.0	38.4
7	82.2	52.5	5.1	41.9	31.8	4.1	97.2	7.9	59.3
8	82.0	54.8	6.4	45.6	29.5	2.5	98.9	6.5	50.5
9	80.2	51.9	4.8	43.5	26.9	2.4	97.0	7.2	67.5
9	84.5	56.9	6.2	46.7	30.3	3.0	97.2	7.4	75.7

¹The chemical constituents are neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose (CELL), hemicellulose (HC), protein (PRO), dry matter (DM), ash (ASH) and in vitro organic matter disappearance (IVOMD).

²The phenological stages when grazing occurred were vegetative (1), boot (2), seedheads emerging (3), anthesis (4), seed shatter (6), mature foliage (8) and ungrazed (9).

³Values are % of total sample weight on a dry matter basis.

Table 10. All NIR predicted winter chemical constituent values for rough fescue and the phenological stage when grazing had occurred during the previous summer.

<u>CHEMICAL CONSTITUENTS¹</u>									
<u>STAGE²</u>	<u>NDF</u> %	<u>ADF</u> %	<u>ADL</u> %	<u>CELL</u> %	<u>HC</u> %	<u>PRO</u> %	<u>DM</u> %	<u>ASH</u> %	<u>IVOMD</u> %
1	79.4 ³	49.4	1.6	41.7	38.3	3.2	96.6	6.7	60.6
1	71.9	46.2	3.0	34.5	18.6	6.5	95.9	8.1	44.8
1	74.1	48.2	3.3	37.5	24.1	6.6	95.3	10.4	47.1
2	84.0	49.4	4.8	49.0	23.5	3.0	97.5	6.9	59.6
2	80.6	47.5	2.8	44.5	34.1	2.4	96.5	4.3	60.8
2	72.8	43.6	3.2	35.8	19.0	6.6	95.7	7.3	45.2
3	79.5	49.1	3.2	41.5	31.6	4.8	95.9	7.3	56.0
3	82.2	48.9	2.7	45.8	30.5	3.1	96.5	5.3	59.0
3	79.4	50.4	2.9	43.9	31.0	3.4	96.5	7.4	58.1
3	76.4	50.3	4.2	39.3	21.6	5.9	96.2	11.6	52.7
3	82.3	51.3	4.2	46.3	26.7	4.1	96.5	7.5	55.0
3	80.6	47.8	3.8	46.6	19.3	2.1	98.5	2.7	60.8
4	76.3	49.0	3.2	41.7	24.0	5.2	96.3	9.1	49.9
5	79.1	50.6	3.4	43.5	29.5	3.3	96.7	7.0	58.3
6	77.8	50.8	3.3	41.6	26.0	3.9	97.0	11.2	57.2
6	79.1	48.3	3.9	41.5	20.5	6.7	95.9	10.7	48.6
6	79.4	50.0	3.1	41.7	29.4	4.3	96.2	8.0	53.8
7	78.4	46.3	3.2	38.9	30.2	5.1	95.8	8.5	55.8
7	79.4	51.3	4.1	42.7	29.7	4.9	95.7	8.0	52.5
7	82.9	49.6	3.8	47.5	28.2	3.3	96.9	7.0	59.2
7	76.8	50.5	4.2	39.7	22.3	5.9	96.2	11.3	52.5
7	79.9	52.4	3.9	40.5	29.2	6.1	95.8	9.8	50.5
7	80.2	49.2	3.4	46.4	23.2	3.8	96.8	8.4	53.5
7	77.6	47.9	2.6	40.9	28.3	4.8	95.9	8.4	52.7
8	78.4	48.8	3.7	40.1	30.1	5.5	95.5	8.7	52.6
8	85.7	49.9	4.1	50.2	25.0	2.5	98.1	6.1	62.6
9	77.5	48.7	2.7	41.6	26.8	5.0	95.9	8.2	50.8

¹The chemical constituents are neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose (CELL), hemicellulose (HC), protein (PRO), dry matter (DM), ash (ASH) and invitro organic matter disappearance (IVOMD).

²The phenological stages when grazing occurred were vegetative (1), boot (2), seedheads emerging (3), anthesis (4), mature flowers (5), seed shatter (6), mature foliage (7), fall regrowth (8) and ungrazed (9).

³Values are % of total sample weight on a dry matter basis.

Table 11. All NIR predicted winter chemical constituent values for Idaho fescue and the phenological stage when grazing occurred during the previous summer.

STAGE ²	CHEMICAL CONSTITUENTS ¹								
	NDF %	ADF %	ADL %	CELL %	HC %	PRO %	DM %	ASH %	IVOMD %
1	71.3 ³	46.2	4.7	35.9	25.3	6.6	93.1	15.4	70.1
1	86.7	49.9	3.0	40.9	27.6	5.1	90.3	10.6	53.6
1	82.1	45.2	3.7	40.2	31.7	6.0	91.1	10.7	55.2
1	82.4	47.3	3.6	39.8	31.7	6.2	90.9	12.3	55.4
1	71.7	46.2	3.8	37.2	25.9	6.1	94.1	5.3	52.7
1	72.9	46.3	3.5	36.3	24.3	6.1	93.7	6.8	51.3
2	77.0	50.2	3.2	40.0	28.7	4.9	95.6	5.4	43.3
2	71.8	46.0	4.2	37.5	28.6	5.8	96.7	3.9	50.9
2	80.8	47.9	2.8	41.8	29.5	4.9	95.6	7.2	42.5
2	75.8	48.1	3.5	39.3	27.4	5.2	95.9	7.4	44.1
2	74.9	45.2	4.2	31.8	25.7	6.3	97.0	8.8	64.0
3	74.4	42.3	3.6	35.1	30.8	6.1	96.8	8.9	57.5
3	75.6	42.8	3.8	35.7	31.5	6.1	96.9	10.8	59.7
3	74.1	52.8	3.7	41.9	27.8	5.7	96.4	6.5	42.3
3	68.1	46.6	3.7	36.3	26.7	5.5	96.2	7.6	53.8
3	67.0	45.3	3.5	36.0	25.6	5.6	97.2	7.3	52.8
6	72.5	42.0	4.5	37.6	26.4	5.9	96.6	9.4	56.0
6	61.0	39.2	6.1	25.7	26.6	6.2	99.6	5.8	80.2
6	65.4	33.9	6.6	26.6	27.7	6.6	97.3	8.5	81.4
7	67.9	41.6	4.3	35.1	29.1	6.5	96.8	8.0	60.8
7	81.1	52.9	5.6	35.2	29.0	9.4	94.4	9.5	44.5
7	69.4	43.4	4.2	35.6	28.4	5.2	97.3	5.1	59.0
7	74.6	48.8	4.3	37.0	26.5	5.0	96.0	7.8	61.1
8	71.7	40.5	3.8	33.5	29.3	5.9	95.5	8.1	60.1
8	73.0	45.8	3.7	36.2	27.9	6.0	96.7	7.9	53.8
9	76.4	44.3	4.6	36.2	30.8	5.5	96.2	9.6	64.0
9	77.1	48.0	4.2	36.7	25.0	4.9	95.6	7.6	55.8

¹The chemical constituents are neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose (CELL), hemicellulose (HC), protein (PRO), dry matter (DM), ash (ASH) and invitro organic matter disappearance (IVOMD).

²The phenological stages when grazing occurred were vegetative (1), boot (2), seedheads emerging (3), seed shatter (6), mature foliage (7), fall regrowth (8) and ungrazed (9).

³Values are % of total sample weight on a dry matter basis.

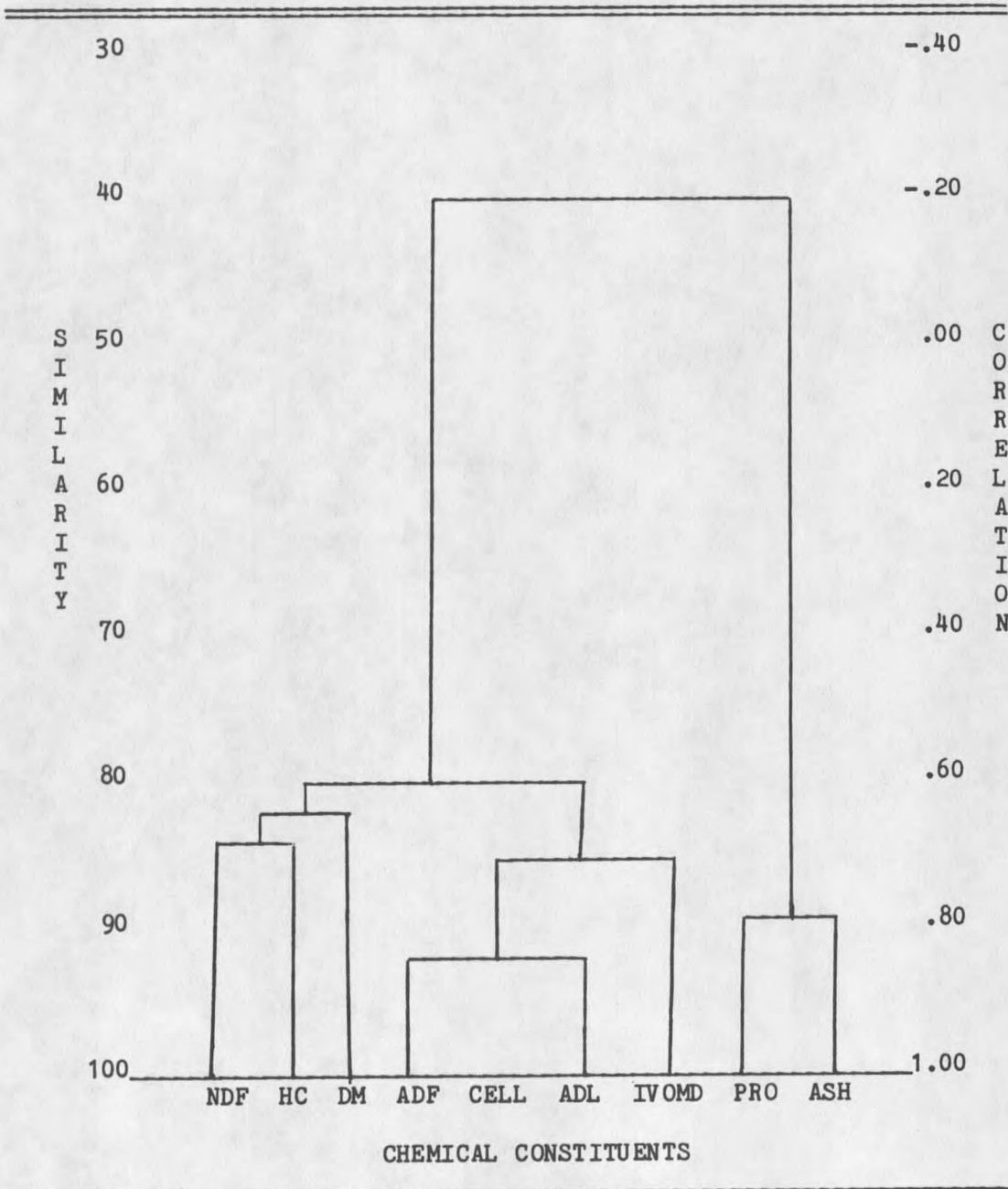
Bluebunch wheatgrass IVOMD results were very poor and ranged from 11% to 105%, two unlikely extremes. The bluebunch wheatgrass IVOMD mean was not significantly different from that of either fescue. However, IVOMD's for all species were higher (50% - 60%) than expected (20% - 40%). Due to these factors, IVOMD will not be further discussed.

The ASH constituent was retained because the values corresponded well with the calibration samples. This may have been due to low phosphorus content in the grasses, a traditional western winter range deficiency.

CHEMICAL CONSTITUENT RELATIONS

Cluster analysis by species segregated winter constituents into fiber and protein clusters. Bluebunch wheatgrass constituents (table 12) formed two large clusters. A cellulose cluster of ADF, CELL and ADL and a hemicellulose cluster with NDF, HC and DM formed and combined into a fiber cluster. A protein cluster with PRO and ASH was also identified. The fiber and protein clusters were negatively correlated. Winter bluebunch wheatgrass represented a "typical" dormant winter grass with low PRO and high ADL and ADF concentrations, and the constituents clustered as expected for several reasons: 1) Caldwell et al. (1981) showed that during the growing season bluebunch wheatgrass did not respond to defoliation, and there was no indication that this situation changed during the winter. 2) Bluebunch wheatgrass appeared dormant in August, earlier than either fescue. This implied that once bluebunch wheatgrass began growth in the spring, its

Table 12. Cluster analysis of winter bluebunch wheatgrass chemical constituents.



growth, development and senescence were mainly fixed and little influenced by external factors such as grazing. After the cessation of active growth differentiation of the cellulose, hemicellulose and protein clusters continued due to leaching and respiration. By March, when the plants were collected, there were identifiable differences between the three clusters.

For rough fescue (table 13) there was a loose fiber cluster which combined a NDF and CELL cluster with DM, HC, ADF and ADL clusters. PRO and ASH formed the protein cluster. In Idaho fescue (table 14) a fiber cluster containing ADF, CELL, NDF, HC and ASH and a digestibility cluster containing ADL, PRO and DM were identified.

SUMMER GRAZING EFFECTS

No rough fescue or bluebunch wheatgrass winter chemical constituent values could predict any of the stages during which the plant had been grazed in the previous summer. Also grazed and ungrazed plants could not be distinguished. It was concluded that the phenological stage when rough fescue and bluebunch wheatgrass had been grazed did not significantly affect winter chemical constituent values.

The following was based on discriminant analysis of chemical constituents from pooled winter and summer samples. In part the discriminant analysis reinforced the cluster analysis in that it tended to pick primary cluster members as discriminating variables. For rough fescue NDF was the discriminating variable, and it was also the initial constituent selected in the fiber cluster. In Idaho

Table 13. Cluster analysis of winter rough fescue chemical constituents.

