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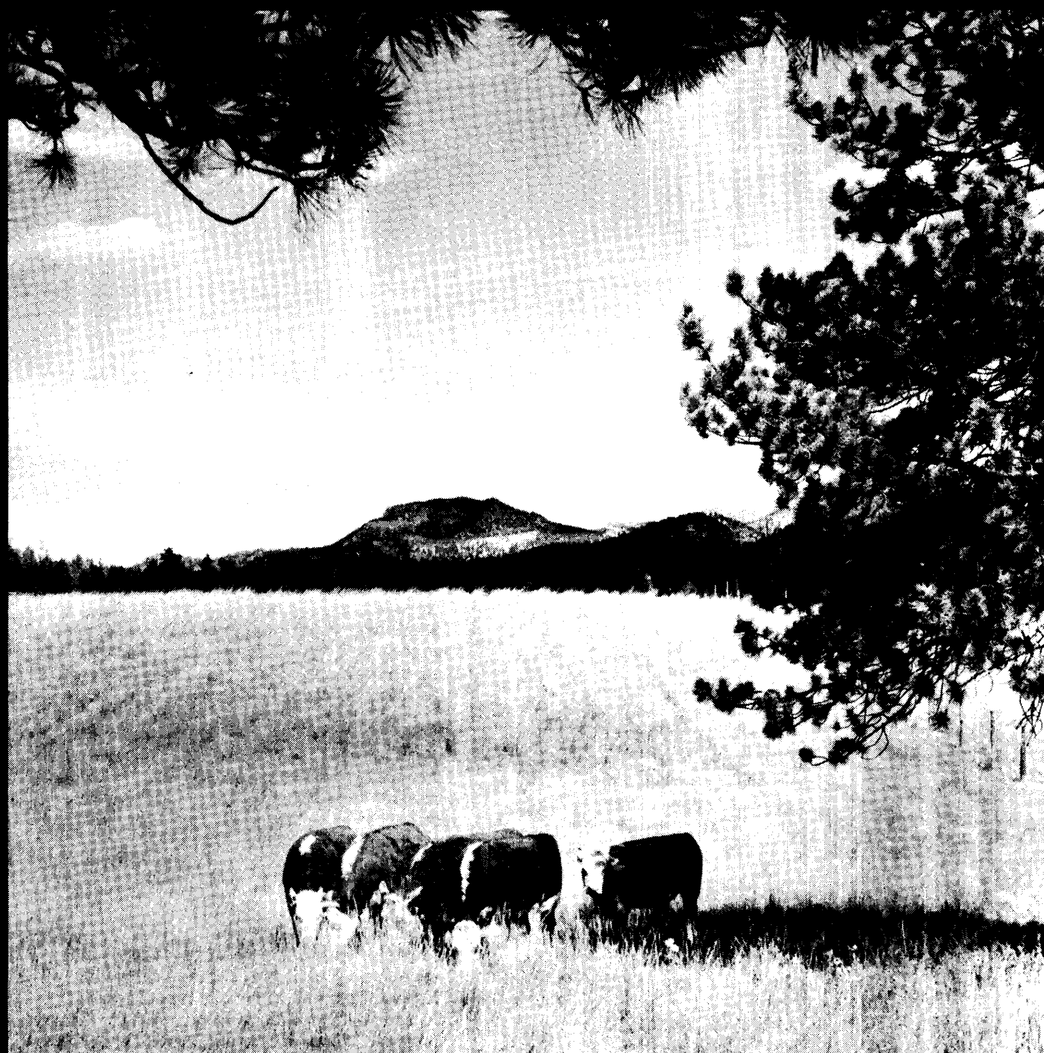

The Trail Boss

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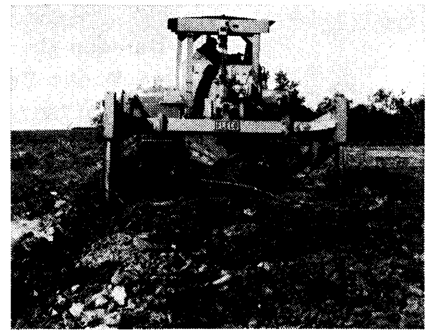

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CATERPILLAR

Journal of RANGE MANAGEMENT

Volume 22 Number 6
November, 1969

Cover Photo—Crested Wheatgrass Range at

Manitou Experimental Forest, Colorado.

See Article by Pat O. Currie, page 432.

Short Duration Grazing in Rhodesia[1]

SID GOODLOE[2]

Former Range Management Advisor, Near East Foundation.

Highlight

Remarkable results from a grazing management system were seen in three visits to Rhodesia between 1964 and 1969. The system, Short Duration Grazing, depends on intensive use for two weeks or less with varying rest periods. There are significant indications that the short duration—high intensity grazing period is just as important to range improvement as the rest period. Production records are essential to the success of the system.

In a recent JOURNAL OF RANGE MANAGEMENT I noticed a plea for a greater exchange of ideas. This article briefly tells the history and principles of a fresh approach to grassland use being tried in Rhodesia. I hope it will stimulate in research scientist and rancher alike, a renewal of interest in seeking a real breakthrough in range management. A success story is always a pleasure to tell, and I consider it a privilege to be able to record the work done by a group of clear thinking and dedicated range men.

It was my good fortune to see a good portion of Rhodesian rangeland in 1964 and I was aware that something was wrong somewhere. Much of the rangeland in Rhodesia had begun a headlong dive toward irreparable deterioration. Palatable species such as *Panicum* spp., *Eurochelea* spp., and *Brachiaria* spp. were being replaced by *Heteropogon* spp. and *Hyparrhenia* spp. resulting in a drastic drop in usable forage production. Like everyone else I assumed that many of the areas were overstocked and that destocking and brush control should be the first moves toward range restoration.

I returned in 1967, a drought year, to discover a few ranches showing a marked improvement in range cover and condition. It was then that I learned of the aggressive step taken toward range reclamation called "Short Duration Grazing."

The basic facts for the development of Short Duration Grazing (SDG) had been there all along—in research publications and journals—but it took men that think originally and independently to marry them to a system that would work on the ground.

Expanding on work done by Andri Voisin of France, Mr. John Acocks and Mr. and Mrs. L. N. Howell of Hillside Farm, Springfontein, South Africa, put into practice what was then called "Non Selective Grazing." Although the system did not eliminate selective grazing, the term was applicable because it reduced selective grazing and thus increased the efficiency of utilization of the pastures. The semiarid grazing land on Hillside Farm responded in a way few stockmen thought possible. Not only was pasture reclamation achieved, but an increase in carrying capacity was obvious from the beginning.

To a young Rhodesian ecologist, Mr. Allan Savory of Bulawayo, the basic principles of the new Acocks-Howell grazing system were ecologically sound. He went to see for himself and returned to Rhodesia convinced that finally a breakthrough had been made. He began immediately with boundless enthusiasm and determination to fit this system, renamed "Short Duration Grazing," to the requirements of his own country.

The skeptics thought it was too expensive, and since it contrasted with the officially recommended slow rotation systems, cold water was poured on the idea. In spite of this significant opposition, Mr. Savory persisted and began to share his ideas with ranchers at local field days.

These ideas made sense to many who heard him, and soon the system was being tried in most parts of the country. I found those pioneers who tried it first, to be extremely open-minded people desperately searching for a solution to the problem of continued pasture deterioration. Only this type of rancher could accept such a radical change.

I made another visit to Rhodesia in early 1969. Progress made by these practical ranchers revealed the importance of economics as a prerequisite to the acceptance of any grazing management system. I saw ranches where existing fences had been stripped of one or two wires and those wires strung from tree to tree to divide pastures until the increased carrying capacity brought in enough money to build permanent fences.

Mr. D. Parkin, a rancher from Bulawayo, stated that he had more than doubled the carrying capacity of his ranch since starting the system in September of 1966. During this period annual rainfall was average or below.

Short Duration Grazing soon became the chief topic of conversation when ranchers got together.

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[1] Manuscript received April 24, 1969; accepted for publication May 29, 1969. The author gratefully acknowledges and expresses appreciation for the courtesy and help given by Mr. Allan Savory, Parliament, Salisbury; Mr. A. R. Mountain, Mayorca Ranch, Que Que; Mr. Robert Vaughn-Evans, Conservation and Extension Service, Que Que; Mr. D. Parkin, Rancher, Bulawayo; Mr. Pop Massen, Glendye Ranch, Que Que; and Mr. B. Rinsford, Rancher, Selukwe, Rhodesia.

[2] Present address is Mountain Top Angus Ranch, Capitan, New Mexico.

As results became apparent, "the penny dropped" for others, and a clamor went up for guidance from the Conservation and Extension Service.

Officially no recognition was forthcoming because of the lack of carefully planned research. The ranchers argued that results were plainly visible and that they couldn't wait for years of research.

After months of discussion, trips by Members of Parliament, research officers and Conservation and Extension Service (CONEX) personnel, SDG has been recognized as a practical, economic method of improving range production. In early 1969 Mr. Savory was employed by the Ministry of Agriculture to train CONEX officers in the application of the SDG system.

As a further vote of confidence, one of the largest ranches in Rhodesia, Charter Estate, has offered full facilities for large scale field trials (Charter Field Trials). The Rhodesian Cattlemen's Association donated $3,360 to ensure that the project began as scheduled March 1, 1969. Comparisons will be between (1) the old three herd, four pasture system, (2) SDG with limited capital, and (3) SDG with adequate capital for immediate water development and fencing.

Mr. Savory stresses that this system must remain highly flexible and no two ranches will follow the same course of development. The underlying principle of "short graze-sufficient rest" remains the same regardless of conditions. This holds true for ranches in the Rhodesian low veld where a scant 10 inches of rainfall is the average, as well as in the Eastern Highlands where over 100 inches is recorded. Altitude varies from 2000 feet to 6000 feet on ranches of from 1500 acres to 750,000 acres.

The ranches I visited had started the system with a maximum grazing period of two weeks and minimum rest period of eight weeks, depending on climatic conditions. I noticed that as further pasture division and water development became possible, there was a tendency to shorten the grazing period.

Some difference of opinion was noted as to the benefits of continuing the two week grazing periods right through the seven to eight month dry season. Some ranchers wanted to let their cattle "relax" during this period but others were adamant in continuing the system the year round. They claim that dry season SDG breaks the parasite cycle, puts the standing dry grass (top hamper) down to litter, eliminates trails to and from water and *chips* the soil surface for better seed germination.

"Details of the system keep changing because we are still learning," says Mr. Savory. Our discussion revealed that the following major points are always kept in mind:

FIG. 1. "Laying the litter" by short duration—high intensity grazing in Rhodesia.

(1) In planning for the use of SDG on any ranch the first consideration is the economics of additional fencing and water development. So far it has proved to be a reclamation system that is able to generate capital and support itself.

(2) Short Duration Grazing is based on a short period of grazing with varying periods of rest. There are significant indications that the short duration-high intensity grazing period is just as important to range improvement as the rest period. The grazing prepares a seed bed by converting the top hamper to litter (Fig. 1) and chipping, but not compacting the soil surface. The following rest period allows seedlings to become established and existing plants to rebuild root reserves. The old emphasis on seed production as the climax of a rest period has been scaled down somewhat in favor of seed bed preparation.

(3) As a ranch starts to increase the complexity of its system, the emphasis begins to be shortening the grazing period rather than lengthing the rest. The rule of thumb is to put the heaviest possible density of stock on the land for the shortest possible time without significant damage to stock condition. The key phrase is "time on the land."

(4) In areas where brush control was normally considered the first move, the method now is to wait until pasture production in unit days per acre ceases to increase, then go into the pasture and find out why. If brush control is needed, then the economics of such a program should be considered.

(5) A compromise must be reached between: (A) What the rancher requires to start the system and what he can afford, and (B) the degree of stock concentration and its effect on stock condition. A slight loss in stock condition is expected compared with continuous selective grazing, but range condition and animal production per acre improve markedly.

FIG. 2. Records of pasture use and production are kept up to date on a blackboard on Mr. B. Rinsford's ranch near Selukwe, Rhodesia.

The judgment and managerial ability of the rancher are of utmost importance in deciding on the movement of animals, the grazing intensity and the need for changes in the general pattern of rotation (Fig. 2). Strict adherence to the fundamentals is necessary.

When starting the system with a given number of pastures and herds, the length of the rest period may be determined in this manner:

$$\text{Number of pastures} - \text{number of herds} \times \text{period of stay} = \text{rest period}$$

$$\text{i.e. } 12 - 2 \times 14 = 140 \text{ days rest}$$

When starting the system using a given rest period, the number of pastures needed may be detemined by using this formula:

$$\frac{\text{Rest period}}{\text{Period of stay}} + \text{number of herds} = \text{number of pastures}$$

$$\text{i.e. } \frac{90}{10} + 2 = 11 \text{ Pastures}$$

An important requirement of the move toward more intensive management of both livestock and grassland is accurate records of actual use. It was very clear to me that ranchers who were not interested in keeping accurate records weren't ready for SDG. Both animal units of use and a simple grading of grass use are recorded in a "Range Register" (Fig. 3).

RANGE REGISTER

PADDOCK (Name or Number): 8 ACREAGE: 100

SOIL TYPE/S: SANDY LOAM – BLACK COTTON PATCHES

DATE IN	DATE OUT	G.P.	NO. AN. UNITS	A	Y	W	C	S	UDA & GRADE	REMARKS SPECIAL TREATMENT; FIRE; PROTEIN SUPPLEMENTED; RANGE CHECKS; STOCK EFFECTS, Etc.
12/2/68	12/15/68	14	360	300			241		50•4/2	LITTER DOWN – GOOD MOISTURE 1/10/69
3/15/69	3/28/69	14	266		380				37•2/1	READ TRANSECT #6 3/13/69
			BULL = 1·25 A.U.	A = 1·0 A.U. (1000# COW)	Y = 0·7 A.U.	W = 0·5 A.U.	C = 0·25 A.U.	5 SHEEP = 1 A.U.		

FIG. 3. A page from the RANGE REGISTER used to keep a running account of pasture performance and conditions.

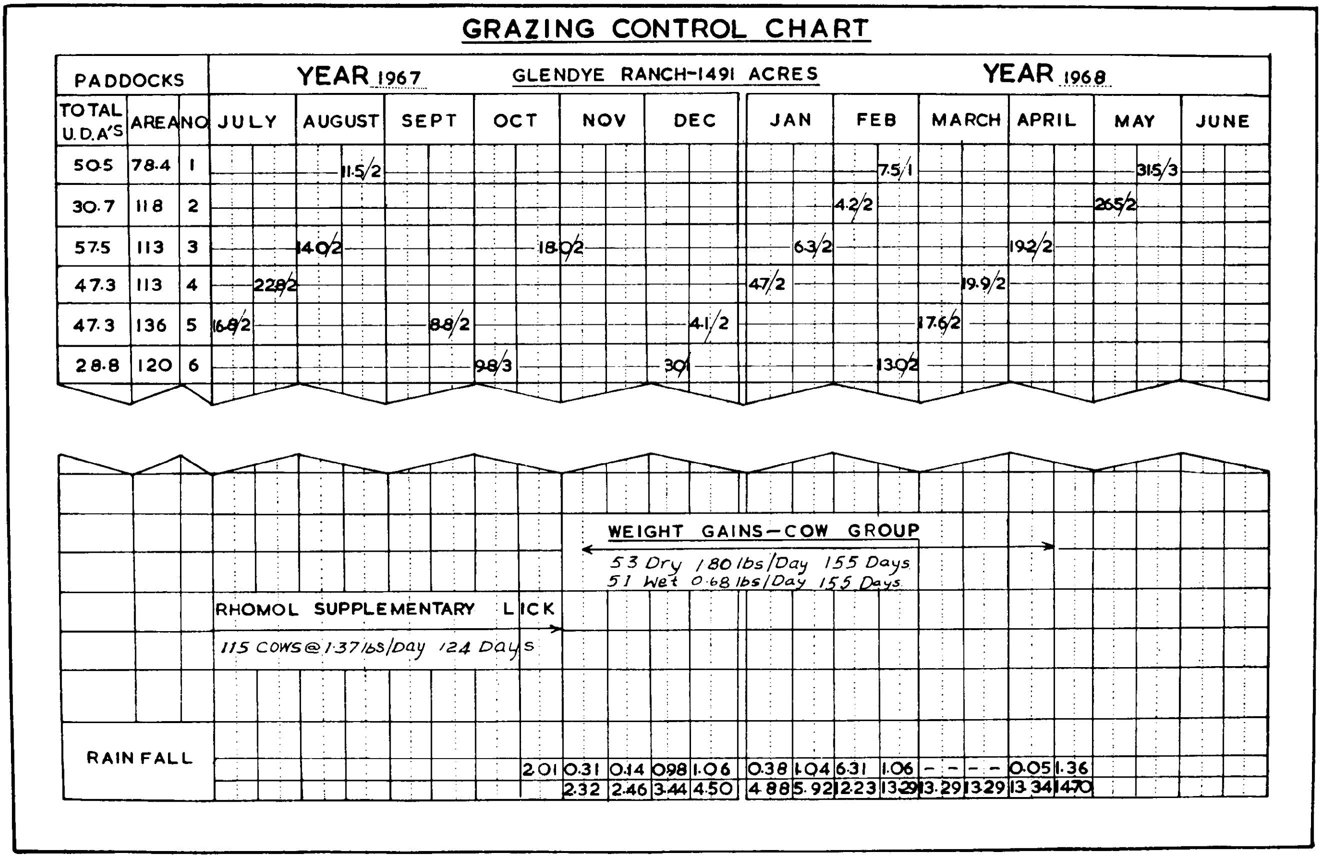

FIG. 4. The Grazing Control Chart as used by Glendye Ranch, Que Que, Rhodesia. Planning for future use of pastures is done in pencil, then production (in UDA's) is recorded in ink after stock is moved.

$$\text{(A)}\ \frac{\text{Animal units} \times \text{days in pasture}}{\text{Acres in pasture}} = \text{Animal unit days per acre}$$

$$\text{i.e.}\ \frac{300\ \text{AU} \times 14\ \text{days}}{200} = 21\ \text{UDA's}$$

(B) Grass Use Record

A grade is given to the pasture at the end of the grazing period to indicate the amount of grass remaining.

1. Abundant grass left (over ¼)
2. Some grass left (about ¼)
3. No grass left (less than ¼)

When written in the Range Register it might read "Pasture No. 9, 21 UDA's/3, Dec. 15 to 31." This would indicate that no further use could be made of pasture No. 9 until the growing season had begun and ample time was given to the grasses to produce forage and resupply the root system. Consideration should be also given to the possibility of reducing the number of stock for the next time the pasture is used.

Should the Range Register read 21 UDA's/1 for pasture No. 9, the manager would be able to (1) graze additional UDA's after sufficient rest even though no more growth had occurred, or (2) increase the number of animal units for the next grazing period after completion of the growth cycle. Above all, the grazing period should not be longer than two weeks. A yearly record of UDA's is kept for each pasture and when plotted on a graph indicates the rise or fall in its forage yield.

The "Grazing Control Chart" (Fig. 4) is used to record the following:

1. Pasture use planning
2. Animal use and grass use
3. Rainfall
4. Herd deployment
5. Supplemental feeding periods
6. Livestock performance records

Summary

The short graze-long rest approach to range management is not entirely new nor has the Rhodesian system had time to prove itself absolutely reliable. However, the enthusiastic welcome it has received from Rhodesian ranchers coupled with official recognition and commencement of large scale field trials are indicators of a worthwhile development in the field of range management.

The SDG system demands that the rancher stay on top of everything that happens on his place—from reading grass species transects to projecting the grazing control chart. This in itself is a significant contribution to more efficient management.

Another significant outcome of the SDG system that will prove invaluable to custodians of range land the world over, is the beginning of pasture production record keeping on a large scale. Working hand in hand with livestock performance records, this finally gives the stockman a way to accurately measure his total off take.

I, for one, will be watching the Charter Field Trials with interest, and wondering where parts of the SDG system might fit our approach to range management in North America.

Fall and Winter Burning of South Texas Brush Ranges[1]

THADIS W. BOX AND RICHARD S. WHITE[2]

Professor of Range Management and Research Assistant, Texas Tech University, Lubbock, Texas

Highlight

Plots with no pretreatment and pretreated by shredding, chopping, scalping, root plowing, and root plowing and raking were subjected to a fall fire, a winter fire, and a fall fire with a winter reburn the following year. All burning treatments reduced brush cover when compared to the unburned control. Burns on pretreated areas were more effective in reducing brush than were fires in vegetation with no pretreatment. Two burns were more effective in reducing brush than was a single fire. Standing crops of herbage on all burned plots were greater than on the control. Fall burned plots had the largest amounts of grass; winter burned areas contained the most forbs.

Control of woody plants is a major problem associated with the management of Texas rangelands. In spite of active brush control practices throughout the state, the extent and density of woody weeds has increased to over 88 million acres (Smith and Rechenthin, 1964). In the South Texas area alone, over 9,600,000 acres were treated to reduce brush density in the decade prior to 1958 (Carter, 1968). Most of these same ranges were treated again in the last 10 years, or need some control of brush at the present time.

Regardless of the method used to control the brush, new woody plants become established soon after the original ones have been destroyed. In most cases, the botanical composition of the brush complex may be altered, but regrowth is so rapid that most ranges need retreatment in 5 to 15 years after the original control program. Control of brush reinvasion following original treatment should be considered a maintenance item in the budget of most Texas ranchers.

An effective and inexpensive method of brush control is needed. Periodic mowing and fertilization of ranges may retard brush encroachment (Powell and Box, 1967), but may be expensive or impractical in some areas.

The cessation of grass fires has been suggested as a major cause of brush increase in South Texas (Allred and Mitchell, 1955; Lehmann, 1965). Conclusions reached by these authors were based primarily on historical reports. All the early writings suggest a positive relationship between the decrease of fires and the increase of brush.

Results from a planned burn by Box, Powell and Drawe (1967) show that fire will decrease brush density and cover without seriously harming grass production. This paper examines the effectiveness of single fires in fall and winter and two fires in consecutive years as tools for maintaining brush free ranges following mechanical control.

The study was conducted on the Rob and Bessie Welder Wildlife Refuge, San Patricio County, Texas. The refuge is located near the southern end of the Texas Gulf Prairies and Marshes described by Thomas (1962) and represents a transitional area between the Gulf Prairies and the South Texas Plains. The soil type on the study area is Victoria clay, and vegetation is a typical chaparral-bristlegrass community (Box and Chamrad, 1966). The study area normally receives about 30 inches of precipitation annually. Temperatures are relatively warm throughout the year, and plant production generally follows rainfall curves.

Methods and Materials

During the summer of 1963, two replications of six mechanical brush control treatments were established in randomized blocks on chaparral communities. Two 20 acre replications of each of the following treatments were used: 1) control with no brush treatment, 2) shredding with a rotary mower, 3) roller chopping, 4) scalping with a K-G blade, 5) root plowing, and 6) root plowing and raking.

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[1] This paper is contribution number 125 Welder Wildlife Foundation and contribution number 60 International Center for Arid and Semi-Arid Land Studies. Received December 23, 1968; accepted for publication March 22, 1969.

[2] Present address is Department of Range Science, Utah State University, Logan, Utah.

In September, 1965 strips 150 × 220 yds were burned on each 20 acre plot. In December, 1966 additional 75 × 220 yd strips were burned on each plot and half the strip burned in 1965 was reburned. The result was three 75 × 150 yd strips on each plot, one fall burned, one winter burned, and one burned two years in succession.

Vegetation was sampled on each strip the summer before the winter burn, August 1966, and again in August 1967. Data were analyzed as a splitplot, randomized block design. Canopy cover of brush species on each strip was sampled using 15 line intercepts, each 100 ft long. Weight of herbage was estimated on 40 plots, each 2.4 ft^2, on each strip.

Results

All plots pretreated in 1963 by mechanical brush control practices burned uniformly. Although there was considerable regrowth of brush species present, grass and other herbaceous material grew in sufficient densities under the brush plants to allow the fire to carry through the brush mottes and under the individual brush plants. Canopy cover was reduced sufficiently to make almost all forage available to livestock. Areas that had not been pretreated by mechanical brush control burned unevenly and resulted in a patchy appearance. Grassy areas between brush clumps burned clean, but insufficient fuel was present within the large brush mottes to allow the fire to burn through them.

Reduction in Brush Canopy

Brush canopy in the summer of 1967 was significantly lower on all burned areas compared to the unburned control (Fig. 1). Burning reduced brush canopy cover an average of 24% on areas that had not been pretreated by mechanical control. There was no statistical difference at the .05 level between the percent reduction following fall, winter, or two successive fires in the area without pretreatment. The uneven pattern of burning was not improved by successive burns. The large mottes probably could withstand repeated fires due to the lack of fuel to carry a fire through them.

Reduction in brush canopy was significantly greater on all pretreated plots than on the untreated control plots. The fall burn reduced brush canopy an average of 55% on all pretreated plots; the winter burn resulted in a 57% reduction; and burning in two successive years gave 71% less brush canopy. With the exception of the root plowed and raked plot, where insufficient fuel resulted in a poor fall burn, there was no difference between the percent reduction following fall and winter burning. Two successive burns resulted in a further significant loss of brush canopy in all instances.

Although there was no statistical difference in the amount of brush canopy cover on fall and winter burned plots in the summer of 1967, the fall fire appeared to damage the brush plants more severely than the winter fire. The fall burned plot was sampled after a full year of regrowth. Box et al.

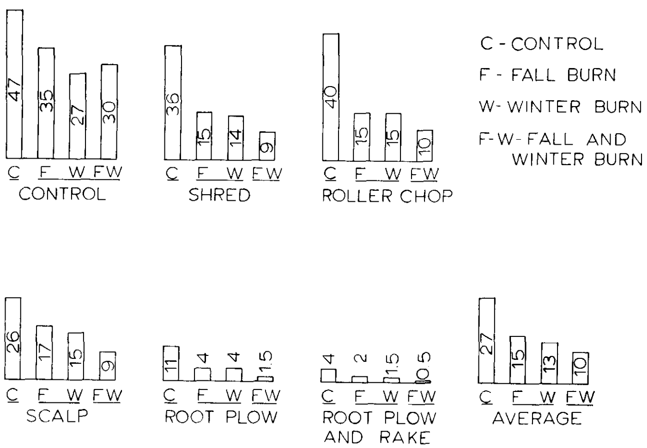

FIG. 1. Canopy cover (%) on pretreated areas of the Welder Wildlife Refuge following prescribed burning treatments. Treatments connected by a solid line are not significantly different from each other at the 0.05 level.

Table 1. Reduction (%) in canopy cover of all brush plants on burned areas of the Welder Wildlife Refuge (measured August 1967).

Pretreatment	Percent reduction		
	Fall	Winter	Fall-Winter
Control (no burn)	33	43	35
Shredded	59	61	75
Chopped	62	62	73
Scalped	36	41	66
Root plowed	70	64	85
Root plowed and raked	44	71	87

Table 2. Composition (%) of brush species on burned areas of the Welder Wildlife Refuge.

Species	Control	Time of burn		
		Fall	Winter	Fall & Winter
Acacia farnesiana	10.0	19.9	16.5	21.3
A. rigidula	9.0	7.9	13.3	12.6
A. tortuosa	T	1.2	0.8	7.8
Berberis trifoliolata	4.1	2.8	1.6	2.2
Celtis spinosa	5.0	8.1	4.3	5.4
Condalia obovata	2.0	3.1	1.3	1.8
C. obtusifolia	2.5	2.9	6.7	3.0
Diospyros texana	1.0	2.3	T	0.9
Lycium berlandieri	1.0	T	T	T
Opuntia leptocaulis	4.7	4.8	1.3	0.9
O. lindheimeri	8.4	5.9	5.1	6.5
Prosopis glandulosa	43.2	31.9	33.9	28.5
P. reptans var. *cinerascens*	4.6	1.3	7.0	3.7
Zanthoxylum fagara	3.8	4.7	7.6	3.5

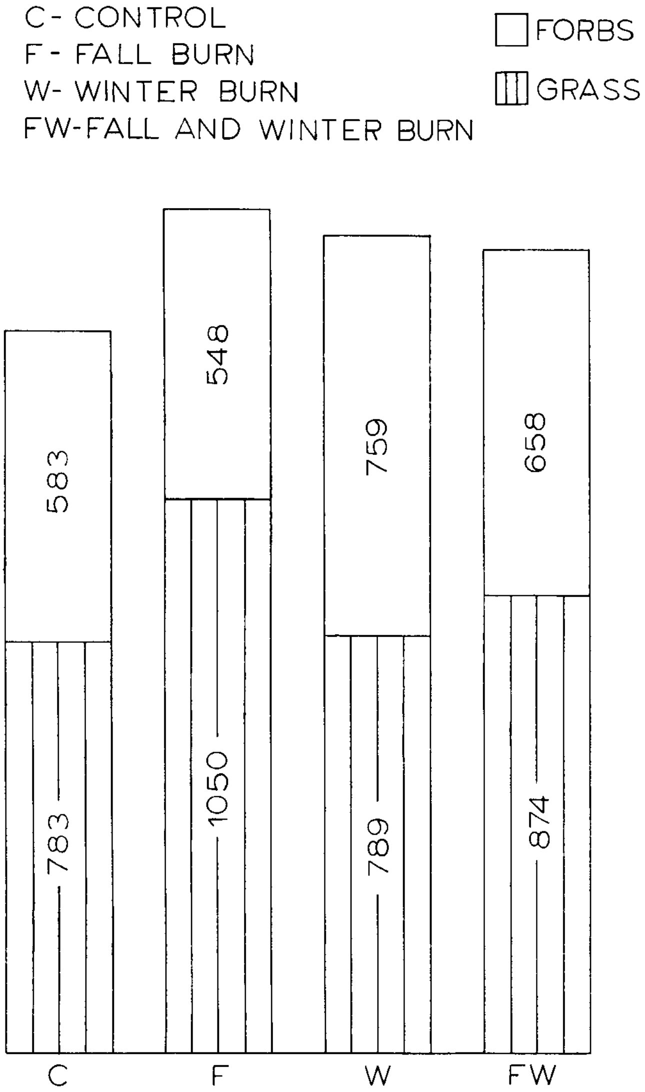

FIG. 2. Standing crop of herbage (lb) on untreated areas of the Welder Wildlife Refuge.

(1967) reported average canopy reduction of 56 to 78% on the fall burned plots the first growing season following the fire.

The least amount of canopy reduction occurred in areas that had been scalped as a pretreatment brush control measure where the brush plants were large. The greatest reduction was in areas that had been root plowed or root plowed and raked. Here brush plants grew singly and were completely surrounded by fuel.

The percent composition of brush canopy cover was altered by the burning treatments (Table 2). Huisache (*Acacia farnesiana* (L) Willd.), blackbrush acacia (*A. rigidula* Benth.), twisted acacia (*Acacia totuosa* (L) Willd.), and lote bush (*Condalia obtusifolia* Hook.) all increased in relative abundance. Agarito (*Berberis trifoliolata* Moric.), lycium (*Lycium berlandieri* Dunal.), tasajillo (*Opuntia leptocaulis* DC.), mesquite (*Prosopis glandulosa* Torr.), and creeping mesquite (*P. reptans* Benth. var *cinerascens* (Gray) Burkart) all declined in relative abundance. Percent kill was not determined for each species. Box et al. (1967) and White (1969) reported varying mortality of brush depending upon conditions at the time of the fire and stage of growth of the plants.

Response of Herbaceous Vegetation

More total herbage was produced on all burned areas than on the unburned control (Fig. 2). The fall burned area produced significantly (.05 level) more grass than any other treatment. The winter burned area had significantly (.05 level) more forbs than any other treatment. The fall and winter burned areas produced more total herbage, and more in both the grass and forb categories, than the control. They produced about the same amount of total herbage as those burned in fall or winter only, but they had less grass and more forbs than plots burned fall only and less forbs and more grass than plots burned winter only. Yield of individual species on the treated areas is included in Table 3. These findings are similar to those of Grelan and Epps (1967) who reported increased production in Louisiana following fire.

In general, plants that increased following burning were those normally considered "disturbance" species. For instance, filly panic (*Panicum filipes* Scribn.) and plains bristlegrass (*Setaria leucopila* (Scribn. and Merr.) K. Schum.), produced more on all burned plots than on the control. Several other grasses were more abundant on fall burned areas than on the control plots or strips that had been burned in the winter. However, statistically significant differences could not be shown between individual species response to the burning treatment.

Conclusions and Recommendations

Both fall and winter burning will effectively reduce brush canopy and frequency in South Texas chaparral communities. Fall burning appears to be slightly more effective in reducing brush cover than winter fires.

Fall burning tends to reduce forb production the following year and increase the amount of grass produced (Box et al., 1967). Winter burning has an opposite effect—forbs are increased and grasses remain unchanged in production. Burning for two successive years, once in the fall and once in the winter, gives a balance between grass and forbs similar to the unburned control, but total production is higher.

Fires are not particularly effective in reducing brush in South Texas unless some form of pretreatment is practiced. Where fire is used without

Table 3. Herbage production (lb/acre) by species, on burned plots on the Welder Wildlife Refuge.

Species	Control	Time of burn: Fall	Winter	Fall & Winter
Grasses				
Andropogon saccharoides	126	119	39	44
Aristida roemeriana	48	79	29	48
Buchloe dactyloides	355	330	315	401
Chloris verticillata	20	8	20	8
Hilaria belangeri	T	24	7	17
Panicum filipes	43	90	60	85
P. obtusum	20	51	49	57
Paspalum pubiflorum	57	12	28	33
Schedonnardus paniculatus	4	11	2	T
Setaria geniculata	13	42	12	3
S. leucopila	12	110	85	82
Sporobolus asper	36	87	33	42
S. pyramidatus	6	5	11	T
Stipa leucotricha	77	28	56	24
Tridens albescens	31	47	39	18
T. congestus	22	5	2	9
Others (4 of less than 1 lb/acre each)	3	2	2	3
Total grasses	873	1050	789	874
Forbs				
Ambrosia psilostachya	72	94	117	70
Cienfuegosia sulphurea	4	1	7	3
Commelina erecta	24	13	15	14
Croton monanthogynus	40	28	42	44
Desmanthus virgatus	30	20	20	31
Lythrum californicum	2	1	3	6
Malvastrum aurantiacum	3	10	3	2
Phyla incisa	8	26	10	27
Portulaca pilosa	8	3	12	9
Ratibida columnaris	2	3	8	3
Ruellia sp.	110	95	86	116
Solanum eleagnifolium	23	26	40	59
Verbesina microptera	30	41	66	64
Xanthocephalum texanum	219	185	322	203
Others (11 of less than 1 lb/acre each)	7	2	8	7
Total forbs	583	548	759	658
Total herbage	1456	1598	1548	1532

pretreatment, the result is an uneven and patchy burn with the large mottes left intact. Repeated burnings could conceivably reduce the size of the mottes by gradually eroding them around the edges, but it is not likely that chaparral areas would burn that often.

Therefore some sort of pretreatment is desirable. It appears that any type of mechanical control that will crush or knock down the larger brush and dense mottes will enhance the effects of fire. Best results can probably be obtained by waiting sufficiently long following pretreatment for the crushed woody fuel to dry and a crop of herbaceous material to mature among the debris.

No detrimental effects on herbaceous vegetation have been observed following a fire. In fact, grass production may be increased (White, 1969). Therefore, we recommend careful use of fire as a management tool in South Texas chaparral.

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Responses of Mountain Grassland Vegetation to Gopher Control, Reduced Grazing, and Herbicide[1]

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Highlight

Deteriorated mountain grassland range on Grand Mesa in western Colorado improved slowly during 19 years of nonuse. It improved almost as much under light grazing. In contrast, grass production increased markedly within a short time after competition from forbs and shrubs had been reduced by herbicide. Pocket gopher control for 9 years increased production of certain plant species and decreased production of others.

Efficient management of mountain grasslands for grazing, recreation, or watershed purposes calls for increased knowledge of responses of the vegetation to different management practices. This paper reports responses of grassland vegetation on Grand Mesa to: (1) exclusion of livestock; (2) reduction in livestock grazing; (3) control of pocket gophers; and (4) herbicide. The study was conducted by the Rocky Mountain Forest and Range Experiment Station between 1941 and 1960 in cooperation with the Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, and the Grand Mesa-Uncompahgre National Forest, Forest Service, U. S. Department of Agriculture.

Study Area and Methods

Grand Mesa is located near Grand Junction, Colorado, between the bordering valleys of the Gunnison and Colorado Rivers. Capped with basalt, it slopes gently upward from an elevation of 9,800 ft at its western edge to over 10,500 ft at its eastern extremity. The terrain is generally flat to rolling. Though rich in organic matter and fertile, soils are generally rocky and shallow. Average annual precipitation is estimated to be about 30 inches. From November through May the ground usually is snow covered; the snowpack commonly attains a depth of 4 to 6 ft.

Near the western edge of the Mesa the aspect of silver sagebrush (*Artemisia cana*) is broken here and there by groves of Engelmann spruce (*Picea engelmanni*) and subalpine fir (*Abies lasiocarpa*). At higher elevations timber stands are more extensive, and grassland "parks," hereafter referred to as the grass-forb type, are occupied mainly by herbaceous plants.

Since about 1880 Grand Mesa has been grazed by cattle. Soon after the turn of the century the range was heavily stocked, and dense stands of Thurber fescue (*Festuca thurberi*), photographed by George B. Sudworth in 1889, were replaced or obscured by sagebrush.

When this study was started in 1941, orange sneezeweed (*Helenium hoopesii*) was conspicuous in the grass-forb type. Grass cover was sparse and the range was heavily populated with northern pocket gophers (*Thomomys talpoides*). After snowmelt the ground was cluttered with cores of soil deposited in snow tunnels, and later with mounds of earth excavated by gophers (Fig. 1). By summer's end, cattle had closely grazed most forage plants.

To determine and compare responses of vegetation to different combinations of gopher and grazing control, eight pairs of 1-acre areas on Grand Mesa were located in 1941 for detailed study. The most distant, 7 miles apart, differed in elevation by 600 ft. The two lowest and westernmost pairs supported mainly silver sagebrush; the others supported a mixture of forbs and grasses. One member of each pair was fenced in 1941 to exclude livestock, and the other continued to be grazed. Grazing was much lighter, however, after the number of cattle and length of grazing season were reduced about one-half during the period 1946 to 1950. The lighter grazing continued through 1960.

From 1941 to 1949, pocket gophers were trapped continuously during the snow-free period from every other pair of study areas. On the average, 18 gophers an acre per year were trapped from control areas (Cummings, 1949). Yearly averages ranged from 9 to 35 and those for individual study areas from 14 to 23 an acre. Equal numbers were trapped from grazed and nongrazed range. Although the number of gophers on gopher-present areas was not determined, soil disturbance indicated populations were generally high.

Between 1955 and 1958, the four pairs of study areas on the western part of the Mesa were sprayed with herbicide. An ester of 2,4-D mixed with diesel fuel was applied by airplane at a rate of 3 lb/acre acid-equivalent. Except during the year of treatment, the open range continued to be grazed after it had been sprayed.

Vegetation records were collected from 1941 to 1960. For sampling purposes, each acre was subdivided into nine units of equal size, and two 12.5 ft^2 plots were located at random in each unit each time records were taken.

Herbage production was measured in 1941 by harvesting and weighing vegetation from each plot; thereafter, it was determined by double sampling in which herbage weight was estimated and the estimates adjusted as indicated by records from clipped plots (Pechanec and Pickford, 1937). Weights were converted to an air-dry basis. Production by individual species was estimated in 1942 and 1960; in other years it was determined only for herbage classes, except for sneezeweed, which was measured separately. Sneezeweed was of particular interest because it was very abundant, is nonpalatable to cattle, and poisonous to sheep.

Plant cover was estimated by the square-foot-density method (Stewart and Hutchings, 1936). An index of plant vigor was obtained by measuring maximum heights of flower stalks of 30 nongrazed plants per acre for each of seven species. Measurements were made in July or August when most plants were fully developed.

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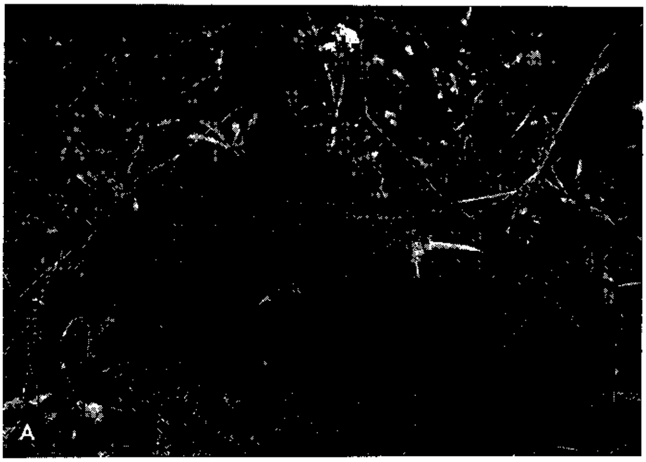
[2] Forest Service, U. S. Department of Agriculture, with headquarters at Fort Collins, Colorado, in cooperation with Colorado State University. The author is grateful to David F. Costello, Clyde W. Doran, Maynard W. Cummings, and others who helped plan and conduct the study.



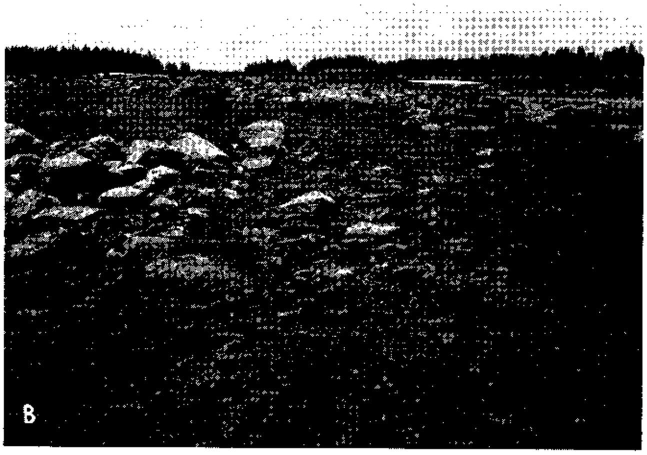


FIG. 1. The mountain pocket gopher commonly buries plants under mounds of soil excavated during summer (A) and under earthen cores deposited in snow tunnels during winter (B).

Table 1. Herbage yields (lb/acre, air dry) where pocket gophers were controlled from 1941 to 1949, and where not controlled. Each entry is the average of eight 1-acre areas.

Herbage class and year	Gophers controlled	Gophers uncontrolled	Difference
Grasses and sedges			
1941	109	140	– 31
1942	165	166	– 1
1946	204	231	– 27
1947	206	202	4
1951	236	310	– 74
Sneezeweed			
1941	114	57	57
1942	172	48	124
1946	80	46	34
1947	62	58	4
1951	34	36	– 2
Other forbs			
1941	600	524	76
1942	652	504	148
1946	699	504	195
1947	766	498	268
1951	931	597	334
Shrubs			
1941	112	210	– 98
1942	66	138	– 72
1946	66	136	– 70
1947	34	125	– 91
1951	57	170	–113
All herbage			
1941	935	931	4
1942	1055	856	199
1946	1049	917	132
1947	1068	883	185
1951	1258	1113	145

Terminal records for the pocket gopher study were obtained in 1951, 2 years after gopher control had been discontinued. Responses to livestock exclusion from 1942 to 1960, and to reduced grazing, are reported only for the eight areas not sprayed with herbicide. Responses to herbicide were measured in 1960, 2 to 5 years after the chemical was applied.

Results and Discussion

Responses to Gopher Control.

Herbage available to livestock was increased 195 lb/acre as the result of gopher control the first year (Table 1). Forbs, which produced about three-fourths of the herbage, accounted for nearly three-fourths of the increase. Though average production of grass increased only 30 lb/acre, the increase was nearly in proportion to the amount present. Changes in browse also were small. The initial increase in available herbage apparently resulted mainly from reduced burial and consumption of plant foliage by gophers.

From 1942 to 1951, forbs other than sneezeweed continued to become more productive. By 1951 the increase attributable to gopher control averaged 258 lb/acre. Meanwhile, production of orange sneezeweed declined. On gopher control areas, the decrease averaged 138 lb/acre as compared to 12 lb/acre where gophers were not controlled. The relatively small changes in grass and browse production evidently were not related to gopher control.

Amount and composition of plant cover also were influenced by gophers. Considered by herbage classes, only forb cover changed significantly between 1941 and 1951. On gopher control areas it increased to 19 from 14%, while on gopher-present areas it remained at 12%.

Changes in crown cover of six individual species were significant. Where gophers were controlled, sedges (*Carex* spp.), lupine (*Lupinus* spp.), and common dandelion (*Taraxacum officinale*) increased, while slender wheatgrass (*Agropyron trachycaulum*), orange sneezeweed, and penstemon (mainly *Penstemon rydbergii*) became relatively

Table 2. Composition (%) of plant cover as influenced by pocket gopher control.

Species	Gophers controlled 1941	Gophers controlled 1951	Gophers uncontrolled 1941	Gophers uncontrolled 1951
Grass and Sedges	percentage of grass-sedge cover			
Slender wheatgrass	7	9	4	14
Sedges	22	32	21	11
Forbs	percentage of forb cover			
Orange sneezeweed	13	3	7	4
Lupines	8	22	11	12
Penstemons	10	9	8	17
Common dandelion	21	27	14	12

less prominent (Table 2). Branson and Payne (1958) reported similar responses of dandelion and slender wheatgrass to gopher control in Montana. On the Wasatch Mountains in Utah, Richens (1965) found that bulbed plants became more abundant, and annual plants less abundant, following gopher control.

The increases in lupine and dandelion on Grand Mesa are in accordance with earlier findings that those plants commonly are eaten by gophers (Keith, Ward, and Hansen, 1959; Ward, 1960; Ward and Keith, 1962). Lupine increased on all areas on which gopher control was attempted, and dandelion increased on seven of the eight areas. Neither changed appreciably where gophers were not controlled. After gopher control was discontinued, lupine again became relatively inconspicuous.

Gopher-Grazing Relationships.

Vegetation responses to gopher control varied considerably with range use by cattle. For example, forbs other than sneezeweed increased most (373 lb/acre) between 1941 and 1951 on grazed range on which gophers were controlled. The increase was smallest (41 lb/acre) on nongrazed range on which gophers were not controlled. Orange sneezeweed, on the other hand, decreased as much as 106 lb where both cattle and gophers were excluded, and as little as 14 lb where neither was excluded.

The largest increase (181 lb/acre) in grass and sedges resulted from exclusion of cattle only. Slender wheatgrass provided most of the additional forage. Grass increased least (96 lb/acre) on grazed range on which gophers were controlled. Browse responses were relatively small and inconsistent.

Changes in sneezeweed cover were similar to its changes in production. Common dandelion and sedge cover increased most on grazed range on which gophers were controlled, and decreased on nongrazed range on which gophers were present.

Table 3. Average production of herbage (lb/acre, air-dry) on four grazed and four nongrazed areas in a grass-forb type not sprayed with herbicide.

Class of herbage	Grazed 1941	Grazed 1960	Nongrazed 1941	Nongrazed 1960
Grass and sedges	124	300	130	353
Forbs	562	433	600	440
Shrubs	20	30	10	8
All herbage	706	763	740	801

Under the latter treatment, slender wheatgrass attained its greatest prominence. Responses of lupine and penstemon to gopher control were not influenced appreciably by grazing.

Comparative changes in vegetation between 1941 and 1951 for the four gopher-grazing treatments are summarized below. Under all treatments, production of grass and forbs other than sneezeweed was higher, and that of sneezeweed and browse lower, in 1951 than in 1941.

Gophers present on grazed range.
1. Average increase in grass production.
2. Below average increase in forbs other than sneezeweed.
3. Least reduction in sneezeweed.

Gophers present on nongrazed range.
1. Largest increase in grass (mainly slender wheatgrass).
2. Least increase in forbs other than sneezeweed.
3. Small reduction in sneezeweed; moderate reduction in dandelion.

Gophers controlled on grazed range.
1. Least increase in grass (no change in wheatgrass).
2. Largest increases in lupine, dandelion, sedges, and forbs (as a group) other than sneezeweed.
3. Average reduction in sneezeweed.

Gophers controlled on nongrazed range.
1. Average increase in grass production.
2. Above average increase in forbs other than sneezeweed.
3. Largest reduction in sneezeweed.

Responses to Reduced Grazing.

Changes in herbage production on areas from which cattle were excluded from 1942 to 1960, and which were not sprayed with herbicide, were not much different from those on adjacent range on which grazing intensity was reduced (Table 3). Under both treatments, grass production increased less than 250 lb/acre, forb production decreased between 100 and 200 lb, and shrub production changed very little. Although total herbage production was somewhat higher in 1960 than in 1941, the increase was nearly the same on grazed and nongrazed range.

Grasses and sedges in 1941 comprised 18% of the herbage, both on areas to be grazed and nongrazed. In 1960 they comprised 39 and 44%, respectively. Contribution of forbs decreased from 80 to 57% under grazing, and from 81 to 55% under nongrazing. Changes in browse were insignificant.

The proportions of herbage contributed by individual plant species changed substantially during the 19-year period. On areas from which cattle were excluded, Letterman needlegrass (*Stipa lettermani*) produced 35% of the grass in 1942. By 1960 its contribution had declined to 18%. Meanwhile, slender wheatgrass increased to 34% from 8%. Bromegrass (mainly *Bromus anomalus*) and trisetum (mainly *Trisetum spicatum*) each contributed 15% of the grass in 1960 but only 3 to 4% in 1942. Increases in brome and trisetum were countered by similar decreases in sedges and bluegrasses (*Poa* spp.).

Changes in composition of forb herbage on nongrazed range were generally smaller than those for grasses. The largest reduction was in western yarrow (*Achillea lanulosa*), which accounted for 20% of the forb herbage in 1942 and 8% in 1960. The largest increase (6%) was in agoseris (mainly *Agoseris glauca*). Comprising 24 to 30% of forb herbage, sneezeweed was the dominant forb both years.

Of interest is the fact that sneezeweed production declined by 61 lb/acre (significant at 0.05 level) on nongrazed range but retained its original level on grazed range between 1941 and 1947. By 1951, however, after the reduction in range stocking, a significant reduction of 34 lb/acre had occurred on the open range. Thus, abundance of sneezeweed was influenced not only by gophers, but by intensity of range use by cattle (Fig. 2).

On grazed areas, changes in herbage composition were generally similar to, but smaller than, those on nongrazed range. Principal exceptions were that Letterman needlegrass and bluegrasses retained their former prominence, and dandelion became more prominent, under continued grazing. In 1960 slender wheatgrass produced 15% of the grass on grazed range as compared to 34% on areas that had not been grazed for 19 years.

Increased height growth indicated that plants of the seven species observed became more vigorous following discontinuance or reduction in grazing. Flower stalks of Letterman needlegrass, which averaged 16 inches tall in 1941, were 5.2 inches taller on nongrazed range and 1.6 inches taller on grazed range in 1947. Stalks within seven of the eight exclosures attained their tallest recorded height within 6 years after grazing was discontinued. By 1951 average heights differed by only 2.4 inches, and in 1960 they were nearly the same. In 1960, however, plants were 2 to 3 inches taller than in 1941. On nongrazed range, the stalks were 2 inches shorter in 1960 than in 1947, possibly because of increased competition from associated plants.

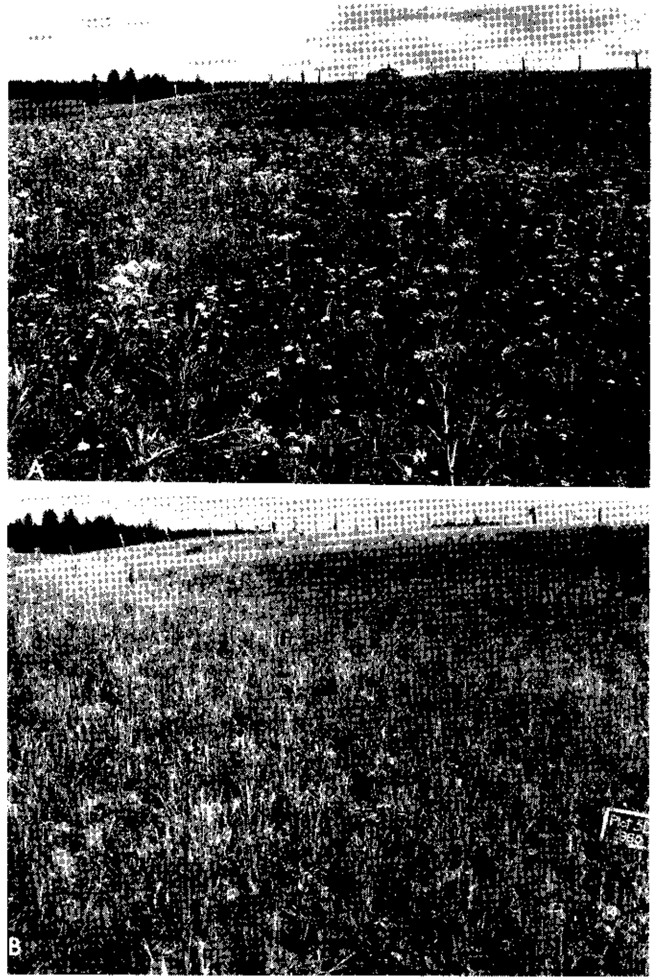


FIG. 2. Orange sneezeweed nearly disappeared from this cattle exclosure between 1941 (A) and 1960 (B) as grass production increased to 576 from 148 pounds an acre. Slender wheatgrass was the dominant grass in 1960. This range was not sprayed with herbicide.

In 1951, flower stalks of slender wheatgrass averaged 3 inches taller, and those of trisetum were 2.4 inches taller, inside than outside the exclosures. Leaves of common dandelion inside the exclosures grew more nearly upright, and in 1951 were 0.6 inch longer than those outside. None of the plants measured had been grazed during the year of measurement.

Heights of western yarrow, orange sneezeweed, and lupine were less influenced by grazing. Although those forbs invariably were shorter on grazed than on nongrazed range after 1941 (pos-

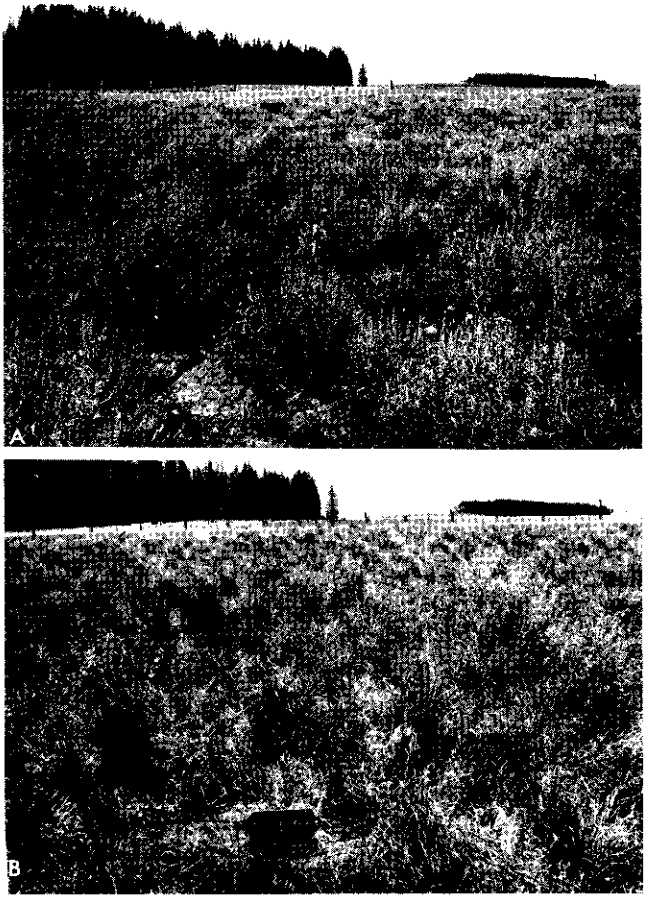


FIG. 3. Sprayed with herbicide in 1958, this site produced 991 pounds of grass an acre in 1960 (B) as compared to 279 pounds in 1941 when silver sagebrush was prominent (A). The increase in grass on sprayed range exceeded that on nonsprayed range by more than 300 pounds an acre.

sibly because of differences in soil tilth), the largest average difference between treatments for any species in any year was 1.7 inches.

Differences in site capability were evidenced by height growth of Letterman needlegrass, orange sneezeweed, and western yarrow. In 1941 their flower stalks were taller on each of the eight lower study areas than at higher elevations. Although differences attributable to site (elevation) averaged only 1.5 to 2.4 inches, they generally persisted throughout the study, or as long as records were taken.

Responses to Herbicide.

Grass production increased substantially more between 1951 and 1960 on areas sprayed with herbicide than on those not sprayed. In the sagebrush type the increase averaged 339 lb/acre (Fig. 3), and in the grass-forb type 255 lb. In comparison, the increase on the eight areas in the grass-forb type that were not sprayed averaged 96 lb (Table 4). During the 19 years of study, grass production on nonsprayed range increased only 200 lb/acre.

Forbs on sprayed range produced 490 to 574 lb/acre less in 1960 than in 1951. However, a decrease of 386 lb on nonsprayed range during that period indicates that factors other than herbicide were responsible for much of the reduction. Some forbs undoubtedly reinvaded sprayed areas prior to 1960, particularly in the grass-forb type. Hansen and Ward (1966) recorded the lowest production of forbs the first year, and the highest production of grass the third year, after similar rangeland on Grand Mesa had been sprayed in 1956.

Herbicide killed nearly all silver sagebrush, the only abundant shrub. In 1960, browse production on areas formerly dominated by sagebrush averaged 12 lb/acre, compared with 354 lb/acre prior to spraying. As a result, herbage composition was greatly altered (Table 4).

Responses to herbicide were also revealed through changes in frequency of individual plant species between 1951 and 1960. Not only sagebrush, but most forbs were less common 2 to 5 years after herbicide had been applied (Table 5). Plants most affected were agoseris, aspen fleabane

Table 4. Herbage production (lb/acre, air dry) and composition (%) on areas sprayed with herbicide and not sprayed.

	Sprayed with Herbicide[1]						Not sprayed[2]		
	Sagebrush type			Grass-forb type			Grass-forb type		
Year	Grass	Forbs	Shrubs	Grass	Forbs	Shrubs	Grass	Forbs	Shrubs
Herbage production:									
1951	429	681	354	206	848	44	230	833	28
1960	768	191	12	461	274	10	326	447	20
Diff.	+339	–490	–342	+255	–574	–34	+96	–386	–8
Herbage composition:									
1951	29	47	24	19	77	4	21	76	3
1960	79	20	1	62	37	1	41	56	3

[1] Four areas in the grass-forb type and two in sagebrush were sprayed in 1955; 2 additional areas in sagebrush were sprayed in 1958.
[2] Each entry is the average for 8 areas.

Table 5. Frequency (%) of common plants on sagebrush and grass-forb types treated with herbicide, and on untreated grass-forb type, in 1951 and 1960. Each entry is based on eighteen 12.5 ft² plots/acre.

	Sprayed with herbicide				Not sprayed	
	Sagebrush		Grass-forb		Grass-forb	
Species	1951	1960	1951	1960	1951	1960
Grasses and Sedges						
Slender wheatgrass	80	95	47	80	40	60
Bromegrasses	54	60	19	28	8	26
Sedges	84	72	83	65	96	77
Alpine fescue	0	0	2	4	74	62
Thurber fescue	39	43	0	0	0	0
Prairie Junegrass	24	14	2	0	0	0
Alpine timothy	0	2	9	6	32	24
Bluegrass	29	29	44	28	68	64
Letterman needlegrass	89	79	99	96	98	88
Trisetums	51	44	47	60	58	66
Forbs						
Western yarrow	99	61	96	81	96	93
Agoseris	56	7	97	26	90	57
Pussytoes	20	0	7	6	21	8
Aspen fleabane	58	4	22	4	2	1
Eriogonums	36	4	7	2	2	1
Prairiesmoke sieversia	17	4	11	6	43	40
Orange sneezeweed	28	10	80	17	86	70
Aspen peavine	74	51	46	26	25	25
Lupines	92	24	43	10	87	46
Penstemons	7	6	30	26	78	73
Douglas knotweed	76	85	72	88	22	41
Cinquefoils	93	71	100	74	22	21
Pseudocymopterus	6	4	8	0	72	46
Common dandelion	86	26	100	71	95	91
American vetch	74	4	47	2	22	20
Shrubs						
Silver sagebrush	92	15	10	3	0	0

(*Erigeron macranthus*), eriogonum (*Eriogonum subalpinum* and *E. neglectum*), orange sneezeweed, lupine, and American vetch (*Vicia americana*). Reductions were smaller or less consistent in western yarrow, pussytoes (*Antennaria* spp.), prairiesmoke sieversia (*Geum ciliatum*), aspen peavine (*Lathyrus leucanthus*), common dandelion, Rydberg penstemon, and cinquefoils (*Potentilla anserina* and *P. pulcherrima*). In 1960 these two species of cinquefoil comprised 30 to 40% of the forb herbage on sprayed areas, much more than any other species.

Changes in frequency of individual grass species were relatively small and generally similar on sprayed and nonsprayed range. This would indicate that causes other than herbicide were mainly responsible, and that increased production of grass on sprayed range resulted not from establishment of new plants but from improved vigor of plants present when the range was sprayed.

Responses to herbicide were influenced by site characteristics and nature of the vegetation prior to spraying. In 1951 frequencies of several plant species within the sagebrush type differed considerably from those for the grass-forb type. Thurber fescue and prairie Junegrass (*Koeleria cristata*), for example, were nearly restricted to the sagebrush type before and after treatment (Table 5). Within the grass-forb type, alpine fescue (*Festuca ovina brachyphylla*), alpine timothy (*Phleum alpinum*) and bluegrasses were much more common in 1951 on areas not to be sprayed than on those subsequently sprayed. By 1960, 2 to 5 years after herbicide was applied, the relative abundance and distribution of these plants had changed very little.

Summary and Conclusions

Vegetation responses to pocket gopher control, exclusion of livestock, reduced grazing, and herbicide were observed on 16 1-acre study areas on Grand Mesa in western Colorado from 1941 to 1960. The sites were paired, one fenced to exclude livestock and the other left open to grazing by cattle. From 1941 to 1949 pocket gophers were controlled during summer months on every other pair of study areas. Livestock were excluded from eight sites from 1942 to 1960, and stocking of the open range was sharply reduced during the period 1946 to 1950. Thereafter, grazed sites received light to moderate use. The western part of the Mesa on which half the study areas were located was sprayed with herbicide during the period 1955 to 1958.

Because control of pocket gophers by poisoning and trapping was feasible only during snow-free periods, some gophers reinvaded gopher-control areas during winter. Consequently, the responses reported are from intensive, but incomplete, control of gophers.

Principal conclusions are:

1. Gopher control resulted primarily in increased production of perennial forbs, particularly lupine and dandelion which commonly are eaten by gophers. Forbs other than sneezeweed increased by 258 lb/acre between 1941 and 1951, the increase on grazed range being considerably larger than on nongrazed range. Orange sneezeweed became less productive as the result of gopher control. Grasses and shrubs were little affected. Responses to gopher control, however, varied considerably with grazing use by cattle.

2. Exclusion of livestock from a grass-forb range for 19 years resulted in an increase in grass of 223 lb/acre, and a decrease in forbs of 160 lb. The proportion of herbage contributed by grasses and sedges increased to 44 from 18%, and that by forbs decreased to 55 from 81%. Slender wheatgrass,

bromegrasses, and trisetum became more prominent, while Letterman needlegrass, bluegrasses, and sedges became less prominent. Composition of forb herbage was generally stable, the largest change being a 12% reduction in western yarrow. Competition from forbs apparently was mainly responsible for the slow and relatively small increase in grass production.

3. Vegetation changes on range grazed lightly to moderately for 10 years after stocking rate and length of grazing season had been reduced were generally similar to those on rangeland not grazed for 19 years. Principal exceptions were that Letterman needlegrass and bluegrasses retained their former prominence, and dandelion became more prominent, under continued grazing. The findings indicate that deteriorated mountain grassland range may improve almost as rapidly under light grazing as under nonuse.

4. Grass production increased considerably more on range sprayed with herbicide than on range not sprayed. Much of the increase evidently resulted from more vigorous growth of grasses present when the range was sprayed. Kind and frequency of grasses on individual sites 2 to 5 years after the range was sprayed were not much different from those prior to spraying. Although many forbs were killed by herbicide, some were almost as abundant a few years after the range was sprayed as before. Apparently the latter were resistant to herbicide or quickly became reestablished.

Although plant cover responded differently to each treatment, the vegetation on each site tended to retain its individuality throughout the study. The nature of existing plant cover and other site characteristics should be considered, therefore, when predicting responses of mountain grassland to specific management practices.

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Francis T. Colbert
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Composition and Yields of Native Grassland Sites Fertilized at Different Rates of Nitrogen[1]

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Highlight

Four range sites were fertilized at three different rates of nitrogen (33, 67, and 100 pounds nitrogen per acre) in southwestern North Dakota. Increasing the production of a range site with nitrogen fertilization is closely associated with the inherent production potential of the site. In general, greatest increases in total dry-matter yields for a given increment of fertilizer were observed at the 67-pound nitrogen application. Total basal cover was reduced by fertilization on the Vebar and Havre sites but increased on the Rhodes and Manning sites. In general, reduction in total cover was due to a decrease in cover of the blue grama grass. An increase in cover and density of western wheatgrass and the sage species was generally observed on all sites.

Fertilization of native ranges has been carried out with varied success in the Northern Great Plains. Differences in climatic conditions, growing season, soil conditions, and management practices play an important role in determining the effectiveness of a given amount of nitrogen and increase in forage yield. Most of the work reported has been carried out on an individual site basis rather than on a variety of range sites covering various edaphic and vegetative conditions.

Heady (1952) applied barnyard manure annually from 1925 to 1935 to a relict native grassland near Havre, Montana. Stand and yield of grass increased after the first two years.

Lodge (1959) used heavy applications of manure and commercial fertilizers on native ranges at Swift Current, Saskatchewan. Heavy applications of manure were both immediate and lasting compared to commercial fertilizers, which may be of short duration and may not cause enough increase in growth to warrant their use.

The use of nitrogen fertilizer on native grassland has been reported by Rogler and Lorenz (1957) at the U.S.D.A. Northern Great Plains Research Center, Mandan, North Dakota. Pastures under moderate and heavy grazing intensities were fertilized annually for a 6-year period at rates of 30 and 90 pounds nitrogen per acre. Highest rates of return were realized from 30 pounds of nitrogen per acre, due mainly to the increase in western wheatgrass. Two years of fertilization of the heavily grazed pasture at the 90-pound rate did more to improve range condition and production than did six years of complete isolation from grazing. Changes in the botanical composition due to nitrogen fertilization were reported by Rogler and Lorenz (1965) and by Smoliak (1965).

Studies of yields from native range fertilization were initiated at the Dickinson Experiment Station, Dickinson, North Dakota by Whitman (1962) applying nitrogen at rates of 33, 67, and 100-pounds per acre. This study included two range sites and was expanded to include detailed studies of four different range sites, which is the basis of this paper.

Experimental Procedure

This study was conducted on four representative range sites within a 35-mile radius of the Dickinson Experiment Station in southwestern North Dakota during the years 1964–1966. The four range sites represented four soil types common in this region. The soil types are the Vebar fine sandy (sandy site), Havre silt loam (loamy site), Rhodes silt loam (panspots) and the Manning silt loam (shallow site). The range sites are designated by the soil type names throughout this discussion. The long-term average precipitation at the Dickinson Experiment Station is 15.42 inches, of which approximately 75 percent is received during the active growing season. A slightly greater amount of precipitation was received during the 1964–1966 study period.

The Vebar fine sandy loam is a soil developed from weathered, weakly-cemented, tertiary sandstone and is associated mainly with gently undulating to moderately steep topography. The site is situated on a gentle, southwest-facing slope and was heavily grazed in late fall of each year. The dominant vegetation consists primarily of the species given in Table 1.

The Havre silt loam soil series comprises a deep, light-colored, alluvial soil occupying creek bottom floodplains. This range site is found extensively only in the Badlands, where it is used for both summer and winter grazing, although it is considered of primary importance for winter use. Summer grazing was practiced on the site studied, with the range condition of the site in excellent condition. The plants regarded as the dominant vegetation are given in Table 2.

The Rhodes silty loam soil was classed as a Solonetz soil type, high in sodium, with a near-impervious layer of dispersed clay particles in the profile varying in depth from the soil surface to approximately 20 inches. This clay layer generally was found to be about 14 to 18 inches thick. The grazing capacity of this site is considerably reduced by claypan and barren panspots which support little or no vegetation. Heavy grazing in the past has further adversely affected the physical characteristics of the soil on this site. The dominant grass and forb species of this site are given in Table 3.

The Manning silt loam soil is a soil type developed on high river terraces underlain by a gravel layer at about 18–24 inches below the surface. The site studied occupied one of the oldest and highest river terraces of this soil type in the area. The site is generally heavily grazed during

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Table 1. Average basal cover on the Vebar range site, and the average number of single-stalked species in each 1-ft² plot on the site, 1964 to 1966.

Species	0 N		33 lb N/acre		67 lb N/acre		100 lb N/acre	
	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²
Western wheatgrass	0.02	2.86	0.02	0.00	0.02	0.15	0.05	0.13
Needle-and-thread	2.13		2.02		2.92		2.20	
Plains reedgrass	0.27a[1]	2.28	0.37b	2.83	0.42b	5.01	0.78a	3.27
Prairie sandreed	0.17a	0.77	0.22b	0.84	0.37a	1.15	0.33b	1.45
Prairie Junegrass	0.10		0.05		0.10		0.07	
Blue grama	32.93		31.68		29.40		28.88	
Threadleaf sedge	1.43a		2.28a		1.02a		2.32a	
Needleleaf sedge	2.13a		1.77b		2.12b		1.70b	
Pennsylvania sedge	0.28		0.50		1.20		0.68	
Fringed sage	0.03	0.67	0.08	1.24	0.07	0.99	0.02	0.74
White sage	0.18	4.01	0.17	4.35	0.28	5.76	0.28	7.01
Skeleton weed	0.05	0.51	0.07	0.23	0.00	0.35	0.02	0.16
Scarlet globemallow	0.08	0.91	0.00	0.69	0.02	0.68	0.02	0.60
Butterfly weed	0.02	0.25	0.02	0.26	0.00	0.35	0.00	0.33
Birdsfoot trefoil	0.07	1.25	0.02	0.88	0.00	0.60	0.00	0.28
Rough pennyroyal	0.00	0.61	0.00	0.27	0.00	0.13	0.00	0.09
Total of site	40.15b	18.21a	39.33a	14.59b	38.22b	19.41b	37.47b	17.49a

[1]Means within a species and treatments are significantly different at the 0.05 level only when designated with the same letter superscript.

the early summer months and was in low good condition. Dominant grasses, sedges, and forbs are given in Table 4.

The experiment was designed as a random block of three different treatments and a check plot (no nitrogen), replicated four times. Individual plots measured 30 × 100 feet with 6-foot wide alleyways between replications. Treatments consisted of check plots, 33 pounds elemental nitrogen per acre, 67 lb N/acre, and 100 lb N/acre. The nitrogen was applied as ammonium nitrate between April 10–15 of each year.

Three 3 × 7 ft steel wire quonset-type cages were placed on each plot of each treatment and site. The cages were placed in a staggered line rather than a straight line to eliminate trailing by cattle. Yield samples were clipped to ground level at the end of the growing season from all treatments each year from the area protected by the wire cages, using a 2.5 × 5 ft steel frame. The forage was hand separated into tallgrasses, midgrasses, shortgrasses, perennial forbs and annual forbs. The plant material was oven-dried and weighed.

Basal cover was determined on each plot each year (1964, 1965, and 1966) by the point method, using an

Table 2. Average basal cover on the Havre range site, and the average number of single-stalked species in each 1-ft² plot on the site, 1964 to 1966.

Species	0 N		33 lb N/acre		67 lb N/acre		100 lb N/acre	
	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²
Western wheatgrass	26.48a[1]	84.84a	28.76b	90.40bc	38.82ab	103.41a	38.63a	114.19bc
Plains reedgrass	5.80	10.05	4.71	7.80	5.66	7.84	4.16	8.19
Green needlegrass	17.54		25.43		23.38		19.44	
Needle-and-thread	2.18		1.73		1.32		0.43	
Dwarf sagebrush	37.06a	1.58	31.32b	1.52	21.91a	1.61	31.55b	2.33
White sage	0.00	0.03	0.21	0.19	0.59	0.05	0.00	0.04
Wolfberry	7.51	0.31	2.43	0.73	3.90	0.34	0.26	0.41
Scarlet globemallow	0.34	0.49	0.00	0.58	0.15	0.11	0.12	0.31
White prairie aster	0.14	0.85	0.69	0.87	1.47	1.79	0.43	1.19
Yarrow	0.20	0.59	0.21	0.30	0.37	0.18	0.19	0.09
Total of site	40.15	99.63a	39.33	102.68ab	38.22	115.85a	37.47	127.00a

[1]Means within a species and treatments are significantly different at the 0.05 level only when designated with the same letter superscript.

Table 3. Average basal cover on the Rhodes range site, and the average number of single-stalked species in each 1-ft² plot on the site, 1964 to 1966.

Species	0 N		33 lb N/acre		67 lb N/acre		100 lb N/acre	
	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²
Western wheatgrass	3.78a[1]	24.23	4.33b	20.67	6.31a	29.58	5.70b	33.25
Sandberg bluegrass	6.88b		7.22a		4.24a		7.14b	
Blue grama	84.71		83.58		85.03		81.69	
Needleleaf sedge	1.08		1.81		1.64		1.54	
Fringed sage	0.05	0.69	0.05	0.15	0.05	0.27	0.00	0.06
Brittle prickly pear	0.83	1.59	0.68	1.44	1.30	1.00	1.16	4.40
Prairie plantain	0.00	0.22	0.00	0.13	0.00	0.20	0.00	0.05
Bracted plantain	0.45	14.48	0.60	15.87	0.13	10.57	0.13	14.08
Plantago elongata	0.00	0.84	0.00	0.54	0.00	1.71	0.00	3.19
Rough pennyroyal	0.13	1.69	0.05	3.29	0.00	1.99	0.05	1.76
Salt sage	0.00	0.08	0.05	0.08	0.00	0.07	0.00	0.09
Yarrow	0.00	0.36	0.00	0.07	0.00	0.85	0.00	0.03
Kochia	0.00	0.16	0.00	0.60	0.00	0.69	0.05	0.39
Total of site	39.70	45.72ab	36.97	44.84ab	38.48	48.85a	38.93	60.77ab

[1]Means within a species and treatments are significantly different at the 0.05 level only when designated with the same letter superscript.

inclined frame with 10 points spaced at 2-inch intervals. The point-frame was placed at 10-foot intervals in 5 lines of 10 sets. The 5 lines were placed 5 feet apart. A total of 2000 points was taken in each treatment, on each site, every year of the study. An additional sampling procedure was carried out using a 1-ft² steel frame for counting all single-stalked plants within each frame in order to more adequately sample the single-stalked species of the sites. Counts were made of all single-stalked species in 10, 1-ft² areas for each plot, treatment, and site each year of the study.

Results and Discussion

Basal Cover and Density

Total basal cover of the plant species on the Vebar site showed a decrease at the end of the 3-year period at all rates of nitrogen applications (Table 1). Data were taken each year and are presented as averages over the 3-year period (1964, 1965, and 1966) in all sites. The lower total basal

Table 4. Average basal cover on the Manning range site, and the average number of single-stalked species in each 1-ft² plot on the site, 1964 to 1966.

Species	0 N		33 lb N/acre		67 lb N/acre		100 lb N/acre	
	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²	Basal cover (%)	Average plants/ft²
Western wheatgrass	0.74a[1]	3.68a	0.93b	3.93a	0.91a	5.44a	1.09b	5.39a
Plains reedgrass	0.33	1.60	0.11	0.96	0.00	1.45	0.10	0.46
Needle-and-thread	2.79a		1.98ab		2.10a		2.02b	
Blue grama	78.39		75.64		76.47		73.12	
Threadleaf sedge	13.19		16.43		14.68		17.38	
Needleleaf sedge	2.50		2.91		3.10		2.30	
Fringed sage	1.45a	12.12ab	1.57b	12.43b	1.90a	18.04a	3.33b	20.77ab
Skeleton weed	0.11	0.30	0.04	0.35	0.06	0.10	0.04	0.20
Green sage	0.00	0.23	0.00	0.07	0.04	0.12	0.06	0.08
Rough pennyroyal	0.00	0.83	0.00	1.68	0.06	1.19	0.00	1.65
Scarlet globemallow	0.07	2.33ab	0.15	1.49ab	0.26	1.41abc	0.06	1.64ab
Gaura		1.10		0.66		0.60		0.69
Total of site	44.88a	24.06a	46.38ab	23.96b	46.20a	30.31b	48.62a	32.44a

[1]Means within a species and treatments are significantly different at the 0.05 level only when designated with the same letter superscript.

cover resulted mainly from a reduction in blue grama (*Bouteloua gracilis*). Slight decreases in cover were noted in needle-and-thread (*Stipa comata*). Plains reedgrass (*Calamagrostis montanensis*) and threadleaf sedge (*Carex filifolia*) showed slight increases in basal cover with increased rates of applied nitrogen. Prairie sandreed (*Calamovilfa longifolia*) showed an increase in basal cover with increased rates of nitrogen to the 67-pound rate but decreased at the 100-pound nitrogen rate. Differences in total basal cover were statistically significant at the end of the 3-year period between the check plots and the 67 and 100-pound-nitrogen treatments. The magnitude of the differences do not, however, appear to be of practical significance. Western wheatgrass (*Agropyron smithii*), needle-and-thread, prairie Junegrass (*Koeleria cristata*), needleleaf sedge (*Carex eleocharis*) and Pennsylvania sedge (*Carex pennsylvanica*) were well represented on the site although no significant differences in basal cover due to fertilization were observed.