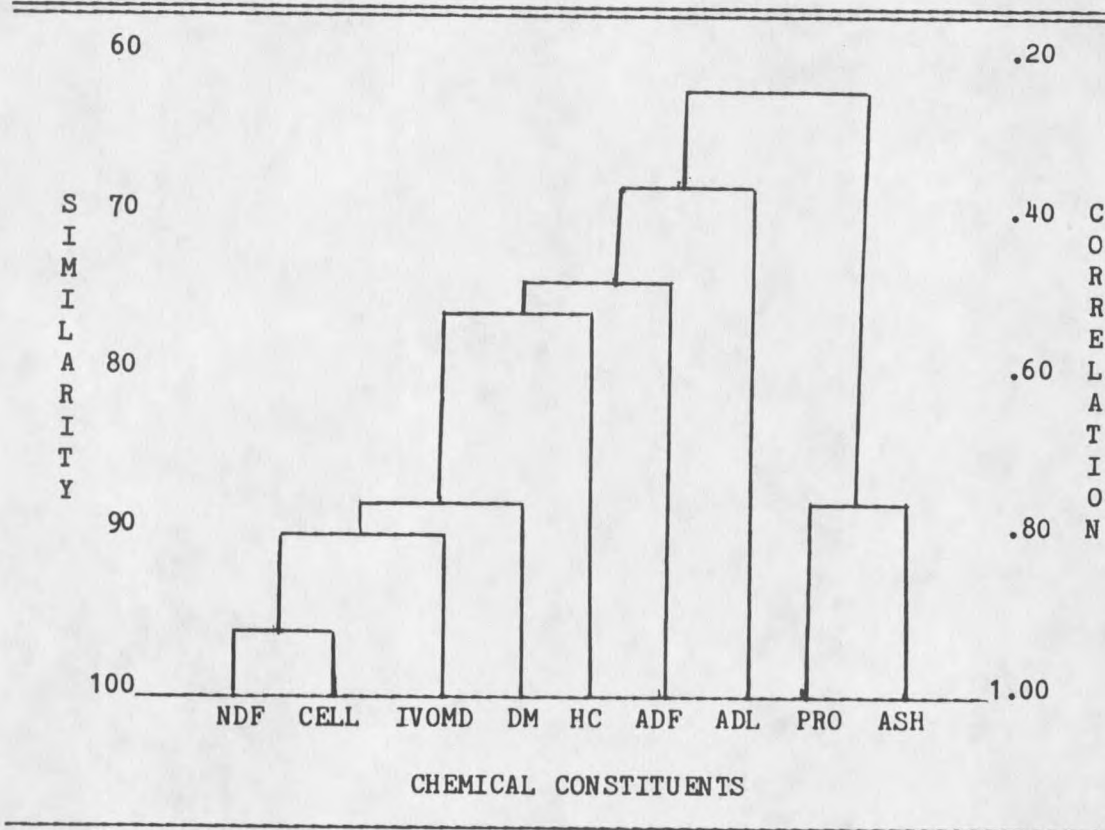
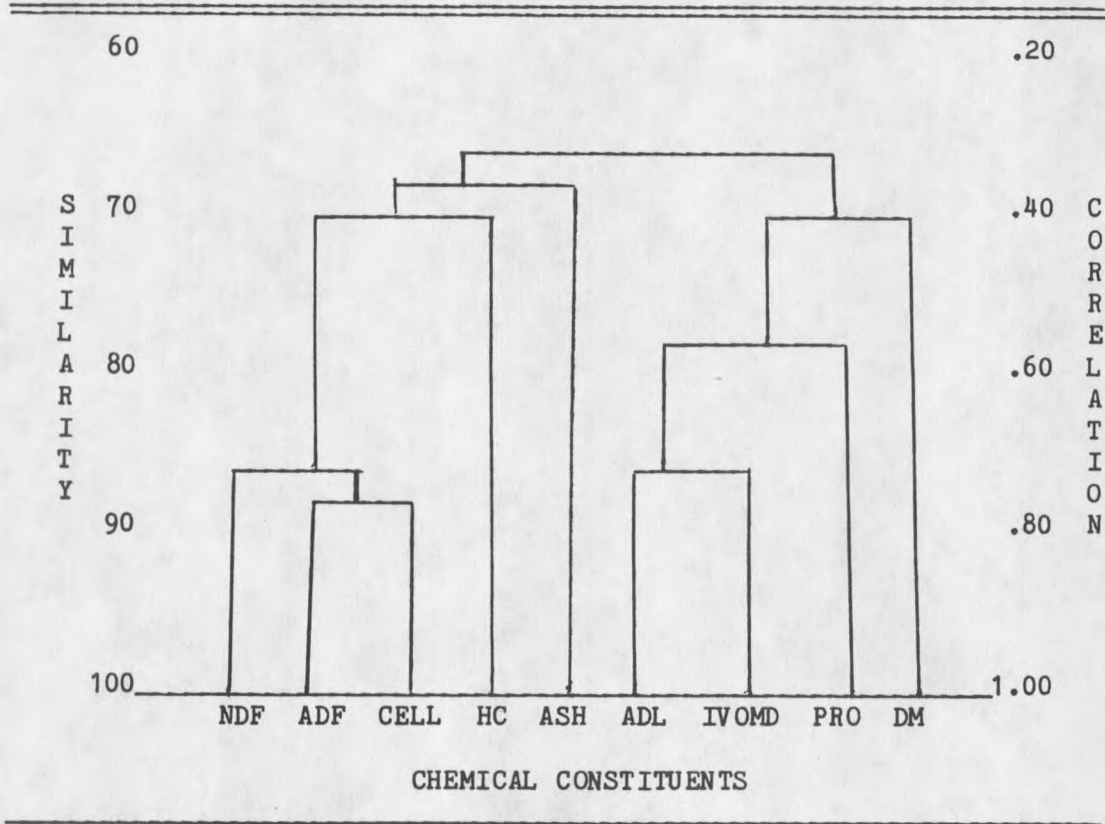


Table 14. Cluster analysis of winter Idaho fescue chemical constituents.



fescue ADL, PRO, NDF and DM were the discriminating variables. ADL and PRO were the two extreme members of the digestibility cluster. NDF was in the fiber cluster. DM formed an independent cluster.

For rough fescue the anthesis, mature flowers and ungrazed phenological stages of grazing were successfully predicted by the chemical constituents. For Idaho fescue vegetative, boot and ungrazed plants were the stages predicted. The seed shatter stage was also successfully predicted 66.7% of the time.

Discriminant analysis was performed on the pooled chemical constituents of both fescues. There were individual species differences in the chemical constituents, so in the samples pooled across species, previously discriminating constituents were averaged into insignificance.

For winter collections of Idaho fescue (not the pooled sample) DM, NDF and ADL were the discriminating variables; however, only the plants grazed during the vegetative stage were 100% predictable by the winter constituents. The seed shatter and ungrazed stages were predicted correctly 66.7% and 50.0% of the time, respectively. Discriminant analysis indicated that the phenological stage during which grazing occurred and grazing itself did not have a significant effect on rough fescue or bluebunch wheatgrass winter nutritional values. By March any differences in chemical constituents that may have resulted from the phenological stage at grazing had been obliterated by more influential processes, such as translocation of nutrients and/or weathering. For Idaho fescue grazing at some stages of growth did have an affect on subsequent winter nutritional values.

There was, however, no pattern of improvement or damage related to grazing at any phenological stage, including ungrazed.

That grasses have species specific responses to grazing has been well documented (White 1973, Cook 1966 and Caldwell et al. 1981). That these differences in grazing response are part of an array of indicators of species specific physiology is a topic of current discussion and research (Caldwell et al. 1981, Robertson and Woolhouse 1984a,b and McLean and Wikeem 1985a,b). In this project bluebunch wheatgrass represented one distinct physiological type and the fescues another type.

Climate is one important grass physiology selection factor. Bluebunchwheatgrass, a Great Basin species, has adapted to the cold desert climate (Caldwell et al. 1981). Conversely the Festuca genus is believed to be of northern origins. Rough fescue distribution is currently centered in the northern Great Plains and Aspen parklands in the northern United States and Canada. Idaho fescue is located in mountains and foothills from the Central Rockies into southern Canada. Rough and Idaho fescue are located in generally moister and cooler habitats than bluebunch wheatgrass.

Due to their geography and elevation, the Elkhorns contain floristic elements of Great Basin, Northern Plains and boreal habitats. By locating transects to include all three key grass species unique microhabitats were sampled which allowed the mixing of three species from different geographic regions. Rough fescue was on the warm and dry end of its potential distribution potential while bluebunch wheatgrass was in the cooler and wetter part of its

potential range. Idaho fescue was in typical habitat. As a consequence, as any of the sampling sites improve in range condition, implying better moisture relations, rough fescue would be expected to have a competitive advantage over bluebunch wheatgrass. This was observed in places with conserved moisture, depressions, snow drifts, shaded areas and apparently ungrazed areas.

Studies of herbivory responses have suggested that none of these three grasses are very grazing tolerant, but that Idaho fescue tends to be the more grazing tolerant and rough fescue the least (McLean and Tisdale 1966, Mueggler 1975 and McLean and Wikeem 1985a,b).

Results from this project supported the concept that bluebunch wheatgrass and the fescues represented two different physiological types. The independence of fescue chemical constituent values was due in part to all plants of both species having green overwintering leaves suggesting some level of winter photosynthesis. Winter photosynthesis by graminoids in harsh winter environments has been reported (Roberts and Woolhouse 1984a,b and Chapin et al. 1980). Winter photosynthetic activity represented a significant physiological difference between the fescues and bluebunch wheatgrass. Differences between rough and Idaho fescue represented differences in winter physiological activity rather than its presence or absence. The general explanation for increased structural carbohydrates during the winter, especially cellulose and lignin, is that more easily metabolized carbohydrates are used in maintenance level respiration. Winter photosynthetic activity provided some highly available

carbohydrates, reducing tissue catabolism and preventing increased concentrations of cellulose and lignin in the winter fiber component.

Idaho fescue had higher winter PRO levels than the other species with little decline in PRO from summer into winter (table 15). Similar findings have been reported by others (McCall 1939 and 1940). Since protein content was measured in percent, no distinction was made between either more protein, less dilution by structural carbohydrates or both. In any case, it must indicate a level of winter physiological activity present in few other grasses. In "typical" grasses, protein concentrations decline by fall and tend to be constant through winter (McCall 1939 and 1940). In Idaho fescue, the late growing season draw down of protein was less than for most other grasses. This could be due to reduced fall translocation of protein into the crown or roots as has been reported for evergreen shrubs (Chapin et al. 1980).

SPECIES COMPOSITION

The species composition on the five sites studied are presented in table 16. The Jenkin's Gulch II site was the most dissimilar, because one transect was destroyed by cattle trampling early in the fall, and the site had snow cover on most of the spring sampling dates. The other sites were very similar. One hundred fifty-four rough fescue, 158 bluebunch wheatgrass and 575 Idaho fescue plants were sampled.

Table 15. Comparisons¹ of NIR predicted chemical constituent mean values² for rough fescue (Fesc), Idaho fescue (Feid) and bluebunch wheatgrass (Agsp).

<u>CHEMICAL CONSTITUENT</u>	<u>SPECIES</u>				
	<u>AGSP</u>	<u>FESC</u>		<u>FEID</u>	
	Winter %	Winter %	Summer %	Winter %	Summer %
NDF	81b	79be	67 d	74af	71 f
ADF	54c	49be	45 d	46af	46 f
ADL	6c	3ad	3 d	4bg	2 f
CELL	44c	42be	34 d	36af	38 f
HC	28a	27ae	23 d	28ag	21 f
PRO	4a	5bd	7 e	6cf	6 f
DM	97b	96ad	96 d	96af	96 f
ASH	7a	8ad	11 e	8af	9 f
IVOMD	53a	54ae	43 d	57ag	51 f

¹Means within the same row followed by the same letter are not significantly different ($p \leq .05$). Three comparisons were made for each chemical constituent: 1) Agsp, Fesc and Feid winter means, 2) winter and summer Fesc means and 3) winter and summer Feid means.

²Values are % of total sample weight on a dry matter basis.

Table 16. Number of rough fescue (Fesc), Idaho fescue (Feid) and bluebunch wheatgrass (Agsp) on each sampling site in the spring, 1984.

<u>SITE</u>	<u>SPECIES</u>			Total n
	Fesc n	Feid n	Agsp n	
South Crow I	36 (15.3%) ¹	150 (63.6%)	50 (21.2%)	236d
South Crow II	28 (15.0%)	118 (63.1%)	41 (21.9%)	187d
Jenkin's Gulch I	33 (14.2%)	168 (72.4%)	31 (13.4%)	232d
Jenkin's Gulch II	29 (41.4%)	29 (41.4%)	12 (17.1%)	70c
Muddy Lake	28 (17.3%)	110 (67.9%)	24 (14.8%)	162d
Total	154 (17.4%)	575 (64.8%)	158 (17.8%)	887
Average	30.8a ¹	115.0b	31.6a	

¹% of key species total on site (or row totals).

²Values followed by the same letter are not significantly different. There were two comparisons: 1) among species (column averages) and 2) among sites (row totals).

WINTER GRAZING EFFECTS

Rough fescue utilization (86%) was greater than either Idaho fescue (49%) or bluebunch wheatgrass (47%) which were not different (table 17). The number of plants grazed per species are reported in table 17. On this winter range elk selected rough fescue > Idaho fescue > bluebunch wheatgrass.

When height data were pooled across sites and/or species there was no date when winter grazing had a significant effect on spring plant heights. For all species there were 52 total individual date/site cases. One of 17 bluebunch wheatgrass and six of 19 Idaho fescue cases had significantly taller plants associated with no winter grazing. No individual cases for rough fescue had significant grazing effects. Five of the individual cases of Idaho fescue with shorter leaves were on the last three sampling dates.