At the conclusion of the 3-year study, analysis of the annual ft^2 count data indicated an increase in plant density of prairie sandreed on the Vebar site with increased rates of nitrogen to the 100-pound nitrogen rate (Table 1). A substantial increase in density also was observed in plains reedgrass, but only to the 67-pound nitrogen rate.

The forb species were well represented on the Vebar site. The dominant perennial forb of the site was white sage (*Artemisia ludoviciana*) which did not show a significant increase in plant density between treatments at the end of the 3-year period, although the individual plants increased appreciably in size in the presence of the nitrogen. Other important forbs of the site were skeleton weed (*Lygodesmia juncea*), birdsfoot trefoil (*Lotus americanus*), and rough pennyroyal (*Hedeoma hispida*).

The vegetation of the Havre site consisted mainly of single-stalked grasses and forb species The data indicated a slight decrease in basal cover at all rates of applied nitrogen at the end of the study period. Western wheatgrass and green needlegrass (*Stipa viridula*) both increased in cover while needle-and-thread and plains reedgrass showed decreases. Reductions in total basal cover also were found in the dominant shrub of the site, dwarf sagebrush (*Artemisia cana*) and wolfberry (*Symphoricarpos occidentalis*). Composition changes were not great at the end of the 3-year period, and the change in total basal cover was not statistically significant. Common forbs of the site were scarlet globemallow (*Sphaeralcea coccinea*), white prairie aster (*Aster ericoides*), and yarrow (*Achillea lanulosa*).

Data for the Havre site showed an increase in total plant density with increased rate of nitrogen at the end of the study period. Western wheatgrass, the dominant and single-stalked species of the site, showed a significant density increase at all rates of nitrogen fertilization as did the total species density of the site at the end of the 3-year study period (Table 2). Dwarf sagebrush indicated a moderate increase in density only at the higher rates of nitrogen. Forb species showed tremendously large variations with respect to the different rates of fertilization.

Total basal cover on the Rhodes site showed a slight annual increase under all treatments at the end of the 3-year study period. Western wheatgrass showed increases in basal cover with increased rates of fertilization each year of the study period. Responses by other species on the site were quite erratic and significant differences are shown in Table 3. Western wheatgrass showed a significant increase in basal cover only at the 67-pound nitrogen treatment, while Sandberg bluegrass (*Poa secunda*) showed significant increases at the 33 and the 67-pound nitrogen treatments.

Single-stalked species, chiefly western wheatgrass, increased with increased rates of fertilization over the 3-year period. Total species density was significant between the check plots and the 100-pound nitrogen treatment at the end of the 3-year study period (Table 3). Brittle prickly pear (*Opuntia fragilis*) was the only forb of the site which showed an apparent steady increase in density with higher rates of applied nitrogen. Other forb species of the site were fringed sage (*Artemisia frigida*), prairie plantain (*Plantago purshii*), bracted plantain (*Plantago spinulosa*), *Plantago elongata*, rough pennyroyal, salt sage (*Atriplex nuttallii*), yarrow, and fireweed (*Kochia scoparius*).

Basal cover increased on the Manning site with increased rates of fertilization each year of the 3-year study period. Western wheatgrass showed a moderate increase while threadleaf sedge showed an appreciable increase in total cover at all rates of nitrogen application. Needle-and-thread showed a decrease in basal cover while blue grama appeared not to be affected on this site. Wide differences in response to nitrogen by various forbs were observed at the different rates of fertilization (Table 4). In general, the largest increase in basal cover of the forbs due to fertilization occurred in fringed sage, which increased each year of the study. Western wheatgrass was the most important single-stalked grass species on this site. There was a significant increase in density of this species and in total plant density at all rates of fertilization during the 3-year study period.

The most important and consistent response by the forbs of the site was observed with fringed sage. Plant density of this species increased significantly each year with increased rates of nitrogen.

Table 5. Three-year average production (lb/acre, oven-dry) on four native grass range sites fertilized with nitrogen at three different rates, 1964 to 1966 seasons.

Site	Treatment	Mid grasses	Tall grasses	Short grasses	Total grasses	Perennial forbs	Annual forbs	Total yields
Havre	0 lbs N	2050	-	9	2059	350	0.7	2410
	33 lbs N	2329	-	4	2333	212	3	2548
	67 lbs N	2942	-	6	2948*	312	1	3261*
	100 lbs N	3046*	-	48	3094*	151	2	3247*
Vebar	0 lbs N	258	46	958	1262	242	99	1603
	33 lbs N	232	58	1324	1614	411	48	2073
	67 lbs N	402*	17	1758	2177*	645*	15	2837*
	100 lbs N	487*	113	1708	2308*	625*	20	2953*
Manning	0 lbs N	265	-	995	1260	321	5	1586
	33 lbs N	260	-	1130	1390	509	6	1905
	67 lbs N	343	-	1572*	1915*	880*	17	2812*
	100 lbs N	411*	-	1673*	2084*	1225*	16	3325*
Rhodes	0 lbs N	309	-	433	742	34	62	838
	33 lbs N	357	-	488	845	29	109	983
	67 lbs N	488	-	606*	1094*	143*	46	1283*
	100 lbs N	500	-	706*	1206*	42	154	1402*

*Means differ significantly from check plot means at the 0.05 level as determined by Duncan's Multiple Range Test.

Profuse branching of individual plants also was observed at the high rates of fertilization. No consistent increases in other forbs were noted at the different rates of fertilization.

Yields

Increases in total dry-matter yields were generally observed from all rates of nitrogen fertilization on all sites studied (Table 5). The 33 and 67-pound nitrogen treatments resulted in the greatest increases in yield per increment of added nitrogen. The 100-pound nitrogen rate did not greatly increase the yields beyond those obtained from the 67-pound nitrogen treatment. On the Manning site, however, the forb component did show an appreciable increase in yield over the check plots at the 100-pound nitrogen rate.

The Havre site was the highest yielding of the four sites studied. The largest increases in yield due to the applied nitrogen were observed at the 67-pound nitrogen treatment, being slightly higher at this level than at the 100-pound nitrogen treatment. Only a very small increase was observed above the yield from check plots at the 33-pound nitrogen treatment. Statistically significant increases in yields over check plots were noted only at the 67 and 100-pound nitrogen treatments. Forbs did not show an appreciable increase in production at any rate of fertilization during the 3-year study period. Data on the botanical composition of this site show that the yield consisted mainly of midgrasses with only nominal amounts of shortgrasses at any rate of fertilization (Table 6). It was apparent at the end of the 3-year study period that the percentage of midgrasses had increased appreciably, while the percent production of forbs had shown a general decrease.

Three-year average yield data for the Vebar range site are given in Table 5. Statistically significant increases in yield over check plots were generally observed at the 67 and 100-pound nitrogen treatments. The yield of the forb component of the vegetation increased substantially on the Vebar site at the 33 and 67-pound nitrogen treatments, but showed no further increase at the 100-pound nitrogen rate. Annual forbs did not contribute appreciably to the total production at any rate of fertilization on this range site. The percent composition of the yields, by midgrass, shortgrass, and forb components, did not show any definite trend at the different rates of nitrogen fertilization over the 3-year study period (Table 6).

The Rhodes site was the lowest producing of the four range sites studied (Table 5). Increases in yield were observed with each increased rate of applied nitrogen although total yields from the treatments were extremely low when compared to similar nitrogen applications on other sites. Significant increases in the shortgrass component were observed at the end of the study period between

Table 6. Three-year average composition (%) of yields of native grass range sites fertilized with nitrogen at three different rates, 1964 to 1966 seasons.

Site	Treatment	Mid grasses	Tall grasses	Short grasses	Perennial forbs	Annual forbs
Havre	0 lbs N	85.0	-	0.4	14.5	T
	33 lbs N	91.4	-	0.2	8.3	0.1
	67 lbs N	90.2	-	0.2	9.6	T
	100 lbs N	93.8	-	1.4	4.7	0.1
Vebar	0 lbs N	16.1	2.9	59.7	15.1	6.2
	33 lbs N	11.2	2.8	63.9	19.8	2.3
	67 lbs N	14.2	0.6	62.0	22.7	0.5
	100 lbs N	16.5	3.8	57.8	21.2	0.7
Manning	0 lbs N	16.7	-	62.8	20.2	0.3
	33 lbs N	13.6	-	59.4	26.7	0.3
	67 lbs N	12.2	-	55.9	31.3	0.6
	100 lbs N	12.4	-	50.3	36.8	0.5
Rhodes	0 lbs N	36.8	-	51.7	4.1	7.4
	33 lbs N	36.3	-	49.7	2.9	11.1
	67 lbs N	38.0	-	47.3	11.1	3.6
	100 lbs N	35.7	-	50.3	3.0	11.0

check plots and 67 and 100-pound nitrogen treatments, mainly in the shortgrass component. A significant increase in the forb production was observed at the 67-pound nitrogen treatment. The greatest increase in yield per increment of nitrogen was at the 67-pound nitrogen treatment.

Conclusions

Variations in the degree of response by individual plant species with respect to level of treatment and site became apparent during this study. Certain species, such as western wheatgrass, showed continued increase in basal cover and density with increased rates of applied introgen on all range sites. Blue grama, in general, decreased in basal cover with increased rates of nitrogen on the sites where it was the dominant plant cover. Still other grass and sedge species increased or decreased in cover and density only at certain levels of fertilization, indicating that optimum amounts of applied nitrogen varied widely for any given species.

A change in botanical composition was becoming apparent on the Vebar and Manning sites at the end of the 3-year study. The grasses showing the greatest increases in basal cover and density on both of these sites were western wheatgrass and plains reedgrass. Although both species were present on both sites, plains reedgrass was increasing more rapidly on the Vebar site while western wheatgrass was increasing faster on the Manning site. Threadleaf sedge showed an increase in basal cover while needle-and-thread appeared to decrease on both sites with increased rates of fertilization. Forb species, mainly white sage on the Vebar and fringed sage on the Manning sites, showed definite responses to the presence of the applied nitrogen, generally increasing with each added increment of nitrogen. In addition to the increase in density of the species, the plants showed definite tendencies toward profuse branching, which greatly increased the area of a single plant. The Havre and Rhodes sites did show some changes in basal cover and plant densities, although the composition of the vegetation of the site had not changed appreciably during this period.

The probability of increasing the production of a given range site is closely associated with the natural productive capacity of the site. The Havre site was considered to be a high producing site and the highest added increase in production with nitrogen fertilizer was obtained at the 67-pound nitrogen treatment on this site. The Vebar and Manning sites were considered to be less productive, although substantial increases in yield to the 67-pound nitrogen treatment were realized. The increases in total production were, however, much greater than the increases in grass alone due to the increase in the forb component, mainly the sages. The increase in the sage species does not represent an increase in actual forage production, as they are largely non-palatable to livestock.

The Rhodes site was the lowest producing of the sites, although increases in production were observed at all rates of nitrogen fertilization. The perennial forb component also increased on this site but only to the 67-pound nitrogen treatment. Annual forbs were present in large numbers during the 1965 season, especially at the high levels of nitrogen application.

It became apparent from the data that caution and good judgment must be exercised when fertilizing native rangelands in western North Dakota. Nitrogen fertilizer may be a valuable tool in range improvement when the factors of plant and soil response to the applied nitrogen are known and applied on a range site basis.

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Effect of Fertilizer on Pinegrass in Southern British Columbia[1]

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Highlight

Response to fertilizers of pinegrass dominated vegetation on Gray Wooded soils was tested in pot and field trials. Ammonium nitrate applied at 100 and 200 kg N/ha increased the yield, nutritive value, and palatability of pinegrass; this increase was accentuated when S in the form of gypsum was applied with N. Response to P, K, and a solution of micro nutrients was negligible. Most of the applied S and all of the applied N were depleted from the upper root zone by the end of the second growing season. At the higher rates of application, only 14% of the N was recovered by pinegrass. This value was even smaller at the lower rates of application. Sulfur considerably improved the ability of pinegrass to respond to N fertilization and 23% of the N was recovered when 100 Kg S/ha was applied with the N. Soils were analyzed for NO_3-N, SO_4-S, field moisture and organic C. These two elements and organic C were found to be mainly concentrated near the soil surface, which experienced the greatest fluctuation in moisture content.

Pinegrass (*Calamagrostis rubescens* Buckl.) is the principal species for summer grazing over 15 million acres of forest land in southern interior British Columbia. In spite of extensive utilization of pinegrass, its response to fertilizer application has not been studied.

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Grazing studies on pinegrass-dominated range have been made in the Douglas-fir (*Pseudotsuga menziesii* (Merb.) Franco) zone of interior British Columbia (McLean, 1967). A decline in daily gain of cattle, as the season advanced, was noted. Feed quality rather than feed quantity influenced these rates of gain since ample feed was available. This finding would probably hold true for most pinegrass ranges since the grass drops rapidly in its nutritive value, is fairly palatable in June, becomes very unacceptable by August, and is seldom utilized completely.

Fertilizer usage affects all three factors on which the productivity of animals on grasslands depend; yield, palatability and nutritive value (Raymond and Spedding, 1965). Fertilization has been widely tested as a way to increase herbage production of western rangelands (Black, 1968; Johnston, Smith et al., 1968; Rauzi et al., 1968; Smith et al., 1968). The improvement of palatability and nutritive value of grasses through application of fertilizers has also been reported (Cook, 1965; Johnston, Bezeau et al., 1968; Reid and Jung, 1965; Reid et al., 1966).

The object of the present study was to determine to what extent fertilizers can improve the palatability, nutritive value, and, of lesser importance, yield of pinegrass.

Study Area and Procedures

Areas under study were located in the Douglas-fir zone of southern British Columbia, which has been described by Tisdale and McLean (1957). Pinegrass is the dominant herbaceous species and occupies about 80% of the ground area.

Soils of the Douglas-fir/pinegrass communities are mainly Gray Wooded (Dawson and Kelly, 1965); in the study area they were found to have thin L-H and Ah (A1) horizons, each less than 5-cm thick; prominent Ae (A2) horizons up to 18-cm thick, and Bt (B2t) horizons about 10-cm thick. Such Gray Wooded soils in southern British Columbia have been found to be particularly low in nitrogen (N) (Dawson and Kelly, 1965).

Three experiments were conducted; two in the field and one in a growth room.

Experiment I.—To determine the response of pinegrass to N, ammonium nitrate (33-0-0) was applied at three rates, 0, 55, and 165 kg N/ha (subtract 10% from kg for lbs/acre), to six replicates of a pinegrass range in a randomized complete block design on May 6, 1966. The plots, 2 × 10 m, were located about 14 miles northwest of Kamloops, in an open site within a mixed stand of lodgepole pine (*Pinus contorta* Dougl) and Douglas-fir at an elevation of 1200 m (3900 ft). Following the fertilizer application, a 1.2-m exclosure cage was placed at random on each plot. Yield and utilization by cattle, which grazed the area from early June to mid-September, was determined by clipping 1-m^2 quadrats from under the exclosure and at random on the grazed portion of the plots; difference in the amount of forage harvested outside and beneath the cage gave an assessment of palatability. The plots were clipped on June 24, 1966, September 22, 1966, July 12, 1967, and July 24, 1968. The forage was separated into grass, shrubs and forbs, oven dried at 90 C, and weighed. The grass was ground through a 60-mesh screen on a Wiley mill and quality was assessed by the following chemical analyses; crude protein by the Kjeldahl method, acid detergent fiber (ADF) and lignin (Van Soest, 1963), silica (Buckner et al., 1967), and soluble carbohydrates (Barnett, 1954). Soil was sampled from these plots to a depth of 35 cm on September 24, 1967, ground to pass a 2-mm sieve, and analyzed for nitrate N by the phenoldisulfonic acid method (Chapman and Pratt, 1961).

Weather records were available from a station maintained in the vicinity of the plots. The summers of 1966 and 1968 were wetter than usual, while the summer of 1967 was particularly dry.

Experiment II.—To confirm field results obtained with N in Experiment I, and to test whether pinegrass would respond to other elements, a potted fertilizer trial was made. Pinegrass sods were dug to a depth of approximately 25 cm and placed in 4.6-liter black plastic freezer cartons. The filled pots were weighed and soil was either added or removed, so that each pot contained approximately the same amount. The grass was clipped at approximately 2 cm, fertilized by surface application, and grown in a growth room at 20 C and 1000 ft-c with lights timed to run 16 hours on and 8 hours off. Nitrogen, Phosphorus (P), Potassium (K), and S were used at three rates 0, 100, and 200 kg/ha (N_0 N_1 N_2, P_0 P_1 P_2, etc.) Long Ashton's solution of micronutrients was applied at a rate of 75 l/ha (1 gal/acre) (Hewitt, 1966). The elements were applied in different combinations (Table 2) giving a total of 21 treatments to six replicates in a randomized complete block design. Nitrogen, P, and K were applied in the form of commercial fertilizer; 33-0-0 ammonium nitrate, 0-45-0 triple superphosphate, and 0-0-60 potassium chloride. Sulfur was applied in the form of 1 N H_2SO_4.

The first cut was made 30 days after fertilization followed by two more cuts at three-week intervals. Yield was measured as the total oven dry weight for the three cuts. The grass was not analyzed chemically.

Experiment III.—On the basis of results obtained from the growth room fertilizer trial, a 3 × 3 factorial field experiment was designed. Two sites were chosen; one in an aspen (*Populus tremuloides* Michx) stand 14 miles northwest of Kamloops, the other in a stand of lodgepole pine 40 miles southeast of Williams Lake. Ammonium nitrate and gypsum were applied at three rates; 0, 100, and 200 kg of the element/ha, (N_0 N_1, N_2 and S_0 S_1 S_2) individually and in combination to four replicates at each site, in a randomized complete block design. Fertilizer was applied to 5 × 5 m plots on May 4, 1967, and an exclosure cage was placed on each plot. Meter square plots were clipped from under the exclosure and on the grazed portion of the plots on July 12, 1967, and July 26, 1968. The samples were separated and weighed as in Experiment I. The grass was analyzed for crude protein, ADF, lignin, silica, and nitrate N (Lawrence et al., 1968). Soil was sampled to a depth of 35 cm on September 22, 1967, and in 1968 at one-month intervals, starting the first of May and ending on the first of September. The samples were analyzed for nitrate N, sulfate S (Bradsley and Lancaster, 1960) organic carbon (Walkley and Black, 1934) and moisture by the gravimetric method.

Results

Experiment I.—Palatability and yield of pinegrass were increased significantly (5% level) in the summer following spring application of 165 kg N/ha (Fig. 1). The crude protein content of forage from the nitrogen fertilized plots was higher, while

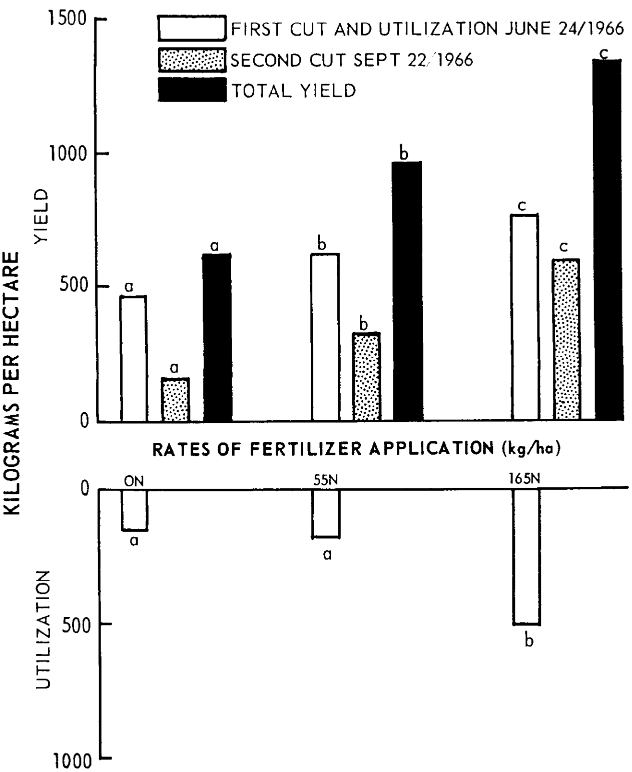

FIG. 1. Average yield (kg/ha, oven-dry), regrowth after clipping, and utilization of pinegrass which was fertilized with amonium nitrate in the spring and sampled in the summer of 1966. Same letters with columns of same pattern indicate no significant difference at .05 level by Duncan's multiple range test.

Table 1. Chemical composition[1] (% dry matter) of pinegrass fertilized in the spring and sampled in the summer of 1966.

N Applied kg/ha	Crude protein	Silica	Soluble carbohydrates	ADF	Lignin
0	9.7 a[1]	9.9 a	15.9 a	37.9 a	3.1 a
55	13.4 b	9.7 a	14.5 b	35.8 a	3.2 a
165	15.8 c	8.4 b	12.4 c	33.1 a	3.2 a

[1] Same letters within a column indicate no significant difference between the values at .05 level by Duncan's multiple range test.

the soluble carbohydrate and silica content were lower than from the non-fertilized plots. Fertilization did not affect the ADF or lignin content (Table 1). In 1967 there was a significant residual effect on yield only at the 165 kg N/ha application. This residual fertilizer did not improve palatability or have any effect on the chemical composition of the grass. By September 1967 the nitrate content of soil from the fertilized plots was the same as that of soil from the non-fertilized plots, and by 1968 no carry-over effects of the N could be measured.

Experiment II.—Nitrogen increased the yield of pinegrass consistently while K and micronutrients had no measurable effect (Table 2). Sulfur in combination with N alone or with other elements increased yields in most instances but this increase was statistically significant only at the lower level of application and in combination with NPK and micronutrients. Sulfur, at the higher rate of application and with N at 100 kg/ha, had a slight herbicidal effect. This effect was not noticed when S was applied alone. Phosphorus at 200 kg/ha in combination with NKS and micronutrients, increased the yield significantly; this increase, however, was not detected at the lower rate of application.

Table 2. Average yield[1] (gm/pot, oven-dry) of potted pinegrass treated with various fertilizer applications.

Treatment	Weight
N_0 P_0 K_0 S_0 M_0	3.9 ab[1]
N_1 P_1 K_1 S_1 M	8.3 efg
N_0 P_1 K_1 S_1 M	2.6 a
N_1 P_0 K_1 S_1 M	7.1 cdef
N_1 P_1 K_0 S_1 M	7.0 cdef
N_1 P_1 K_1 S_0 M	5.2 abcd
N_1 P_1 K_1 S_1 M_0	6.3 bcde
N_2 P_2 K_2 S_2 M	10.1 g
N_0 P_2 K_2 S_2 M	3.9 ab
N_2 P_0 K_2 S_2 M	7.8 def
N_2 P_2 K_0 S_2 M	9.1 fg
N_2 P_2 K_2 S_0 M	8.6 efg
N_2 P_2 K_2 S_2 M_0	8.6 efg
N_1 S_0	6.3 bcde
N_2 S_0	8.7 efg
N_0 S_1	4.2 ab
N_0 S_2	4.8 abc
N_1 S_1	6.7 cdef
N_1 S_2	5.8 bcde
N_2 S_1	9.2 fg
N_2 S_2	10.8 g

[1] Yields having a letter in common are not significantly different at the .05 level by the Duncan's multiple range test.

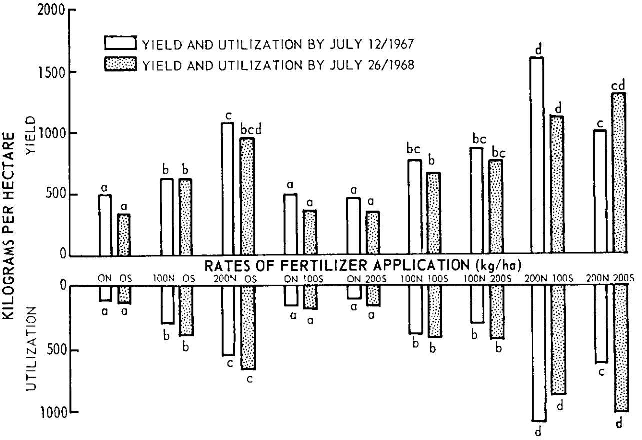

FIG. 2. Average yield (kg/ha, oven-dry) and utilization of pinegrass which was fertilized in the spring of 1967 and sampled in the summers of 1967 and 1968. Same letters with columns of same shading indicate no significant difference at .05 level by Duncan's multiple range test.

Experiment III.—In spite of a very dry summer, (total precipitation May 1 to September 30, 11 cm; 7-year average is 19 cm) there was a marked response in the first year to the fertilizer application. Nitrogen, alone and with S, significantly increased the yield and palatability of pinegrass (Fig. 2). Sulfur alone did not have a significant effect either on the yield or palatability, however, there was a significant N × S interaction. There was a highly significant difference (1% level) in both yield and palatability between N_2S_1 but not N_2S_2 and N_2. Regrowth after clipping was insignificant both years.

The amount of shrubs and forbs growing on the plots was highly variable and did not show any consistent response to the fertilizer application. The forbs, which were mainly leguminous, tended to respond more to S than to N and their palatability was improved by both elements. The shrubs were hardly grazed at all, and showed some response to both N and S, the differences, however, were non-significant. Pinegrass in all cases dominated the vegetation.

The crude protein content of pinegrass was increased significantly by the application of N, but not of S (Table 3). However, both rates of S, in combination with N, increased the crude protein significantly over that of N alone. The nitrate content was influenced by the amount of N applied and not by S and was well below levels considered toxic to cattle (Lawrence et al., 1968). The silica concentration of the plant was depressed by N and

Table 3. Chemical composition[1] (% dry matter) of pinegrass which was fertilized in the spring of 1967 and sampled in the summers of 1967 and 1968.

Fertilizer kg/ha	1967					1968	
	Crude Protein	Silica	ADF	Lignin	Nitrate N	Crude Protein	Silica
0 N 0 S	8.5 a[1]	12.5 ab	42.0 a	7.8 a	114 ab	8.8 ab	11.3 ab
100 N 0 S	10.3 bc	10.4 cd	40.3 a	7.5 a	128 ab	9.3 abc	11.3 ab
200 N 0 S	14.3 e	9.4 de	38.4 a	6.5 a	820 c	10.3 d	11.1 ab
0 N 100 S	8.8 ab	11.2 bc	42.6 a	6.3 a	75 a	8.8 a	11.9 a
0 N 200 S	7.8 a	12.9 a	44.5 a	6.3 a	78 a	8.8 a	12.0 a
100 N 100 S	11.7 cd	8.5 ef	37.5 a	6.8 a	162 ab	9.4 abcd	10.5 bc
100 N 200 S	12.0 d	8.6 ef	39.3 a	6.0 a	387 b	9.6 abcd	10.3 bc
200 N 100 S	15.6 ef	5.6 g	38.5 a	7.4 a	1342 d	10.1 bcd	9.3 cd
200 N 200 S	17.0 f	7.1 fg	35.7 a	5.4 a	868 c	10.2 cd	8.9 d

[1] Same letters within a column indicate no significant difference between the values at .05 level by Duncan's multiple range test.

generally was not affected by applications of S. The ADF and lignin content of pinegrass were not affected by the fertilizers.

In 1968 the highest soil moisture was recorded in early June and decreased rapidly, especially in the surface horizon, reaching a low by early August (Fig. 3). The moisture content started increasing again in September. Judging from rainfall data, this would appear to be a fairly typical pattern of soil water distribution in the upper 35 cm.

The applied N remained in the surface 10 cm, and most of the nitrates were absorbed and/or lost during the growing season following application. There was also considerable N loss during the winter (Fig. 4) and by the end of the second summer no residual effect from the applied ammonium nitrate could be detected.

The applied S was not lost from the soils as rapidly as the applied N (Fig. 5) and by the end of the second growing season residual S could still be detected.

Like N, most of the applied S was found in the surface horizons, which also were highest in organic carbon (C) content (Fig. 6).

Discussion

Results of the experiments confirm earlier findings (Dawson and Kelly, 1965) that Gray Wooded soils of interior British Columbia are particularly low in N, since yield of pinegrass was increased considerably through the application of ammonium nitrate. The residual effect of the N depended on the amount of precipitation during the year of application.

Soil analyses revealed an N : S ratio lower than 8 : 1, which has been found to be remarkably constant in soils throughout the world (Walker, 1968). Under normal growing conditions, therefore, Gray Wooded soils could be expected to supply adequate S for plant growth, which was confirmed by the lack of response of pinegrass to application of gypsum alone. However, when ammonium nitrate was applied the ratio of N : S was increased considerably, creating an S deficiency, and a marked response to S was noted with applications of N.

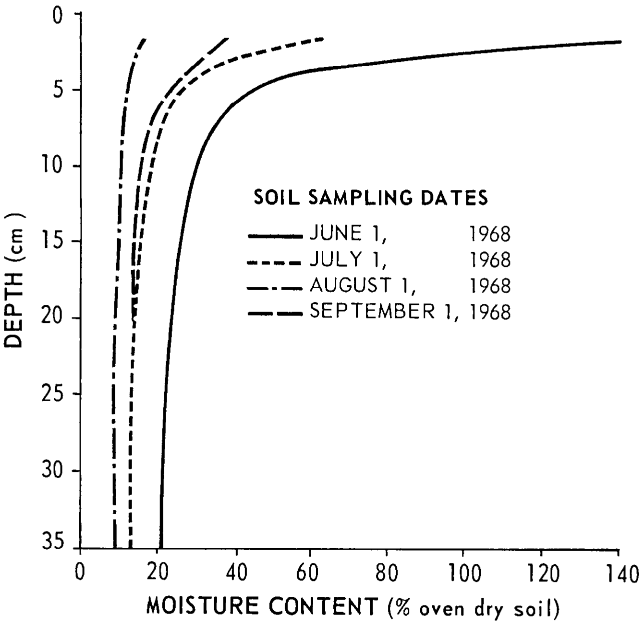

FIG. 3. Vertical distribution of soil moisture measured at monthly intervals from May to September 1968.

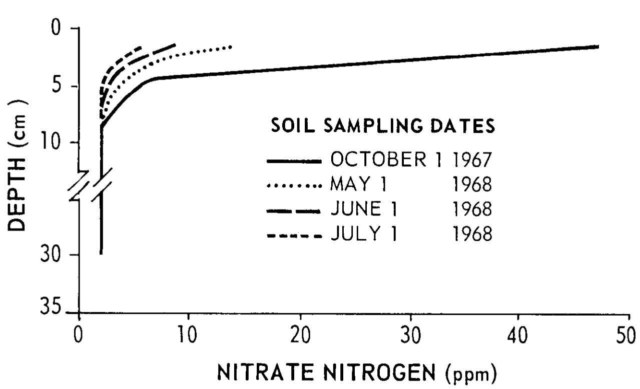

FIG. 4. Vertical distribution of soil nitrate nitrogen following an application of 200 kg N/ha in the spring of 1967.

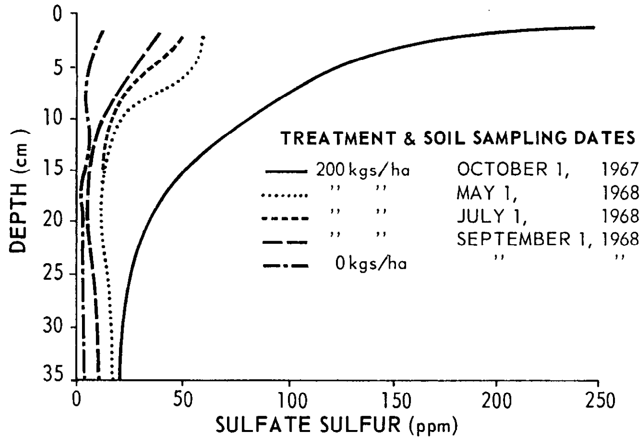

FIG. 5. Vertical distribution of soil sulfate sulfur following sulfur fertilizer treatments in the spring of 1967.

In light of the 8 : 1 ratio the rates of S used in the present study were higher than would normally be considered necessary for growth and protein formation, and the response of pinegrass to lower levels of S in combination with N remains to be tested. Furthermore, these heavy rates would be unjustifiable since a large amount of the applied S was lost especially during the winter; losses of S, however, were not as great at N.

Only 14% of the N, applied at the heavier rates, was recovered by pinegrass during the two growing seasons. At lower rates of application the recovery values were even smaller. In the experimental areas pinegrass constituted approximately 80% of the herbaceous vegetation, therefore, only about 17.5% or less of the N was recovered by the herbage (assuming the N content of the forbs to be same as of pinegrass). Presumably some of the N was absorbed by shrubs and trees, while appreciable quantities were probably lost. Various routes of soil N loss have been proposed but it is apparent in the literature that the mechanisms involved are incompletely understood. This is particularly true with regard to non-enzymatic losses in soils such as the Gray Wooded, of slight or moderate acidity (Wullstein and Gilmour, 1964).

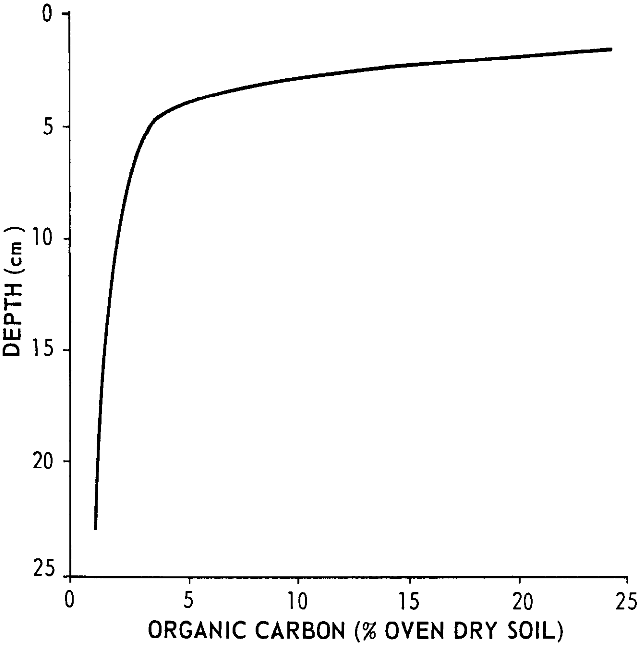

FIG. 6. Vertical distribution of soil organic carbon.

When S at a 100 kg/ha was applied with N at either rate, 23% of the applied N was recovered by pinegrass. The added S, therefore, considerably improved the ability of pinegrass to respond to N fertilization.

Pinegrass failed to regrow when cut around the middle of July, by which time much of the water in surface horizons had been exhausted (Fig. 3). The applied nitrogenous fertilizer remained concentrated in this surface horizon, and without adequate moisture pinegrass would be unable to absorb the N, which is essential for growth. It appears, therefore, that this lack of regrowth is due to a combination of lack of moisture and a deficiency of a major plant nutrient in the subsoil.

Many workers have studied the relation between chemical composition of plants and their palatability and many conflicting results have been reported as to what components influence forage preference (Heady, 1964).

The improvement of palatability of grasses by the application of nitrogenous fertilizers has been observed (Ivins, 1955) and usually there is a high positive correlation between protein and animal preference. On the other hand, herbage high in sugars was also found to be very palatable (Kare and Halpern, 1961). Reid et al., (1967) reported that acceptability and the soluble carbohydrate content of orchardgrass declined with increasing levels of N fertilization. In this study it was found that ammonium nitrate increased the crude protein and decreased the soluble carbohydrate content while greatly improving the palatability of pinegrass. The crude protein content of unfertilized pinegrass normally drops toward the end of June to below the minimum required for active growth of calves (12%), for lactating cows (8.3%) by mid-August and for maintenance (7.3%) by early September (McLean et al., 1969). The crude protein content for a large part of the grazing season is therefore inadequate. In this respect, ammonium nitrate, as well as S in combination with the N, had a definite beneficial effect on the nutritive value of the grass.

There also seems to be considerable confusion regarding palatability and digestibility (Garner, 1963). Some consider there is a close correlation between these two, while others question it. Neither N nor S, in combination or alone, had an effect on the ADF or lignin content of pinegrass, in spite of improved palatability. Similar negligible effects of fertilizers on the digestibility and lignin content of forage plants have already been reported (Knox et al., 1958; Calder and McLeod, 1968).

Silica may affect both the palatability and digestibility of forage (Jones and Handreck, 1968). Like lignin, silica is an integral part of the matrix of plant cell walls, and may similarly reduce the accessibility of cell wall carbohydrates to attack by digestive microorganisms. This aspect has as yet received little attention.

There is substantial evidence that fertilizing with N causes a decrease in the concentration of silica in plants (Jones and Handreck, 1968) and this effect has been confirmed in the present study. Such a decrease in the silica content, which normally is extremely high in pinegrass, was associated with a parallel increase in palatability but not with a noticeable decrease in fiber.

The results of these trials tend to support some workers (Heady, 1964) who feel that there is no consistent correlation between the chemical composition of forage and its preference and suggest that possibly more significant than the amount of any chemical component is the combination of chemical compounds.

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The Piosphere: Sheep Track and Dung Patterns[1,2]

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Highlight

The basic ecological unit in arid areas under grazing animals is envisaged as a zone round a watering point and is termed the *piosphere* (from the Greek "pios" = to drink). A piosphere in which sheep tracks can be distinguished in aerial photographs has been investigated; length, direction and type of track are described; remarkable adherance of the tracks to the near radial (significant deviation of 2.5° to left) indicate navigational skill in sheep. Sheep forage but do not cut visible tracks between the radial tracks. Sheep density can be estimated from dung density since pellets of dung persist for long periods in the arid regions. It is suggested that understanding the piosphere will contribute to management in arid rangelands.

At present little is known about the long term (or even short term) effects of grazing on the vegetation in Australia's arid zone. 'Management' of the vegetation is quite empirical, based on the personal knowledge of the station (ranch) managers concerned, and alterations in the stock numbers probably follow observations on the condition of the animals.