STANDING DEAD EFFECTS

More bluebunch wheatgrass (63%) and Idaho fescue (60%) plants had standing dead remaining at the end of winter than did rough fescue (20%). When height data were pooled across site and/or species standing dead was associated with taller plants on 5/10, 6/12, 6/18 and 6/24. Individual site/date cases per species are shown in tables 18 to 20. On the South Crow II site all three species had significantly taller plants associated with standing dead. For rough fescue and bluebunch wheatgrass this was the only site where standing dead appeared important. There were two additional cases for each species when plants with standing dead were significantly taller. For

Table 17. Frequencies and number of plants grazed (G) and with standing dead present (SD) for rough fescue (Fesc), Idaho fescue (Feid) and bluebunch wheatgrass (Agsp) plants on each site.

<u>SPECIES</u>		<u>SITE</u> ¹						Mean	
		SCI	SCII	JGI	JGII	ML	Total	%G	%SD
FESC	G	% ²	81	89	91	69	100	132	86b ³
	n		29	25	30	20	28		
	SD	%	36	25	30	10	0	33	20c
	n		13	7	10	3	0		
FEID	G	%	62	43	44	28	69	302	49a
	n		93	51	74	8	76		
	SD	%	65	80	63	66	26	346	60d
	n		98	94	106	19	29		
AGSP	G	%	58	51	45	67	13	75	47a
	n		29	21	14	8	3		
	SD	%	72	73	68	50	54	106	63d
	n		36	30	21	6	13		
Mean	G	%	67e	61e	60e	55e	61e		
	SD	%	58f	59f	54f	42f	27f		

¹Sites are South Crow I (SCI) and II (SCII), Jenkin's Gulch I (JGI) and II (JGII) and Muddy Lake (ML).

²Values are % of species' total on site.

³Means followed by the same letter are not significantly different ($p < .05$). Four comparisons were made: 1) grazing among species (Mean %G column), 2) standing dead among species (Mean %SD column), 3) grazing among sites (Mean G % row) and 4) standing dead among sites (Mean SD % row).

Table 18. Average rough fescue heights (cm) on six sampling dates for plants without (no SD) and with (SD) standing dead at the beginning of new growth in 1984.

SAMPLING DATES	SCI		SCII		SITE ¹ JGI		JGII		ML	
	no SD	SD	no SD	SD	no SD	SD	no SD	SD	no SD	SD
4/18	10.43 (ns) ⁴	11.1	NA ⁵	NA	NA	NA	NA	NA	5.5	6
5/10	11.0 (ns)	12.4	NA	NA	8.2 (ns)	7.7	6.5 (ns)	5.0	NA	NA
5/19	18.9 (*)	21.7	NA	NA	NA	NA	NA	NA	NA	NA
6/12	27.3 (ns)	27.0	NA	NA	21.1 (ns)	22.5	NA	NA	22.7	6
6/18	NA	NA	27.5 (**)	33.8	22.7 (ns)	24.8	23.4 (ns)	30.5	NA	NA
6/24	29.2 (ns)	31.5	31.4 (*)	37.7	25.2 (ns)	25.5	26.8 (*)	35.7	26.3	6

¹Sites are South Crow I (SCI) and II (SCII), Jenkin's Gulch I (JGI) and II (JGII) and Muddy Lake (ML).

²Absent = 10% of overwintering tillers with residual leaves. Present > 10% of tillers with residual leaves.

³Mean height (cm) of longest leaves.

⁴AOV of plant heights comparing no SD to SD, (ns) = $p > .05$, (*) = $p \leq .05$, (**) = $p \leq .01$.

⁵Date/site cases with more than 50% missing data were not analysed.

⁶No plants on the ML site had standing dead.

Table 19. Average bluebunch wheatgrass heights (cm) on six sampling dates for plants without (no SD) and with (SD) standing dead at the beginning of new growth in 1984.

SAMPLING DATE	SITE ¹									
	SCI		SCII		JGI		JGII		ML	
	no SD ²	SD	no SD	SD	no SD	SD	no SD	SD	no SD	SD
4/18	NA ³	NA	NA	NA	NA	NA	NA	NA	2.0 ⁴	2.5 ⁵ (ns)
5/10	7.8 (ns)	8.2	NA	NA	5.5 (ns)	5.9	6.3 (ns)	6.4	3.7 (ns)	4.3
5/19	14.4 (ns)	14.7	8.9 (ns)	8.4	NA	NA	NA	NA	NA	NA
6/12	19.8 (ns)	21.7	19.1 (ns)	21.3	17.0 (*)	21.1	NA	NA	16.9 (ns)	19.5
6/18	NA	NA	19.5 (**)	26.4	19.8 (ns)	23.4	25.2 (ns)	25.4	NA	NA
6/24	23.8 (ns)	24.6	23.7 (**)	27.9	20.8 (*)	27.4	31.0 (ns)	32.5	23.4 (ns)	23.4

¹Sites are South Crow I (SCI) and II (SCII), Jenkin's Gulch I (JGI) and II (JGII) and Muddy Lake (ML).

²Absent = 10% of overwintering tillers with residual leaves. Present > 10% of tillers with residual leaves.

³Date/site cases with more than 50% missing data were not analysed.

⁴Mean height (cm) of longest leaves.

⁵AOV of plant heights comparing no SD to SD, (ns) = $p > .05$, (*) = $p \leq .05$, (**) = $p \leq .01$.

Table 20. Average Idaho fescue heights (cm) on six sampling dates for plants without (no SD) and with (SD) standing dead at the beginning of new growth in 1984.

SAMPLING DATE	SITE ¹									
	SCI		SCII		JGI		JGII		ML	
	no SD ²	SD	no SD	SD	no SD	SD	no SD	SD	no SD	SD
4/18	NA ³	NA	NA	NA	NA	NA	NA	NA	NA	NA
5/10	6.9 ⁴ (**) ⁵	8.5	5.7 (**)	9.2	5.0 (**)	6.3	4.5 (ns)	5.1	3.8 (*)	4.3
5/19	10.1 (**)	12.9	NA	NA	NA	NA	NA	NA	NA	NA
6/12	11.0 (**)	15.8	10.1 (**)	14.5	9.4 (**)	12.2	NA	NA	10.4 (ns)	10.9
6/18	NA	NA	9.7 (**)	14.8	9.7 (**)	12.7	10.0 (ns)	11.6	NA	NA
6/24	11.4 (**)	15.8	11.0 (**)	16.8	10.2 (**)	13.2	11.4 (ns)	12.7	11.0 (ns)	12.0

¹Sites are South Crow I (SCI) and II (SCII), Jenkin's Gulch I (JGI) and II (JGII) and Muddy Lake (ML).

²Absent = 10% of overwintering tillers with residual leaves. Present > 10% of tillers with residual leaves.

³Date/site cases with more than 50% missing data were not analysed.

⁴Mean height (cm) of longest leaves.

⁵AOV of plant heights comparing no SD to SD, (ns) = $p > .05$, (*) = $p \leq .05$, (**) = $p \leq .01$.

3 of 4 rough fescue cases and 3 of 4 bluebunch wheatgrass the cases with taller plants were on the last two sampling dates.

For Idaho fescue in 13 of 18 individual cases plants with standing dead had significantly longer leaves. The Jenkin's Gulch II site was the only one without a standing dead affect.

WINTER LEAF LOSS

Bluebunch wheatgrass is considered one of the more desirable forage plants on western rangelands. In the Elkhorns the situation was different. In both summer (DeSimone et al. 1984) and winter, bluebunch wheatgrass utilization was less than that of either fescue. In all seasons, bluebunch wheatgrass had elongated vegetative culms. Neither fescue exhibited this response. During the winter bluebunch wheatgrass had the highest values for fiber constituents and dry matter (ADF, ADL and DM were significant maximum values among the three species) and the lowest protein values. It was apparently less palatable. The combination of coarse erect culms and chemical constituents associated with lower palatability combined to reduce grazing pressure on bluebunch wheatgrass through the entire year.

Sauer's (1978) hypothesized mechanisms for standing dead influence included improved microsite moisture conditions. The results from this study supported such an hypothesis.

The standing dead and grazing parameters appeared to be positive and negative indicators of litter, respectively. The primary site impact of litter is shading, cooling the soil surface and reducing evaporation. On the first sampling date there were individual cases

of plants that had been grazed and had no standing dead having longer leaves, but the differences were not significant (NS). Plants with less residual material began growth earlier, presumably because they could warm up sooner. On all other dates for all cases, plants with standing dead and/or no grazing were taller, though not always significantly. The presence of standing dead was more important than the method of its removal.

The amount of litter in one year's standing dead was not adequate to independently influence growth of rough fescue or bluebunch wheatgrass, but on the South Crow II site standing dead was augmented by litter. South Crow II was the only site with an observable abundance of litter, especially Idaho fescue (casually measured at 6 - 10 cm deep). The percent standing dead for Idaho fescue and bluebunch wheatgrass was higher on South Crow II than any other site (NS) indicating that the year of the study would also be contributing litter. The litter layer maintained moisture and temperature conditions adequate for leaf expansion longer into the active growth period allowing longer leaves. On the other sites, which had much less litter, soil moisture depletion did not allow the expression of standing dead effects. The strong association between Idaho fescue leaf growth and standing dead was a function of its much denser standing dead creating a cooler moister microsite. In addition, Idaho fescue may experience optimum photosynthesis at radiation levels resulting from less than direct sunlight (Caldwell et al. 1981).

There were some generalizations applicable to all three species. The influence of overwinter leaves was important later in the spring,

following initial new leaf production. The dates when standing dead was important corresponded to plant phenological stages with higher metabolic demands, such as seedhead emergence and development. That all species had significant standing dead effects on South Crow II suggested that moisture availability was the more important factor, perhaps exacerbated by the stage of development.

Rough fescue and bluebunch wheatgrass spring plant heights were not affected by the presence of spring standing dead or winter grazing. Idaho fescue plants with standing dead were taller, but winter grazed plants were only occasionally shorter. These results helped corroborate the findings from the chemical constituent analysis and further differentiate physiological differences between the species.

Bluebunch wheatgrass plants were entirely dormant over the winter. They had the highest fiber and lowest protein concentrations. The loss of overwintering leaves implied no further consequences to the plant. It was the least palatable of the three species studied.

Rough fescue was the intermediate species. Although it was not measurably as palatable as Idaho fescue, it was certainly the most preferred grass on the South Crow winter range. It did have the lowest lignin values of the three species. Rough fescue's lower lignin levels, intermediate levels of protein and fiber constituents and greenish winter leaves all indicated some level of winter photosynthetic activity. Fall floral primordia initiation and slow winter development have been reported in rough fescue (Johnston and McDonald 1967) furthering the demand for a winter respiratory energy supply.

Idaho fescue was the most physiologically active plant through the winter. Plants had many greenish winter leaves. The winter constituent values, other than lignin and hemicellulose, were similar to midsummer values. Loss of most winter leaves depressed leaf growth in the following spring. More individual Idaho fescue plants were grazed than either of the other two species in spite of periods of ice crusting. Fall initiation of floral primordia has also been reported in Idaho fescue (Hodgson in Johnston and McDonald 1967). All of these considerations suggested relatively high winter metabolic demands, too high to be met by stored nutrients alone.

WINTER NUTRIENT ALLOCATION PATTERNS

The winter chemical constituent and leaf loss data plus the literature reviewed suggested fall-winter nutrient strategies for each species. Bluebunch wheatgrass is one of the most extensively studied range grasses. The following is generally supported by that body of literature (previously cited). After seedhead filling or leaf expansion in nonreproductive plants, new photosynthate is directed to root crown nutrient storage pools. As summer water stress deepens, more available nutrients, cell solubles, proteins and some minerals, are translocated from aerial tissue to the root crowns. When fall moisture occurs additional photosynthate is produced and translocation may be reversed. Upon cessation of fall growth and often coincident with the first frost, easily metabolizable components from the leaves are rapidly translocated into root crown storage pools. These nutrient pools support a very low maintenance level of winter

respiration and fuel the production of the initial new spring leaves. So by the three leaf stage carbohydrate reserves are nearly depleted.

From midsummer through March, Idaho fescue chemical constituent levels were constant. Lignin and hemicellulose were the exceptions, both being higher in winter plants (table 15). There appeared to be no significant summer or fall translocation from the leaves and/or continued photosynthetic nutrient fixation.

Evergreen shrubs have been shown to have lower rates of carbon fixation during the growing season, less translocation of photosynthate out of the leaves and low rates of photosynthetic activity on favorable winter days. Idaho fescue appears to employ a similar strategy. Evergreen plants also have thick leaf cuticles that reduce leaf moisture loss. The analogous adaptation in Idaho fescue is its very densely tufted growth form. Chapin et al. (1979) have shown that the caespitose growth form creates an interior thermal regime several degrees warmer than ambient temperatures. A densely tufted bunch also reduces wind and solar evaporation and increases the internal relative humidity. Idaho fescue, following rapid and metabolically demanding growth stages, settles into a condition of stasis during which the plant maintains itself through submaximal and opportunistic photosynthesis from summer through fall and winter.

Rough fescue had an intermediate strategy sharing characteristics with both other species. Rough fescue had many greenish winter leaves, but there was a change in chemical constituent values between summer and winter (table 15). Lignin was the only exception. Rough fescue appeared to respond to winter in a manner similar to that

reported for Eriophorum vaginatum. With the completion of leaf elongation and reproduction, photosynthate and some tissue components are translocated to root crown storage pools. Following fall regrowth the rate of translocation increases (Chapin et al. 1979, Chapin et al. 1980 and Roberts and Woolhouse 1984a,b). Some photosynthetic pigments do remain intact all winter as indicated by the greenish color. That lignin did not increase between summer and winter while all other fiber constituents did, indicated some level of winter production but not enough to prevent the catabolism of some structural carbohydrates for respiratory energy. New spring growth is fueled by both reserves and current photosynthate from overwintering leaves.

SUMMARY AND CONCLUSIONS

METHODS

1) The transect approach used in this project was an amalgamation of little used methods. The traditional approach to vegetation in range management has been on a per acre, per pasture or per vegetation type basis. As a result there are no standard individual plant sampling methods. Fortunately the situation is changing towards more emphasis on individual plants. The method used in this project would be suitable for measuring observable plant characteristics and identification of individual plants. Species with obvious individuals are easier to deal with than smaller plants with indistinct individuals. This method would be difficult to adapt to rhizomatous species.