It is clearly necessary that the effects of grazing on the vegetation should be investigated in detail, especially along the lines of inquiry pursued by Osborn, Wood and Paltridge (1932), who showed how the growth of saltbush (*Atriplex vesicarium*) in paddocks was determined by the location of the watering-points used by the grazing animals. In an arid zone, the animals forage outwards from a watering-point, to which they are obliged to return frequently for drink. Except in wet periods, when there is casual water and succulent herbage, this situation is different from that in non-arid regions, involving more dispersed, drier, more variable and less palatable forage, and much more walking for the animals, frequently under higher heat loads and generally harsher conditions. This leads to the development of a distinct ecological system, in which the interactions are determined by the existence of the water-point and by the capacity of the animals to forage away from the water-point. For convenience, the system is called in this paper the *piosphere* (from the Greek word 'pios' = to drink). It may be envisaged as a zone, but it is defined by the interactions, not by any spatial limits of area. It is a complex system, focussed at one extreme on the water-point and attenuating imperceptibly at the other. This paper reports a first investigation into the characteristics of the piosphere on a sheep station in South Australia. Data are presented describing the length, direction and type of tracks made around the water-hole and the density of dung deposited by the sheep. The view advanced is that what happens around one water-point may reflect principles that govern interactions around the thousands of similar water-points in Australia's arid zone and this may be important in management as well as understanding of vegetation in arid areas generally.

Reconnaissance

Low-level aerial reconnaissance was made of various tracts of pastoral lease in South Australia. Intricate patterns of sheep tracks occur and can be resolved clearly on enlargements of 5½ inch × 5½ inch vertical photographs taken at altitudes up to 4,500 feet with a hand held 6 inch focal length camera.

From the many examples observed an area of myall (*Acacia sowdenii*)—bluebush (*Kochia sedifolia*) vegetation was chosen for initial study. It was located on Lincoln Gap Station, west of Port Augusta, South Australia (137.5°E, 32.6°S). Several reasons governed this choice. Track patterns were sharply incised through a soil lichen crust of markedly different reflectivity, and hence were clearly resolvable in aerial photographs. The landscape was plane, and the vegetation relatively simple and uniform in both structure and floristic composition. Piosphere track patterns within the vegetation were less complicated than those found elsewhere, and were radial, uniform and precise. The history of grazing and management was known in fair detail.

Reference targets were placed, and a single run of photographs taken from 3,000 feet on July 23, 1965 as shown in figure 1. Enlargements to a scale 1 : 650 were assembled, without trigonometrical ground control. Figure 2 illustrates a small section of this assembly.

Inspection of photographs, together with ground traverses, permits the following reconnaissance summary of track features in this particular piosphere:

(1) In any sector, tracks are radial about the water-point but are perturbed, by the presence of obstacles to radial traverse, into a network of diverging and converging bowed segment.

(2) The resulting mesh relates to the number, size and disposition of bushes or obstacles, but since

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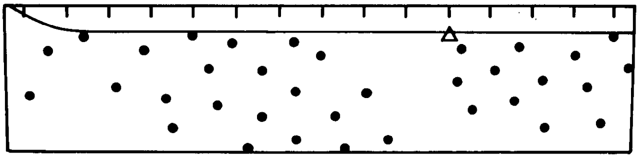

FIG. 1. Scale plan of the study area on Lincoln Gap Station, South Australia. The rectangle demarcates the area covered by the photograph assembly. The solid circles indicate the positions of samples; scale units = 200 yards; triangle represents watering-point.

this does not vary greatly from place to place in this piosphere, neither does the mesh. Almost every discrete obstacle to radial traverse (permitting passage on either side) is individually meshed by track, except where obstacle density is lowest.

(3) There is no tangential track development except at one end of the study area along a watercourse and ecotone into saltbush (*Atriplex vesicaria*) vegetation. Segments at appreciable angles to the radius bisect only an interstice of the continuous radial pattern, or circumvent the larger obstacles.

(4) The degree to which obstacles are meshed individually shows no marked attenuation from the water-point to 2,000 yards, although there do appear to be fewer obstacles further out from the water-point, and the tracks there are less well incised.

(5) Tracks are incised with sharp-edged precision through the soil lichen crust, which extends unpulverised into the apex of the interstice between converging / diverging tracks. Tracks range in width from about 2 feet to about 6 inches, but any particular segment is fairly constant in width. Tracks are incised up to 4 inches deep in places.

(6) Sheep dung is scattered over the interstices of the track network; hence two distinct patterns

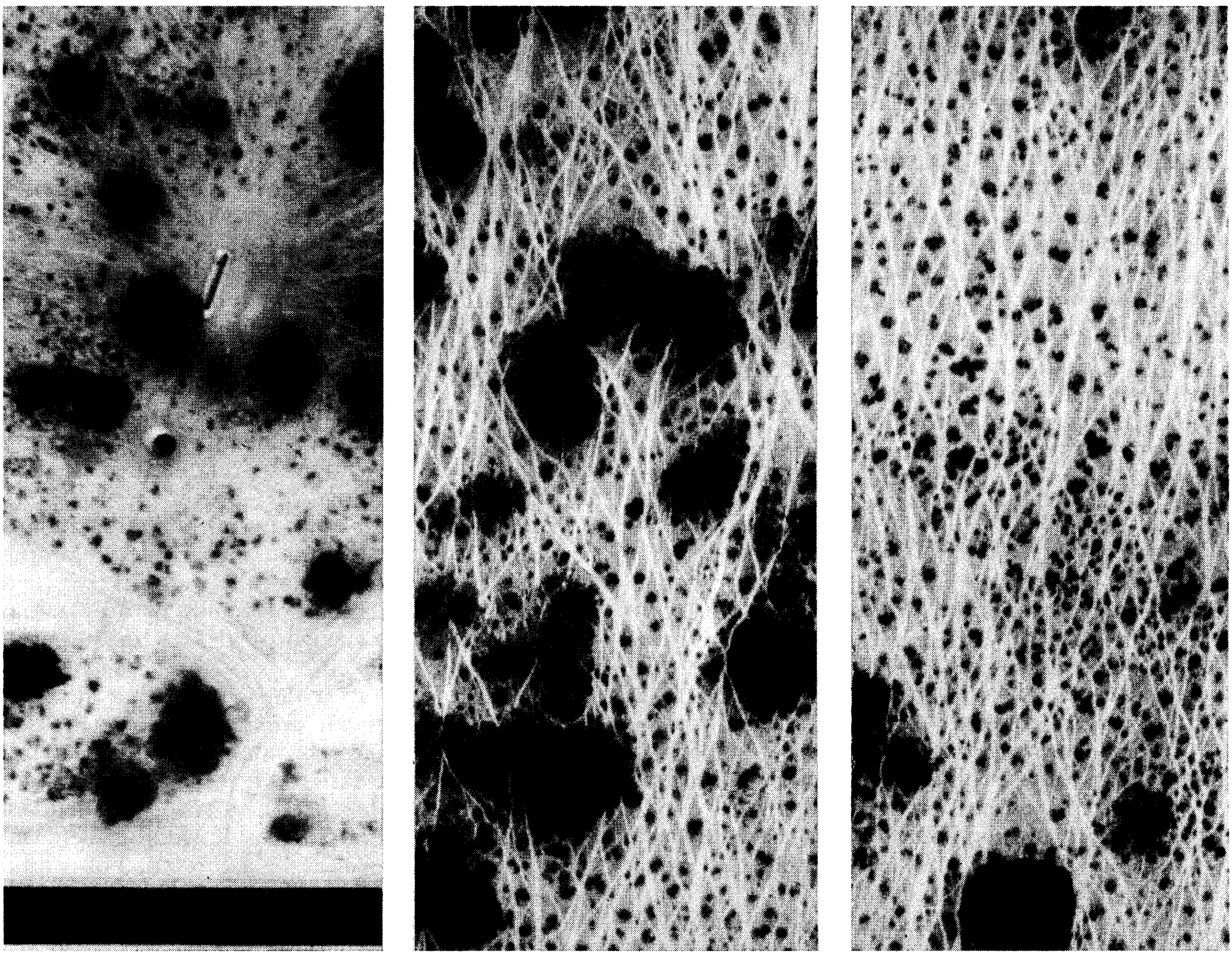

FIG. 2. Small sections of the aerial photograph assembly used to study track patterns in a sheep bluebush-myall piosphere on Lincoln Gap Station, South Australia. (Left) The tank and trough upon which the pattern is centered (The black strip is Highway 1 to Western Australia); (center) track patterns among myall with large canopy; and (right) bluebush with small canopy. Scale = 1 : 650.

Table 1. Track intensity, obstacle number, and interstice length in the Lincoln Gap piosphere: Summary of significant relationships.

Y	X	Relation	Probability
Track intensity (miles/mile²)	Distance from water (yards)	(1) $Y = 1083.91 - 0.28\ (X - 898.53)$	$P < 0.001$
Obstacle number/acre	Distance from water (yards)	(2) $Y = 196.88 - 0.10\ (X - 904.55)$	$P < 0.001$
Track intensity (miles/mile²)	Obstacle number per ¼ acre	(3) $Y = 1095.81 + 1.98\ (X - 193.66)$	$P < 0.001$
Length of interstice (1.2 × yards)	Distance from water (yards)	(4) $Y = 898.57 + 118.68\ (X - 9.76)$	$0.001 < P < 0.01$
Length of interstice (1.2 × yards)	Obstacle number per ¼ acre	(5) $Y = 196.88 - 26.21\ (X - 9.81)$	$P < 0.001$
Length of interstice (1.2 × yards)	Track intensity (miles/mile²)	(6) $Y = 1083.91 - 88.70\ (X - 9.75)$	$P < 0.001$

of walking behaviour must be postulated for sheep in this piosphere, (a) a track-cutting walking and (b) a walking on the interstices.

(7) The track-cutting pattern must involve strict repetitive adherence to prescribed routes as demonstrated by the sharp edges and narrow widths of tracks, and the preservation of abutting lichen crust. Tracks must be followed regularly, since they are deeply incised and maintained. Track-cutting involves point to point navigation, in the sense of maintaining the straightest course amongst thousands of essentially similar obstacles of which the few proximal ones set the visual horizon. The tracks are almost radial to the water-point, through 180° of arc in this piosphere.

(8) Walking on interstices involves none of the features of track-cutting. It cannot involve repetitive adherence to prescribed routes, or tracks would be cut. The sheep must change from tracks to walking on interstices, move tangentially on erratic courses, and resume walking on tracks for radial traverse.

Measurements

On the photograph assembly, concentric circles were drawn around the water-point to the scale equivalence of 100-yard radial intervals. Arbitrary radii were constructed from the water-point, distributed more or less evenly throughout the area, to intersect the concentric circles. Squares of scale equivalence to quarter-acre areas were inked on the photographs near points of intersection. From these, 35 were selected on clarity of track resolution, to represent conditions at 100-yard intervals up to a maximum of 2,000 yards from the water-point.

Optical projections enlarged 10-fold were charted on paper for tracks, obstacles and coordinates of location. Track lengths were measured with a calibrated wheel. Obstacles were counted, but not very precisely, since resolution of obstacles was poor. A minimum of 15 interstices per chart was taken at random. For each, a line was constructed between its acute ends and a radius to the water-point constructed through the midpoint of this line. The length of each interstice long axis was measured. Angles of departure of the interstice long axis from the radial were measured and recorded as left or right departure. This measure of radiality overemphasizes departures, since sinuosities in clearly continuous track of considerable length cancel out, and track direction measured over some distance greater than interstice length would be less variable.

These data were appraised both to build a description of the track system, and to examine some obvious possibilities, namely: that mean departure from radiality might vary systematically with range or bearing from the water-point; that the variance associated with the mean might increase with range; and that interstice length, track intensity and obstacle density might correlate mutually, and with direction and range.

Mean departures from radiality and standard deviations, of interstice long axes in the 35 sample areas, with n between 14 and 22, were investigated. A remarkable adherence of tracks to near radial was established, so navigational skill must be attributed to the sheep.

Occasional significant departures from absolute radiality are expected, when obstacle densities, sizes and patterns are considered, but the overall resulting mean deviation of 2.49° left (variance 70.96, $t = 7.0292$, $p < 0.001$) is surprising and inexplicable. On the hypothesis of radiality, left and right fluctuations would be expected, but would also be expected to cancel out. Nevertheless, this mesh is undoubtedly biased left of radial.

Linear regression analyses showed no significant relationships between mean departure and bearing, range, or obstacle number, but showed a marginally significant relationship with track intensity.

Similarly, linear regression analyses showed no significant relationships between the variance of mean departure and the variables; range from water, obstacle density and track intensity.

Table 1 shows the relationships of interest. It appears that the track intensity falls off slightly, and in a linear manner, with increasing distance from water (Equation 1). There is also a falloff in obstacle density with increasing distance from water (Equation 2). Track intensity increases linearly with obstacle density (Equation 3). A further analysis, using obstacles as a co-variat, confirmed that when the effect of distance on obstacle is removed, distance from water does not affect the intensity with which sheep tracks are laid down in the study area.

Significant linear regressions relate mean length of interstice long-axis to several other variables. The mean length increases linearly with distance from water (Equation 4), decreases linearly with increasing obstacle density (Equation 5) and again decreases as track intensity increases (Equation 6).

The variances associated with means used in Equations 4–6 also relate to the same three variables as do the means, thus:

$Y = 898.57 + 26.87\ (X - 11.99),\ 0.001 < p < 0.01$, where Y is the variance and X the distance from water in yards. The variance increases with distance from water.

$Y = 196.88 + 5.43\ (X - 12.24),\ 0.001 < P < 0.01$, where Y is the variance and X the number of obstacles per quarter acre square. The variance decreases with increase in obstacles.

$Y = 1083.91 - 22.43\ (X - 12.04),\ P < 0.001$, where Y is the variance and X the track intensity in miles / mile square. The variance decreases as track intensity increases.

Equations 4–6 and the three equations above express the influence of obstacle pattern upon the track-laying activities of sheep. Taken as a whole, the results confirm quantitatively the impressions gained in the reconnaissance survey (and summarized above).

Some quantitative data were collected concerning the distribution of sheep dung within the study area. This followed the idea that dung/unit area might index average sheep time/unit area throughout the piosphere, except perhaps in heavily trampled places. Sheep dung resolves itself into small, relatively uniform hard pellets, which may persist for years upon the surface of arid soils and which, by virtue of this cumulation, may convey averages for sheep time/area smoothed out over long periods.

Pellets were counted within 66′ × 1′ strip-quadrats at ranges along one bearing from 200–800 yards from the water-point.

A linear regression with grouped data was performed, thus:

between groups. var.	1	117000.0750	117000.0750	35.4407	***
deviation from var.	2	5950.3833	2975.1917	.9902	N.S.
total between groups.	3	122950.4583			
within groups.	20	66100.5000	3305.0250		
total	23	189050.9583			

$$Y = 145.04 - 0.12\ (X - 980),\ p < 0.001$$

where Y is pellet number per 66 square feet and X is distance from water in yards.

In this piosphere, pellet density drops linearly from about 4/ft^2 at 200 yards, to a little less than 1/ft^2 at a mile from water, a very slight attenuation (1 in 5) indeed when contrasted with the fact that a circle of 200 yards radius is only about 1 in 70 of the area enclosed by a circle of radius 1 mile.

Discussion

Using the techniques described above, the intensity, length and direction of sheep tracks in any piosphere may be measured and analysed in detail. Most piospheres observed during reconnaissance were much less regular than the Lincoln Gap example. Such irregularities reveal the operation and existence of other piosphere inter-relationships. For example, changes in vegetation are accompanied by changes in track pattern. Figure 3 shows "flow lines" about a black-oak (*Casuarina cristata*) grove in bluebush, with a contrasting pattern in the grove, and a complete absence of radial pattern. Fence lines clearly influence piosphere relationships, mostly by truncating them in a manner suboptimal for exploitation and conservation alike. The influence of fences may extend into the piosphere for 1000 yards, giving rise to marked curvatures in track courses. Paddocks devoid of obvious obstacles may exhibit meshed track, with interstices. Elsewhere, paddocks bare except for a few scattered trees show patterns of tracks radiating from the trees, presumably a shelter effect, and not centered on water. In other places, track patterns exist but are not incised, due to the nature of the ground. A list of such features is large.

The results of the dung counts are particularly interesting, for several reasons. Because a very highly significant regression can be revealed from as few as 12 samples, the smoothing effect of long term cumulation under arid conditions is verified. Such counts may be used to obtain an integrated picture of what, taken in piecemeal detail, would be extraordinarily variable, complicated and confusing. Direct observation of sheep in this vegetation is difficult, costly and time consuming, and,

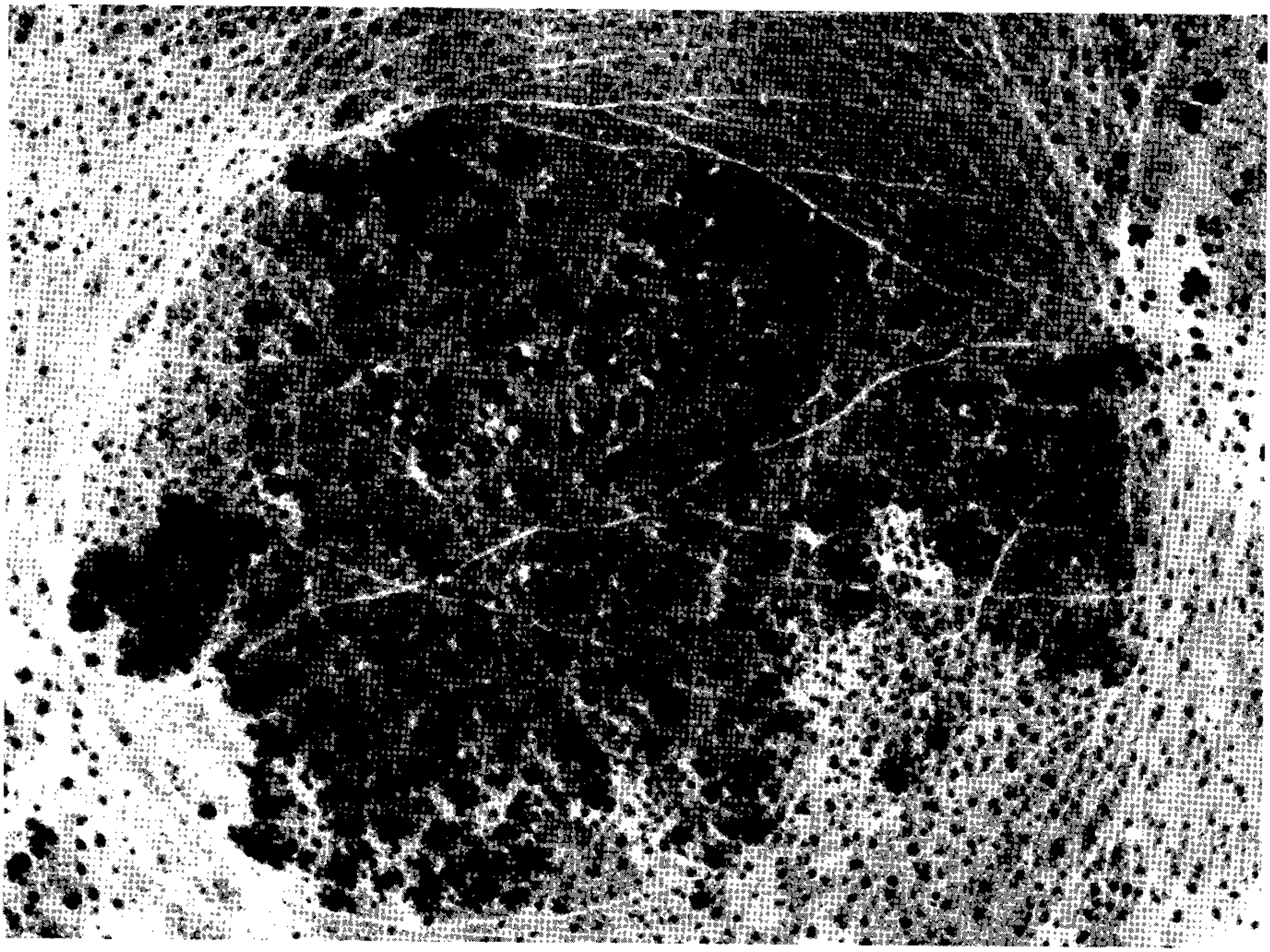

FIG. 3. Track flow lines about a black-oak grove in bluebush vegetation, with a contrasting intra-grove track pattern and an absence of radial control. Scale is about 1 : 800.

unless extended, yields masses of variable details but no precise overall picture. The dung count takes one trained man about two hours.

This work suggests that piosphere relationships will be much more complex than seems commonly to be recognised. The chance of an individual plant escaping sheep attention in this piosphere is negligible. Just as the rhizosphere effect about plant roots involves the stimulation of some microbial populations and the suppression of others, so the piosphere effect about water-points will involve deterioration of some plant populations (e.g. bluebush) and the stimulation of others (e.g. black bluebush), in their place. The broad features of this phenomenon are common knowledge but there must be subtle effects of changed selection pressure under sheep, operative on most functions of all plant species at all stages of their life cycles.

It is these subtle effects which are of significance with respect to conservation or management of the vegetation. Considerable information could be obtained by an extension of the approach adopted in this study; for example, a programme of photographic recording would be obviously appropriate. The interpretation of aerial photographs is an advanced discipline, but with judicious guidance from trained ecologists, dossiers of photographs from the ground could be obtained by station lessees. Such dossiers would provide a useful basis for recording vegetational changes, and possibly for eventual scientific range management.

The piosphere concept is likely to be important for management of rangelands in arid and semi-arid areas. These investigations establish principles that govern interactions around thousands of similar water-points in Australia and will have application wherever animals graze away from a central water-point.

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Ecological Effect of a Clay Soil's Structure on Some Native Grass Roots[1]

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Highlight

Dense Clay Range soils have larger structure peds or groups of smaller peds in the upper part of the soil when moisture is at the wilting point than do Clayey Range soils of the same moisture and clay content. Large peds, which are bordered by cracks when dry, apparently constrict roots as they dry and hold the roots so that they are stretched across the bordering cracks. Blue grama and buffalograss grow on the Clayey Range soils and have a fine, spreading root system near the soil surface. However, these grasses do not grow on Dense Clay Range soils where presumably their fine roots are not strong enough to withstand the constricting and stretching forces. Western wheatgrass and green needlegrass have larger, more deeply placed roots which are more vertically oriented than the short grasses and are able to utilize subsoil moisture and grow on the Dense Clay soils.

The range site concept is an essential part of the basic resource inventory of rangeland (Dyksterhuis, 1949, 1958; Aandahl and Heerwagen, 1964). In the Northern Great Plain, range sites have been designated by range soil groups, precipitation zone, and geographical location, for example; Silty, 15 to 19 inch precipitation belt, Mound City to Rosebud, South Dakota. Range soil groups were described by Dyksterhuis (1964) but are continually being revised as better criteria are established.

In the Northern Great Plains, some clay soils support an understory of short grasses and midgrasses (Clayey Range Soil Group) while others do not have the short grasses (Dense Clay Range Soil Group). The separation of these range soil groups is important since overgrazing deteriorates the Clayey site to shortgrasses and the Dense Clay site to a thin stand of western wheatgrass (*Agropyron smithii*)[2] and green needlegrass (*Stipa viridula*) with annuals, except during dry years when the ground is nearly bare of cover. Attempts to separate these soil groups on the basis of textures or dispersion have not been very satisfactory. This paper considers the use of soil structure to differentiate these fine-textured soils into the Dense Clay and Clayey groups.

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[2] Nomenclature follows Chase (1951).

Methods

Five soil profiles on gently sloping uplands were studied. All were in the Chestnut-Chernozem transition zone of southwest central South Dakota with 16 to 17 inches average annual precipitation. All were in ranges in upper good or lower excellent range condition (Dyksterhuis, 1949), usually distant from water. The profile are typical of many observed in the field.

Laboratory and field data are from studies on soil structure (White, 1967), on volume changes in clay soils (White, 1962), and from other soils to complete the data. Methods used were reported earlier (White, 1962, 1967). The vegetation reported for the soils was restricted to perennial grasses. Forbs and annual grasses were not abundant.

Results

The Dense Clay and Clayey Range soils studied have different structure and vegetation. In the following order, Profiles 1, 2 and 3 have proportionately more blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*) and less western wheatgrass (*Agropyron smithii*) (Table 1). However, the texture of Profiles 1 and 3 are nearly identical and finer textured than Profile 2 (Table 2), so texture probably does not cause the difference in the composition of the grasses.

Soil structure[3] appears to be the controlling factor. Profile 1 has a cloddy surface and parallelepipeds in the subsoil. Profile 2 has granular structure in the coarse clay surface layer and irregular subsoil prisms. Profile 3 has a granular to subangular blocky surface structure and weak subsoil prisms that contain a few parallelepiped faces. The increase in bulk density (Table 1), caused by the drying and shrinking of moist clods, is least for Profile 2, intermediate for Profile 3, and greatest for Profile 1.

Profile 4, a Clayey Range soil, has about equal amounts of blue grama and western wheatgrass. In comparison to Profiles 1, 2, and 3, Profile 4 has more organic matter and consequently the prisms are relatively better developed than the blocks and parallelepipeds. In contrast to the preceding four clay soils, Profile 5 has a silty upper part and a coarse clay in the 13- to 20-inch layer. This soil had dominantly western wheatgrass vegetation with a sparse understory of blue grama. The vegetation is comparable to that of the Clayey Range soils although the upper soil layers are silty. On the adjacent silty soils without a clay subsoil, western wheatgrass was less abundant so there was relatively

[3] Individual structure units or peds have different shapes and sizes. A ped may be composed of smaller peds of the same kind or a different kind. Ped shapes are: angular blocks = cubical, subangular blocks = cubical with some rounded corners, granules = spherical, plates = tabular in horizontal direction, prisms = polygonal prism elongated vertically, and parallelepiped = tabular but oblique to the horizontal plane.

Table 1. Range soil group and composition (percent by weight) of 5 profiles studied.

Profile Number	Range Soil Group	Major Grasses: Species	Composition
1	Dense clay	Western wheatgrass	85
		Green needlegrass	5
2	Dense clay	Western wheatgrass	80
		Green needlegrass	5
		Blue Grama	5
3	Clayey intergrading to thin clayey	Western wheatgrass	50
		Blue grama	10
		Sideoats grama	10
		Buffalograss	10
		Green needlegrass	5
4	Clayey	Western wheatgrass	45
		Blue grama	35
		Buffalograss	5
		Green needlegrass	10
5	Silty intergrading to clayey	Western wheatgrass	70
		Blue grama	10
		Sand dropseed	5

more blue grama and considerable needleandthread (*Stipa comata*). The blocky, clay subsoil of Profile 5 apparently favors the dominance of western wheatgrass over blue grama. Thus, subsoil as well as surface soil properties are important in defining range soil groups.

Discussion

The Dense Clay soil structure seems to be detrimental to roots of blue grama and buffalograss but not to those of western wheatgrass and green needlegrass (*Stipa viridula*). Roots of blue grama and buffalograss, in contrast to the two taller grasses, are finer, grow more profusely in the soil surface layer, and less profusely vertically into the subsoil (Weaver, 1958; Weaver, 1919; Coupland and Johnson, 1965). Root distribution is influenced also by soil profile properties (Weaver and Darland, 1959) and by grazing intensity (Weaver, 1950; Schuster, 1964). In contrast to the fibrous roots of the short grasses, western wheatgrass has rhizomes at a depth of 1 to 4 inches below the soil surface (Weaver, 1919). Roots from the rhizomic nodes extend nearly vertically into the subsoil. They are less affected by soil surface properties than the shortgrass roots which grow from the base of the plant at the soil surface. Sideoats grama (*Bouteloua curtipendula*), with a root distribution intermediate between western wheatgrass and the short-grasses, has some vertically and obliquely oriented roots and others which spread horizontally at a depth of 2 to 4 inches before they turn down (Weaver, 1920). Green needlegrass has a similar but deeper root system than sideoats grama. Thus, the mid-grasses growing on the soils studied are less dependent on the soil surface layer than the short-grasses.

The Dense Clay soils have larger and more com-

Table 2. Bulk densities, clay content, and structure for five range soils studied.

Profile Number and Soil Horizon	(Inches) Depth	Bulk Density Measurements (gm/cm^3): Field	Dry Clod	Wet Clod	(%) Clay	Structure
Profile 1						
A	0-1	0.96	1.66	0.96	64.0	Vesicular; irreg. c. crumb-gran. in blocky clods
B2	1-11	1.18	1.79	0.99	69.7	v. wk., m. bl.; obliq.; v. wk. irreg. pris.
B3	11-18	1.17	1.77	0.99	67.1	v. wk., m. bl.; obliq.
Profile 2						
A	0-1	n.d[2]	1.56	1.17	50.2	wk., v. f. gran.
B21	1-7	n.d	1.85	1.35	56.3	wk., v. f. subang. & bl.; v. wk. irreg. pris.
B22	7-14	n.d	1.71	1.37	60.8	wk., v. f. bl.; wk. irreg. pris.
B3ca	14-18	n.d	1.67	1.43	58.0	bl. in partially weathered mudstone
Profile 3						
A	0-1	1.26	1.54	1.01	62.7	v. wk. gran. -subang.
B2	1-10	1.24	1.79	1.07	68.7	wk., v. f. subang.; v. wk., m. & c. pris.; few obliq.
B3	10-18	1.29	1.89	1.03	69.7	wk., v. f. subang.; obliq.; v. wk., m. & c. pris.
Profile 4						
A	0-1	n.d.	n.d.	n.d.	50.6[3]	wk., v. f. gran. with platy orientation
B21	1-7	1.12	1.92	1.30	60	wk., m. pris.; wk., v. f. subang.; few obliq.
B22	7-15	1.44	1.93	1.28	60	wk., m. pris.; wk., v. f. subang.; obliq.
B31	15-22	1.60	2.01	1.31	60	wk., m. pris.; v. wk., v. f. subang.; obliq.
B3-C	22-30	1.63	1.97	1.38	60	v. wk., m. pris.; v. wk., v. f. subang.; obliq.
Profile 5						
A-C	0-4	n.d.	1.52	1.38	18.2	v. wk., v. f. gran.
A1	4-6	n.d.	1.44	1.38	19.5	wk., m. & f. prism.; v. wk., m. & f. gran.
B2	6-8	n.d.	1.47	1.36	18.6	wk., f. & m. pris.; (very porous peds)
B3	8-13	n.d.	1.55	1.35	28.4	wk., m. pris.; wk., f. subang.
B-C	13-20	n.d.	1.63	1.51	42.2	mod. & wk., f. bl.; wk., m. pris.

[1] Abbreviations used: bl. = angular blocks; c. = coarse; f. = fine; gran. = granules; irreg. = irregular; m. = medium; mod. = moderate; obliq. = parallelepiped faces; pris. = prisms; subang. = subangular blocks; v. = very; wk. = weak.
[2] Not determined
[3] Determined for 0-6 inch layer and estimated for lower layers

pact structure units or peds, when the soil is nearly dry, than do the Clayey soils. The larger peds usually contain smaller peds which are not distinct in Dense Clay soils. In nearly dry Clayey soils, the smaller peds are more distinct and are separated by narrow cracks. Thus, the average size of the ped, which is unattached to an adjacent ped, is smaller in the Clayey soils than in the Dense Clay soils. In addition, prisms are more distinct, have a more uniform size, and smoother faces in the Clayey soils than in the Dense Clay soils. Vertical cracks surrounding prisms in nearly dry Clayey soils have a more uniform width than those in Dense Clay soils. Parallelepipeds and blocks jut out from the prisms in nearly dry Dense Clay soils so the prism faces are irregular and the cracks are not uniform in width. The kind of structure is caused mainly by changes in the soil volume due to wetting and drying. Volume-change forces tend to be largest if parallelepipeds form, intermediate if blocks form, and least if prisms form (White, 1967). Thus, soil structure is indicative of the shrink-swell forces to which roots are subjected.

A root removes moisture from the adjacent enclosing cylinder of moist soil first before the soil farther away is dried. As this surrounding cylinder is dried and contracts, the root is compressed radially. Root constriction was reported for cotton plants which had roots growing through a thin, compact clay layer (Taubenhaus et al., 1937). In addition to simple radial compression, longitudinal compression occurs because a soil contracts in all directions. Wheat yields from pots in the greenhouse where soil self-compaction during the experiment increased the soil density from about 1.08 to 1.35 were less than from pots with a constant bulk density of about 1.35 (Abroe and Pathok, 1967). Longitudinal compression may have been a factor in this study. Barley (1963) and Gill and Miller (1956) found corn radicals could not elongate if sufficient pressure were placed on a surrounding artificial soil.

The pressure a functioning mature root can withstand apparently has not been measured. However, grass roots with deciduous cortices (Weaver, 1958) would be less affected than normal roots by soil contraction because the living stele can bend in the space left after the cortex disintegrates. Deciduous cortices have been observed for roots of western wheatgrass, green needlegrass, and indistinctly for sideoats grama. Thus, these grasses may be able to withstand soil contraction more effectively than blue grama and buffalograss which apparently do not have distinct deciduous cortices. The root tensile strength may decrease when the cortex slough but it apparently is a function of root diameter (Troughton, 1957) regardless of the species.

Cracks which form between soil peds may transect and break roots (Thorp, 1948) if the root is anchored securely by lateral roots in the soil on the two sides of the cracks. Western wheatgrass and green needlegrass apparently have fewer lateral roots than many common grasses (Coupland and Johnson, 1965) which may be a factor in their survival in Dense Clay soils. Hubbard (1950) reported crowns of blue grama were disrupted by cracks in clay soils although this disruption has not been observed on South Dakota soils. Soil cracks affect western wheatgrass less than blue grama (Hubbard, 1950) because a new plant may grow from a node on a rhizome fragment broken from a parent plant. In addition, western wheatgrass roots stretch considerably before breaking (Weaver and Darland, 1949, fig. 10).

A root would be stretched most frequently along the prisms where a vertically oriented crack forms. Horizontal cracks usually are very narrow because the weight of the overlying soil counteracts their formation. Thus, roots of western wheatgrass and green needlegrass that tend to grow vertically downward would cross fewer cracks than the shortgrass roots that grow more obliquely or horizontally. Other factors must be involved because the shortgrasses, which do not grow as abundantly on silty soils with a clay subsoil as on one with a silty subsoil, have lower subsoil roots oriented vertically. Constriction or pinching of the fine roots may occur in the clay subsoil as it dries. But this root damage by constriction or by breaking apparently would require large clods or ped aggregates.

A ped or ped aggregate must be at least a minimum size before it can constrict or compress the root rather than break into smaller fragments. The nearly dry ped or ped aggregate size determines the width of the desiccation cracks in the soil. With small peds, the cracks are more numerous and have a narrower width than if the peds were larger. Thus, the size of the finest ped or ped-aggregate is an important factor as far as root growth is concerned. The large peds or ped aggregates bordered by irregular cracks in the Dense Clay soils will cause more root damage than the smaller peds in the Clayey soils. The distance between cracks is larger and the width of the cracks is less uniform in clay soils with parallelepipeds in comparison to those with prisms.

The roots of western wheatgrass and green needlegrass, sideoats grama, and blue grama and buffalograss decrease in this general order in size and also in abundance with increasing soil depth. The soils with blue grama and buffalograss in comparison to those of the other species had more stable structure and/or smaller volume-change with drying so that the roots are not damaged. This relationship between grass species and soils supports the contention that soil structure determines the distribution of these species on the clay soils because it permits better utilization of soil water which is the limiting factor. In support of this hypothesis, western wheatgrass is most abundant in the more mesic or moist site of an area of silty soils where it can compete with the shortgrasses for the more abundant supply of water. Less water is available for western wheatgrass on clays in comparison to silty soils because: (1) less plant available water is stored (Black, 1968), (2) more water is usually lost by runoff, and (3) more water is needed to wet an air-dry soil surface layer to a content where moisture is available to a plant. Thus, summer showers are less beneficial for the clays than for the silty soils. Paradoxically, soil structure, or rather the lack of it, permits the more mesic species to compete with more xeric species for soil moisture in a clay soil which is effectively drier than the silty soils where these mesic species are relatively less abundant.

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See preview and tentative program beginning on page 436.

Heavy Precipitation Influences Saline Clay Flat Vegetation[1,2]

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Highlight

A vegetational analysis was made of the native grasses on a saline clay flat range site located on the Rio Grande Plains of Texas prior to and two months following Hurricane Beulah in 1967. Data prior to the hurricane indicated a mean grass plant density of about 26,000 per acre with negligible yield. Following the hurricane, an influx of annual and short-lived perennial grasses increased the density to approximately 700,000 grass plants per acre. Herbage yields increased to over 1200 pounds per acre. Presence of short-lived grasses provided forage and a desirable microenvironment for the establishment of seedlings of the more desirable grasses.

The Rio Grande Plains are commonly known as the "brush country of South Texas." This vast expanse (17,000,000 acres) of grazing land has been almost completely invaded by brush species and cacti since settlement (Johnston, 1963). Brush invasion has greatly reduced grazing capacity and has increased the difficulty of working livestock.

Potential productivity varies widely in the Rio Grande Plains. In this region, the saline clay flat site is low in productivity. It is difficult to predict the potential on sites of this type due to the complexity of edaphic and climatic influences on vegetation (Fanning et al., 1965).

A fortuitous combination of events presented the opportunity to study the effect of higher than average precipitation on the ecology of a saline clay site in 1967. A vegetation study that involved detailed analysis of the composition, density, and herbage yield had been completed in August, 1967, just prior to the advent of Hurricane Beulah. The same type of analysis was repeated two months following the hurricane, during which more than 13 inches of precipitation was received.

Study Area and Methods

The study area was located on the Rio Grande Plains of South Texas approximately 18 miles NNE of Zapata in Zapata County, Texas. A nearly homogeneous vegetative cover of native grass species form the vegetation of the area. It was rootplowed, raked and stacked in 1962.

The area is a saline clay flat range site on a Montell clay soil type. Montell is a Montmorillonitic clay having an AC horizon with high shrink-swell properties. All horizons of the Montell series have been described as strongly calcareous and possessing blocky structure. The A horizon has an exchangeable sodium concentration above 25% and the AC horizon in excess of 30% (Fanning et al., 1965).

Typical of the Great Plains of North America, the precipitation in Zapata County is erratic. Laredo, 35 air miles from the study area, has a 26-year average annual precipitation of 20.47 inches; ranging from a low of 9.61 inches in 1955 to a high of 23.81 inches in 1967 (Table 1). Precipitation of 26.39 inches was recorded at the study area in 1967. The greatest monthly precipitation usually occurs in May and September, and the least from December to April. The average annual temperature is 74.6 F with midday temperatures in excess of 100 F from June to September and nighttime lows below freezing from December to February. Evaporation normally exceeds precipitation every month of the year. However, in 1967 precipitation exceeded evaporation in September and November.

Vegetational history of the area, although sketchy, indicates this was primarily a grassland composed of moderately to highly salt tolerant species prior to development of artificial water sources and the advent of heavy grazing. Along with heavy grazing and the removal of the more desirable herbaceous species came the encroachment of spiny woody species and an increase in less desirable grass species (Smith, 1899). Old records and scattered remnants indicate that the climax vegetation included alkali sacaton (*Sporobolus airoides*) twoflower trichloris (*Trichloris crinita*), Arizona cottontop (*Trichachne californica*) and several of the tridens (*Tridens* spp.). Woody species were probably located only along the arroyos and in scattered mottes. The current woody species include, in descending order of density, pricklypear (*Opuntia* spp.), saladillo (*Varilla texana*), mesquite (*Prosopis juliflora*) and retama (*Parkinsonia aculeata*). The two important grasses are curlymesquite (*Hilaria belangeri*), and whorled dropseed (*Sporobolus pyramidatus*).