2) NIR prediction of chemical constituent values was only moderately successful, which in part demonstrated the resilience of the procedure. Many recognized cautions and safeguards were violated and still the results for the two fescues were acceptable based on values from the wet chemistry and the literature. Most of the values for bluebunch wheatgrass were also acceptable. The main problems encountered in this project were sample size for calibration and the small volume of individual samples for multiple readings on the NIR spectrophotometer. The results of this project should not be taken as an argument against using NIR, but rather a first experience which elucidated some special problems associated with adapting this technique for use in range research.

SUMMER GRAZING EFFECTS

3) Bluebunch wheatgrass winter chemical constituents formed three distinct clusters representing cellulose, hemicellulose and protein. The protein cluster was inversely correlated with the first two clusters. Rough fescue winter chemical constituents formed a loosely correlated fiber cluster and a protein cluster. Idaho fescue winter chemical constituents formed fiber and digestibility clusters.

4) Discriminant analysis of the winter chemical constituent data showed that grazing Idaho fescue at some phenological stages did affect subsequent winter nutritional values. But there did not appear to be a management implication associated with these results.

WINTER GRAZING EFFECTS

5) Winter grazing had no apparent effect on rough fescue and bluebunch wheatgrass plant heights in the next spring's new growth period. In some cases ungrazed Idaho fescue plants were taller than grazed plants.

6) The presence of standing dead resulted in taller Idaho fescue plants on most sites and in taller rough fescue and bluebunch wheatgrass plants on the South Crow II site.

7) It was concluded that grazing and standing dead were in fact two measures of litter accrual to the site, and that the impact of standing dead was due to shading which improved plant moisture relationships.

PLANT WINTER PHYSIOLOGICAL ACTIVITY

8) Bluebunch wheatgrass was dormant during the winter. Protein levels were lower and fiber levels were higher than in the two fescues. Removal of standing dead in the winter did not impact the next spring's leaf growth.

9) Idaho fescue had the highest level of winter physiological activity of the three species. Winter chemical constituent values were not different than summer values, and winter protein levels were higher than for the other two species. The loss of overwintering leaf material reduced leaf growth in the next spring. Leaves remained light green during the winter.

10) Rough fescue had an intermediate level of winter physiological activity. Winter chemical constituent values tended to lie between the other two species. Generally fiber increased from summer to winter, but lignin did not increase. The loss of overwintering leaves did not affect leaf growth in the next spring. Rough fescue did have light green winter leaves.

MANAGEMENT IMPLICATIONS

11) The primary winter forage management consideration on the South Crow winter range is the amount of forage available, because no summer grazing treatment substantially improved winter forage quality.

12) Some grasses are not dormant during the winter.

13) A key to grazing tolerance may be a plant's ability to photosynthesize during the winter. Plants such as rough and Idaho fescue may better tolerate perennial growing season utilization

because of winter photosynthetic production, Idaho fescue more than rough fescue.

14) Conclusions 12) and 13) (above) imply that if such species are grazed all year long they will be damaged.

15) Perennial grasses of genera with northern origins, such as Festuca and Poa, may be higher quality winter forages than other grasses.

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APPENDICES

APPENDIX A

Regression Equations for NIR Predicted
Chemical Constituent Values

Table 21. Regression equations¹ used for the NIR prediction of rough fescue chemical constituent values.

NDF	$3622(1818)^1 - 8281(1759) + 4953(1722) + 363.8(1445) - 625(1680) + 60.39^2$
ADF	$1101(2348) - 1227(2139) - 227.7(1982) + 3251(1759) - 4758(1722) + 1786(1680) + 53.13$
ADL	$-301.9(2348) + 130.3(2310) + 421.5(2270) + 286.4(2139) - 198.1(1778) - 523.1(2100) + 178.6(1445) - .3584$
CELL	$2724(2348) - 2582(2310) - 189.1(2230) - 165.8(1982) + 69.94$
HC	$1996(2139) + 5895(1818) - 2387(2100) - 475.6(1940) + 1694(1445) - 6204(1680) - 59.86$
PRO	$89.07(2190) - 1945(1778) + 77.64(1940) + 1054(1734) - 314.7(1445) + 1074(1680) + .2152$
DM	$179.3(2336) - 261.7(2180) + 725(1778) - 592.2(1734) - 65.78(1445) + 95.13$
ASH	$1035(2208) - 1111(2180) + 2618(1734) - 2416(1722) - 185(1445) + 48.01$
IVOMD	$2195(2230) - 2178(2180) + 4030(1818) - 353.3(1940) + 1427(1445) - 4887(1680) - 39.24$

¹IN EACH PAIR OF NUMBERS THE FIRST IS THE COEFFICIENT AND THE SECOND IS THE FILTER WAVELENGTH (NM).

²THE LAST NUMBER IN EACH EQUATION IS THE Y-INTERCEPT.

Table 22. Regression equations¹ used for the NIR prediction of Idaho fescue chemical constituent values.

NDF	$-1910(2270)^1 + 2962(2230) - 3960(2208) + 2596(2139) + 3442(1778) - 3047(1722) + 136^2$
ADF	$2341(2336) + 595.9(2348) - 2667(2310) + 389.1(2230) - 503.7(2100) - 321.7(1940) + 351.4(1445) - 6.59$
ADL	$487.3(2348) + 211.6(2230) - 789.7(2139) + 24.07(1982) - .3831$
CELL	$2555(2348) - 3478(2310) + 2505(1982) + 1082(2100) - 2107(1940) + 496.4(1445) - 829.5(1680) + 35.08$
HC	$-4149(2336) + 6162(2348) - 1991(2310) - 269.5(1445) + 64.76$
PRO	$160.6(2310) + 517(2190) - 517.2(1982) - 638.9(2100) + 440.7(1940) + 5.547$
DM	$742.6(2270) + 748.8(2190) - 2088(2139) + 282.6(1818) + 533.6(2100) + 52.54(1940) - 251.2(1734) + 79.16$
ASH	$347.8(1982) - 4999(1818) + 1370(1778) + 4013(1759) - 876.6(1734) - 8.11$
IVOMD	$0.0001(2208) - .0001(2180) + 824.2(1940) + 8933(1722) - 8350(1680) + 99.26$

¹IN EACH PAIR OF NUMBERS THE FIRST IS THE COEFFICIENT AND THE SECOND IS THE FILTER WAVELENGTH (NM).
²THE LAST NUMBER IN EACH EQUATION IS THE Y-INTERCEPT.

Table 23. Regression equations¹ used for the NIR prediction of bluebunch wheatgrass chemical constituent values.

NDF

$$2096(2310)^1 - 1030(2270) + 1776(2230) - 3613(2208) + 201.4^2$$

ADF

$$-1682(1734) + 1330(1680) + 145.4$$

ADL

$$-114.6(1734) - 43.95(1680) + 39.87$$

CELL

$$-904(1734) + 424.4(1445) + 137.5$$

HC

$$1628(2310) - 1668(2270) + 307.6(1445) - 788.3(1680) + 107.1$$

PRO

$$-94.71(1982) + 535.3(1778) - 23.64(2100) - 176.1(1445) - 35.62$$

DM

$$889.3(1722) - 1062(1680) + 121.9$$

ASH

$$-157.1(2230) + 580.1(1778) - 310.9(1680) - 3.886$$

IVOMD

$$-3090(2230) - .0001(1818) + .0001(1778) - 834.7(1445) + 472.6$$

¹In each pair of numbers the first is the coefficient and the second is the filter wavelength (nm).

²The last number in each equation is the y-intercept.

Table 24. NIR predicted rough fescue summer chemical constituent values and treatments.

<u>TREATMENT</u> ²	<u>CHEMICAL CONSTITUENTS</u> ¹								
	NDF %	ADF %	ADL %	CELL %	HC %	PRO %	DM %	ASH %	IVOMD %
10	66.3	45.1	3.3	32.6	27.2	5.7	96.6	10.7	48.4
10	65.7	45.3	3.3	33.9	24.7	5.3	96.6	10.8	48.7
10	67.2	44.8	3.0	34.8	22.7	6.3	96.1	10.8	42.1
10	66.6	45.0	3.2	31.8	23.0	6.9	96.1	11.8	41.8
10	67.5	44.8	2.8	34.9	22.2	6.0	96.1	10.9	42.1
10	70.6	47.2	3.6	37.9	21.8	5.7	96.2	10.3	44.9
10	65.9	46.4	3.6	30.5	27.0	7.1	96.1	11.7	45.1
10	69.0	47.0	3.9	32.7	26.9	6.0	96.0	9.9	48.1
10	69.9	45.4	3.5	34.4	24.9	6.3	96.1	10.0	45.8
10	69.1	47.1	3.1	36.7	22.3	6.2	96.1	11.7	44.6
11	67.3	44.2	4.3	33.3	22.8	6.6	96.1	10.3	42.5
11	68.7	46.9	4.1	36.2	18.2	7.5	96.4	13.1	40.7
11	67.4	45.4	4.2	34.6	20.9	6.3	96.5	11.4	42.2
11	70.5	47.0	4.3	37.6	21.5	6.1	96.8	11.9	45.7
11	65.4	45.0	3.1	34.7	21.0	9.1	95.7	12.3	31.9
11	65.1	45.6	2.7	35.4	20.9	7.8	96.0	12.7	35.6
11	67.1	45.2	3.3	33.9	23.4	6.8	96.4	11.8	42.6
11	69.5	44.4	3.7	34.9	23.0	6.8	96.5	10.3	43.5
11	66.4	44.6	3.0	33.3	24.8	6.0	96.2	10.5	44.9
11	65.5	43.8	2.9	31.6	28.3	6.6	96.0	10.1	44.2
11	64.9	45.1	2.4	34.9	22.5	6.7	96.1	12.2	37.6
11	62.4	43.6	2.3	33.3	20.6	8.3	95.7	12.6	32.4

¹ The chemical constituents are neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose (CELL), hemicellulose (HC), protein (PRO), dry matter (DM), ash (ASH), and invitro organic matter disappearance (IVOMD).

² The treatments are control (10) and burn (11).

³ Values are % of total sample weight on a dry matter basis.

Table 25. NIR predicted Idaho fescue summer chemical constituent values and treatments.

<u>TREATMENT</u> ²	<u>CHEMICAL CONSTITUENTS</u> ¹								
	NDF %	ADF %	ADL %	CELL %	HC %	PRO %	DM %	ASH %	IVOMD %
10	68.7	45.2	3.1	36.5	22.0	6.0	95.9	10.8	59.4
10	67.0	46.2	3.3	35.4	19.6	5.8	96.7	9.8	55.8
10	74.1	47.0	1.8	38.9	18.7	4.9	95.6	7.4	47.7
10	74.4	47.6	1.9	39.8	20.6	4.9	94.8	9.3	48.4
10	81.2	52.6	1.1	46.3	19.6	3.4	94.1	6.1	34.2
10	75.8	48.8	2.1	41.2	21.6	4.6	94.5	8.5	44.4
10	73.4	46.7	2.7	39.1	22.9	4.9	95.2	9.6	50.5
10	71.9	45.2	2.7	37.0	21.4	5.3	95.4	10.4	55.3
10	73.1	48.4	2.1	41.3	21.4	5.2	95.6	7.5	43.0
10	69.6	48.1	2.3	36.8	20.6	6.1	95.6	10.0	49.2
11	61.7	46.3	1.7	36.7	15.0	5.7	97.5	10.4	53.2
11	66.6	42.1	2.2	34.7	21.1	6.5	96.5	10.0	52.6
11	72.1	45.8	2.1	38.1	21.3	5.5	95.6	6.6	49.8
11	70.1	37.8	2.6	32.2	23.9	6.5	95.8	9.9	65.4
11	69.4	41.8	2.9	34.6	23.1	6.6	96.6	9.2	63.0
11	68.9	50.9	1.9	42.6	21.6	5.4	95.8	9.3	41.6
11	68.6	46.5	2.3	39.8	22.9	6.3	96.0	8.9	46.9

¹ The chemical constituents are neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose (CELL), hemicellulose (HC), protein (PRO), dry matter (DM), ash (ASH), and invitro organic matter disappearance (IVOMD).

² The treatments are control (10) and burn (11).

³ Values are % of total sample weight on a dry matter basis.