The study area was fenced to prevent domestic livestock grazing in July, 1966. Prior to this, it had been part of a cattle ranching operation. The vegetation was initially sampled in mid-August 1967. Three months later, 60 days following the heavy precipitation of Hurricane Beulah, the plots were again sampled. Measurements taken on both dates included species composition and density. Due to drought condition herbage production was not measurable in August. However, it was obtained in November.

One hundred, 2-acre plots were systematically established on this area. Nineteen of these were randomly selected for study. Each plot was sampled at 20 randomly spaced points along a diagonal transect. These provided 30 or more measures on the dominant species as recommended by Dix (1961) for the point-center quarter method.

The sampling technique used in this study was a modification of the point-centered quarter method (Dix, 1961). This method has the advantage of being quantitative and can be objective if the sampling units are selected at random. Three measurements normally used in characterizing a grassland were obtained with this sampling method. In addition to density and species composition, the nearest plant in each quarter was clipped for yield determinations. As indicated by Penfound (1963) weight may be a valuable

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[2] Technical bulletin No. T.A. 7583, Texas Agricultural Experiment Station, College Station, Texas. Received November 29, 1968; accepted for publication March 17, 1969.

Table 1. Temperature (°F) and evaporation (inches) for 1967 and 26 year average precipitation (inches) at Laredo, Texas and 1967 precipitation at the study area.

	LAREDO					
	Temperature					Study
Month	High	Low	Avg	Evap	26 yr. avg. Precipitation	Area Ppt
Jan	85	29	58.5	3.34	1.14	0.94
Feb	86	30	61.4	3.96	0.88	0.27
Mar	96	43	74.0	7.02	0.84	0.61
Apr	101	63	82.7	9.08	1.14	3.10
May	103	58	83.7	10.50	3.64	0.06
June	104	67	87.1	12.38	1.77	0.87
July	105	68	87.9	13.65	1.60	0.55
Aug	104	67	84.8	9.42	1.46	2.62
Sept	96	52	78.9	5.07	3.35	13.26
Oct	89	44	73.1	4.71	2.04	0.46
Nov	89	40	66.3	2.19	1.25	3.08
Dec	79	31	57.3	2.25	1.36	0.57
Total				83.57	20.47	26.39

Table 2. Grass composition (%) by density and yield, and total density and yield for August and November 1967 on saline clay flat range site.

Species	Composition by density		Composition by yield	
	Aug.	Nov.	Aug.	Nov.
Curlymesquite	69.7	24.7	t[1]	20.0
Whorled dropseed	7.4	13.1	t	10.4
Red grama	7.6	2.4	t	1.7
Bristlegrass	3.1	1.7	t	3.6
Panicum spp.	0	51.0	t	56.2
Green sprangletop	0	6.2	t	4.7
Prairie cupgrass	0	0.3	t	0.2
Sandbur	0	0.5	t	1.4
Buffelgrass	0	0.1	t	2.9
Unidentified species	9.3	0	t	—
Total density and yield	26,000[2]	700,000[2]		1210[3]

[1] Denotes presence, but insufficient quantity to collect.
[2] Grass plants/acre.
[3] Pounds/acre, ovendry.

parameter in measuring dominance. Clipped plants were composited by species, oven dried, and weighed. Yield by species was the average dry weight per plant times the species density. Total production per acre was the sum of the species yield.

A plant was considered to be a visually discernable unit including rooted stems and foliage but excluding stolons. Distance measurements were from the center point to the nearest living plant tissue at ground level. Grasses were the only plants measured.

Results

Climatic conditions at the study site were about average for the year preceding Hurricane Beulah except for below normal precipitation. From August 1966 to August 1967 the precipitation at Zapata was 10.25 inches. However, in the next three months 19.39 inches were received with 13.26 inches occurring in September, primarily as a result of the hurricane.

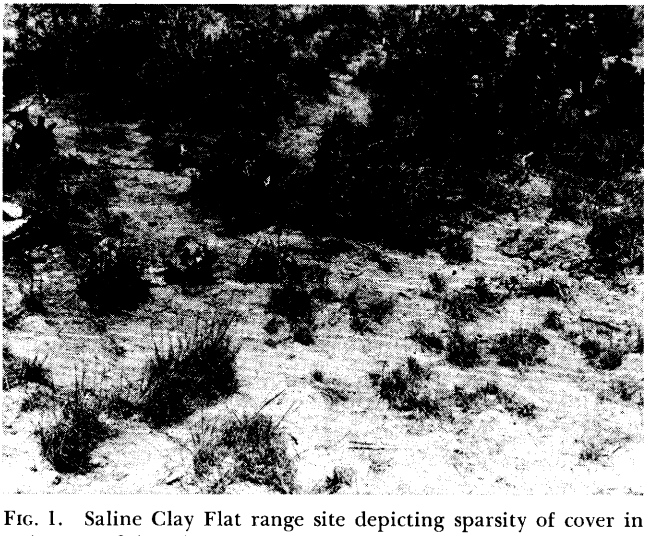

Fig. 1. Saline Clay Flat range site depicting sparsity of cover in August, 1967, prior to Hurricane Beulah.

Average plant density in August 1967 was 26,237 grass plants per acre, ranging from 2505 to 66,000 (Fig. 1). Only four grass species were identified: Curlymesquite, red grama (*Bouteloua trifida*), whorled dropseed, and plains bristlegrass (*Setaria macrostachya*). Curlymesquite, a mat forming shortgrass, was the dominant species and made up 69.7% of the composition ranging from 41.3 to 96.3%. Due to the dessicated state of the vegetation 10% of the composition was composed of unidentified grass species. Species of tridens, green sprangletop (*Leptochloa dubia*), prairie cupgrass (*Eriochloa contracta*), and Hall's panic (*Panicum hallii*) occurred on the area, but were not sampled.

Herbage production was not measurable in August (Table 2). Rarely did any grass exceed 2 inches in height or 1 inch in basal diameter. The herbage was so dry that when clipped shattering was common. In November, at maturity of most grasses, a drastic change had occurred in density, production, and composition of the herbaceous vegetation (Fig. 2).

Plant densities in November had increased over 22 fold and ranged from about 400,000 to 1,000,000 plants per acre. Species composition had also undergone major change (Table 2). Curlymesquite contributed only 24.7%, while *Panicum* spp. and green sprangletop, absent in the August sample, contributed substantially to the total composition.

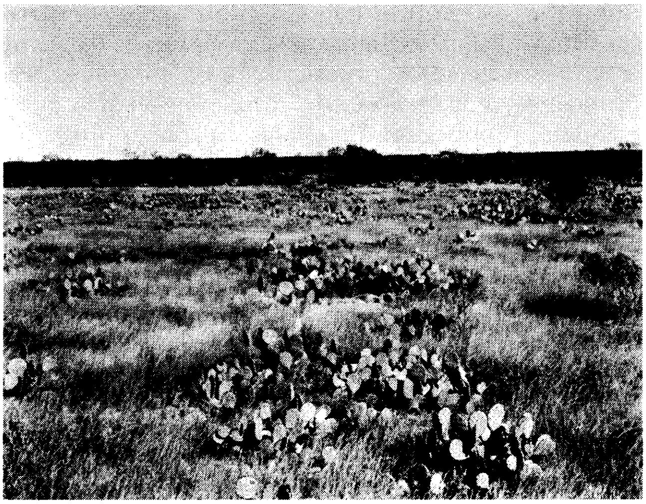

FIG. 2. Saline Clay Flat range site November, 1967, two months following Hurricane Beulah.

Mean production was approximately 1200 pounds/acre ranging from 731.7 to 1743.7 pounds/acre between plots. Production on most plots grouped quite closely around the mean.

Discussion

Two facts stand out in this study: (1) a large increase in grass production and (2) considerable change in composition and density. These changes occurred in a relatively short time in the fall following excessive precipitation. The saline soils of the Rio Grande Plains are considered to be droughty due to high salt content, low rainfall, and high evaporation. Fanning et al. (1965) point out that the high salt concentration, particularly with increasing depth, limits not only the species present but also herbage production. Some species can tolerate salt concentration in the surface soil but few will root into the subsoil. They also report salt concentrations of 7.0, 16.2, and over 20.0 mmhos/cm at depths of 0–9, 9–17, and 17–48 inches, respectively in the Montell clays. The United States Salinity Laboratory (1954) reports that salt concentrations greater than 4.0 mmhos/cm limits production of most forage crops, above 8.0 permits growth of only moderately salt tolerant species, and above 12.0 mmhos/cm allows only the most salt tolerant species to survive.

Data in Table 2 indicate that with adequate rainfall a lush growth of mostly ephemeral grasses occurred in the saline clay flat sites of the Rio Grande Plains. Plant density increased from about 26,000 to approximately 700,000 plants per acre in the 60-day period following heavy precipitation. This increase indicated rapid germination and growth of these species. Composition change was illustrated by the high percentage of panic grasses (*Panicum* spp.) following the fall rains. Also indicated was the rapid recovery and potential cover provided by short-lived perennial and annual grass species. Most species of *Panicum* that occurred were members of the subgenerus Eupanicum. They have been described by Hitchcock and Chase (1951) as perennials exhibiting ephemeral characteristics of extremely short life cycle and a relatively shallow root system. Characteristically, such grasses show an immediate response to precipitation (Weaver and Clements, 1938). Although this type of plant is not highly desirable it does furnish a desirable environment for seedling establishment and limited short-term production.

Percentage of composition contributed by the dominants, based on density, was comparable to that based on herbage yield (Table 2). Curlymesquite, a sod forming grass, and a bunch grass, whorled dropseed, were represented in the dominants. Apparent differences were also noted in composition of the minor species. The density-weight relationships exhibited by the dominants may indicate the usefulness of density in predicting yield of native perennial grass species. Based on plant density in August, curlymesquite, whorled dropseed and red grama were the dominants, indicating that production during dry periods could be related to the occurrence of these species rather than the dominant species indicated by the November data.

Curlymesquite is the major species in this soil type due to persistence during dry periods. It does not appear to make the rapid growth of other species, but its herbage remains available longer. This is indicated by the high percentage of the composition contributed in August following an unusually long uninterrupted drought.

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A Field Test of the Relative-Weight-Estimate Method for Determining Herbage Production[1]

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Highlight

Reliable estimates of total herbage yield can be made by the relative-weight-estimate method. The method is based on the concept that it is easier and more accurate to estimate herbage yield as a percent of yield from a base plot than it is to estimate yields directly in grams or pounds. Estimates of total herbage are reasonably accurate, but they are less accurate for vegetation classes of grasses, forbs, and shrubs and for individual species. This method generally contains an inherent bias that cannot be detected unless a double-sampling procedure is used to check and correct field estimates.

Weight estimates of herbage production proposed by Pechanec and Pickford (1937) have been widely used to measure and compare herbage yields on native ranges. Several difficulties are inherent when making direct estimates of herbage as follow:

1. Extensive training periods are required before observers can estimate accurately, and frequent checking of estimates against actual weights is necessary during the inventory period.
2. Estimates probably are always somewhat biased; consequently, it is often advisable to apply a double-sampling procedure in which estimates are checked against actual weights from a series of clipped plots. This provides a correction factor for estimated plots.
3. The observer must develop and maintain a constant mental image of the weight units for the various species. The tendency is to try to remember the weight units for too long a period.
4. Estimates are affected by changes in light conditions and observer fatigue or attitude.

The relative-weight-estimate method is one we believe will minimize or eliminate some of these difficulties. This method generally contains some personal bias, which cannot be corrected unless double sampling is applied to provide correction factors. However, in the field tests reported in this paper, bias was considered to be minimal and the estimates on most sites were suitable.

The relative-weight-estimate method is based upon the assumption it is easier to make comparisons than it is to estimate actual yields. That is, it is easier to estimate production in a plot as a percentage of that in a nearby base plot than it is to estimate production in grams or other units of weight. Since absolute yields are not estimated, no mental image of a weight unit is required.

Areas Sampled and Methods

The three areas selected for sampling represent different levels of production. Area 1, Montana Power Park, is a relatively dry, mixed grass-forb type under a sparse overstory of mature ponderosa pine. Production is low, averaging about 720 lb per acre. Grasses make up about 75% of the vegetation. Major grasses are *Festuca idahoensis, Danthonia unispicata, Koeleria cristata,* and *Agropyron spicatum.* Forbs are not uniformly distributed; in some areas few or none are found. Principal forbs encountered are *Antennaria luzuloides, A. rosea, Solidago missouriensis,* and *Achillea millefolium.*

Area 2, Vigilante, is a moderately dry range in fair condition, producing about 1,000 lb herbage per acre: 55% grasses, 17% forbs, and 28% shrubs. Principal grasses are *Festuca idahoensis, Koeleria cristata,* and *Agropyron spicatum.* Important forbs are *Phlox canescens, Perideridia gairdneri, Geum triflorum,* and *Comandra pallida.* The major shrub, often the only one, is *Chrysothamnus viscidiflorus.*

Area 3, Modesty Creek, is a high-producing grass-forb range in good condition. This area produces approximately 2,500 lb per acre, green weight. Grasses make up 68% of the herbage produced and forbs the rest. The important grasses are *Festuca idahoensis, F. scabrella, Stipa columbiana, Agropyron spicatum,* and *Koeleria cristata.* The rich mixture of forb species present includes *Viola nuttallii, Achillea millefolium, Geranium viscossimum, Solidago missouriensis, Antennaria rosea,* and *Erigeron spp.*

Clusters of five 1- by 2-ft plots were located randomly within the three ranges. Ten clusters were located in Area 1 and two clusters in each of Areas 2 and 3. The five plots in a cluster were located in a pattern similar to the five spots on the face of a die, with plot centers 3 to 4 feet apart.

Production in each of the four corner plots was estimated as a percentage of that in the base plot. Only the herbage within the vertical projection of the plot boundary was included in the estimates.

Total production was estimated first; then production by vegetation classes—grasses, forbs, and shrubs. Finally, production of individual species was estimated as percentages of the total herbage produced in the base plot. Weight of herbage was computed by multiplying percent production by clipped weight of the base plot.

To test the accuracy of estimates of relative production, vegetation in the base plot and in the four corner plots was clipped and weighed by species. These clippings were recorded as green weights.

Five men made the estimates: men 1, 4, and 5 at Montana Power Park, and men 1, 2, 3, and 4 at Vigilante and Modesty Creek. None had any training in the relative-weight-estimate method. Three men had little, if any, experience in estimating herbage production by any method, but the other two had used weight estimates extensively in other studies.

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[1] Received October 16, 1968; accepted for publication April 19, 1969.

Table 1. Mean yields (grams per plot).

Area	Actual means	Estimated means by men 1	2	3	4	5
Montana Power Park	14.76 ± 6.64	14.19 ± 6.46	—	—	14.44 ± 7.07	14.14 ± 6.51
Vigilante	21.33 ± 11.74	16.34 ± 8.32	16.74 ± 9.70	17.73 ± 8.02	20.73 ± 10.72	—
Modesty Creek	83.33 ± 23.26	88.40 ± 24.88	83.55 ± 13.08	85.78 ± 22.43	135.44 ± 53.46	—

Accuracy of Estimates

Estimates of total production of all species combined were more accurate and consistent than estimates of production for the three forage classes —grasses, forbs, and shrubs—or for individual plant species.

Total herbage production.—In general, the men's estimates of total herbage production were reasonably accurate and consistent. All were within 20% of the actual mean, except on Modesty Creek (Table 1).

At Montana Power Park, estimates of average total production for the 40 plots were remarkably close to the actual average yields; these varied from the actual mean by only a fraction of a gram. At Vigilante, all estimates of average yields from eight plots, though low, also were close to the actual mean. At Modesty Creek, the estimates of three men for the average yields from eight plots also were close to the actual mean. However, the fourth man markedly overestimated the yield on each plot; his estimate of mean production was more than 60% greater (135 g) than the actual (83 g).

Although the estimates of mean production were fairly close to the actual, the estimates of individual plot yields varied widely, especially on the high-yielding Modesty Creek area. Analysis of variance of the differences between actual and estimated yields shows the estimates of individual plots were significantly different at the 1% level at Montana Power Park and Vigilante (Table 2). However, the differences were not considered to be of practical importance.

Prediction equations for estimating total herbage yield vary from area to area. Regression coefficients were below 1.0 for all men on the dry Montana Power Park area, and they were greater than 1.0 for the intermediate Vigilante area. At Modesty Creek, where yields were high, two men's regression coefficients were below 1.0 and two men's above. The ideal would be to have all regression coefficients equal to unity.

Relations between the actual and estimated values are shown graphically in Figures 1–3. On the dry fescue range at Montana Power Park area, all men underestimated low-yielding plots and overestimated high-yielding plots. At Vigilante, all men tended to underestimate all plots, and at Modesty Creek three men overestimated all plots; but one man overestimated the low-yielding plots and underestimated the high-yielding ones.

Vegetation classes.—Estimates of yields for the grasses, forbs, and shrubs were more variable and less accurate than estimates of total herbage production. Shrubs were not abundant enough in Montana Power Park or Modesty Creek to furnish reliable data. On the Vigilante area, correlations between the actual and estimated shrub yield were very high for the four men ($r = 0.99$). Although these correlations were high, the mean yields for the men's estimates varied from 80 to 116% of the actual.

All men estimated grass yields at less than actual on low-yielding plots but more than actual on high-yielding plots on the two dry sites, Montana Power Park and Vigilante. On the high-yielding

Table 2. Analysis of variance of differences between actual and estimated total yields.

Area and source of variation	Degrees of freedom	Sums of Squares	Mean square	F
Montana Power Park:				
Clusters	9	556.73	62.97	3.39**
Plots (P/C)	30	558.10	18.60	2.29**
Men	2	37.75	18.88	.83
Clusters X men	18	408.29	22.68	2.79**
Error	60	487.49	8.12	
Total	119	2,058.36		
Vigilante:				
Clusters	1	7.90	7.90	0.13
Plots (P/C)	6	366.50	61.08	13.57**
Men	3	73.67	24.56	4.66
Clusters X men	3	14.82	5.27	1.17
Error	18	81.01	4.50	
Total	31	544.90		
Modesty Creek:				
Clusters	1	22.95	22.95	0.18
Plots (P/C)	6	754.65	125.76	.29
Men	3	11,902.84	3,967.61	4.73
Clusters X men	3	2,516.86	838.95	1.93
Error	18	7,809.09	433.84	
Total	31	23,006.39		

** Significant at 1% level.

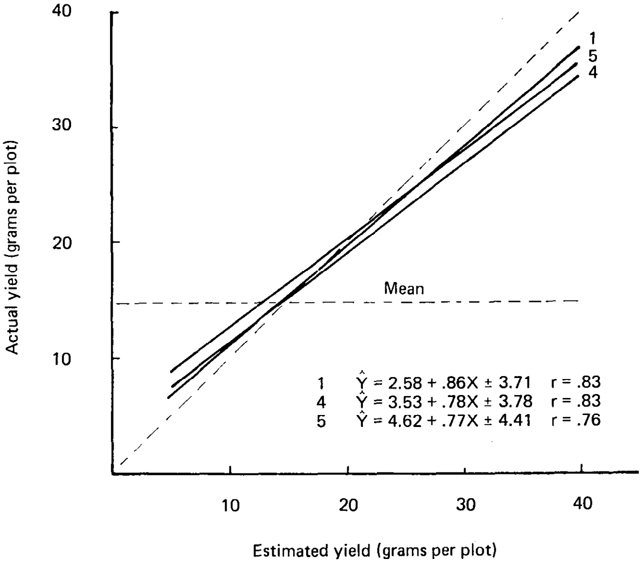

FIG. 1. Comparison of herbage yield estimates by individual men (1, 4, 5) with actual yield at Montana Power Park. Dashed line shows 1 : 1 ratio.

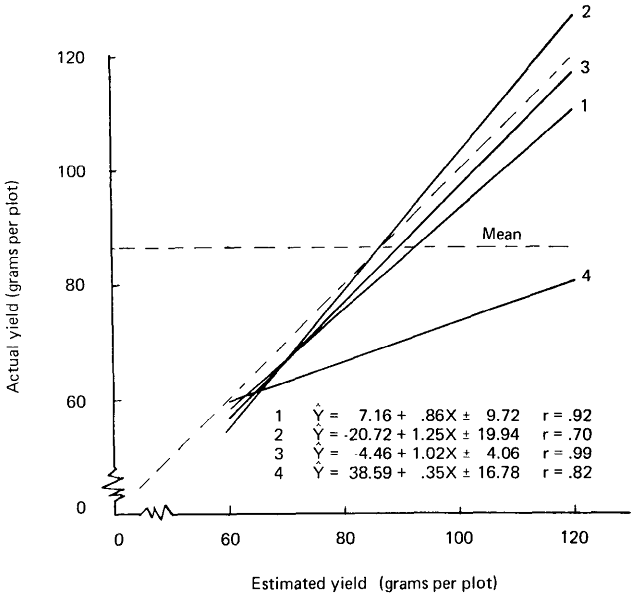

FIG. 3. Comparison of herbage yield estimates by individual men (1, 2, 3, 4) with actual yields at Modesty Creek. Dashed line shows 1 : 1 ratio.

grass-forb range at Modesty Creek, two men's estimates were high for all plots. The third man's estimates were very close to actual yield; the fourth man's were fairly accurate on low-yielding plots but extremely high on high-yielding plots. Correlations between actual and estimated yields on all sites ranged from 0.42 to 0.93. Estimates by three men of total grass at Montana Power Park were exceptionally close; correlations ranged from 0.73 to 0.81, and means of the estimated weights ranged from 9.44 to 9.98 g, as compared to the actual yield of 10.59 g per plot.

All estimates were low for forb production at Montana Power Park. At Vigilante, all estimates of forb production were fairly accurate on low-yielding plots; however, on high-yielding plots, the estimates of two men were extremely high, while the estimates of the remaining two men were extremely low. At Modesty Creek, one man overestimated all plots, while the remaining three men underestimated on low-yielding plots and over-estimated on high-yielding plots.

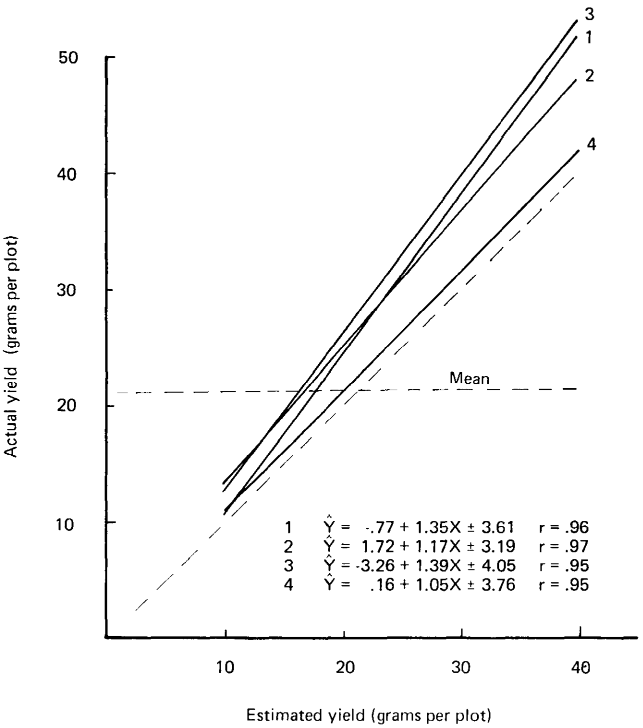

FIG. 2. Comparison of herbage yield estimates by individual men (1, 2, 3, 4) with actual yields at Vigilante. Dashed line shows 1 : 1 ratio.

Individual Species.—Estimates of yield for individual species were much more erratic than estimates for total herbage or for the three vegetation classes. Estimates of yields for *Festuca idahoensis* and *Erigeron* spp. were very accurate. Correlations between actual and estimated yields for *Festuca idahoensis* ranged from 0.83 to 0.90, and the means were within 21% of the actual. Correlations between the estimated and actual yields of *Erigeron* ranged from 0.92 to 0.99 and the means were within 15% of the actual. Estimates of *Artemisia frigida, Chrysothamnus viscidiflorus, Achillea millefolium, Agropyron dasystachyum,* and *Agropyron spicatum* were extremely varied and often inaccurate.

Discussion and Summary

The men participating in the test obtained reliable estimates of total herbage yield quite consistently using the relative-weight-estimate method.

However, their estimates of yield by vegetation class or by species were less reliable. Apparently this was due chiefly to their inability to see or to recognize all individuals of a species, especially of grasses. As many as 15 species, eight of which were grasses, were encountered on some plots. Frequently, the smaller grasses and forbs were hidden underneath taller vegetation. On some plots, it was difficult to distinguish between old growth and new growth; this added to the variation in estimates.

Therefore, this method seems appropriate only for studies requiring estimates of total production, or where compositions are not complex. It seems especially adaptable for use on ranges where vegetation is monospecific and growth is uniform.

Estimates of yields by vegetation classes and by species probably would be improved by estimating them as percentages of the same vegetation class in the base plot instead of the total yield. In this procedure the base plot would have to be clipped by vegetation classes. The base plot would not be selected arbitrarily. Rather it would be selected to contain all the vegetation classes present in the other four plots in the sample cluster. Grouping or lumping minor species into a single estimate should also improve the yield estimates. Also, it would be desirable to include a double-sampling procedure so that personal bias could be corrected. This could be done by harvesting some estimated plots as well as the base plot at randomly selected clusters.

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Carbohydrate Reserves of Six Mountain Range Plants as Related to Growth[1]

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Highlight

The total available carbohydrate reserves of six native mountain range plants were studied through a growing cycle. The reserves showed somewhat similar trends as plants advanced in growth during their annual cycle. Minimum root reserves were reached during the early spring after producing approximately 15 percent of their annual growth. Maximum reserves were reached at or near flowering. The average level of root reserves at any one period varied widely among species, however.

The general trend of seasonal carbohydrate reserves is similar for most perennial plants. However, growth behavior or environmental conditions may influence the level of storage. Knowledge of reserve levels for plants allows correlation of grazing practices with the physiology of the plant.

With the onset of new growth there is universally a decline in stored carbohydrates (Jameson, 1963; Cook, 1966). The decline of reserves during early growth is well known. The magnitude and time of carbohydrate low may vary widely among species. Research indicates the storage of carbohydrates in roots and stem bases is inversely related to rate of herbage production (McCarty, 1938; McCarty and Price, 1942).

Mooney and Billings (1960) reported the carbohydrate cycle for several alpine plants. Early shoot growth utilized considerable carbohydrate reserve material but adequate amounts were present even at the lowest point of the cycle to maintain growth. McCarty (1938) and McCarty and Price (1942) found approximately the first 10 percent of the annual growth consumed about 75 percent of the root reserves before any replenishment occurred. Bluebunch wheatgrass (*Agropyron spicatum*) produced approximately 45 percent of the annual growth before ceasing to decrease carbohydrate reserves (McIlvanie, 1942).

When studying total water soluble carbohydrates in range grasses in Oregon, Hyder and Sneva (1963) found a definite low occurred early in growth, followed by a high accumulation during June and July. The reserve carbohydrates decreased slightly during the fall for six native range grasses studied. Brown (1943) reported late autumn to be the most favorable period for storage of carbohydrates in the underground parts of Kentucky bluegrass (*Poa pratensis*). The carbohydrates were synthesized more rapidly than they were used during the cool weather following early spring growth.

Experimental Area and Procedures

During 1965 and 1966 the carbohydrate levels were determined for six native range species at three replications on typical mountain range approximately 22 miles northeast

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[1] Portions of this paper were presented to the School of Graduate Studies of Utah State University in a Ph.D. dissertation. This study was a cooperative project between the Bureau of Land Management and Utah State University. Submitted as Utah Agric. Exp. Sta. Journal Paper 827. Received October 26, 1968; accepted for publication February 3, 1969.

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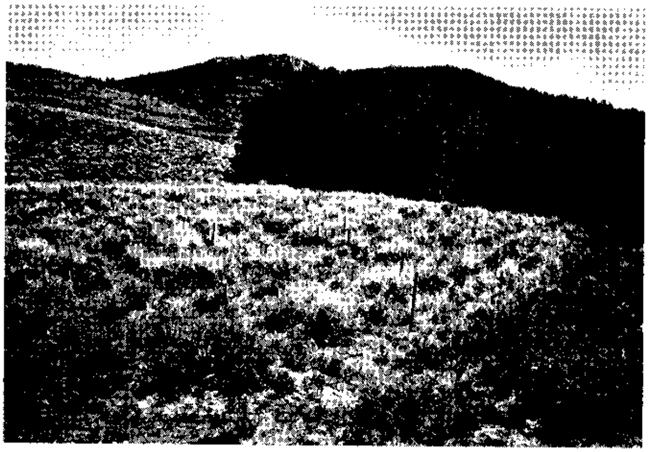

FIG. 1. Distribution and location of plants on a typical southwest slope in a sagebrush-grass type.

of Logan, Utah. All study sites represented the open, sagebrush-grass vegetative type (Fig. 1).

The translocation of total available carbohydrates for two grass species, beardless wheatgrass (*Agropyron inerme*) and Letterman needlegrass (*Stipa lettermanii*); two browse species, snowberry (*Symphoricarpos vaccinioides*) and rabbitbrush (*Chrysothamnus viscidiflorus*); and two forb species senecio (*Senecio integerrimus*) and geranium (*Geranium fremontii*) were evaluated. Duplicate root samples from each of the six species were collected from each location at two-week intervals to study fluctuations of carbohydrate reserves throughout the growing season. Collections of root material commenced on May 11, and terminated August 27. In September and October, following summer dormancy, collections of root samples from the two grass species were made to determine the effect of fall regrowth on the carbohydrate root reserves.

Root samples were removed to a depth of 12 inches for carbohydrate reserve determinations. Cubes of soil, 12 × 12 × 12 inches, were placed in wooden boxes with a bottom constructed of one-eighth inch mesh screen and the soil washed from the roots by gentle agitation. The samples were blotted dry and cut into short segments starting immediately below the crown. Caution was taken to remove all visible dead root material. Only live roots less than 0.25 inch in diameter were collected from the browse and forbs. Root material of larger dimension was considered to have large amounts of xylem and cortex with little storage value.

After the samples were cut into short segments they were covered with 95 percent ethanol to prevent enzyme activity. The samples were then taken to the laboratory and placed in an air-draft dryer at 90 C for 2 hours and then dried for approximately 48 hours at 70 C. After drying, the samples were ground in a Wiley micromill equipped with a 40 mesh screen.

A 1-gram sample of the root material was placed in a Waring blender with hot 80% ethanol for 10 minutes (Noggle, 1953). The mixture was filtered through a Buchner funnel fitted with Whatman No. 40 filter paper and the alcoholic filtrate stoppered and retained for further analysis. The ethanol extraction removed alcohol soluble carbohydrate constituents, thus reducing the amount of carbohydrate material involved with later extractions.

The residue was removed from the filter paper, placed in a 250 ml beaker in an ice bath before addition of perchloric acid (Pucher, et al., 1948). Three ml of 72% perchloric acid and 4 ml of water were added rapidly to the residue with constant agitation. After 30 minutes, with occasional shaking, the mixture was centrifuged, the liquid decanted and saved. The residue was again treated with 7 ml of the perchloric acid-water mixture and allowed to stand for 30 minutes to assure complete removal of starch (Pucher, et al., 1948). The mixture was then filtered into the decanted liquid from the first perchloric acid extraction and washed twice with water.

The perchloric acid liquid was neutralized with approximately 10 ml of 25% sodium hydroxide and allowed to cool. After cooling, the mixture was added to the alcoholic extraction and diluted to a constant volume. An aliquot of the combined filtrate was evaporated on an electric hot plate until the odor of alcohol had disappeared. The solution was clarified with barium hydroxide and zinc sulfate (Moyer and Holgate, 1948), filtered through Watman No. 42 filter paper and made to a constant volume. An aliquot of the clarified solution was inverted and the total available carbohydrates determined by a modification of Forsee's photocolormetric method (Morell, 1941).

The percent transmittance of the sugar solutions was read at a wave length of 420 mμ. The readings were compared to a standard glucose curve and the values converted to milligrams of glucose per gram of plant sample by dividing the value by a conversion factor of 0.90.

Results and Discussion

Letterman Needlegrass and Beardless Wheatgrass.—Carbohydrate reserves of beardless wheatgrass and Letterman needlegrass followed the general depletion pattern described by McCarty (1938), McCarty and Price (1942), and Mooney and Billings (1960). Data collected for May 11, represents collections from only two locations. Thereafter the data were collected from three locations. Inclement weather prevented collection of root material from more than two locations on the first sampling date. While the number of samples constituting the average for the first date was from only two locations, the information was of considerable value.

Roots of Letterman needlegrass contained 86.7 mg of total available carbohydrates per gram of root material at the initiation of sampling. By May 18 when the grass had reached the three leaf stage, this value had reduced to 49.2 mg. It increased to 107.1 mg by the end of May (Fig. 2).

The carbohydrate reserves were replenished through the four-leaf stage after which they receded temporarily. The decrease continued until the early boot stage (July 1). Following the boot stage, on July 12 the carbohydrate reserves replenished to a seasonal high of 112.4 mg per gram of root sample which occurred during late anthesis to the milk-dough stage. At seed production there was a temporary decrease followed by a replenishment to

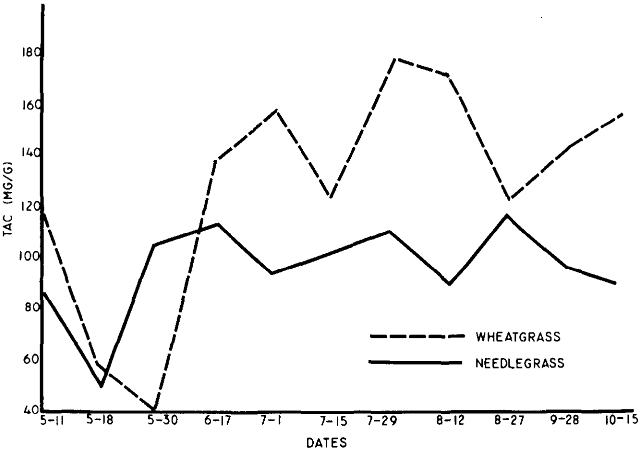

FIG. 2. Total available carbohydrate (TAC) reserves of beardless wheatgrass and Letterman needlegrass from initial growth to maturity. Values are averages expressed as milligrams of glucose equivalents per gram of root.

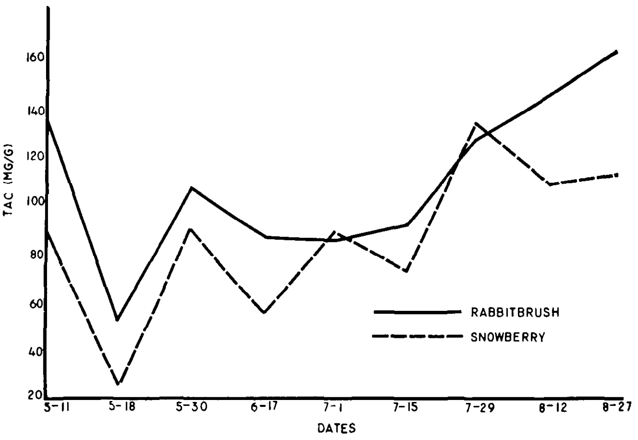

FIG. 3. Total available carbohydrate (TAC) reserves of little rabbitbrush and snowberry from initial growth to maturity. Values are averages expressed as milligrams of glucose equivalents per gram of root.

120.4 mg as the plant approached maturity by August 27.

While the general depletion and replenishment pattern followed a trend similar to previously reported studies, mid-season fluctuations were not understood. McCarty (1938) and McCarty and Price (1942) reported mountain brome (*Bromus carinatus*) began depleting the reserves with the development of flower stalks. This depletion continued until seeds were fully developed. After seed development, the carbohydrate reserves steadily increased through seed dissemination with no marked fluctuations. A marked increase occurred prior to fall dormancy. In the present study this same trend was evident in Letterman needlegrass. Initial fall dormancy and seed dissemination occurred concurrently.

Beardless wheatgrass was in the three-leaf stage at the initiation of the sampling and the root reserves were 116.6 mg per gram of sample (Fig. 2). With continued growth the reserves diminished to a seasonal low of 40.8 mg on May 30. The carbohydrate low for beardless wheatgrass coincided with the 4- to 5-leaf stage when development of the boot stage was initiated. This was two weeks later in the season than with Letterman needlegrass and at a much later phenological stage of development.

A rapid increase in the root reserve occurred after the seasonal low. Carbohydrate content increased to 137.4 mg and it coincided with the late boot stage (June 17). The increase continued through the next collection period at which time beardless wheatgrass was in the early heading stage (July 1). At anthesis, which occurred by July 15, the reserves were diminished to 124.0 mg. The depletion was found to be temporary as the highest seasonal reserve of 180.0 mg occurred 28 days later when the wheatgrass was in the hard dough stage. As beardless wheatgrass went into maturity the reserve declined from 175.3 mg to 125.3 mg August 27. The final fall concentration was still slightly higher than the initial concentration of 116.6 mg during the spring.

Regrowth occurred for both grasses during the fall. Hence, on September 28, and October 15, root samples showed that Letterman needlegrass reserves underwent a continual decline as a result of regrowth, going from 120.4 mg to 93.0 mg per gram of material (Fig. 2). Conversely beardless wheatgrass showed an increase from 125.3 mg to 152.6 mg per gram of root sample during the same period.

Although not investigated in this study, the leaf area index of the two plants may possibly explain the behavior of the root reserve. Brougham (1956) indicated rates of growth were correlated to the percentage of light intercepted by the leaves. Since beardless wheatgrass produced larger leaves and thus had more leaf area it would be possible with slow fall growth that the leaf area was sufficient to produce more carbohydrate material than was being used. In addition, it is possible that storage of reserve carbohydrates in the stubble and stem bases of beardless wheatgrass could have been greater than in Letterman needlegrass. This additional amount of stored carbohydrates would allow root reserves to increase slightly as a result of continued translocation to the roots, in addition to providing for some fall growth.

Little Rabbitbrush and Snowberry.—Roots of little rabbitbrush contained 137.4 mg of total available carbohydrates per gram of root material at the initiation of spring sampling (Fig. 3). The plants were in the late leaf-bud stage. One week later the seasonal low (55.6 mg) of total available carbohydrate reserve occurred when the rabbitbrush plants were in an early leaf stage and flower buds were present. Following the seasonal carbohydrate low, root reserves increased to 107.2 mg on May 30 when the basal leaves of the rabbitbush were mature and the apical leaves were in the process of unfolding. The increase appeared to coincide with a period of high photosynthetic activity which was in excess of the amount needed for growth.