APPENDIX B

Frequency of Phenological Stages

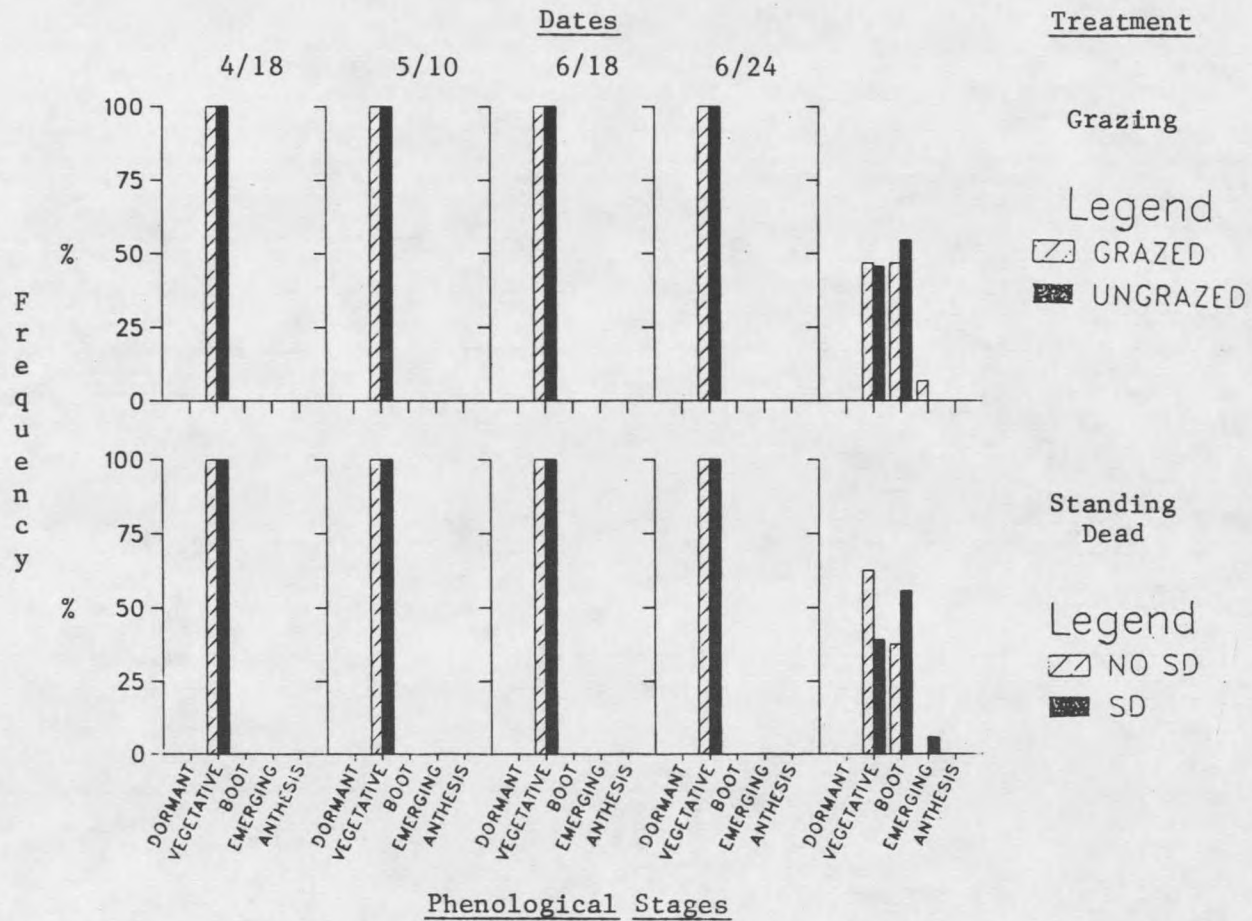


Figure 4. Frequency of Agsp phenological stages after two treatments on the JGI site, spring 1984.

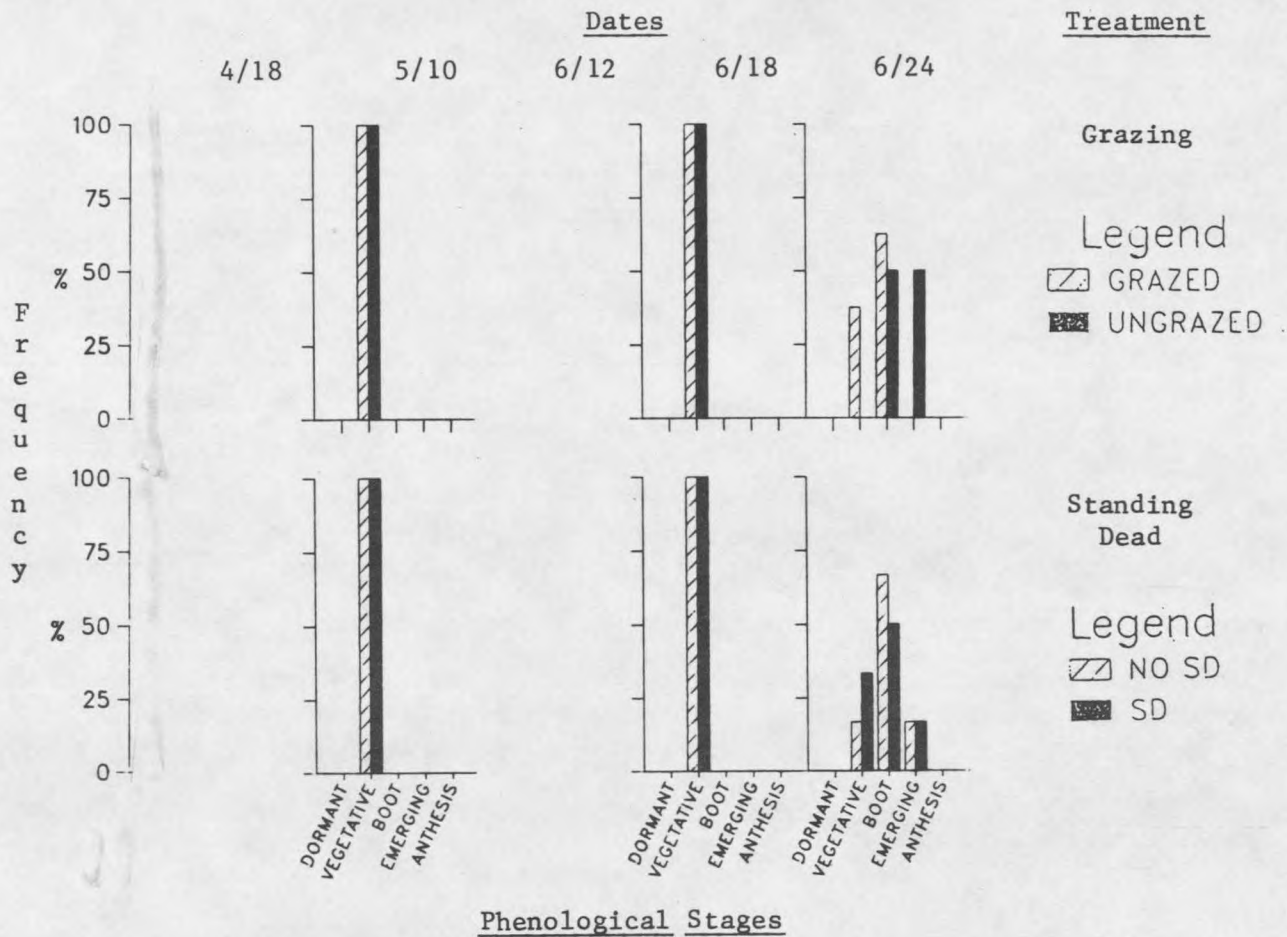


Figure 5. Frequency of Agsp phenological stages after two treatments on the JGII site, spring 1984.

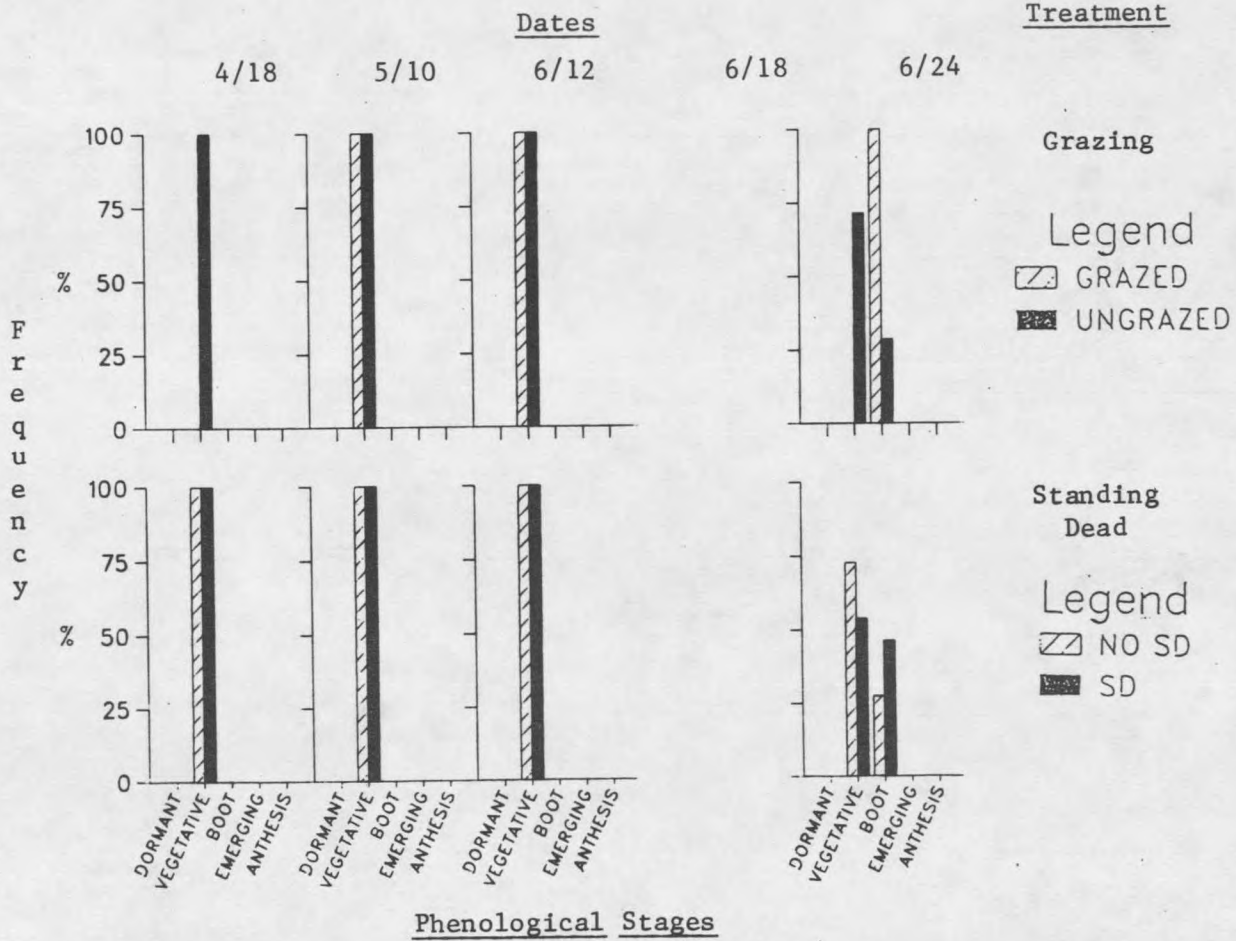


Figure 6. Frequency of Agsp phenological stages after two treatments on the ML site, spring 1984.

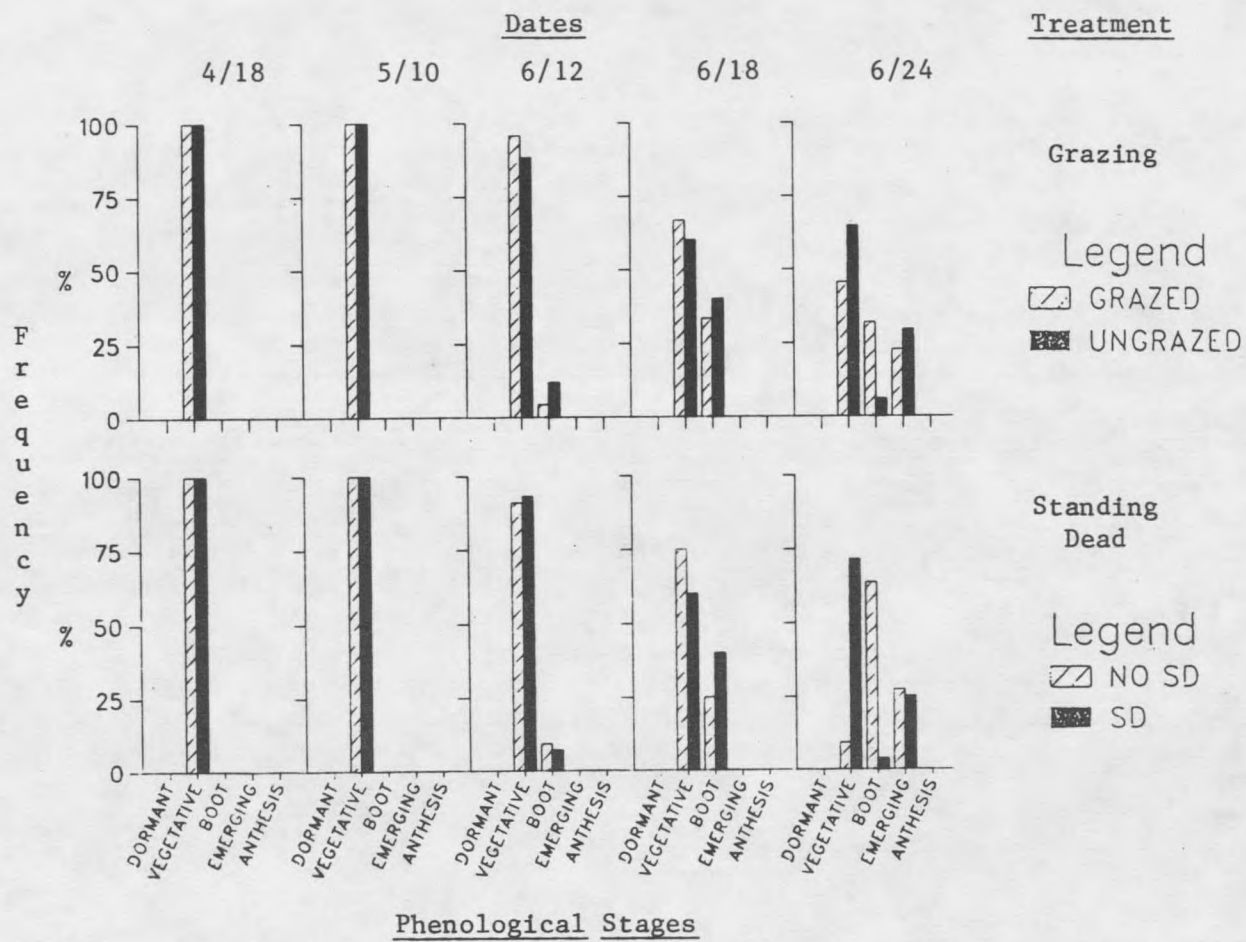


Figure 7. Frequency of Agsp phenological stages after two treatments on the SCI site, spring 1984.

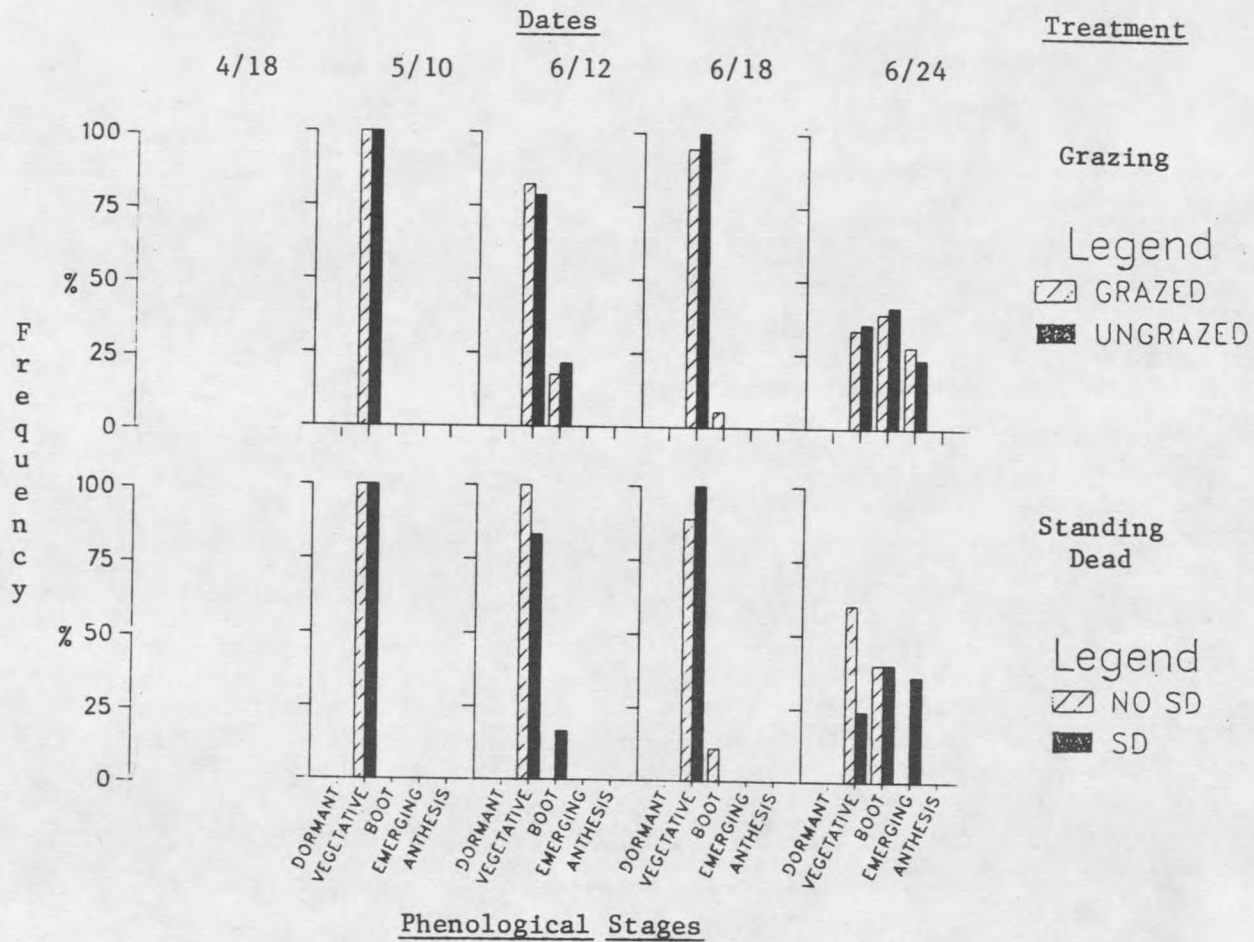


Figure 8. Frequency of Agsp phenological stages after two treatments on the SCII site, spring 1984.

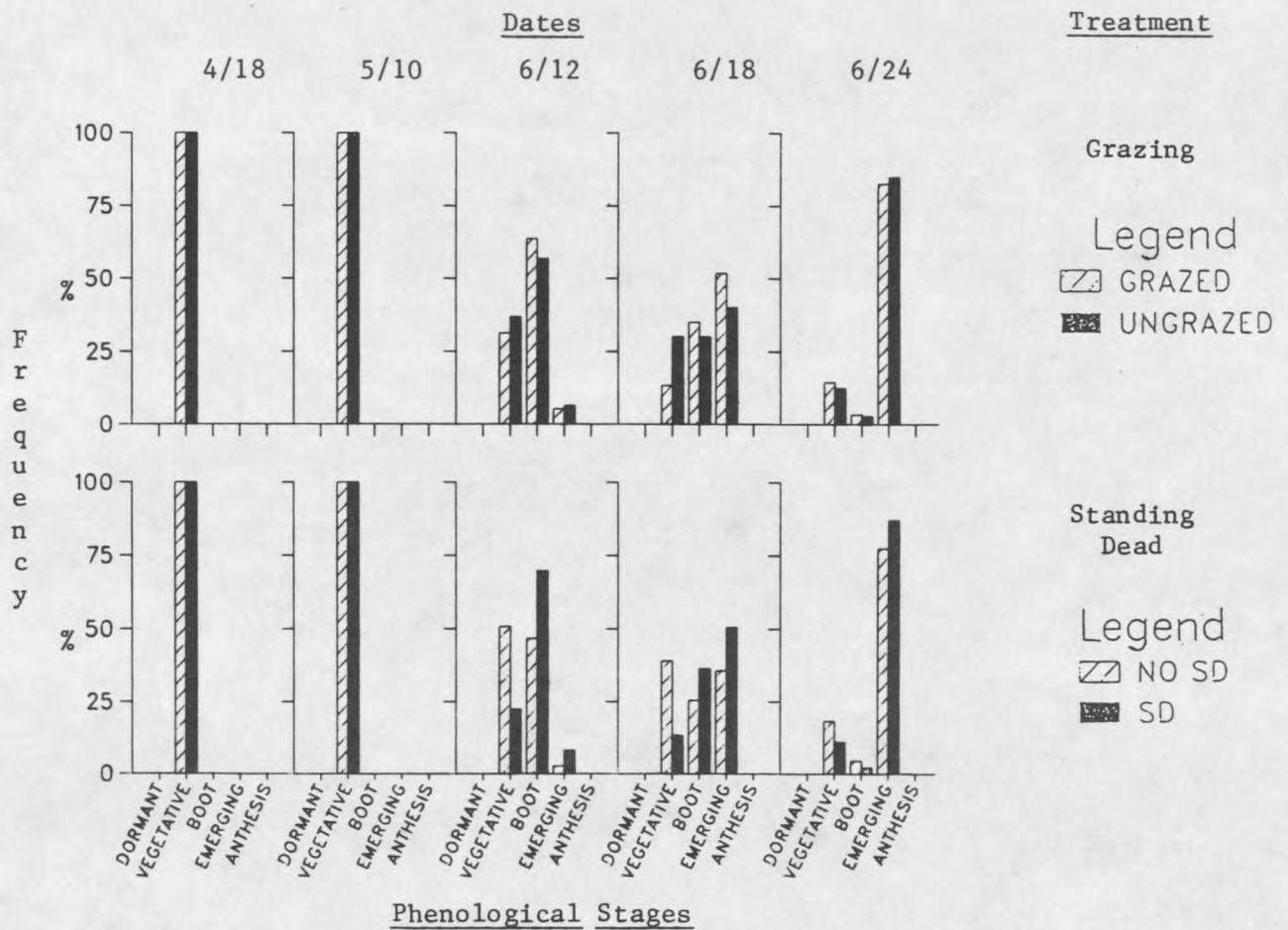


Figure 9. Frequency of Feid phenological stages after two treatments on the JGI site, spring 1984.

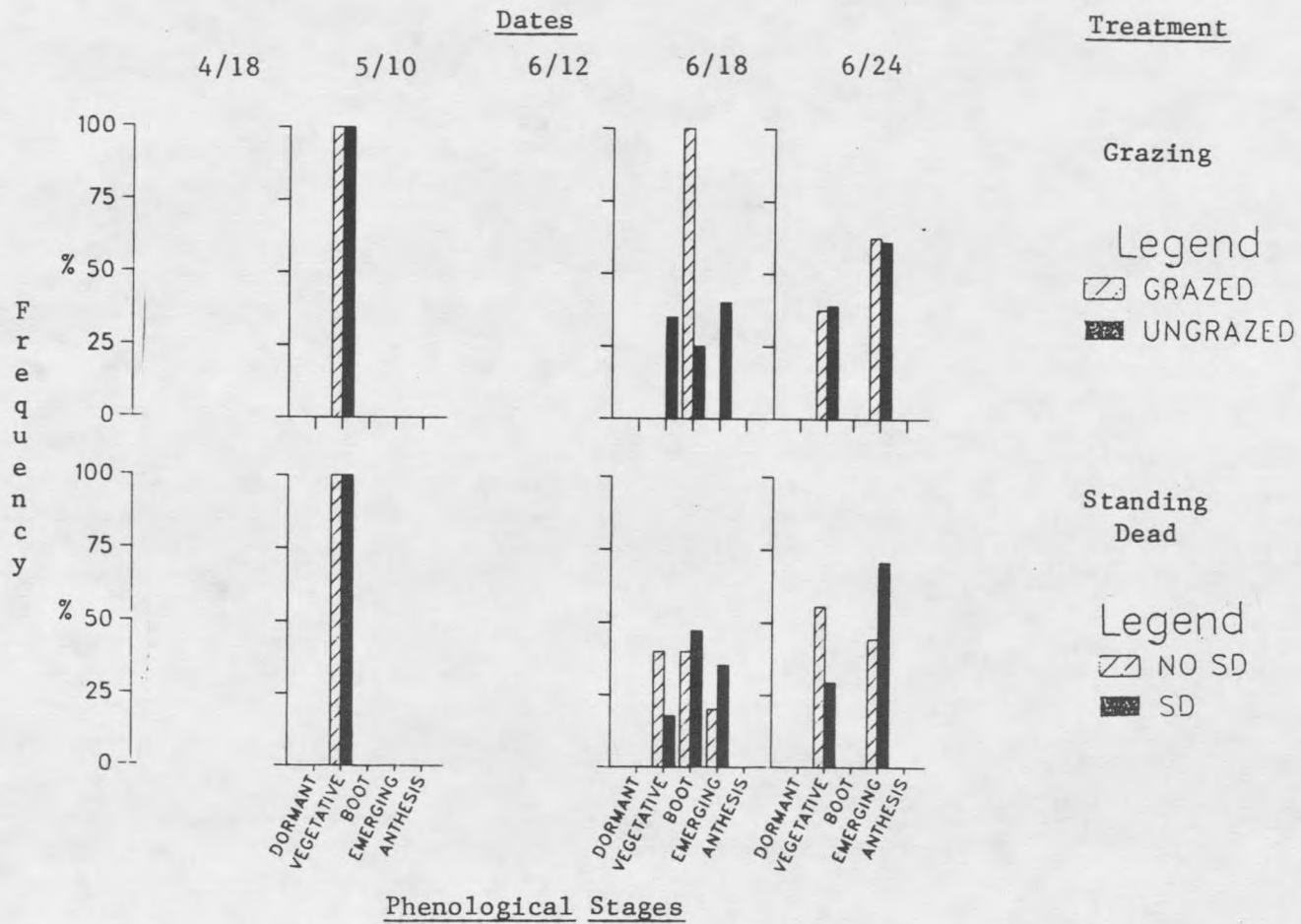


Figure 10. Frequency of Feid phenological stages after two treatments on the JGII site, spring 1984.

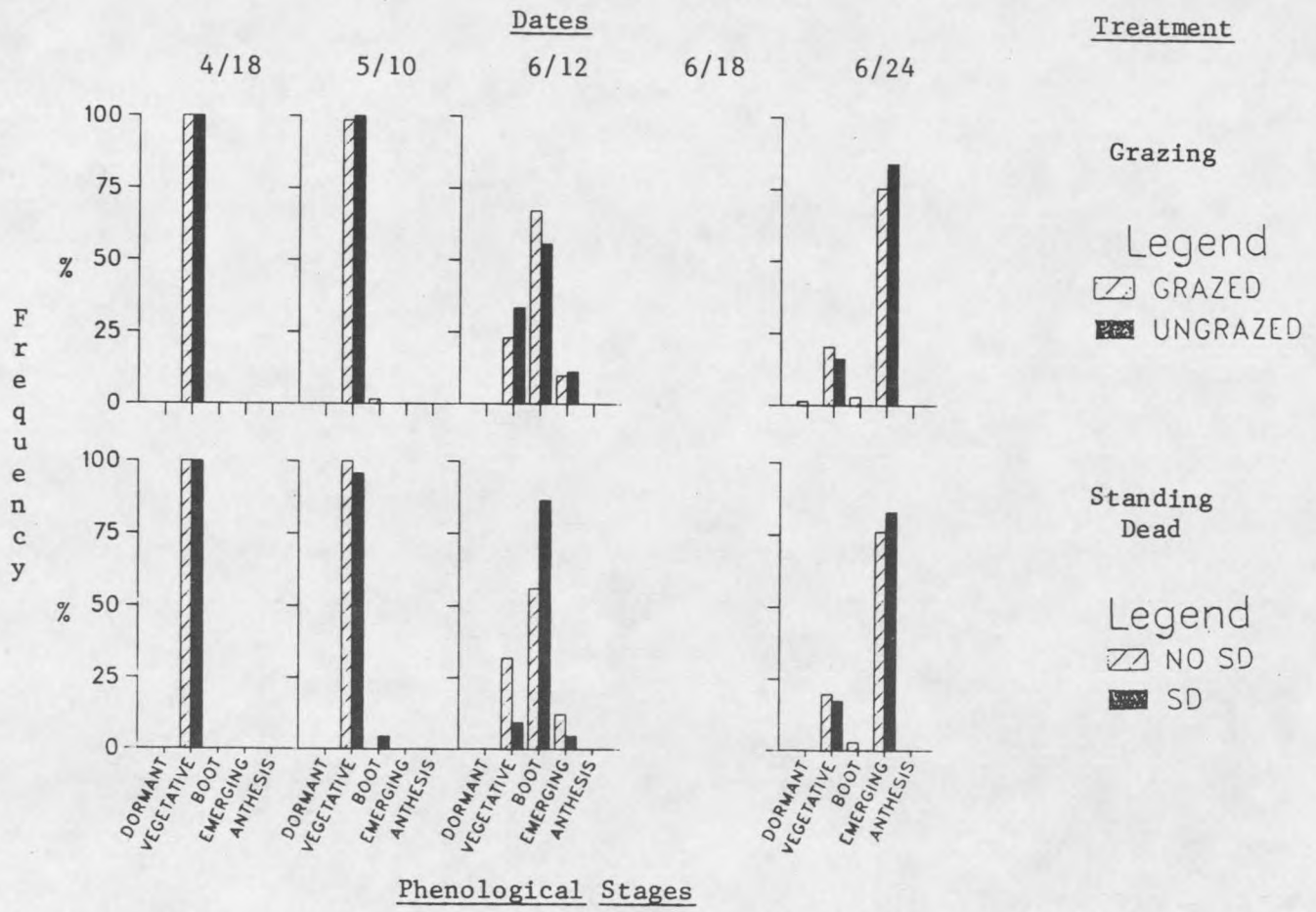


Figure 11. Frequency of Feid phenological stages after two treatments on the ML site, spring 1984.