Two weeks later on June 17, the reserves of little rabbitbrush decreased slightly to 91.9 mg with little change in phenology. At this time the apical leaves had developed to three-quarter size. No other change in phenology was evident. Leaf development, however, was occurring at a more rapid rate than during the earlier sampling period. The lower carbohydrate level remained relatively stable for a period of 4 weeks during which time leaf development was completed and flower buds had become evident. With the onset of flowering the root reserves of little rabbitbrush displayed a rapid increase through the maturing process, increasing from 93.1 mg (July 15) to 163.0 mg per gram of root sample (August 27).

The carbohydrate root reserves of snowberry were 86.7 mg per gram of root sample at the initiation of the study in early spring. They declined to a seasonal low of 25.6 mg one week later. The low level for snowberry occurred at almost the same stage of phenological development as rabbitbrush, when the leaves were one-half to three-fourths mature and leaf buds still remained at the apex of the stems. Following the minimum seasonal carbohydrate level, snowberry portrayed a most unique food reserve pattern, as it progressed to a peak of 92.5 mg per gram when vegetative development was about one-half complete on May 30, dropping when apical leaves were three-fourths mature (June 17) and then increased to 91.6 mg per gram (July 1) of root sample before any appreciable change occurred in leaf development. The initiation of flower buds resulted in an additional decline which was followed by the seasonal maximum of 141.4 mg at the time of full flower development on July 29. Contrary to other work, where it was found that maximum reserves were reached at maturity (Jameson, 1963; McCarty, 1938), the carbohydrate content of snowberry declined slightly during late flowering and maturation. After this decrease on August 12, a rather stable plateau occurred during the remainder of the season.

Senecio and Geranium.—Senecio is an early-growing forb, therefore the first collection was made when the plants were already in full leaf, just prior to flower bud formation. The root reserves were at the seasonal maximum at this time

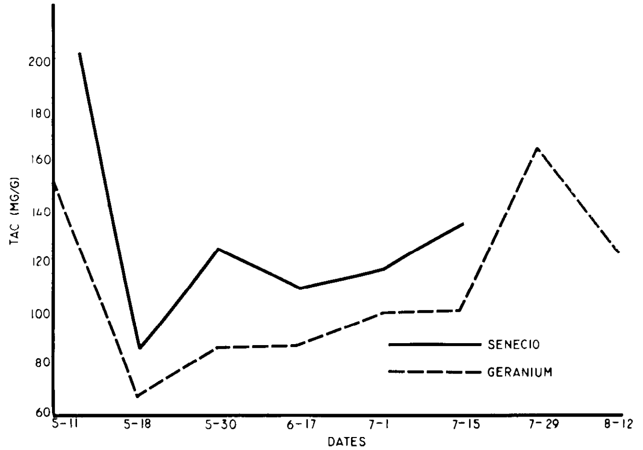

FIG. 4. Total available carbohydrate (TAC) reserves of Fremont geranium and senecio from initial growth to maturity. Values are averages expressed as milligrams of glucose equivalents per gram of root.

and contained 265.0 mg per gram of sample. One week later the carbohydrate content diminished to 81.0 mg as the plant initiated flower bud development. With the onset of flowering it rose to 127.9 mg on May 30, only to decline slightly in the late flower stage on June 17 (Fig. 4). Following the decline reserves increased until maturity, reaching 131.2 mg per gram of sample at the end of the growing season which occurred on July 15. Two weeks after maturity few plants remained and the species was no longer collected. In the present study senecio did not replenish the original carbohydrate reserve level of the roots that were present during early spring.

The carbohydrate reserve level of geranium roots was 150.1 mg per gram during early spring (Fig. 4). The plants had produced an average of two leaves per plant which were approximately one-third mature. Geranium plants displayed a sharp decline in root reserves one week later when an average of three leaves of one-half mature size were evident. The carbohydrate level then increased to 86.7 mg per gram on May 30. At this stage an average of six leaves, all of mature size were present. The increase in leaf area was most likely associated with an increase in root reserves. By June 17, the geranium plants exhibited occasional flowering but the carbohydrate level remained rather constant.

The onset of full flowering occurred about July 1, and corresponding with flowering was a marked rise in total available carbohydrates. Within a two-week period, all geranium plants were in full flower and the reserves declined to 105.1 mg per gram.

Following this slight decrease of carbohydrate reserves an increase to 161.2 mg per gram occurred on July 29. This level was the seasonal maximum and occurred when the plants were in late flower and seed set had begun. For an unknown reason, the reserves declined 2 weeks later when the plants were at full maturity. The trend in total available carbohydrate storage for Fremont geranium was similar to the trend described by McCarty and Price (1942) for sticky geranium *(Geranium viscossissimum)*. Sticky geranium likewise displayed a similar pronounced decline in root reserves with the onset of maturity.

Conclusions

Beardless wheatgrass was the last plant, chronologically and physiologically, to reach the minimum carbohydrate level in its roots during early growth. Carbohydrate reduction during early growth approached one of the lowest values recorded for any species analyzed. After descending to the minimal value the carbohydrate concentration increased quickly to the highest late season reserve recorded.

The reserve level of needlegrass was similar to that of beardless wheatgrass except it occurred earlier and was somewhat lower. A late season decline occurred at the time of seed development while with the beardless wheatgrass this decline occurred during flower development.

Snowberry and little rabbitbrush contained intermediate concentrations of available carbohydrates throughout the growing season compared with other species. However, the fluctuation of reserves throughout the season for snowberry was pronounced. No explanation was available for the fluctuation. Rabbitbrush root reserves increased steadily from a seasonal low through a mid-season plateau to a maximum value at maturity.

At the time of initial growth, senecio contained the highest carbohydrate level in the roots of the plants studied. Senecio plants grew faster and were in a more advanced stage of phenology than the other species. The reduced growth period resulted in rapid changes in total available carbohydrates in a short period of time.

The root reserves of geranium increased slowly through mid season. A late season maximum occurred at the time of full flower followed by a slight decline with maturity.

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Abstracting Journal Articles

Past procedure with all articles published in the Journal of Range Management has been for authors to prepare abstracts for Biological Abstracts. This practice was discontinued with the September 1969 issue (Volume 22, Number 5). Beginning with that issue, abstracts of articles appearing in the Journal of Range Management will be prepared by Biological Abstracts from the "Highlight" of each article, supplemented as necessary.

Authors preparing articles for the Journal should consider this use of the "Highlight" when it is being prepared.

Vegetative Response Following Pinyon-Juniper Control in Arizona[1]

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Highlight

Mean percentage calcium carbonate levels of near 13% in the surface foot of soil and low pinyon-juniper crown cover (13% and 26%) were associated with no increase in perennial grass herbage production four to five years after pinyon-juniper control in north-central Arizona. Both percentage calcium carbonate in the surface soil and percentage pinyon-juniper crown cover are expressions of the long-time moisture regime of a site and may be good indices for predicting potential understory response which might be expected from pinyon-juniper control.

Clearing pinyon and juniper overstory is a practice frequently recommended to improve rangeland. Arnold, Jameson, and Reid (1964) found herbage production increased about three and one-half times (to near 700 lb per acre) by five to ten years after juniper control. Understory vegetative production, however, does not always improve greatly with overstory removal. Brown (1965) reported that the average production of perennial grasses increased on parts of one watershed with control of overstory. The change was not statistically significant because production was spotty and also increased on untreated watersheds. Jameson (1966) has pointed out that, since the influence of trees on blue grama (*Bouteloua gracilis*) is concentrated on the litter-covered areas, there is little response of blue grama to tree removal where the litter covers only a small part of the area.

A knowledge of the factors influencing understory response following pinyon-juniper control is necessary to determine what areas may profitably be treated.

The objectives of the study reported in this paper were to determine the soil, precipitation, and vegetative characteristics associated with production and basal cover changes of understory plants following pinyon-juniper (*Pinus edulis, Juniperus monosperma,* and *J. osteosperma*) control in north-central Arizona.

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[1] Journal Paper No. 1433 of the Arizona Agricultural Experiment Station. Based on Masters thesis, University of Arizona, Tucson, 1967; and paper presented at Annual Meeting, American Society of Range Management, Albuquerque, New Mexico, February, 1968. Received January 24, 1969; accepted for publication June 5, 1969.

[2] Now serving with the U. S. Army in Korea.

Experimental Sites and Methods

The study area was located within the Heber Ranger District of the Sitgreaves National Forest in Coconino and Navajo Counties, Arizona. The soils of the study area are shallow and originated from limestone parent material. Four comparison sites were selected in the pinyon-juniper type along the Arizona Public Service Powerline right-of-way on which the overstory vegetation had been removed by bulldozing and hand-chopping. In the spring of 1961, a 195 ft strip along the southeast side of the right-of-way was cleared; the remaining 120 ft on the northwest side were cleared in the spring of 1962. Site names and elevations are: Boundary, 6200 ft; Ryan, 6300 ft; Second, 6500 ft; and Chevelon, 6600 ft. Understory vegetation on all sites is primarily blue grama. The Chevelon site was seeded in October of 1963 but success was so poor that any influence from the seeding was ignored in this analysis. Squirreltail (*Sitanion hystrix*), wolftail (*Lycurus phleoides*), and sand dropseed (*Sporobolus cryptandrus*) were the three main species contributing to the herbage production shown for other perennial grasses in Fig. 1. Following clearing, the cleared area was rested from grazing by domestic stock for two growing seasons and then returned to grazing use in 1965. All four sites were grazed by sheep during July and August of 1965 and 1966. Data were collected during the summer of 1966.

Within each year of control at each site, two clusters of five 100-step pace transects were established, and a corresponding number of transects were located in each adjacent uncontrolled area. Thus, the two years of control, each with an adjacent uncleared area, were compared as four treatments at each of the four sites. Basal cover of vegetation by species was recorded along the transects, and pinyon and juniper overstory was also determined along transects in the uncleared areas. Overstory was determined by recording the presence of cover above the pace transect points. To avoid bias resulting from pacing around obstacles, pace points were marked on a staff. When the line passed through areas where it was not practical to pace, the staff was laid along the line to determine data points. At the last pace of each transect, a 9.6 ft^2 herbage production plot was established. Herbage production was determined by species for all grasses by weight estimate.

The design of sampling was hierarchal, but the treatments within sites mean square was partitioned into the treatment and treatment times site components and analyzed as a factorial design. The cluster within treatment mean square with 16 degrees of freedom was utilized as the error term for testing significance of the treatment and site effects.

Soil was sampled at the 0- to 6-inch depth and the 6- to 12-inch depth and these held separate for analyses. Soil samples were collected from two locations within each cluster of transects. The four samples for each depth within each treatment at each treatment date were composited for laboratory analyses. The means of the analyses are given in Table 1. The sampling was hierarchal but the treatment within sites mean square was partitioned into its factorial components. The year within treatment mean square was utilized as the error term for testing treatment effects.

Laboratory analyses on soil samples were made for texture, moisture holding capacity at ⅓ atm and 15 atm tension, soil reaction, calcium carbonate, total soluble salts, potassium, nitrate-nitrogen, total nitrogen, and phosphate.

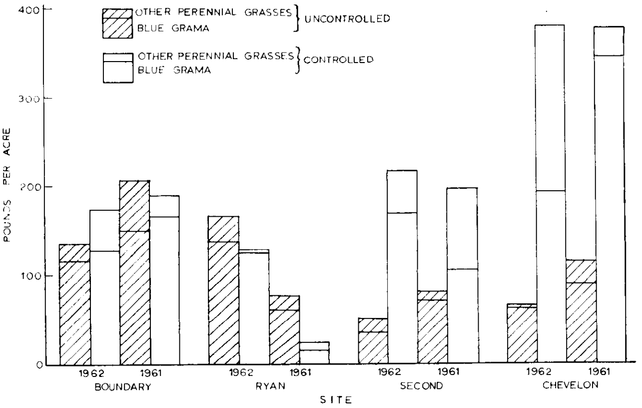

FIG. 1. Perennial grass and blue grama production on controlled and uncontrolled areas within four pinyon-juniper sites.

The phosphates and nitrates were extracted for 15 minutes in water through which CO_2 was bubbled. Phosphate was determined using molybdic acid and stannous chloride reagents. Nitrate was determined by the phenoldisulfonic acid method. Potassium was determined in a CO_2 extract with a Beckman-D4 flame photometer, and total nitrogen percentage was determined by Kjeldahl analyses.

Precipitation from June to November of 1966 was collected in three Tru-Chek rain gauges at each of the four sites.

Results and Discussion

Perennial grass basal cover averaged 21.4% at the Boundary site and 14.4% at the Ryan site, and control of pinyon-juniper overstory vegetation did not increase perennial grass cover at these sites. Pinyon-juniper control did increase perennial grass cover at the Second and Chevelon sites. The treatment times site interaction was significant. Perennial grass cover averaged 7.8% on uncleared areas at the Chevelon site and 24.0% where pinyon-juniper had been removed. At the Second site, the uncleared area had a perennial grass cover of 15.9% and perennial grass cover on the cleared areas was 23.4%. These cover responses are reflected in the herbage production data shown in Fig. 1. Perennial grass production along the cleared right-of-way was very nearly the same as for adjacent pinyon-juniper areas at the Boundary site. Clearing pinyon-juniper decreased perennial grass production at the Ryan site but resulted in over twice the production at the Second site and nearly four times the production of adjacent noncleared areas at the Chevelon site. Perennial grass production, as measured by 9.6-ft^2 plots, was extremely variable on all sites. The coefficient of variation among plots was 90%.

Annual grass basal cover averaged 1% to 2% on the uncontrolled areas of all sites and was little different from this after control for the Boundary and Ryan sites but averaged 13% to 14% on the Second and Chevelon sites after control. Basal area of forbs ranged from 0.0% to 0.3% on uncontrolled areas but ranged from 1.2% to 5.6% after control. The increase of forbs with pinyon-juniper overstory removal was evident at all sites.

Table 1. Elevation, precipitation, vegetative cover, and mean soil characteristics for the surface foot of soil as measured at four comparison sites in north-central Arizona.

Characteristic		Site Name			
		Boundary	Ryan	Second	Chevelon
Elevation	ft	6200	6300	6500	6600
June to November, 1966 precipitation	inch	5.04	5.52	6.58	9.32
Pinyon-juniper overstory on uncontrolled areas	%	13	26	36	44
Perennial grass cover on uncontrolled areas	%	22	16	16	8
Soil texture					
Sand	%	48	72	59	57
Silt	%	30	10	20	24
Clay	%	22	19	21	18
Water held at 1/3 atm	%	19.8	16.1	14.6	16.0
Water held at 15 atm	%	11.6	9.5	9.1	9.1
Difference		8.2	6.6	5.5	6.9
Soil reaction	pH	7.8	7.7	7.5	7.5
Calcium carbonate	%	13.2	12.5	4.4	6.9
Soluble salts	ppm	375	405	447	355
Nitrogen	%	.19	.16	.15	.14
Nitrates	ppm	20	29	17	11
Phosphate	ppm	4.3	3.8	5.0	5.0
Potassium	ppm	45	48	57	32

Basal cover of shrubs and half shrubs averaged 2.1%, 1.7%, 0.5%, and 0.3% for the Boundary, Ryan, Second, and Chevelon sites, respectively. Statistical significance was not shown for the slightly higher cover of shrubs on the cleared right-of-way. Snakeweed (*Gutierrezia* sp.) was the primary half shrub which showed an increase with control.

Pinyon-juniper control could be recommended for increased herbage production on the Second and Chevelon sites but not for the Boundary and Ryan sites. When a comparison of the site characteristics (Table 1) is made with the response, a number of factors are shown to be associated with the response obtained. Perhaps the most obvious factor associated with poor understory herbage increase is the high calcium carbonate percentage of the soils at the Boundary and Ryan sites. Since phosphorus availability and soil reaction are closely associated with calcium carbonate content in the soil, these characteristics were also correlated with response. The calcium carbonate percentage of the surface foot of soil was about 13% for the poor sites and averaged near 5% for the two better sites.

Phosphates averaged 4.1 ppm for the two poor sites and 5.0 ppm at the two better sites. Soil reaction averaged a pH of 7.75 for the two lower sites and 7.52 at the higher elevations.

Higher percentage calcium carbonate, higher pH, and a lower phosphate level were found for the 6- to 12-inch depth than for the 0- to 6-inch depth at all sites. Because of the mechanical disturbance of the soil profile with control operations, calcium carbonate and pH were slightly higher and phosphorus lower in the surface soil of treated areas compared to the check areas. These measurements seem to indicate that clearing operations tend to decrease production potential of the sites by severe soil disturbances.

The higher calcium carbonate percentage, higher pH, and lower phosphorus availability of the soils at the Boundary and Ryan sites compared to soils at the Second and Chevelon sites are a reflection of the precipitation and leaching which has occurred at these sites. The June to November precipitation data for 1966 support this observation (Table 1).

The Ryan site, with a higher percentage sand and a lower level of available soil moisture than the Boundary site, was a poorer site than Boundary in terms of blue grama response, but neither site yielded a favorable increase in forage yield with pinyon-juniper control.

Total nitrogen was associated with the understory vegetative cover prior to control and was not positively associated with response. Nitrates followed the same general trend as total nitrogen, higher on the two lower sites than at the two sites at the higher elevations. Control of pinyon-juniper overstory resulted in higher nitrate in soils on controlled than uncontrolled areas. Total soluble salts and potassium were not factors limiting response in this study.

Conclusions

The characteristics of the Boundary and Ryan sites which were associated with poor understory response following pinyon-juniper removal were high calcium carbonate (13%), high pH (7.8 & 7.7), low phosphorus (4.3 and 3.8 ppm), and low (13% and 26%) pinyon-juniper overstory. These characteristics are a reflection of the long-time meager precipitation received at these sites and could be utilized as indicators of sites on which pinyon and juniper control may not be practical. The high sand content of the soil (72%) at the Ryan site intensified the drouthiness of this site.

Total nitrogen, nitrates, total soluble salts, and potassium were not major factors influencing differences in understory herbage response following pinyon-juniper overstory control in this study on limestone soils of north-central Arizona.

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Effects of Grazing on a Hardland Site in the Southern High Plains[1]

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Highlight

The vegetation and soil characteristics of an ungrazed butte are compared with those of a similar site on an adjacent High Plains area. Woody plant cover was greater and more diverse on the butte while herbaceous vegetation was more productive and of higher quality. Species composition and production was representative of shallow hardlands of the Southern High Plains region. Soil characteristic differences reflected the detrimental influence of continued herbage removal and trampling by livestock on the grazed area.

[1] Received January 6, 1969; accepted for publication March 22, 1969.

An ungrazed isolated butte was studied to learn the effects of grazing on the vegetation and soils of a hardland site on the Southern High Plains. Such relict areas commonly serve as the basis for determining range site potential. The comparison of the relict area with an adjacent area which had received unrestricted grazing by cattle since the late 1800's also let us determine the effects of grazing on the soils and vegetation.

The butte (Flat Top Mountain) is located approximately 20 miles northwest of Snyder, Texas, and 8 miles southeast of Justiceburg on U.S. Highway 84. Flat Top Mountain (Fig. 1), adjacent to the escarpment (Cap Rock) of the Llano Estacado, straddles the line between Garza and Scurry Counties. The grazed area is located in Scurry County and is the nearest point to the isolated butte, which lies approximately 2 miles to the east of the Cap Rock. Elevations of the Cap Rock and the butte are 2,885 ft and 2,865 ft respectively.

The Llano Estacado, or Staked Plains, is the

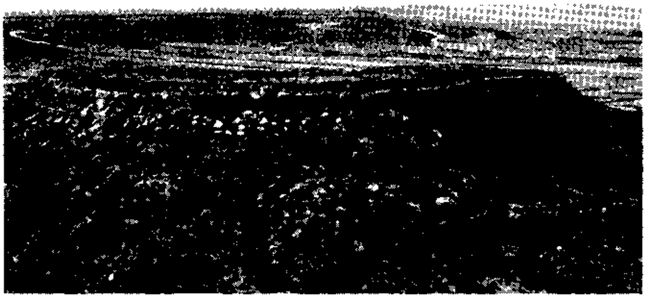

FIG. 1. Flat Top Mountain relict area was once part of the Cap Rock of the Llano Estacado in the background.

southernmost part of the High Plains province. The surface is a nearly flat plain, having an average southeastward slope of only 8 or 10 ft per mile. It is essentially a plateau, bounded on the north by the breaks on the Canadian River, on the east and west by escarpment rising above stream-eroded lower lands, and on the south it merges physiographically with the Edwards Plateau (Evans and Brand, 1956).

Both study areas are capped by cretaceous material of the Fredericksburg formation which overlies the exposed Trinity formation, which is also cretaceous material (Evans and Brand, 1956). The cretaceous deposits consist of rather hard fossiliferous limestone. These deposits are confined to the top of Flat Top Mountain and the adjacent Cap Rock area (Fluvanna Flat) in Scurry County (Templin and Reitch, 1931). The soils on both study areas are clays of the Lea-Slaughter complex series and the Kimbrough series.

Climatic conditions in this area of the High Plains of Texas vary from maximum temperatures greater than 100 F in the summer to readings below zero for short periods in the winter. Variations of 30 to 40 F is one feature of the daily temperature changes in the summer (Lotspeich and Everhart, 1962). Rainfall records from Post, 25 miles north, and Snyder, 20 miles to the south, show that they receive an average of 19.6 inches and 19.9 inches, respectively. The seasonal distribution follows the usual pattern for both towns with peaks in May and September (Hildreth and Thomas, 1956). However, the pattern of rainfall, the high wind velocities, and the high evaporation rates tend to reduce the effectiveness of the precipitation (Lotspeich and Everhart, 1962).

Two distinctly different range sites occurred on both study areas. They are a shallow hardland site (Lea-Slaughter complex) and the very shallow site (Kimbrough series). This study was limited to the shallow hardland site on both areas. This site differs from the deep hardland site commonly recognized in the Southern High Plains mainly in depth, and generally supports a more mesic type vegetation due to better soil moisture relationships.

Methods

Canopy cover of shrubs was measured by the line intercept method using a 100-ft line. Herbage production for each area was determined at the end of the 1967 growing season by the weight-estimate method. Estimates of green plant weights occurring within sixty 2.4 ft^2 plots per area were made. Twelve of the estimated plots from each area were selected at random and clipped. These clipped samples were oven-dried to a constant weight at 160 F. The regression of actual green weights on estimated green weights was used to correct all estimated weights. Wire cages were used to determine utilization on the grazed area. Production estimates on the grazed area were adjusted according to utilization estimates to obtain total production.

Soil samples were taken at 0–4 inches and 6–10 inches on both study areas. Soil pH, organic matter content, phosphorus content, and soluble salts were analyzed by the Texas Agricultural Experiment Station's South Plains Research Center. Bulk densities were determined from core samples of known volume. Soil texture was determined by the hydrometer method. Infiltration and compaction data were collected directly in the field.

A double-ring infiltrometer was used for infiltration data. The process was repeated four times in each area. Soil compaction measurements were taken with a soil penetrometer. One-hundred readings were taken at 1-inch depths on each area.

Herbage production data were statistically analyzed by paired comparison. Differences in infiltration rate, soil compaction, and bulk density were tested by the group comparison method.

Results and Discussion

Vegetation

There was considerable difference in the vegetation between the ungrazed butte and the grazed area, both in quantity and in quality.

The butte supported 14 woody plant species compared with only eight on the grazed area (Table 1). Redberry juniper was the dominant species on the butte, but other plants such as shinnery oak, narrowleaf yucca, mesquite and skeleton goldeneye added considerable cover (Fig. 2). On the other hand, mesquite was the dominant species on the grazed area (Fig. 3).

There was more than twice as much total woody plant cover on the butte as on the grazed area (Table 1). The difference was largely due to the large amount of redberry juniper on the butte and the absence of several species on the grazed area. The absence of palatable species such as skeleton goldeneye, vine ephedra and elbowbush are explainable by grazing pressure. The presence of shinnery oak, feather dalea and narrowleaf yucca

Table I. Woody plant cover (percent) on an ungrazed butte and the adjacent Cap Rock area, 1967.[1]

Species	Ungrazed Butte	Grazed Cap Rock Area
Redberry juniper *Juniperus pinchoti*	6.3	0.3
Narrowleaf yucca *Yucca angustifolia*	2.3	0
Skeleton goldeneye *Viguiera stenoloba*	1.5	0
Feather dalea *Dalea formosa*	1.4	0
Shinnery oak *Quercus havardii*	1.3	0
Honey mesquite *Prosopis glandulosa*	1.2	5.5
Vine ephedra *Ephedra antisyphilitica*	1.0	0
Elbowbush *Forestiera pubescens*	0.5	0
Skunkbush *Rhus aromatica*	0.2	0
Lotebush *Condalia obtusifolia*	0.2	0.8
Littleleaf sumac *Rhus microphylla*	0.1	0.3
Agarito *Berberia trifoliolata*	0.1	T[2]
Catclaw acacia *Acacia greggii*	T	0
Engelmann pricklypear *Opuntia engelmannii*	T	T
Cholla *Opuntia imbricata*	0	0.3
TOTAL	16.1	7.2

[1] Common and botanical names are according to Gould (1962).
[2] T = Amounts less than 0.1%.

FIG. 2. Jimmy Brown and Jack McClung examine a motte of shinnery oak, one of 14 woody species found growing vigorously on the Flat Top Mountain relict area.

FIG. 3. The grazed shallow hardland site is dominated by mesquite with only scattered juniper and lotebush. Buffalograss and tobosagrass are the most prevalent herbaceous species.

on the ungrazed butte and not on the grazed area is not, however. Since soils and climate are not factors either, some other factor such as the lack of fire on the butte may be involved. Another study (Ellis and Schuster, 1968) indicated that fire might have been instrumental in keeping redberry juniper off the Cap Rock area but not from isolated buttes. This is assumed to be the case on this butte for redberry juniper, but further study is needed to determine the causes of the presence or absence of the other woody species from the two areas. The presence of woody species on the butte indicates that the soils and climate are favorable for growth of these species. Their absence from hardland sites on the Southern High Plains is apparently due to factors other than soils and climate.

The butte produced 706 lbs. more oven-dry herbage per acre than the grazed area (Table 2). Sideoats grama, rough tridens and blue grama were the most productive species on the butte. These species produced 70% of the herbage on the butte, while only one of them, blue grama, was found on the grazed area on the Cap Rock.

Buffalograss was the most productive species on the grazed area, making up 65% of the herbage production. Tobosagrass and vine mesquite, apparently increasers on this site, were the next most productive species. These three species produced 85% of the herbage on this area.

Table 2 presents the classification of the herbaceous species according to their reaction to cattle grazing pressure. The classification is based on their presence or absence on the ungrazed butte and general knowledge of the species' reaction to grazing in this region. We classified the site as shallow because the soils (Lea-Slaughter complex)

Table 2. Herbage yields (lb/acre) and classification of herbaceous species in relation to reaction to grazing.[1]

Species by class	Butte	Grazed
Decreasers		
Sideoats grama *Bouteloua curtipendula*	816	0
Rough tridens *Tridens elongatus*	246	0
Blue grama *Bouteloua gracilis*	163	21
New Mexico feathergrass *Stipa neomexicana*	15	0
Greenthread *Thelesperma filifolium*	42	0
Total decreasers	1282	21
Increasers		
Buffalograss *Buchloe dactyloides*	315	692
Tobosagrass *Hilaria mutica*	112	136
Vine mesquite *Panicum obtusum*	34	100
Halls panicum *Panicum hallii*	17	11
Threeawn *Aristida* sp.	16	15
Sand dropseed *Sporobolus cryptandrus*	10	0
Hairy tridens *Tridens pilosus*	4	3
Hoary euphorbia *Euphorbia lata*	3	0
Green false-nightshade *Chamaesaracha coronopus*	3	0
Purple groundcherry *Physalis lobata*	3	0
Texas skeleton plant *Lygodesmia texana*	1	0
Scarlet globemallow *Sphaeralcea coccinea*	4	6
Fall witchgrass *Leptoloma cognatum*	T	0
Louisiana sagewort *Artemisia ludoviciana*	T	0
Total increasers	522	957
Invaders		
Sand muhly *Muhlenbergia arenicola*	0	50
Leatherweed croton *Croton pottsii*	T	34
Indian rushpea *Hoffmanseggia densiflora*	0	13
Silverleaf nightshade *Solanum elaeagnifolium*	T	4
Sideranthus *Machaeranthera pinnatifida*	0	3
Stinkgrass *Eragrostis megastachya*	0	1
Low milkvetch *Astragalus lotiflorus*	0	1
Texas filaree *Erodium texanum*	0	T
Pigweed *Amaranthus* sp.	T	0
Total invaders	0	106
Total all species	1804	1090

[1] Common and botanical names are according to Gould (1962).

were shallower than 20 inches and the species and composition differed from those found on the deep hardlands of this land resource area. Several of the species found in abundance on the butte are not included as climax species on the current soil conservation service range site condition guide for the deep hardland site. For example, New Mexico feathergrass and rough tridens, both palatable grasses were present in abundance on the butte and should be considered climax decreasers for this site. Similarly, the palatable perennial forb, greenthread should be included as a decreaser for this site. Other perennial forbs such as Texas skeleton plant, purple groundcherry, green false nightshade and hoary euphorbia all found in substantial quantities on the ungrazed butte, are apparently present in the climax. Their reaction to grazing is not known so we tentatively classified them as increasers. Vine mesquite reacted as an increaser and because of its mediocre palatability is classified as an increaser.

The herbaceous vegetation on the butte is representative of climax vegetation of shallow hardland sites of the Southern High Plains. It is dominated by mid- and short grasses but contains several perennial forbs. The five species we consider decreasers (Table 2) produced 71% of the herbage. Sideoats grama is by far the most productive species.

Difference in plant distribution patterns also existed between the grazed and ungrazed areas. On the butte, each species tended to occupy very distinct areas with very little intermixing of species except in narrow transition zones. This colonization was not apparent on the grazed area.

Soil Characteristics

The differences in soil characteristics reflect the influences of herbage removal and trampling by grazing livestock. The infiltration rate was almost

Table 3. Soil characteristics found on grazed and ungrazed shallow hardland sites in the Southern High Plains, 1967.

Characteristic	Ungrazed Butte	Grazed Area
Infiltration Rate*	15.3 in/hr	3.9 in/hr
Soil Compaction*	7.9 lb/in²	47.7 lb/in²
pH		
0–4″ depth	7.8	7.7
6–10″ depth	8.0	8.0
Bulk Density*		
0–4″ depth	.996 gms/cc	1.180 gms/cc
6–10″ depth	1.020 gms/cc	1.150 gms/cc
Organic Matter		
0–4″ depth	3.6%	2.8%
6–10″ depth	2.9%	2.5%
Available Phosphorus		
0–4″ depth	35 lb/acre/ft	92 lb/acre/ft
6–10″ depth	18 lb/acre/ft	50 lb/acre/ft
Sodium		
0–4″ depth	140 lb/acre/ft	140 lb/acre/ft
6–10″ depth	240 lb/acre/ft	220 lb/acre/ft
Soil Texture		
A horizon		
sand	18.8%	21.0%
silt	33.2%	37.7%
clay	48.0%	41.3%
B horizon		
sand	14.6%	12.8%
silt	28.3%	31.2%
clay	57.1%	56.0%

* = Differences between areas tested and found significant at the .05 level.

four times as great on the ungrazed butte as on the grazed area (Table 3). This highly significant ($P < 0.01$) difference in infiltration rate was probably due to better soil structure, less compaction by grazing animals, increased organic matter content in the top soil, and increased accumulation of litter on the soil surface on the relict area. Similar differences in infiltration rates have been reported. Hopkins (1954), comparing water absorption of grazed and ungrazed sites on rangelands with a ring-type infiltrometer, found that water was absorbed much faster on ungrazed than on grazed sites. Reed and Peterson (1961) found that grazing reduced infiltration rates by about one-half. Even the lightest intensity of grazing lowered the rate of infiltration in their study. Evidently, continual removal of organic matter and trampling by livestock causes soil conditions that prevent water penetration.

Penetrometer readings indicate about six times as much compaction on the grazed area as on the butte (Table 3). This highly significant difference points out the effect grazing animals have on the physical structure of the soil. Other investigators have found similar effects. Keen and Casheen (1932) used a penetration rod to measure compaction by sheep to a depth of 10 cm. Compaction was greatest in the 3 to 4 cm layer. Kucera (1958) also found the greatest soil compaction by cattle in the surface inch, with no apparent influence below 4 inches. Such conditions are probably also influenced indirectly by decreases in organic matter and soil porosity at the soil surface with continued grazing.

Measurements of soil texture, pH, sodium, organic matter, and available phosphorus for the two areas are shown in Table 3. Although not tested statistically, differences in pH, sodium content, and soil texture do not appear significant. The differences in available phosphorus does appear real, however. A previous study (Lodge, 1954) also reported higher amounts of phosphorus in the 0–4 inch soil layer on grazed sites. The lower amount of organic matter on the grazed area was also expected, and assumed to be a significant decrease due to grazing effects.

Soil bulk densities were significantly ($P < .05$) greater at both levels in the grazed area than on the butte (Table 3). Our findings agree with other studies that found grazing increased bulk density. Alderfer and Robinson (1947) found that bulk densities in the 1-inch surface layer on a variety of pasture sites ranged from 1.54 to 1.91 gms/cc for heavily grazed sites and from 1.09 to 1.51 gms/cc for ungrazed and lightly grazed sites in Pennsylvania. Kucera (1958) also found bulk densities higher under grazed conditions. The loss of organic matter and compaction due to livestock trampling are commonly considered the causes of increases in bulk density on grazed sites.

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ERRATA

In the July 1969 issue of the *Journal of Range Management,* the list of Sciential Committees contains the following error: The committee headed **Native Haylands** mistakenly lists the members of the committee on **Native Pasture Lands of Farms and Forest Climates.** Following are the correct listings of the two Sciential Committees in question:

Native Haylands

Donald F. Burzlaff, *Chairman,* Department of Agronomy, University of Nebraska, Lincoln, Nebr. 68503

Arthur W. Bailey — Robert W. Lodge
E. Irving Hackett — Robert S. Rummell
Arnold Heerwagen

Native Pasture Lands of Farms and Forest Climates

L. F. Bredemeier, *General Chairman,* P. O. Box 11222, Fort Worth, Tex. 76110

Appalachian Region

Thad B. Trew, *Chairman,* 609 Cardinal Dr., Pulaski, Va. 24301

Ivan W. Dodson — Willis G. Vogel
James B. Newman

Coastal Plains Region (over 40 inches precipitation)

D. B. Polk, *Chairman,* 4205 Woody Lane, Bryan, Tex. 77801

David W. Sanders — Lewis L. Yarlett
Alton T. Wilhite, Jr.

North Central Section

Clayton S. Williams, *Chairman,* 2313 Parkwood Dr., Midland, Mich. 48640

Herbert E. Boe — Marc A. Moore
James A. Deane — John W. Voight

Ozark-Ouachita Region

Ardell J. Bjugstad, *Chairman,* Rm. 1-26 New Agriculture Bldg., University of Missouri, Columbia, Mo. 65201

Roger L. Kirkman — Ivan R. Porter
Samuel A. Lowance — Henry N. Stidham

TECHNICAL NOTES

Magnetic Pin Brakes and a Base Mounting for Point Frames[1]

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Highlight

Point frame pins receive a smooth, even brake tension from horseshoe magnets. A point frame mounted on a rigid base allows quick, even spacing of points.

Modifications in design of pin brakes for point frames have been suggested by Heady and Rader (1958), Smith (1959), and Neal, Hubbard, and Conrad (1969). The magnetic brake described in this paper was designed independently of the one described by Neal et al. (1969) and was used on a base-mounted point frame (Fig. 1). The base mounting permits points to be equally spaced on square sample plots. The magnetic brakes allow pins to be pushed down smoothly with a constant pressure, free of vibrations, and without causing the points to wobble.

The magnetic brake for each pin is a shallow U-shaped magnet,[3] the ends of which extend from 1/16 to 1/8 inch through two 1/2 inch diameter holes from the flange side of a tee-shaped aluminum beam (thickness 75/1000 inch, flange width 3¼ inch, and stem height 1 7/16 inch). Ten magnets are held in place with a rectangular aluminum strip fastened to the flange of the aluminum tee with aluminum bushings and brass screws (inset of Fig. 1B). The bushings permit some forward and backward movement of the magnets. This movement allows a magnet to aline itself automatically into full contact with a pin when the pin is in position through the guide holes. Pin guide holes in the stem of the aluminum tee and in a rectangular aluminum bar below the tee are very slightly oversize to allow for accurate pin guidance and minumum friction. A pin can be moved past a magnet with weights of 1/2 to 3/4 lb. or only slight finger pressure.

With the magnets, of course, the bronze pins preferred by Smith (1959) cannot be used. To avoid rust problems, rods of stainless steel (type 416, annealed, cold drawn) were used as pins. However, not all stainless steel is attracted to magnets and prospective users should specify the type that is. The pins were 1/8 inch diameter, 36 inches long, and sharpened to a point. When not in use the pins were carried in a small diameter electrical conduit with rubber stoppers for end plugs.

[1]Received October 10, 1968; accepted for publication January 1, 1969.

[2]Headquarters maintained at Ogden, Utah. Author stationed at Forestry Sciences Laboratory maintained in cooperation with Utah State University, Logan, Utah.

[3]Stock number P-40,909; Edmund Scientific Company, Barrington, New Jersey, 1 in. wide by 7/16 in. high by 13/32 in. thick; weight 1/2 oz; average lift 4 lb. 13 oz. Use of trade names herein is for identification only and does not necessarily imply endorsement by the Forest Service, USDA.