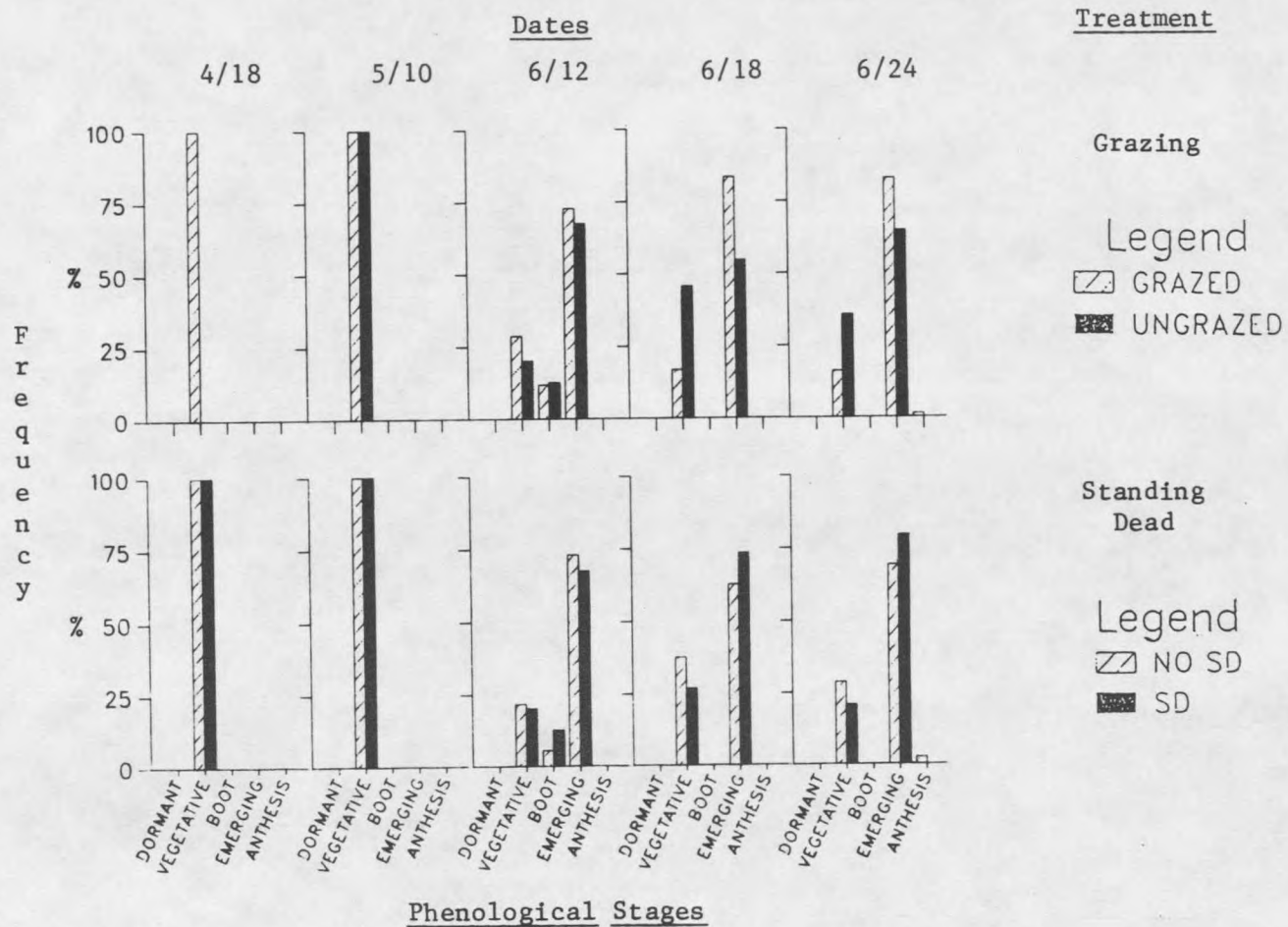


Figure 12. Frequency of Feid phenological stages after two treatments on the SCI site, spring 1984.

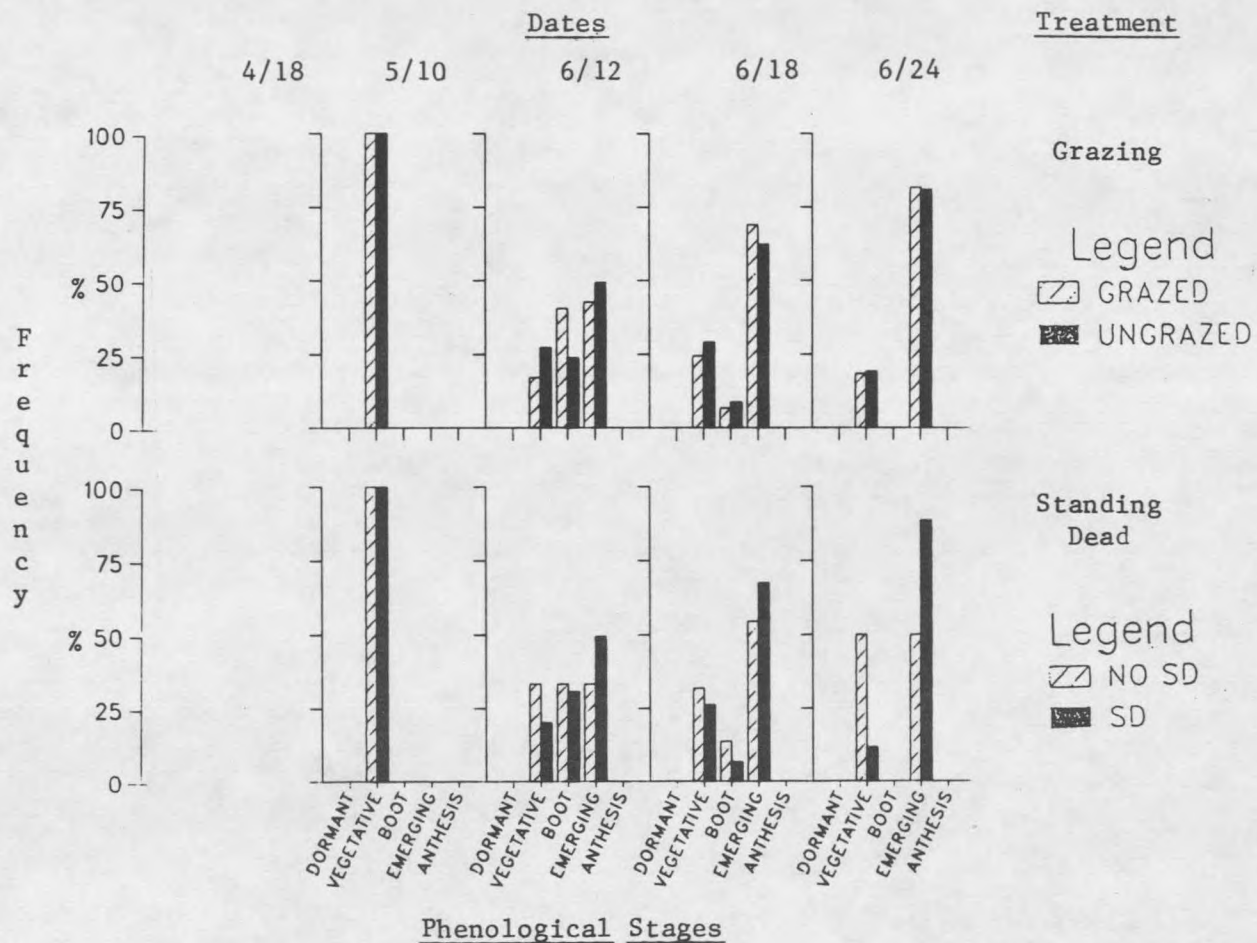


Figure 13. Frequency of Feid phenological stages after two treatments on the SCII site, spring 1984.

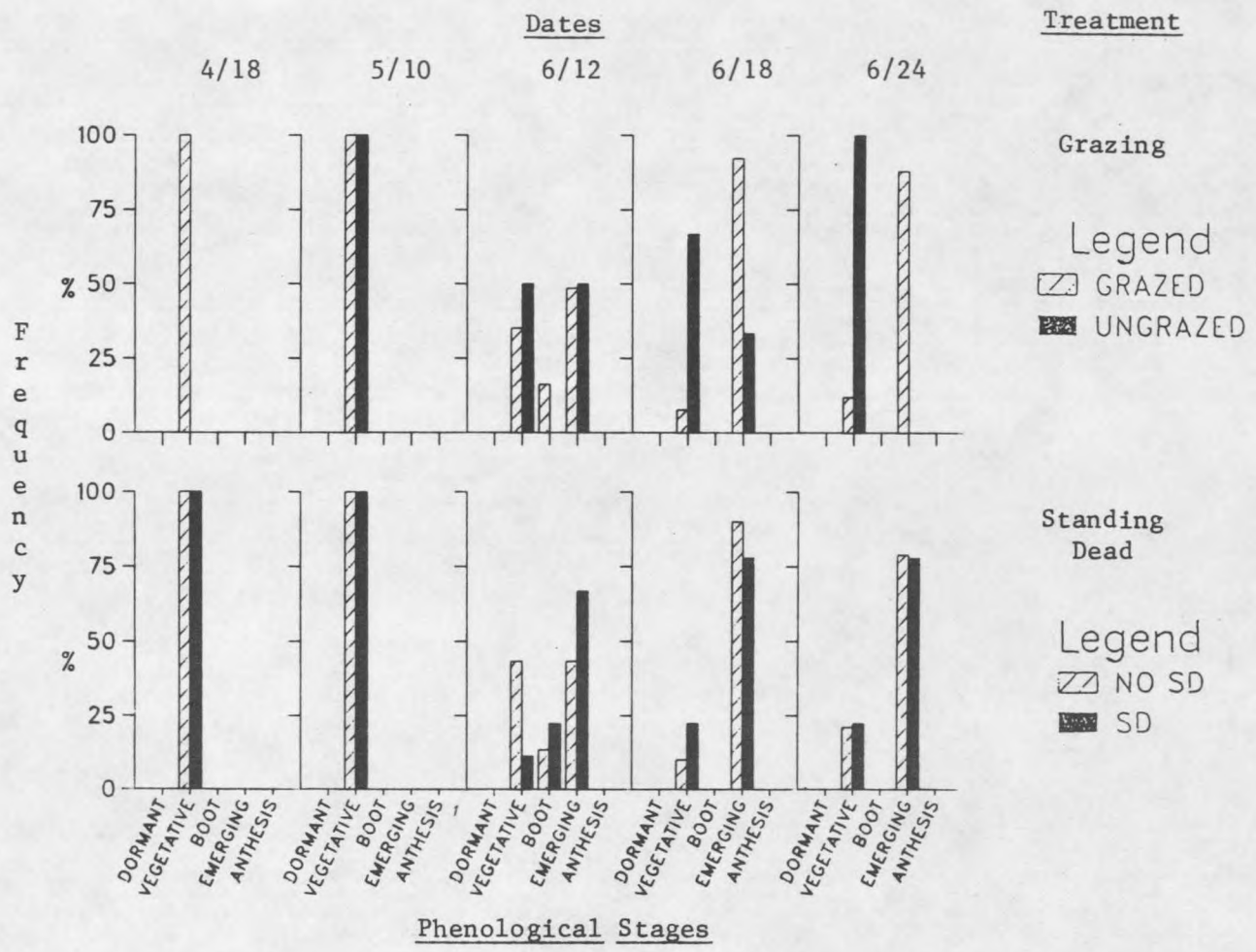


Figure 14. Frequency of Fesc phenological stages after two treatments on the JGI site, spring 1984.