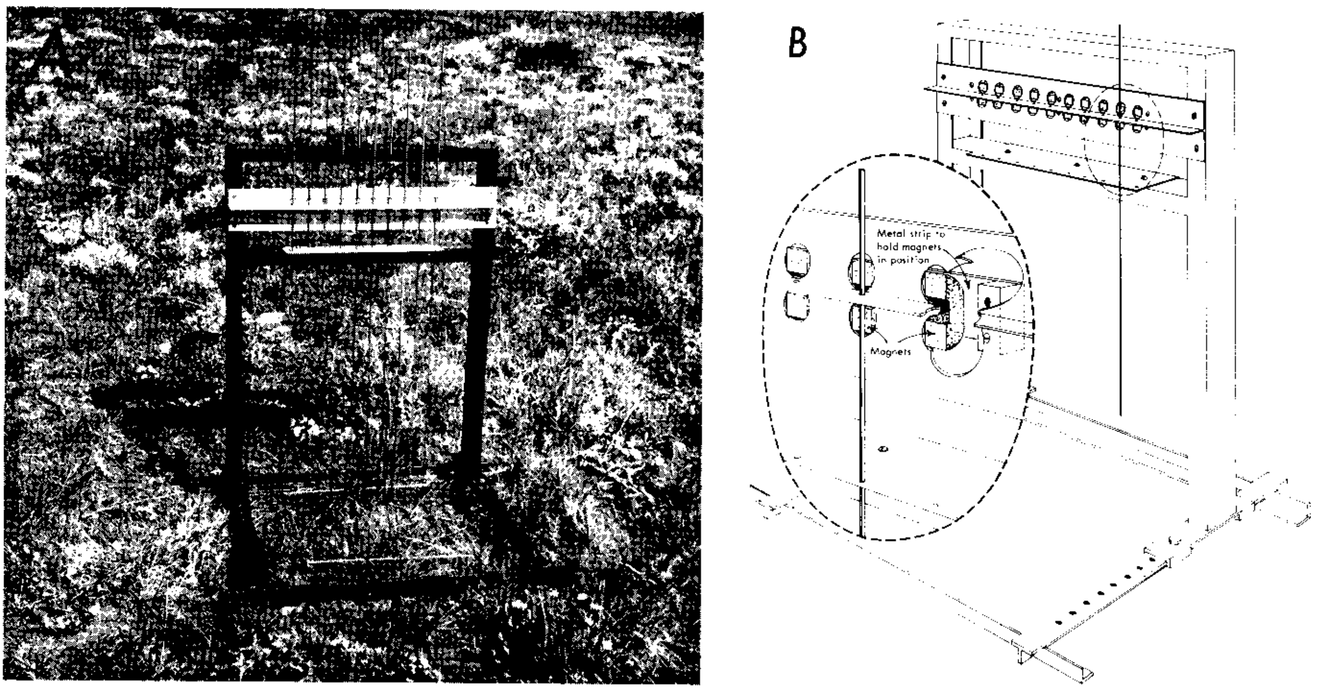

FIG. 1. Base-mounted point frame with magnetic pin brakes: A, Frame in field use; B, detail of magnetic brake and base mount.

The point frame can be moved to the stop points along the rigid base mounting (Fig. 1B). At each stop a short bolt is placed through a hole in each foot of the frame and into a hole in the base. Springloaded catches, which would automatically drop into the stop holes along the base, could be built into the feet of the frame. If desired, an inclined point frame could be built to slide along a rigid base, provided the base was heavy enough or long enough to support the inclined frame. Wedge blocks or small adjustable legs may be used to steady the base on uneven ground.

The unit shown in Figure 1 samples a 1 ft^2 plot. Once the frame is centered over a plot, 100 equally spaced points can be sampled with just 10 settings of the frame along the base. Inside dimensions of the base are 17 by 18 inches and stop points are spaced at 1.2 inches. The frame is 30 inches tall and 20 inches wide, with a lower pin guide bar 21 inches above the ground and 4 inches below the stem of the aluminum tee.

Except for the aluminum and brass parts used for mounting the magnets and guiding the pins, the frame and base were of 2 by 1 by ⅛ inch channel iron and 1¼ by 1¼ by 3/16 inch steel tee and steel angle iron. The unit weighs 32 lb. If weight were an important consideration, the same unit could be made entirely of aluminum.

Cost of this point frame was as follows:

10 magnets @ 20¢	$ 2.00
Other material	13.00
Labor	55.00
Total	$70.00

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Effect of Spring Burning on Tobosa Grass[1]

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Highlight

During a wet year tobosa produced more herbage on burned plots than on unburned plots at five locations. Ash from the burns had a slight fertilizing effect, but removal of litter stimulated production more than any other factor. Based on this data, fire can be used as a tool to control mesquite without harming tobosa.

Since our recent research indicates that fire has the potential to kill mesquite in tobosa (*Hilaria mutica*) communities (Stinson and Wright, 1969), this study was undertaken to see how seriously fire will damage tobosa. Tobosa is a dominant of the Southern Desert Plains of North America (Clements and Shelford, 1939) and is the climax on adobe soils (Campbell, 1931). Moreover, it is a productive grass type (Paulsen and Ares, 1962) that is cherished by southwestern ranchers as a "reserve" feed during dry years. Therefore we do not want to damage it by burning if fire proves to be a useful tool to control mesquite. The objective of this study was to see if spring burning would damage tobosa.

Since tobosa is a coarse plant that is generally unpalatable and builds up large amounts of litter, several researchers have tried various methods of increasing its palatability and utilization. Heavy grazing, mowing, and burning have all been tried, and have all increased utilization. Mowing, however, is impractical on large areas, and burning has only been tried in late summer (Gonzalez, 1957) when little time was left for regrowth.

Methods and Procedures

Yields on pure stands of tobosa were measured on five burned and unburned locations in northwest Texas: two near Post, one about 15 miles east of Guthrie, one about 7 miles north of Quanah, and one 15 miles south of Colorado City. In addition a clipped plot, where all growth was removed at time of burn on an associated plot, was sampled at Colorado City.

All plots were burned in late spring from March 23 to 28, 1968. Burning is being concentrated at this time of year for three reasons: (1) ranchers can decide whether they need tobosa as a reserve feed and are willing to burn if they do not need it, (2) an evaluation of adequate soil moisture for plant regrowth can be made, and (3) top removal of the dormant tobosa should be least harmful.

Size of the burned plots varied from 1 to 90 acres and elevation varied from 1602 to 2880 ft. Precipitation averages about 19 inches per year. The vegetation at each location was nearly a pure stand of tobosa grass with a few annual forbs.

Mesquite also existed on all plots. At both locations near Post the mesquite had no prior treatment. At Quanah and Guthrie the mesquite had been shredded 2 to 3 years previously. And at Colorado City the mesquite had been sprayed in 1965 with no apparent kill.

Firelines were graded around the plots that were to be burned. In general the plots to be burned or not burned were chosen at random. But in two burns, this was not possible because of the necessity to place firelines where the plot could be burned safely. At these locations comparable unburned areas were chosen before burning.

Thirty 1 × 2.4 ft quadrats were clipped to sample growth and litter on treated and untreated plots at each location. The vegetation at all locations was clipped after one full growing season in August 1968. All samples were oven dried and weighed.

Results and Discussion

Yield of tobosa was higher on the burned plots than on the unburned plots at all locations (Table 1). Moreover, undesirable annual forbs which had emerged before the burning treatment were less abundant on burned

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Table 1. Yield of herbaceous vegetation on tobosa plots one growing season after treatments (lb/acre, over-dry).

Location	Clipped	Burned	Control	
			Current growth	Litter
Tobosa grass				
Post I		2084[1]	1244	4754
Post II		2220[1]	1424	3672
Guthrie		2205[1]	1332	3228
Quanah		2314[1]	1893	3308
Colorado City	3100[2]	3572[1]	920	4430
Forbs[3]				
Post I		8	48	
Post II		7	21	
Guthrie		39	60	
Quanah		9	30	
Colorado City	49	13	295	

[1] Different from control treatment at .01 level of probability.
[2] Different from burn treatment at .05 level of probability.
[3] The dominant species on unburned plots was *Gutierriezia dracunculoides*; other species present were *Conyza canadensis, Erigeron bellidiastrum,* and *Sphaeralcea coccinea.* On burned plots the dominant species were *Chenopodium leptophyllum* and *Solanum elaeagnifolium.*

Table 2. Rainfall (inch) for town near burned plots.

Month	Location			
	Colorado City	Quanah	Post	Guthrie
Before burn				
Jan.	1.67	3.37	3.00	3.08
Feb.	1.75	1.02	1.76	1.72
Mar.	1.77	2.25	3.01	2.39
	5.19	6.64	7.77	7.19
After burn				
Apr.	1.37	1.14	.94	.64
May	1.74	3.64	1.87	1.97
June	2.26	2.63	2.05	3.27
	5.37	7.41	4.86	5.88
Total	10.56	14.05	12.63	13.07

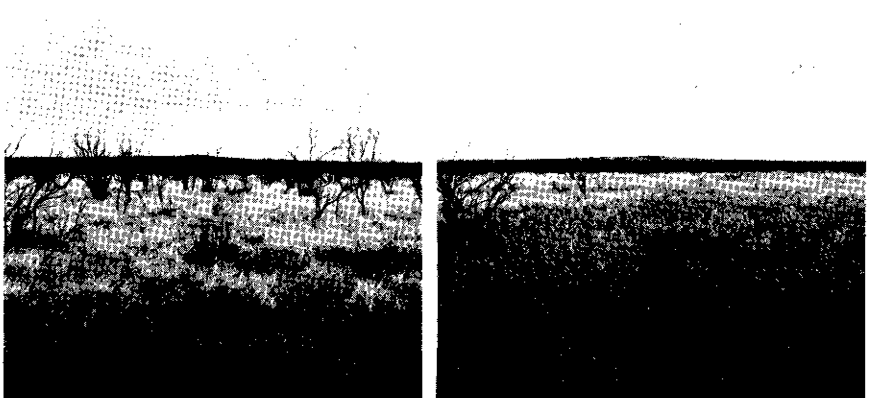

FIG. 1. View of tobosa grass community at Colorado City before and after burning. Yield of tobosa after burning was 3572 lb/acre and mortality of mesquite was 32%.

Table 3. Average maximum temperature (°F) for each burn.

Location	Temperature
Post I	540
Post II	590[1]
Guthrie	690
Quanah	820
Colorado City	980

[1] Estimate based on a comparable burn.

plots. Clipping increased yields of tobosa almost as much as burning.

The increased yield of tobosa on the burned plot vs. the clipped plot at Colorado City (Table 1) suggests that ash has a slight fertilizing effect. The superior yields, however, of both of these treatments compared with the unburned plots show that large accumulations of litter severely depress production.

Burned plots, except for the one at Colorado City, produced a little over 2000 lbs of tobosa per acre. The one at Colorado City produced 3572 lbs/acre. I do not have an explanation for this difference except that Colorado City has the lowest elevation and is an area where tobosa is very well adapted. This particular site was a bottomland that may be subject to flooding. Total rainfall, however, before the burn and after the burn was lowest in the Colorado City area (Table 2).

Since this was a wet year, we can only say that fire does not damage tobosa during a wet year. Having some moisture in the soil before burning seems to be a sensible requirement before using fire as a tool to control mesquite, if one wants to minimize damage to tobosa.

The range of weather conditions at time of burns were as follows: temperature 65–83 F, wind 6–11 mph, and relative humidity 25–50%. Fuel moisture varied from 13 to 22%. Percent soil moisture in the surface inch varied from 18.1 to 22.8%.

Average maximum soil surface temperatures for each burn are shown in Table 3. Compared to other grass species, tobosa burns hot (Stinson and Wright, 1969). But evidently these high temperatures have no detrimental effect on tobosa, at least when there is moisture in the soil at time of burn.

At Colorado City it looks as if burning can effectively kill mesquite that has been sprayed and has resprouted (Fig. 1). We killed 32% of the trees and seriously damaged those that were not killed. In our other burns we did not kill any mesquite, some of which had no previous treatment and some of which had been shredded. There were, however, no young plants in any of the burns.

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Pre-emergence Herbicides for Seeding Range Grasses[1]

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Highlight

Three herbicides were evaluated for use in seeding range grasses. Propazine, applied as a pre-emergence at rates up to 3.0 lb/acre, controlled broadleaf weeds and crabgrass but had no apparent retarding effect on the germination and growth of switchgrass and Old World bluestems. Siduron applied at 1.5 lb active ingredient/acre controlled large crabgrass and had no apparent retarding effect on switchgrass, big bluestem, and indiangrass. Sideoats grama was harmed by all pre-emergence herbicides tested. Norea applied at 2 lb/acre retarded germination and seedling establishment of those species tested. None of the herbicides tested has been cleared for use on grazing lands.

Range grass seeding in the Great Plains has a history of a limited probability for success. A survey of grass plantings from 1960 to 1962 revealed that 18% of these were failures (Great Plains 6 Technical Committee, 1966). Seedbed preparation has been studied extensively (Launchbaugh and Anderson, 1963; Burnham, 1955; and Cooper, 1957) and it is generally agreed that seeding into a stubble mulch using double disk banded openers and press wheels offers the best chance for success.

Starter fertilizers have been tried and a small degree of improvement in stand establishment was occasionally noted (Cosper and Alsayegh, 1964; Welch et al., 1962). Bryan and McMurphy (1968) found that the addition of fertilizer did not enhance stand establishment. In their study weedy grasses present during the first year of establishment reduced second year forage yield by 28 to 70%. Weed control during establishment was considered mandatory before any benefits might be obtained from starter fertilizers. Arnold and Santelmann (1966) tested 4amino-3,5,6-trichloropicolinic acid (picloram) and 2,4-dichlorophenoxyacetic acid (2,4-D) for pre-emergence treatment of four native grasses and reported no germination from the picloram treated plots. Seven months after application Klomp and Hull (1968) found no residual effect from 4 lb of 1-(2-methylcyclohexyl)-3-phenylurea (siduron)/acre using crested wheatgrass (*Agropyron desertorum*) for bioassay.

Pre-emergence herbicides for use at the time of seeding have long been available for many cultivated crops. The purpose of these studies was to evaluate some promising herbicides in rangeland grass seeding for their selectivity as pre-emergence treatments to permit the seeded grasses to grow and to control the weedy species.

Materials and Methods

The herbicides tested were 2-chloro-4, 6-*bis*(isopropylamino)-s-triazine (propazine); 3-hexahydro-4,7-methanoindan-5-yl)-1,1-dimethylurea (norea), and 1-(2-methylcyclohexyl)-3-phenylurea (siduron). Grasses used in the tests included experimental blends of the Old World bluestems (*Bothriochloa* spp.) not yet released as cultivars (Harlan et al., 1964). These included *B. ischaemum* var. *ischaemum* (S-Blend and M-Blend), *B. ischaemum* var. *indica* (L-Blend, LL-Blend, B-Blend, T-Blend, and H-Blend), *B. intermedia* var. *montana* (I-Blend and J-Blend). Other grasses in the tests were King Ranch bluestem (*B. ischaemum*), Caucasian bluestem (*B. caucasica*), 'Kaw' Big bluestem (*Andropogon gerardi*), 'Woodward' sand bluestem (*A. hallii*), indiangrass (*Sorghastrum nutans*), 'Caddo' switchgrass (*Panicum virgatum*), sideoats grama (*Bouteloua curtipendula*), and weeping lovegrass (*Eragrostis curvula*).

Three separate field tests, two at Stillwater and one at Muskogee, Oklahoma, were conducted using the same basic experimental design. The grass drill planted five species at a time which made it inconvenient to randomize the species; therefore, each species was an individual experiment involving a randomized complete block design with five replications. A single plot was one row wide by 18 ft long. Treatments involved different herbicides and rates of application. Herbicides were applied immediately after seeding using a small compressed air sprayer. A known amount of herbicide in one gallon of water was applied to a measured plot area.

Grass stands were evaluated by sampling an eight foot row length of each plot. An eight foot stick marked in 4-inch units was used, and a single plant in a 4-inch unit was considered successful for the unit. Percent stand as reported refers to the percentage of these 4-inch units occupied by at least one plant and is actually a frequency of occurrence in a 4-inch unit of row.

The two field tests at Stillwater were planted on an abandoned field in early secondary succession characterized by prairie threeawn (*Aristida oligantha*) the lesser amounts of broomsedge (*Andropogon virginicus*). The Muskogee test site was a cultivated field. Seedbed preparation for each of the three tests involved plowing and harrowing to produce a clean firm seedbed.

Stillwater 1967.—These plots were

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seeded June 6, 1967, on a moderately eroded Renfro-Kirkland soil. This upland soil has a 2–5% slope and a clay subsoil which limits water infiltration, thus making it a claypan prairie range site. Precipitation was timely, above average, and totaled 16 inches for the period from May 1 through August 31. Stand evaluation readings were taken August 25, 1967.

Stillwater 1968.—These plots were seeded June 19, 1968, on a Kirkland silt loam soil. This upland soil has a 1–3% slope with a clay subsoil which restricts infiltration rate making it a claypan prairie range site. Precipitation was timely but below average in August. The May 1 through August 31 rainfall totaled 12 inches. Stand evaluation readings were made on August 20, 1968.

Muskogee 1968.—Grass seeding was accomplished on June 11, 1968, at the Eastern Oklahoma Pasture Station, Muskogee, on a Taloka silt loam soil. This is a loamy prairie range site. Moisture conditions were excellent with 17 inches of precipitation from May 1 through August 31. Stand evaluation readings were made July 22, 1968.

Results and Discussion

The data on stand establishment are summarized in Tables 1, 2, and 3. From the standpoint of grass seedling survival propazine was the most promising pre-emergence herbicide in the 1967 tests. Norea at 2 lb/acre significantly reduced the stand of the various grasses tested and was not included in subsequent tests. Siduron was applied at such high rates in 1967 that a soil sterilant effect was achieved. Nothing grew in those plots throughout the season. Greenhouse studies (data not shown) indicated that lower rates of siduron might have promise on the native species but not for the Old World bluestems.

Old World bluestems and switchgrass.—Propazine at rates up to 3 lb/acre permitted good stand establishment of the Old World bluestems. In only 3 of the 22 separate experiments were there significant reductions in stand, but in two experiments significant improvements in stand were noted. Siduron at the lowest rate, 1.5 lb/acre, often caused significant reductions in the stand of Old World bluestems.

Switchgrass stands were not reduced by propazine at rates up to 3 lb/acre. The low rate (1.5 lb/acre) of siduron caused no significant stand reduction, but higher rates of siduron significantly reduced the stands of switchgrass.

Big bluestem.—Siduron at 1.5 lb/acre produced no significant reductions of big bluestem stands. Higher rates of siduron and all rates of propazine did on occasion reduce the stand of big bluestem.

Indiangrass.—Siduron at rates up to 4.5 lb/acre produced no significant reductions of Indiangrass, but propazine caused significant reductions in the 1967 tests and at 3 lb/acre at Muskogee in 1968.

Sideoats grama, weeping lovegrass, and sand bluestem.—Sideoats grama was sensitive to all herbicides, suffering significant stand reductions from nearly every treatment. Weeping lovegrass stands were significantly reduced by 2 lb of propazine/acre. Sand bluestem survived both propazine and siduron treatments with no significant stand reductions (Table 2). Considerable variation occurred in the limited tests with weeping lovegrass and sand bluestem. Therefore, it is believed that more information is needed about weeping lovegrass, sand bluestem, and sideoats grama to determine their resistance to these pre-emergence herbicides.

Table 1. Stand establishment (%) of different grasses as affected by pre-emergent herbicides. Stillwater, 1967.

Species	Herbicide and Rate (lb/acre)						
	Check	Propazine		Norea		Siduron	
		1	2	1	2	8	12
S-Blend	45	23	76@	23	18*	1*	0*
M-Blend	40	32	40	9*	1*	0*	0*
L-Blend	92	95	78	66*	18*	0*	0*
LL-Blend	39	52	34	14	3*	0*	0*
King Ranch bluestem	38	34	24	5*	0*	0*	0*
Big bluestem	34	14*	9*	10*	3*	1*	0*
Switchgrass	89	83	73	33*	4*	0*	0*
Indiangrass	42	21*	3*	12*	3*	1*	1*
Sideoats grama	73	28*	14*	45	30*	1*	1*
Weeping lovegrass	51	40	26*	22*	7*	0*	1*

* Indicates a significant stand reduction (P = .05) from the check.
@ Indicates a significant stand improvement (P = .05) from the check.

Table 2. Stand establishment (%) of different grasses as affected by pre-emergent herbicides. Stillwater, 1968.

Species	Herbicide and Rate (lb/acre)						
	Check	Propazine			Siduron		
		1.0	2.0	3.0	1.5	3.0	4.5
S-Blend	47	37	48	47	11*	3*	0*
M-Blend	100	96	97	98	63*	13*	12*
L-Blend	94	93	98	98	90	63*	48*
LL-Blend	98	87	98	98	57*	29*	11*
H-Blend	98	97	98	100	85*	30*	11*
I-Blend	99	98	98	98	84	28*	43*
J-Blend	84	50*	76	77	21*	3*	0*
T-Blend	76	72	65	52*	12*	2*	1*
King Ranch bluestem	37	25	33	41	5*	2*	2*
Caucasian bluestem	83	76	70	78	7*	0*	2*
Big bluestem	28	34	49@	46	57@	38	21
Switchgrass	82	85	83	84	79	29*	34*
Indiangrass	28	23	22	23	26	15	16
Sideoats grama	90	64*	41*	18*	67*	35*	18*
Sand bluestem	20	25	13	14	33	16	23

* Indicates a significant stand reduction (P = .05) from the check.
@ Indicates a significant stand improvement (P = .05) from the check.

Table 3. Stand establishment (%) of different grasses as affected by pre-emergent herbicides. Muskogee, 1968.

	Herbicide and Rate (lb/acre)						
	Check	Propazine			Siduron		
Species		1.0	2.0	3.0	1.5	3.0	4.5
M-Blend	99	100	98	98	62*	13*	14*
L-Blend	47	78	80@	88@	19	0*	1*
LL-Blend	93	98	92	94	57*	17*	5*
H-Blend	91	95	98	89	38*	8*	13*
I-Blend	86	94	93	83	8*	2*	3*
T-Blend	78	78	88	83	1*	0*	0*
B-Blend	82	87	72*	81	11*	3*	6*
Big bluestem	43	28*	26*	28*	40	28*	28*
Indiangrass	63	45	57	24*	56	48	60
Sideoats grama	60	3*	6*	3*	25*	16*	6*

* Indicates a significant stand reduction (P = .05) from the check.
@ Indicates a significant stand improvement (P = .05) from the check.

Weed control from 2 lb of propazine/acre has been described as completely controlling some broadleaf species but not completely adequate on annual grasses (Santelmann and Davies, 1965). Weeds in their tests were carpetweed (*Mollugo verticillata*), pigweed spp. (*Amaranthus retroflexus* and *A. hybridus*), foxtail millet (*Setaria italica*) and large crabgrass (*Digitaria sanguinalis*).

Weedy grasses were no problem in the tests at Stillwater, but the test near Muskogee was heavily infested with large crabgrass. While complete control of large crabgrass was not achieved with propazine, the level of control was a tremendous asset to establishment of healthy seedlings. No forage yields were taken, but a visible improvement in plant vigor was noted in the propazine treated plots. At Muskogee all propazine treatments gave complete control of the broadleaf species encountered, pigweed spp. and carpetweed (data not shown). Venice mallow (*Hibiscus trionum*) was present in the Stillwater plots and complete control was achieved with propazine.

In contrast with propazine, siduron was an effective chemical for large crabgrass control, but allowed many broadleaf weeds, pigweed spp. and carpetweed, to survive. In fact, a bad infestation of the above broadleaf weeds would have necessitated 2,4-D for their control because siduron was not effective at the low rate.

These herbicides have not been cleared for use of grazing lands, and their major value at present would be in establishment of small plots for research purposes. Crabgrass control has been a dominant problem in the establishment of our variety test plots for yield, and propazine and siduron were effective in reducing crabgrass competition.

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Observations on the Mating System of Basin Wildrye[1]

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Highlight

Basin wildrye appears to be an obligate cross pollinator. Under forced self-pollination seed set is less than 2%.

Before an effective plant breeding program can be initiated, certain basic information about the species to be improved is essential. In order to utilize genetic variation effectively and to select desirable genotypes efficiently, some knowledge of the mating system of the species is required. In addition knowledge of the relative levels of self- and cross-pollination are of value in determining isolation requirements for the production of foundation and certified seed of improved crop varieties, in accordance with the regulations set forth by the Association of Official Seed Certifying Agencies.

Basin wildrye (*Elymus cinereus*) is a relatively unstudied species with significant potential as a native, perennial forage grass in the western United States. Currently, selection programs are in progress at Montana State University to increase yield and palatability in this species. In the summer 1968, levels of self- and cross-pollination were determined by scoring seed set on open pollinated heads, on single bagged heads, and on groups of heads from the same plant under a common bag. As the tip of the head emerged from the boot, it was placed in a glycine bag and the base of the bag was sealed without pinching the culm. The tillers with bagged heads were supported with twine loosely fastened to bamboo poles to allow normal culm elongation and to avoid wind damage to the culm and bag; however, bags were freely agitated by wind throughout the flowering period. Groups of from two to five heads from the same plant were treated in a similar manner. All observations were made on plants grown at Bozeman from a seed collection, Wy 107, obtained through the Soil Conservation Service Plant Materials Center, Bridger, Montana. Studies are currently in progress to determine the chromosome number and meiotic behavior in this population.

At maturity all bagged heads were harvested separately and a random collection of 100 heads from 87 plants was made. Seed set from single bagged heads reflects a minimum level of self-pollination. The difference in seed set between single bagged heads and groups of heads from the same plant in a common bag (Table 1) reflects possible difference in self-pollination due to differences in maturity of stamen and pistils within a head, or structural differences which inhibit self-pollination.

Table 1. Mean seed set per 100 florets and standard deviation of mean for three systems of mating in Basin wildrye.

Sample type	Number of samples	Mean seed set	$S_{\bar{x}}$
Single bagged heads	66	1.08	3.41
Groups of heads	12	1.79	2.96
Random open pollinated heads	17	82.00	6.54

The difference between single bagged heads and groups of heads is nonsignificant. Mean seed set under open pollination is significantly greater than mean seed set under either method of forced self-pollination. Thus, it is apparent basin wildrye is not apomictic. This is further verified by the magnitude of within progeny variation for several quantitative traits (Kushnak and Chapman, in preparation). The cause of the low level of self-pollination cannot be determined with the present data. Based on the uniformly high seed set under open-pollination breeding stocks of basin wildrye will be treated as randomly mating and maximum isolation will be enforced.

[1] Contribution of the Montana Agricultural Experiment Station Published with the approval of the Director as Number 977 in the Journal series. Received May 17, 1969; accepted for publication June 14, 1969.

Nitrogen Concentration of Grasses in Relation to Temperature[1]

C. C. DUNCAN, MARIE SCHUPP, AND C. M. McKELL

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Highlight

Six cool-season grasses and two warm-season grasses were grown in controlled environment chambers under cool- or warm-temperature regimes, fertilized with increasing rates of N, and analysed for total N and nitrate content. The effect of warm or cool temperatures on percent N was different for warm- and cool-season grasses and varied among individual species. Only two species accumulated nitrate in the cool-temperature regime. Nitrate accumulation under the warm-temperature regime occurred for most of the species, but only after an application of 100 lb N/acre.

[1] Received January 24, 1969; accepted for publication June 6, 1969.

Characteristically nitrogen-deficient soils limit rangeland forage production in the western United States. Results from nitrogen fertilization have been varied. Although a lack of increasing forage production after N applications often may be attributed to inadequate rainfall or some other limiting factor, recent studies have indicated that range species react differently to applied N. Thus, knowledge of how each species responds to N fertilization under different environmental conditions would prove valuable in determining the practicability of increasing forage production by N applications. Such knowledge would make it possible to select range species for reseeding that would respond to fertilization, help establish an optimum rate and time of N application, and avoid some losses from nitrate poisoning.

Wright and Davidson (1964) showed that the response to N fertilization of a given plant species is affected by factors in addition to moisture, including temperature, soil, light intensity, rate of N application, micronutrients, herbicides, and stages of plant growth. Nitrogen applications to a mixed stand of downy brome (*Bromus tectorum*) and perennial bluebunch wheatgrass (*Agropyron spicatum*) in Washington increased yields of downy brome much more than those of the wheatgrass, which often decreased (Wilson et al., 1966). In a mixed stand of hardinggrass (*Phalaris tuberosa*) and soft chess (*Bromus mollis*) in California, 60 lb N/acre doubled the yields of soft chess, whereas 120 to 240 lb N/acre were required to produce a similar response in hardinggrass (Martin et al., 1964). Soft chess yields were no greater with the very high rates of N than with the lower rate.

The present study was designed to observe the effects of warm and cool temperatures on N concentration of eight grass species, most of which are useful as livestock forage. Two of the species studied were warm-season or summer growing grasses and the other six were cool-season grasses.

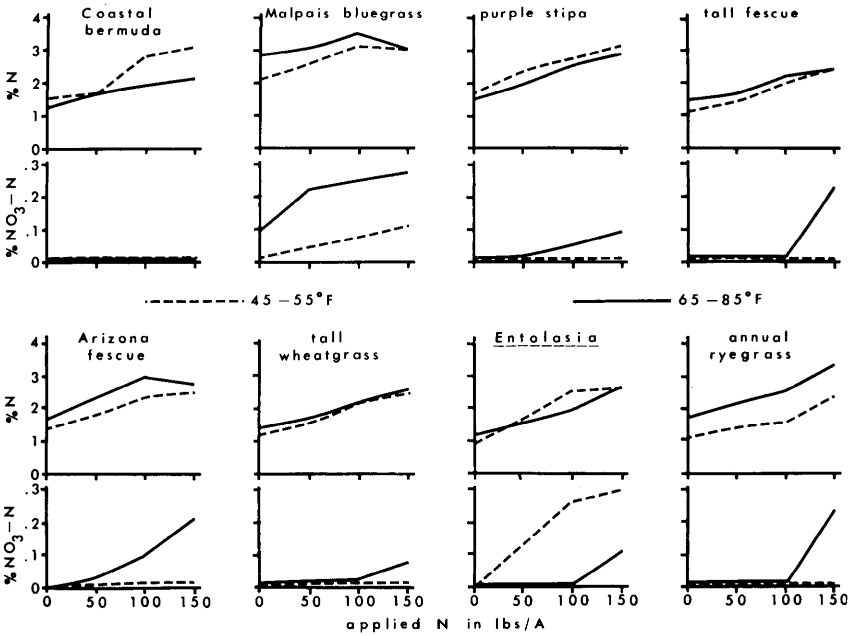

FIG. 1. Nitrogen and nitrate-N levels of two warm-season and six cool-season grass species in response to four rates of applied N and two temperature regimes.

Materials and Methods

The two warm-season grasses studied were coastal bermudagrass (*Cynodon dactylon*) and *Entolasia imbricata*, an East African species. Cool-season grasses included Malpais bluegrass (*Poa scabrella*), purple stipa (*Stipa pulchra*), tall fescue (*Festuca arundinacea*), Arizona fescue (*Festuca arizonica*), tall wheatgrass (*Agropyron elongatum*), and annual ryegrass (*Lolium multiflorum*).

Six plants of each species, with the exception of annual ryegrass, were cloned to four separate plants and planted in 6-inch clay pots. Annual ryegrass was planted from seed. A standard greenhouse soil mix was used, consisting of a 1 : 1 combination of fine sand and peat moss plus necessary plant nutrients.

Grasses were grown in the greenhouse for 35 days. Four rates of NH_4NO_3 (equivalent to 0, 50, 100, and 150 lb N/acre, based on surface area in the pots) were then applied, and the six replicates were divided into two groups. One group was placed in a controlled environment chamber set at 45–55 F. The other group was placed in a similar chamber set at 65–85 F. Daylength in both chambers was 14 hr of light. Plants were irrigated daily as needed with deionized water.

Three weeks after fertilization, visual observations were made of growth response for each species to the two temperature ranges and four fertilization rates. Leaves were then harvested, oven dried, ground in a Wiley mill equipped with a 40-mesh screen, and dried to a uniform moisture level.

Total N content of the samples was determined by the mirco-Dumas method, employing a Coleman Model 29 Nitrogen Analyser. Nitrate was determined by the phenodisulfonic acid method of Johnson and Ulrich (1950) and expressed as percent nitrate-N.

Results and Discussion

The N concentration of each plant species generally increased in proportion to the increase in applied N, but the species differed in their responses to warm- or cool-temperature regimes (Fig. 1). Differences in N concentration due to temperature were not significant for stipa, tall fescue, and tall wheatgrass, but Malpais bluegrass, Arizona fescue, and annual ryegrass were significantly higher in N when grown under the warm-temperature regime. The total N content of coastal bermudagrass was significantly higher under the cool-temperature regime. The total N content of Malpais bluegrass was consistently higher than any of the other species at all of the fertilizer rates and under both temperature regimes.

The nitrate concentration of each species also varied with temperature. Except for bluegrass and *Entolasia*, no significant nitrate accumulation occurred before 100 lb N/acre was applied. Bermudagrass and tall wheatgrass did not accumulate significant levels of nitrate in response to increased application of N in either temperature range. Under the cool-temperature regime, only *Entolasia* and bluegrass accumulated significant levels of nitrate. Since a lack of nitrate accumulation indicates that all nitrate taken up into the leaves has been assimilated, one might conclude that the other six species are adapted for N assimilation at cool temperatures. However, coastal bermudagrass, which did not accumulate nitrate under the cool-temperature regimes, also failed to produce any growth. It appears unlikely that bermudagrass would utilize much nitrate in a state of dormancy; therefore, its lack of nitrate under cool temperatures may result more from root inactivity than efficient assimilation.

Under the warm-temperature regime, all species except coastal bermudagrass and tall wheatgrass accumulated significant levels of nitrate but usually only after 100 lb N/acre was applied. Since nitrate accumulation indicates that more nitrate is available than can be utilized, it would appear that more N was applied than needed. Hylton and Ulrich (1968) and Hylton et al.

(1964) suggested that for maximum growth nitrate-N levels of 500 and 1000 ppm are required in the blades of Idaho fescue and Italian ryegrass, respectively. These values are similar to the nitrate-N concentrations of 0.09 to 0.11% which we found to represent statistically significant accumulations of nitrate in the species studied. Thus, it appears that nitrate accumulation at these levels in a grass indicates that maximum growth is being produced under the existing conditions and that additional N is unnecessary.

Nitrate accumulation was greatest in Malpais bluegrass growing under the warm-temperature regime and in *Entolasia* growing under the cool-temperature regime, even though both grasses were semidormant under these conditions. Obviously, N applications to Malpais bluegrass during the warm season or to *Entolasia* during the cool season could be hazardous. Application of N to any of the other species during the cool season at rates up to 150 lb N/acre and during the warm season at rates up to 100 lbs N/acre (150 lb N/acre to tall wheatgrass and coastal bermudagrass) would not be hazardous. Except for coastal bermudagrass, which would be dormant under cool conditions, this additional N would be utilized and increase production as long as there was sufficient moisture for growth.

The most significant result of this study, however, is the indication that the total N and nitrate concentrations of grass species are affected by temperature and that the response to temperature changes among grass species is variable. Furthermore, generalizations as to plant response to N by groups of similar grasses such as warm-season or cool-season species should be avoided in the absence of supporting data. Thus, successful rangeland fertilization or selection of range species for reseeding require an awareness of temperature-nitrogen effects. Only those species which can utilize additional N under anticipated temperatures should be fertilized.

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Use Seeded Ranges in Your Management[1]

PAT O. CURRIE

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Highlight

Seeded ranges in conjunction with native range can effectively increase productivity and income from ponderosa pine ranges of Colorado. Average weight of weaned calves was 33 lb higher, and gross income per calf $8.95 larger from combined use of seeded and native range than from native range alone. Cows received better nutrition on seeded ranges, which may increase their lifelong production. Similar benefits can be expected by grazing yearlings. Seeding requires an initial investment of about $8.50 per acre which can be repaid within 3 years as a result of increased grazing capacity. Several grasses are recommended for seeding on the basis of their proven performance to meet specific forage needs.

Seeded ranges help a livestock operator balance his yearlong forage supply and maximize profits in his operation. To take advantage of seeded ranges, though, an operator should be aware of the value and potential uses of various species. For more than 20 years the Rocky Mountain Forest and Range Experiment Station has been conducting research in the ponderosa pine zone of Colorado to determine adaptability, establishment, forage values, proper seasons of use, and general management of ranges seeded to introduced or indigenous grasses. From this work, in which 85 species of grass were tested for adaptability, several were found to be very good. Each had its own unique characteristics to fill certain needs and provide green feed during spring or fall when native ranges are dry.

Three grasses are outstanding for furnishing early spring and late fall grazing: Russian wildrye, crested wheatgrass, and Sherman big bluegrass. Russian wildrye has the desirable characteristic of starting growth early in the spring so that it can be used to good advantage in providing forage early and reducing winter feeding. In comparative tests it consistently had sufficient height growth to be grazed in early or mid-April, 5 to 20 days earlier than crested wheatgrass. Grazing to approximately a 3-inch stubble height was found best; weight gains, although smaller than for crested wheatgrass, averaged about 1.5 lb/day and 50 lb/acre for yearling heifers.

At Manitou Experimental Forest, with typically a moist April followed by lower moisture in late May and early June, Russian wildrye often stops growth and leaves tend to dry and turn yellow as moisture decreases. Crested wheatgrass, on the other hand, usually grows some and remains green with limited precipitation. Because of this difference

[1] Received June 6, 1969; accepted for publication July 24, 1969.

[2] Forest Service, U. S. Department of Agriculture, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

in response to moisture, we found it was hard to beat crested wheatgrass for late spring grazing either in pure stands or planted as a mixture of 40% crested wheatgrass, 40% smooth brome, and 20% yellow sweetclover. Yearling gains were consistently good with daily and per acre gains averaging 1.67 and 59.2 lb, respectively, for pure stands and 1.81 and 71.6 lb for the mixture ranges.

Sweetclover disappeared from the mixture stands 2 years after grazing began, and the smooth brome in about 5 years. As these species were lost from the stands, however, they were replaced by crested wheatgrass. The fact that weight gains were 11% higher than average during the first 5 years indicates the relative importance of brome and sweetclover in the mixture.

Crested wheatgrass, either in pure stands or a mixture, is quite tolerant of grazing to a 2-inch stubble height or approximately 65% use by weight year after year. In fact, it will tolerate grazing to a 1-inch stubble height or about 80% use, but this level is not recommended because it will decrease livestock gains. It should be grazed to a 2-inch level to keep wolf plants from developing and to maintain a good, vigorous stand.

Sherman big bluegrass, like Russian wildrye, is ready to be grazed in early April, about 20 days earlier than crested wheatgrass. Its most notable feature, however, is its growth in late fall. Though grazed as late as October 31, it has grown 3 or 4 inches in November. Sixty-five percent use is recommended, as for crested wheatgrass. At this level, gains during 7 years averaged 1.71 lb/day and 78.4 lb/acre. Daily gains were 0.2 lb lower, and gains per acre 6.7 lb higher, than those from the mixture of crested wheatgrass and smooth brome.

Management Application

To further evaluate the seeded species and determine their place in a yearlong management system, 24 range cows owned by Glen Johnston of Woodland Park are being grazed on the Manitou Experimental Forest under the management plans shown in Fig. 1. One herd of 12 cows grazes native ranges according to practices usually followed on mountain ranches. The other 12 graze seeded ranges part of the time.

Stocking rates are based upon average forage yields and proper uses for the ranges and species concerned. Between 30–40% of the forage on native range is grazed each year as recommended by Smith (1967). Stocking of seeded ranges is regulated so as to obtain degrees of use recommended above.