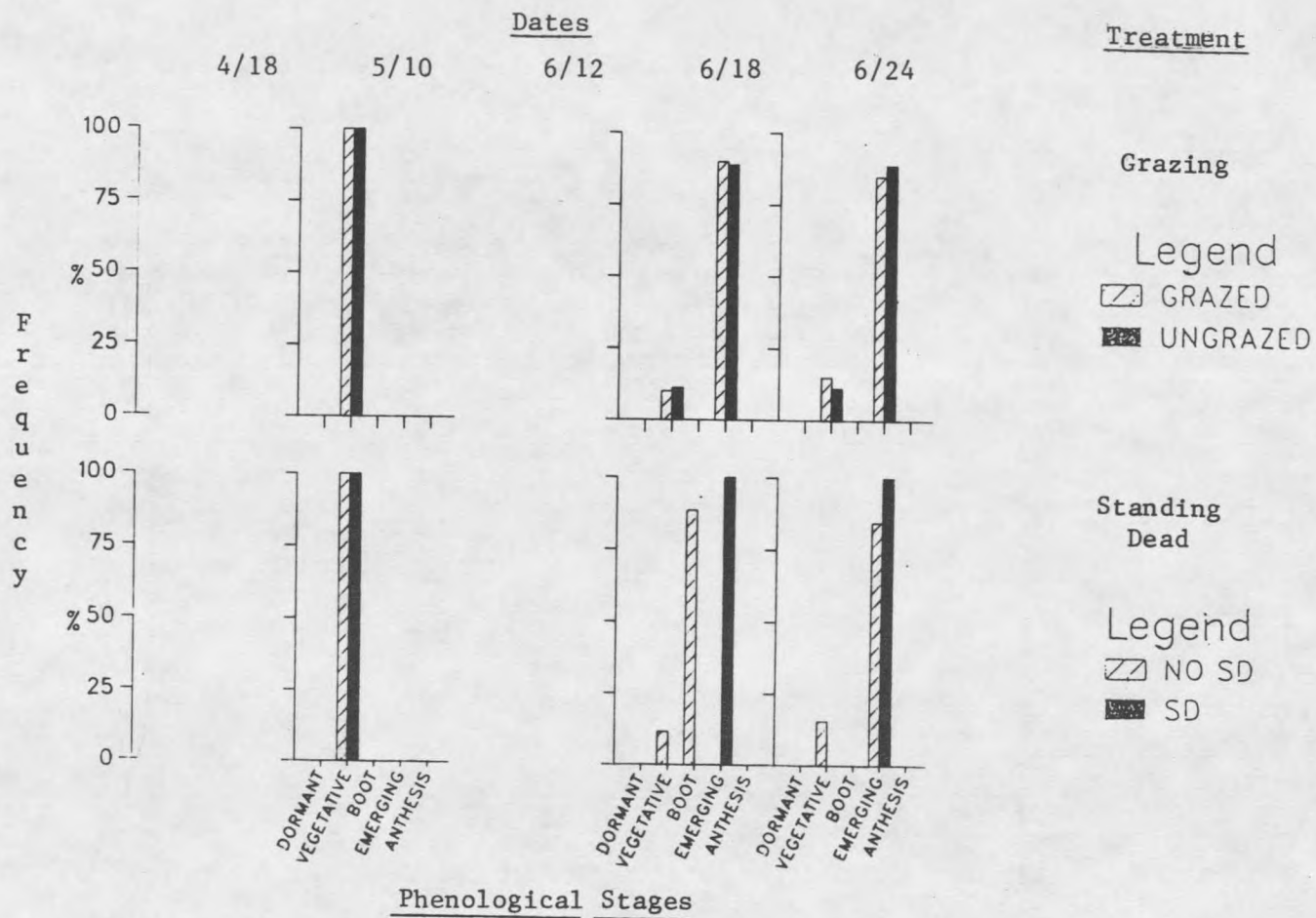


Figure 15. Frequency of Fesc phenological stages after two treatments on the JGII site, spring 1984.

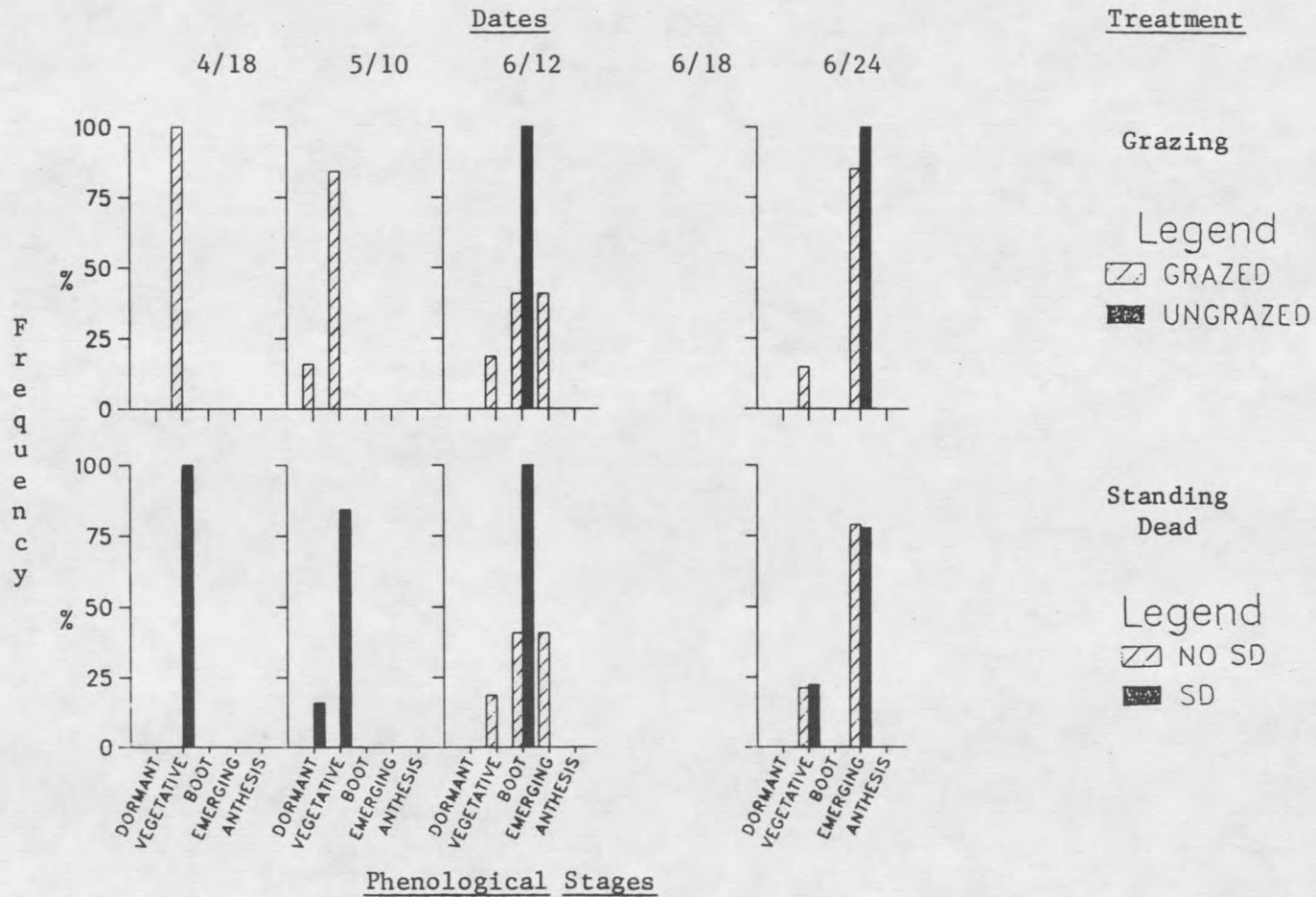


Figure 16. Frequency of Fesc phenological stages after two treatments on the ML site, spring 1984.

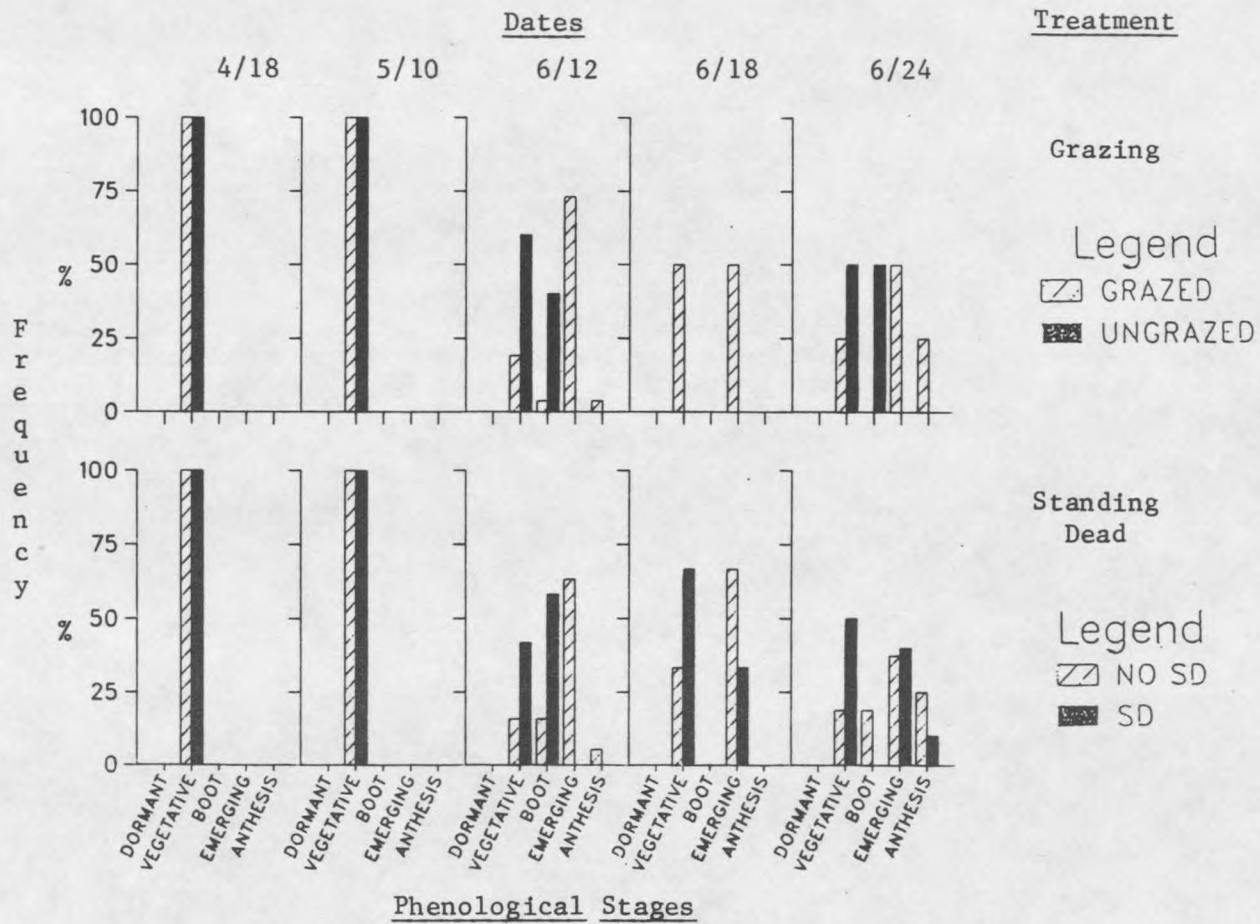


Figure 17. Frequency of Fesc phenological stages after two treatments on the SCI site, spring 1984.

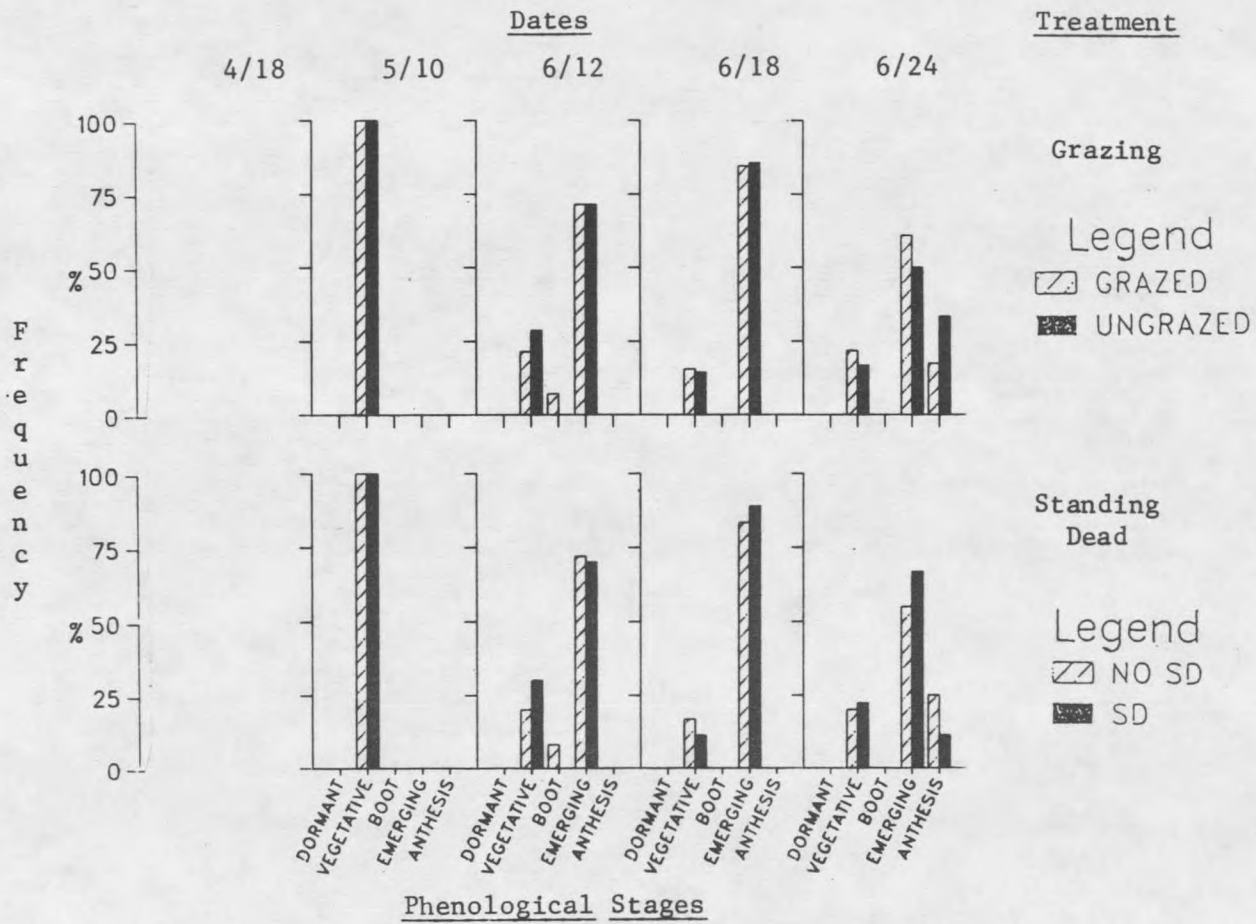


Figure 18. Frequency of Fesc phenological stages after two treatments on the SCII site, spring 1984.

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