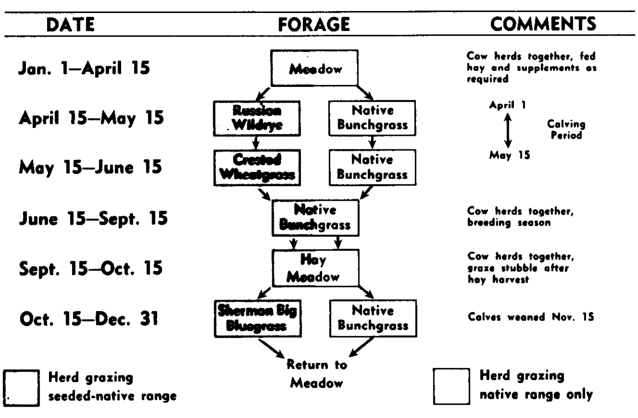

FIG. 1. Schematic for comparing two systems of grazing management. Two cow herds of 12 head each follow the same systems year after year.

The same cows are used in each management system year after year. When the study was started 6 years ago they were 2-year-old heifers, similar in weight and grade. To minimize genetic variation in calves, one herd sire was used to breed all 24 cows for the first 5 years. Currently his younger half-brother is the herd sire. Calves are usually dropped between April 1 and May 15, and weaned approximately November 15 each year.

Weaning weights of calves for the 6 years of study have averaged 451 lb where seeded ranges are included in the grazing system, compared to 418 lb where only native ranges are grazed. Based on the average price of calves on the Denver market each year, the additional gross income per calf weaned from the seeded-native range system averaged $8.95.

Both the quality of the forage and fluctuation in market prices from year to year, can markedly influence returns. In 1964, for example, forage supply on native range was sufficient but cured early in the fall. Calf prices on the Denver market averaged lower than usual at approximately $23/CWT. Calf weights for the seeded management system averaged 415 lb compared with only 358 lb for calves weaned from the early cured native range. As a result, gross income for that year was $13.19/calf more from the seeded ranges; these ranges gave back their highest return under adverse growing and market conditions.

The difference in weaning weights was apparently a true function of forage quality. For the first 5 calf crops, the average age at weaning differed by only one day between the 2 herds. In 2 years, calves from the native range systems were a little older and in the other years calves from the seeded-native range system were oldest. These differences were not in successive years so that a trend for cows to breed back earlier has not been established. Adjusted 200-day weaning weights have also consistently favored the seeded-native system of management. In the 2 years when calves on this system were youngest, their 200-day adjusted weights averaged 40 lb/calf heavier than those where only native range was grazed.

Most of the difference in weaning weights during all years resulted from grazing Sherman big bluegrass in the fall. As shown in the following tabulation, the 43 lb gain during the 30-day fall period was almost double that on native range; and from mid-April til mid-June, gains on seeded stands were only 2 or 3 lb higher than on native range.

	Seeded-native	Native only
Russian wildrye (spring)	47	44
Crested wheatgrass (spring)	46	44
Big bluegrass (fall)	43	22

The possible long-term influence of Russian wildrye and crested wheatgrass should not be minimized, however, particularly from the standpoint of nutrition. For example, Malechek (1966), from fistulated animals in the same study, found that protein in the diet of cows that grazed both seeded and native range was adequate or excessive during 10 months of the year, as compared to 8 months for cows that grazed only native range. Earlier growth and later dormancy of the seeded species probably accounted for this difference.

In addition to larger weaning weights of calves and better nutrition of the cow herd, a further advantage of seeded ranges is that they require a much smaller acreage. The larger weight gains and added income were produced on 120 acres of seeded range while 220 acres of properly grazed native range were required to produce the weights shown. If an additional 100 acres were seeded to make the ranges comparable on an acreage basis, approximately 10 more cows and calves could be grazed for 4.5 months. Thus, the same amount of seeded range would produce about 13.5 lb/acre or 3,000 lb more beef/year than native range. Based on a seeding cost of $8.50/acre and 6% return on the investment, seeding costs on the full 220 acres would be repaid in less than 3 years by selling calves at the average $27/CWT market price.

The decision whether or not to incorporate cool-season grasses into an operation depends of course on each livestock operator and his particular circumstances. Should he decided to use cool-season grasses, however, then ranges suitable for seeding would be taken from those native bunchgrass ranges normally used in early spring or late fall. This would extend the green forage period on either side of the summer ranges, reduce feeding costs, and provide a longer period of higher nutrition for the cow herd.

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VIEWPOINTS

Are We Going to Be The Last to Convert?

In recent times most scientific societies have converted to the metric system in order to be in step with scientists around the world. During the transition period both systems are being used by some societies to facilitate easy adjustment of readers to the new units. Are we going to wait until everyone else has made the change before we give the idea our consideration? Appropriate committees in the Range Society should begin to study ways and means of making the conversion.

Great Britain will change to the metric system of measurements in 1971 and the U.S. Government is presently studying the possible effects of a switch on American industry. The advantages for simpler calculations in Great Britain are certainly obvious to anyone who has struggled with currency in England in addition to other units of measurement. We cannot afford to continue with our present haphazard mixture of units while the rest of the world uses the metric system—especially while other societies in the U.S. make the transition.

The change would not be as difficult as one might imagine since kilograms per hectare are almost equal to pounds per acre. Other easy equivalents would become obvious if we started using the metric system. The problem is similar to learning a foreign language because only when you use the language enough to begin thinking in that language do you use it with facility.

In setting up experiments where a conversion to the metric system is planned we should use round numbers for the metric system rather than fractions or odd numbers within the English system. For example, use 20°C and 30°C (equal to 68°F and 86°F) rather than 65°F and 85°F (equal to 18.3°C and 29.4°C). A good example of equivalent values was printed in the May 1969 issue of Agronomy News which many will find easy to remember: a "round" female figure measuring 36–24–36 in inches is an amazing 914–610–914 in milimeters!—*C. M. McKell. Department of Range Science, Utah State University, Logan, Utah.*

Individual Sustaining Members

In recognition of additional support to the American Society of Range Management for the calendar year 1969.

Alan A. Beetle
Francis T. Colbert
E. J. Dyksterhuis
Clinton H. Wasser

The Prairie World. By David F. Costello, Thomas Y. Crowell Company, New York. 242 p. 1969. $7.95.

This latest of Dave Costello's books is, I think, one that performs a valuable service: although it deals with ecology, it has been written not for ecologists but for Everyman—it's a book for *people* to read, to enjoy, and in the process gain an appreciation of the basic ecology of North America's mid-continental prairie.

In an easy and refreshing manner, the author tells what the prairie is and why it is what it is. The reader becomes conscious of the interrelationships between its climate, soil, and myriad life forms; he is rewarded with an insight into the prairie's vastness, complexity, unity, and variety.

"I have attempted," Costello has said, "to preserve memories of this and other magnificent grasslands, now gone, that have haunted me through a lifetime." And it is these memories the author has woven into his story of the prairie that put the reader in close personal touch with the grassland sea, its shoreline, its seasonal aspects, and, in successive chapters, its plants, mammals, birds, insects, reptiles and amphibians, waters, and "great wanderers"—buffalo, wolves, waterfowl, insects, Russian thistle, and even eels!

Costello tells, too, of "catastrophe and renewal." A graphic description of a 1930's dust storm is followed by his comment that at the time he did not appreciate experiencing ". . . a rare opportunity to see one of nature's phenomena that have recurred through thousands of years . . . a reshuffling process . . . followed by renewal of plant and animal life as it always had in the past."

This book is concerned only with the past and present, and in the final chapter on "Man and the Prairie," Costello does not attempt to look into the future. He concludes simply with the questions, "Will the remaining portions of the prairie disappear if he (man) can achieve the fullest potential of the contribution it can make to mankind?" and "Will he be able to meet the caprices of nature in the artificial habitat he has established where once the earth thundered with . . . countless bison and the sky rang with the clarion calls of geese and the whooping of the great cranes?"

These questions seem to sum up the haunting of the author's memories, and I cannot help but lay along side them a comment by John Kenneth Galbraith (in *The Scotch*): ". . . Iowa with the red barns and green corn must be more agreeable than when it was a monotonous waste of high grass."

The Prairie World is not without its faults, but whatever they are they do not detract from a word picture of a prairie that is never monotonous, and which is agreeable to the extent that man understands its dynamics and limiting factors.—*Francis T. Colbert*, Denver, Colorado.

NEW PUBLICATIONS

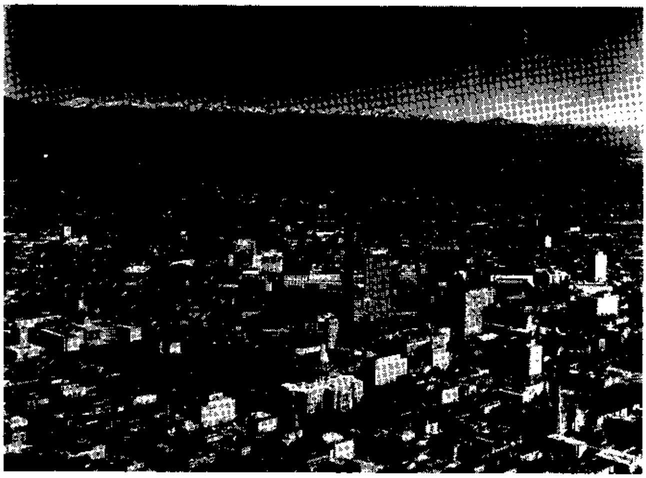
A new journal of research and development in conservation communications makes its debut this fall, called ENVIRONMENTAL EDUCATION. The magazine will specialize in research articles, project reports, and critical essays that advance the scientific study of ecological communications and improve field practices in conservation education. Built around the theme of defining "the new environmental education," the first issue of the quarterly contains contributions by such leaders at Matthew J. Brennan, Samuel T. Dana, Raymond F. Dasmann, Wilson Clark, Gordon Harrison, and William Stapp. Thirty conservation education and communications research specialists from around the country compose the board of editors of the pioneer journal. The executive editor is Clay Schoenfeld, joint professor of journalism and wildlife ecology at the University of Wisconsin, Madison. ENVIRONMENTAL EDUCATION will be published each September, December, March, and June by Dembar Educational Research Services, Inc., Box 1605, Madison, Wis. 53701. The introductory subscription rate is $7.50 a year.

Current practices and the state of knowledge in the field of weed control are examined in PRINCIPLES OF PLANT AND ANIMAL PEST CONTROL: VOLUME 2—WEED CONTROL. This book reviews and summarizes the principles of weed-control methods that are basic tools for increasing the yield of farms, rangelands, and forests. Its extensive bibliography directs readers to additional sources of information that deal with many specific problems of weed control, but the lack of citations in the text is unfortunate. Brush and weed control on range and pastures is treated is a separate chapter. National Academy of Sciences, Printing and Publishing Office, 2101 Constitution Avenue, Washington, D.C. 20418, 476 p., $8.00 paperbound.

FLOWERS OF EUROPE—A FIELD GUIDE by Oleg Polunin is a beautiful book that describes about 2,800 of the commonest and most interesting wild flowers growing in Europe. Over 1,000 plants are illustrated by color photographs and a further 280 by line drawings. There are keys to the families and genera of plants described. FLOWERS OF EUROPE is the first book to attempt, in a single volume, to provide the traveller to Europe with a ready means of identifying the plants he sees. Oxford University Press, 200 Madison Ave., N.Y., N.Y. 10016, 662 p., 1969, $15.00.

A detailed, and sometimes fascinating, account of the Tule Elk of California is given by Dale R. McCullough in THE TULE ELK—ITS HISTORY, BEHAVIOR, AND ECOLOGY. The author claims that the Tule elk is the most specialized race in North America, living in open country under semi-desert conditions. Everyone interested in the study and management of elk will be glad to have this new publication. University of California Press, 2223 Fulton Street, Berkeley, California 94720, 209 p., 1969, $6.50 paperbound.

Preview of DENVER!!
Host City for the 23rd Annual Meeting
American Society of Range Management, February 9–12, 1970



Denver—Queen City of the Plains

The Bronco Buster—State Capital Mall

"Strike it rich or bust" was the slogan of the handful of gold-seekers who founded Denver in 1858, jumping the townsite claim of the St. Charles Town Association. Mining, followed by agriculture, travel, wholesale and retail trade, financial institutions, and light industry, developed the settlement at the confluence of the South Platte River and Cherry Creek into present-day Denver: a five-county metropolitan market center of more than 1,100,000 people.

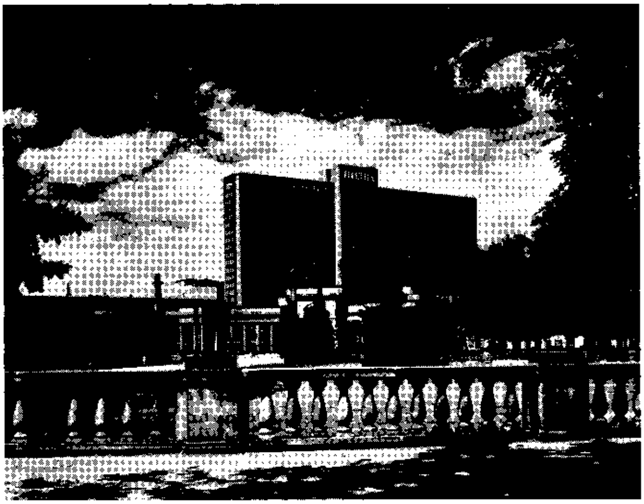
Since the wild and raucous beginnings of Denver, of which Horace Greeley said there were "more brawls, more pistol shots with criminal intent . . . than in any community with equal numbers on earth," the city has grown to be the focal point of the Rocky Mountain region. It is the home of the Martin Company, builder of the Titan space booster rocket; hundreds of federal offices, second in number only to Washington, D.C.; and one of the two US mints, with the largest gold depository outside of Fort Knox. Such industries as petroleum, mining, agriculture, and meat packing and livestock distributing add to the city's economy. It is a hub for commercial and passenger traffic to major US cities and markets, being just west of the geographical center of the 48 adjacent states.

Known as the "Mile High City" and the "Queen City of the Plains," Denver is the capital of the highest state in the US, the average elevation in Colorado being 6,800 feet. The 13th step on the west side of the capitol building is marked by a plaque exactly 5,280 feet above sea level. Her rarified air and low humidity give Denver a unique climate with an average 310 days of sunshine per year.

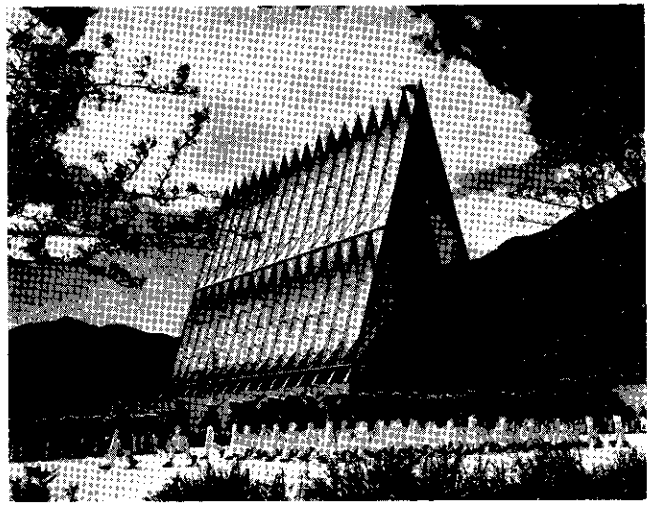
Hunting, fishing, hiking, and camping in the Front Range of the Colorado Rockies are a 30-minute drive from downtown. In the city-owned park system there are 20,000 mountain acres, including several developed picnic areas, Buffalo Bill's Grave and Museum on Lookout Mountain, the 10,000-capacity, natural, open-air Theatre of the Red Rocks, Echo Lake (on North America's highest mountain road to Mount Evans), and a herd of buffalo in Genessee Park. There are also more than 100 named parks and 26 miles of parkway within the metropolitan area, with no "Keep Off the Grass" signs.

Down the streets where "Buffalo Bill" Cody, "Baby Doe" Tabor, Kit Carson, the "unsinkable" Molly Brown, and "Pathfinder" John C. Fremont once rode and strolled, now travel automobiles, tourists, hippies, and other wonders of the 20th century. Denver tries to maintain the best and most colorful of the old amid its modern bustle. A walk along the Civic Center, a three-block grassy mall downtown, is a course in Colorado history, dominated by the State Capitol with its stately dome gold-leafed in tribute to past mining glories. Around the Capitol are the Colorado State Museum, with its relics of the past, a 1-million-volume modern Public Library, a new 5-million-dollar Art Museum, Denver's City Hall, and the US mint.

On the most famous street in the frontier West now stands Larimer Square, a revitalization of the first commercial block in Denver. Having slid downhill since the days when it was the meeting place of the first legislature of the new Colorado Territory and the site of the first bank, theatre, library, post office, and dry goods store, the Square was once considered the "worst slum block in lower downtown Denver." Restoration of the Square began in 1965 as a part of the city's Skyline Renewal project. There are now more than 40 business firms operating in the buildings restored to their 1863 appearance, and the rebuilding and repairing of old buildings is spreading beyond the Square into the blocks on each side.



23rd Annual Meeting Headquarters



For the Ladies—A Trip to the Air Force Academy

Denver prides itself on a well-rounded cultural program. Throughout the winter, the Symphony Orchestra presents weekly concerts, with internationally-known guest artists and conductors. Bonfils Civic Theatre and several new professional and semi-professional groups are active with exciting and varied fare. Broadway musicals and productions appear in Denver's City Auditorium Theatre.

Denver is alive with professional and amateur sporting events. It is the home of the Denver Broncos, AFL football team; the Denver Bears, AAA League baseball; the Denver Rockets, ABA professional basketball; and the Denver Spurs, Western Hockey League. It is the scene of the National AAU Basketball Tournament and the National Western Stock Show and Rodeo. Denver is also in the bidding for the Winter Olympics at some future date.

Rocky Mountain Ranching

The Mile High City's location determines much of its life and character. Nestled at the foot of the majestic Front Range of the Rocky Mountains, Denver is the gateway to a marvelous vacation up "away from it all."

One-day trips into and along the mountains are easy to arrange with no loss of the creature comforts. No trip to Denver would be complete without seeing the US Air Force Academy, one of the state's main attractions. Between Denver and Colorado Springs, the Academy buildings are made of steel, aluminum, glass, granite and white marble, designed to blend with the beautiful terrain of the Rampart Range.

Other places to visit in Denver are the US mint, the most modern mint in the world; the Denver Botanical Gardens; the House of Carvings and Buffalo Bill Museum at Lookout Mountain; the Wax Museum, with a collection of national and Western personalities in historic settings; and Clock Manor, a unique collection of clocks and watches. It is only 60 miles to Colorado's famed powder snow. Golf and tennis are year-round sports; the warm sunlight quickly melts off Denver's infrequent winter snows.

Denver is easy to get to by highway or air and the 1970 Annual Meeting promises to be exciting and informative. The program is broad in scope and the subjects are pertinent. Headquarters will be at the Denver Hilton; other hotels and motels will be listed in the December *Rangeman's News*. Additional information is available from Mr. Royal G. Holl, Chairman, Local Arrangements Committee, 10165 West 23rd Avenue, Denver, Colo. 80215.

Special Notice

Annual meeting of Great Plains Council Technical Committee GP-9 (Growth and Development of Great Plains Grasses) begins on Sunday, February 8 at 1:00 PM, Denver Hilton Hotel.

Tentative Program
Twenty-Third Annual Meeting

American Society of Range Management
Hilton Hotel, Denver, Colorado
February 9–12, 1970

ALL THE RANGE RESOURCES

Registration

Pre-registration check-in on Monday and Tuesday. Regular registration from 8:30 AM, Monday, February 9 until 5:00 PM, Wednesday, February 11.

Special Meetings

Sunday, February 8—Board of Directors and other groups and committees as called.

Monday, February 9—(1) Board of Directors, (2) Advisory Council, (3) Range Management Education Council, (4) Team coaches—Range Plant Judging Contest, (5) Sciential Committee members, (6) 1970 committee chairmen with president elect, (7) other ASRM committees as called.

Ladies Program

Sunday, February 8—Informal tour available for ladies arriving early.

Monday, February 9—Hospitality Room open all day; coffee in the afternoon.

Tuesday, February 10—"Get-Acquainted Coffee" in the morning. Denver city tour in the afternoon.

Wednesday, February 11—Tour to the Air Force Academy, Colorado Springs. Leave mid-morning, return early afternoon; lunch included.

Thursday, February 12—Free day, or short informal trips for those who wish to go. Banquet in evening.

Employment-Interview Service

This service will be available for submitting employment applications and arranging for interviews on Tuesday, Wednesday, and Thursday, February 10, 11, 12.

Range Plant Judging Contest

Team coaches will have a special meeting on Monday afternoon, February 9. Contest is Wednesday morning, February 11, followed by a sponsored luncheon for team members and coaches.

Youth Range Forum

Tuesday, February 10—Orientation and opening session. Selected delegates to present talks at ASRM "Reports and Installation" meeting in the evening.

Wednesday, February 11—Concluding sessions.

Photo Contest

All meeting registrants may vote for selecting winners. Photos will be on display from 12:00 noon, Tuesday, February 10, until 5:00 PM, Thursday, February 12.

Tuesday Morning, February 10

PLENARY SESSION: **Range Resources and Livestock Industry of the Central Rockies.** *Chairman*: President Donald A. Cox

Preliminary Remarks and Welcomings

The Central Rockies as a Range Resource. Wallace M. Johnson, USFS (retired), Fort Collins, Colorado.

The Cattle Industry of the Central Rockies. Leonard Horn, rancher, Wolcott, Colorado.

The Sheep Industry of the Central Rockies. Paul O. Stratton, Animal Science Division, University of Wyoming, Laramie.

Challenges in Managing Wildlife and Its Habitat in the Central Rockies. Dwight R. Smith, Department of Fisheries & Wildlife Biology, Colorado State University, Fort Collins.

Tuesday Afternoon, February 10

SESSION A: **Wildlife and Wildlife Habitat Resources on Rangelands.** *Chairman*: Jack Lyon

Range Management on the National Bison Range. Marvin R. Kaschke and Joseph C. Zacek, Bureau of Sport Fisheries & Wildlife, Moiese, and SCS, Missoula, Montana.

Effects of Reindeer Trampling on Tundra Vegetation. Robert E. Pegau, Department of Fish & Game, Nome, Alaska.

The Vicuna and the Puna. James D. Yoakum, BLM, Reno, Nevada.

Diets of Five Herbivores on a Mountain Herbland in Northern Colorado. D. N. Ueckert and R. M. Hansen, Range Science Department, Colorado State University, Fort Collins.

Estimating Shrub Component Production with an Electronic Capacitance Instrument. Meredith J. Morris, Donald L. Neal, and Kendall L. Johnson, USFS, Fort Collins, Colorado, Berkeley, California, and Laramie, Wyoming.

Multiple Use and the Private Landowner. Wayne E. Long, Resource Ecology Associates, Red Bluff, California.

Shrubs for Improving Dry California Rangeland. Donald R. Cornelius and Leonard Askham, ARS, Berkeley, California.

SESSION B: **Range Watershed Resources Management.** *Co-Chairmen*: John H. Ehrenreich and George B. Coltharp

Hydrologic Research in the IBP Grassland Biome Studies. W. D. Striffler, Department of Recreation & Watershed Management, Colorado State University, Fort Collins.

Infiltration Studies on Disturbed Big Sagebrush Sites in Central Nevada. D. J. Jaeger and C. M. Skau, Renewable Resources Center, University of Nevada, Reno.

Influence of Cover, Soil and Micro-relief on Runoff from Desert Grasslands. Phil R. Ogden, Department of Watershed Management, University of Arizona, Tucson.

Factors Influencing Infiltration and Erosion on Chained Pinyon-Juniper Sites in Utah. G. F. Gifford, G. Williams, and G. B. Coltharp, Department of Range Science, Utah State University, Logan.

Chaparral Modification, Improved Range Forage and Water Yield in Arizona. Charles P. Pase, Rocky Mountain Forest & Range Experiment Station, USFS, Tempe, Arizona.

Summer Water Use of Vegetation in an Aspen-Grassland Watershed. Teja Singh, Department of Fisheries & Forestry, Calgary, Alberta.

Salt Cedar of the Middle Brazos River as Determined from Standard Aerial Photographs. Frank E. Busby, Jr., and

J. L. Schuster, Department of Range & Wildlife Management, Texas Tech University, Lubbock.

SESSION C: **Recreational Resources on Rangelands.** *Chairman*: Robert W. Harris

Landscape Analysis: A Basis for Environmental Planning. Robert H. Twiss, Pacific Southwest Forest & Range Experiment Station, USFS, Berkeley, California.

Applied Landscape Management in Plant Control. Robert Williamson and W. F. Currier, Division of Range & Wildlife Management, USFS, Albuquerque, New Mexico.

Recreation's Role in Range Management. Phillip W. Schneider, National Wildlife Federation, Portland, Oregon.

The California Desert. J. Russell Penny, BLM, Sacramento, California.

Winged Protectors of Forest and Rangelands. Milton J. Griffith, Deschutes National Forest, USFS, Bend, Oregon.

Principles and Problems in Management of Rangelands for Recreation—A Preliminary Approach. Richard L. Bury, Department of Recreation & Parks, Texas A&M University, College Station.

Tuesday Evening, February 10

REPORTS AND INSTALLATION

Presidential Address: Donald A. Cox

Executive Secretary's Report: Francis T. Colbert

Editor's Report: Elbert H. Reid

Other Reports: As may be scheduled

Special Talks: Selected Youth Range Forum delegates

Installation of New Officers

Response: Wm. D. Hurst

Wednesday Morning, February 11

SESSION A: **The Ecosystem Concept.** *Chairman*: James K. Lewis

Anaylsis of the American Grassland Biome: An Overview of an Integrated Research Program. Peter Haug, Range Science Department, Colorado State University, Fort Collins.

A Mathematical Model of a Grassland Ecosystem. Don Jameson, Range Science Department, Colorado State University, Fort Collins.

Computer Simulation of Shrubland Grazing in Australia. David W. Goodall, Range Science and Botany Departments, Utah State University, Logan.

The Ecosystem Concept in an Undergraduate Curriculum in Range Science. C. W. Cook, Department of Range Science, Colorado State University, Fort Collins.

Effective Presentation of Range Ecology to the Layman: A Look at a Self-Guiding Communities Approach. Leonard Askham and Donald R. Cornelius, Crops Research Division, ARS, Berkeley, California.

The Ecosystem Concept in the Management and Interpretation of the National Parks. Douglas B. Houston, Grand Teton National Park, Moose, Wyoming.

SESSION B: **Socio-Economic Aspects of Range Management.** *Co-Chairmen*: Wayne Cloward and Lynn Rader

A Social and Economic Profile of National Forest Range Users in the South. Robert N. Gashwiler, Range Management Branch, Division of Wildlife & Range Management, USFS, Atlanta, Georgia.

Cattle and Culture: Some Preliminary Considerations. John L. Schultz, Department of Anthropology, Oregon State University, Corvallis.

Measuring Social and Economic Benefits from Public Range Programs. Gilbert Duran, Jr., Range Program Evaluation Branch, Division of Range Management, USFS, Washington, D.C.

Range Resource Management in a Changing Socio-Economic Environment. Darwin B. Nielsen, Department of Agricultural Economics, Utah State University, Logan.

The First American and His Range Resource. Orville N. Hicks, BIA, Aberdeen, South Dakota.

SESSION C: **International Dimensions in Range Management.** *Co-Chairman*: Less Albee and W. R. Chapline

Grazing in the Middle East—Past, Present, and Future. C. Kenneth Pearse, Food and Agriculture Organization of the United Nations, Tehran, Iran.

Range Education in East Africa. Joseph H. Robertson, Renewable Resources Center, University of Nevada, Reno.

Australian Range Management. Thadis W. Box and Ray Perry, International Center for Arid and Semi-Arid Land Studies, Texas Tech University, Lubbock, and CSIRO, Rangeland Research Programme, Canberra, Australia.

Soviet Rangelands in Central Asia. Charles W. Luscher, BLM, Washington, D.C.

Range Management and the Agrarian Reform in Mexico. Martiń H. González, Rancho Experimental La Campana, Chihuahua, Chihuahua.

Range Management Problems and Potentials in the Sudan. Weldon O. Shepherd, Southeastern Forest Experiment Station, USFS, Lehigh Acres, Florida.

A Veterinarian's Viewpoint of Range Management. Linneo Nello Corti, Italconsult, Rome, Italy.

Wednesday Afternoon, February 11

SESSION A: **New Developments in Range Livestock Production (In Cooperation with the American Society of Animal Science).** *Co-Chairmen*: E. H. McIlvain and D. C. Clanton

Methods for Estimating Dry-Weight Composition in Diets of Large Herbivores. James C. Free, R. M. Hansen, and Phillip L. Sims, Eastern Colorado Range Station, Akron.

Correlation of Botanical with Chemical Composition of Sheep's Diet on a Sagebrush-Bluebunch Wheatgrass Spring Range, as Affected by Range Condition, Stage of Plant Growth, and Grazing Intensity. R. O. Harniss, D. C. Tomlin, and R. L. Barber, ARS, Dubois, Idaho.

Vegetation Trends under Different Grazing Systems and Stocking Rates. M. M. Kothmann and G. W. Mathis, Texas Experimental Ranch, Seymour.

Cattle-Sheep Dual and Single Use Grazing of Grass-Clover Dryland Improved Pastures. Thomas E. Bedell, Animal Science Department, Oregon State University, Corvallis.

Irrigated Pasture as a Complement to Native Range. D. C. Clanton, North Platte Station, North Platte, Nebraska.

A New Approach to the Use of Supplements on Pasture. R. J. Raleigh, Squaw Butte Station, Burns, Oregon.

Crossbreeding to Improve Range Livestock Production. Delwyn Dearborn, Animal Science Department, University of Nebraska, Lincoln.

SESSION B: **Modeling and Systems Analysis in Range Science.** *Chairman*: Donald A. Jameson

Optimization Techniques in Land Management Planning. Frank Bell and Frank Price, USFS, Berkeley, California.

Optimization Techniques in Livestock Production. Kenneth Monfort, Monfort Packing Company, Greeley, Colorado.

Simulation Techniques in Forest-Range Management. Clifford Myers and P. O. Currie, Rocky Mountain Forest & Range Experiment Station, USFS, Fort Collins, Colorado.

Simulation Techniques in Wildlife Habitat Management. Robert Giles and Nathan Snyder, Forestry & Wildlife Department, Virginia Polytechnic Institute, Blacksburg, Virginia, and USFS, Missoula, Montana.

Data Acquisition Storage and Retrieval for Range Management Planning. Thomas Shiflet, SCS, Lincoln, Nebraska.

SESSION C: **Morphology, Development, and Physiology of Range Plants.** *Chairman*: Floyd Kinsinger

Growth and Development of Arizona Cottontop. Dwight R. Cable, Rocky Mountain Forest & Range Experiment Station, USFS, Tucson, Arizona.

Tillering of *Phalaris tuberosa* L. Ecotypes in Response to Nitrogen. Cyrus M. McKell and Cameron Duncan, Department of Range Science, Utah State University, Logan, and Department of Agronomy, University of California, Riverside.

Morphological Development of *Bouteloua gracilis* (H.B.K.) Lag. Donald F. Burzlaff and James L. Stubbendieck, Department of Agronomy, University of Nebraska, Lincoln, and Big Springs Field Station, Big Springs, Texas.

Nature of Phytomer Growth in *Bouteloua gracilis* (H.B.K.) Lag. J. L. Stubbendieck and D. F. Burzlaff, Big Springs Field Station, Big Springs, Texas, and Department of Agronomy, University of Nebraska, Lincoln.

Leaf-Weight Management on Blue Grama Range. R. E. Bement, Crops Research Division, ARS, Fort Collins, Colorado.

Developmental Morphology of Four Warm-Season Grasses. Phillip L. Sims, D. N. Hyder, Lucas J. Ayuko, and Robert K. Lang'at, Eastern Colorado Range Station, Akron, and Crops Research Division, ARS, Fort Collins, Colorado.

Response of Indian Ricegrass to Various Intensities and Dates of Clipping. Jim W. Doughty and Brent J. Harrison, SCS, Big Piney, Wyoming.

Response of Needleandthread (*Stipa comata*) to Herbage Removal. Myron J. Wakkuri, SCS, Douglas, Wyoming.

Germination and Early Growth Characteristics of Selected Annual Rangeland Legumes. Charles A. Raguse, Department of Agronomy and Range Science, University of California, Davis.

Metabolism and Germination of Crested Wheatgrass Seed. A. M. Wilson, J. R. Nelson, and C. J. Goebel, Crops Research Division, ARS, and Washington State University, Pullman.

Competition Between Seedlings of Annual and Perennial Grasses. Grant A. Harris and A. M. Wilson, Washington State University and Crops Research Division, ARS, Pullman, Washington.

Influences of Grazing and Timing of Precipitation on Plant Water-Use Efficiency on Sandy Rangeland. B. E. Dahl, Department of Range & Wildlife Management, Texas Tech University, Lubbock.

The Leaf Replacement Potential of Grasses. D. N. Hyder, Crops Research Division, ARS, Fort Collins, Colorado.

Wednesday Evening, February 11

Improvement in Grass on a Northwest Montana Cattle Ranch. Charles M. Jarecki, rancher, Polson, Montana, presents an excellent movie. This film shows how maximum livestock production can be obtained on range operations through proper stocking and the management of grazing.

Thursday Morning, February 12

SESSION A: **Improving the Range Resources.** *Chairman*: J. Boyd Price

Production and Vertical Distribution of Nitrate-Nitrogen in Chemically and Mechanically Fallowed Soils. Richard E. Eckert, Jr., Gerard J. Klomp, Raymond A. Evans, and James A. Young, ARS, University of Nevada, Reno.

Lending Policy Regarding Loans for Range Improvement Work. Lee Buffington, First National Bank, Miles City, Montana.

Water Control Structures Improve Vegetation Composition on Louisiana Marshes. Alton T. Wilhite and H. L. Leithead, SCS, Alexandria, Louisiana, and SCS, Fort Worth, Texas.

Grass Management Extends the Grazing Season on Indian Leased Land. Sherman Swim, rancher, Arbon, Idaho.

The Relationship of Herbage Production on Springerville Soils to Utah Juniper Overstory and Precipitation. Warren P. Clary, Rocky Mountain Forest & Range Experiment Station, USFS, Flagstaff, Arizona.

Take the Water to the Grass. Robert L. Sitz, rancher, Harrison, Montana.

Range Improvement Practices in Western South Dakota. James T. Nichols and James R. Johnson, US Irrigation & Dry Land Field Station, Newell, South Dakota.

Getting the Most Out of Dry Climate Grass Plantings. Joe B. Norris, SCS, Abilene, Texas.

Control of False Hellebore (*Veratrum californicum* Durand). W. H. Brooks III, D. E. Bayer and J. E. Street, Agricultural Extension Service, University of California, Davis.

Environmental Factors Related to Medusahead Distribution in Idaho. B. E. Dahl, Department of Range & Wildlife Management, Texas Tech University, Lubbock.

Vegetation Changes Following Mechanical, Chemical, Prescribed Burns and Combination Treatments. S. T. Holtz and J. D. Dodd, Department of Range Science, Texas A&M University, College Station.

SESSION B: **Remote Sensing and Other New Technologies for Managing Range Resources.** *Chairman*: Richard S. Driscoll

Minimal Observations Needed to Determine Dry Weight Composition in Herbivore Diets by the Microscopic

Method. R. M. Hansen and J. C. Free, Range Science Department, Colorado State University, Fort Collins.

Population Dynamics Studies of the Causes of Range Condition and Trend. Juan Gasto, and Neil E. West, University of Santiago, Chile, and Utah State University, Logan.

Interpretation and Application of Large-Scale Aerial Photographs for Evaluation of Range Resources. Richard E. Francis, Rocky Mountain Forest & Range Experiment Station, USFS, Fort Collins, Colorado.

Range Vegetation Measurements from Aerial and Space Photographs. David M. Carneggie, School of Forestry & Conservation, University of California, Berkeley.

Space Photography and Other Remote Sensing Systems for Range Resource Inventories. Charles E. Poulton, Range Management, Oregon State University, Corvallis.

Automatic Interpretation of Remotely Procured Data for Vegetation Inventories. Lee D. Miller, Recreation & Watershed Department, Colorado State University, Fort Collins.

SESSION C: **The Range Science Curriculum.** *Co-Chairmen*: Charles Leinweber and Raymond M. Housley

The Three I's of Range Education. Paul T. Tueller, Renewable Resources Center, University of Nevada, Reno.

Panel: **Students and Graduates Appraise Their College Programs in Range Management.**

My Range Education and My Range Conservationist Position. Gary Westmoreland, SCS, Graham, Texas.

My College Major—A Personal Appraisal. Patrick L. Jackson, student, Colorado State University, Fort Collins.

Range Education: Education or Training; Union Card or Passport for Life; What Good It Is or Can Be. John Malechek, student, Texas A&M University, College Station.

Panel: **Employers' Perspectives of Higher Education Needs for Range Employees.**

Rangeland Action-Agencies' Views. Robert E. Williams, SCS, Washington, D.C.

Private Ranching, Business and Industry's Needs. W. J. Waldrip, Colorado City, Texas.

Specialized Education Needs of Research, Teaching and Extension Personnel. R. Keith Arnold, USFS, Washington, D.C.

Challenges and Orbits of Higher Education in Range Management and Science for the 1970's. C. Wayne Cook, Range Science Department, Colorado State University, Fort Collins.

Thursday Afternoon, February 12

PLENARY SESSION: **Goals and Objectives of the American Society of Range Management—And How to Meet Them.** *Co-Chairmen*: Fred Kennedy and Bob Ross

From the Standpoint of an Educator. D. F. Hervey, Experiment Station, Colorado State University, Fort Collins.

From the Standpoint of a Researcher. J. F. Pechanec, Intermountain Forest & Range Experiment Station, USFS, Ogden, Utah.

From the Standpoint of a Natural Resource Specialist. T. L. Kimball, National Wildlife Federation, Washington, D.C.

From the Standpoint of a Rancher. P. V. Jackson, Harrison, Montana.

From the Standpoint of a Land Administrator. Charles Connaughton, USFS, Portland, Oregon.

Thursday Evening, February 12

ANNUAL BANQUET

Master of Ceremonies: Dick C. Whetsell, Foraker, Oklahoma.

Speaker: Ned D. Bayley, Director, Science and Education, US Department of Agriculture, Washington, D.C.

Entertainment: Koshare Indian Dancers

Presentation of Awards

Notice

All *range management extension personnel* are invited to a special meeting called for Monday, February 9 at 7:30 PM, Denver Hilton Hotel.

The December issue of *Rangeman's News* will contain complete information and forms for *pre-registration.*

Room reservation cards for The Denver Hilton are being mailed to each member with his 1970 membership card.

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