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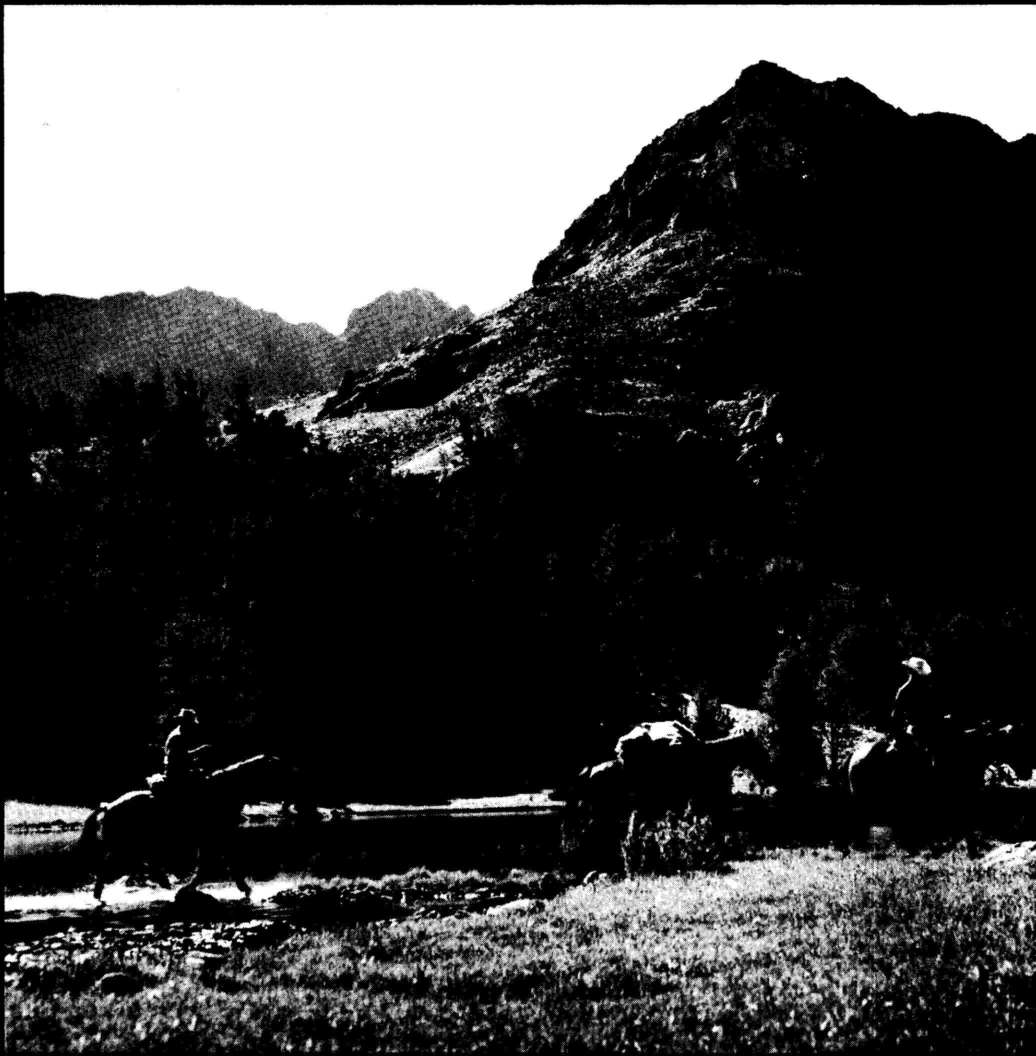

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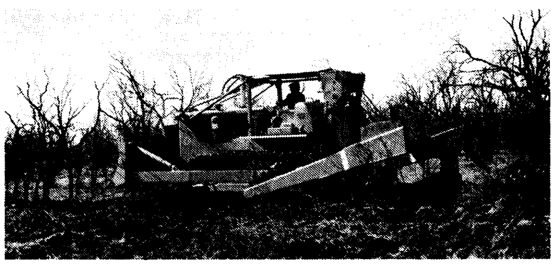

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Journal of RANGE MANAGEMENT *Volume 21 Number 4 July, 1968*

RE = Resumen en Espanol por Dr. Martin H. Gonzalez, Chihuahua, Chih., Mexico.

Cover Photo—Recreation Stock Need Forage Too

Lower Echo Lake, Beaverhead National Forest, Montana

See Management Note by George R. Wolstad, page 270.

Diet of Black-Tailed Jackrabbits on Sandhill Rangeland in Colorado[1]

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Highlight

The diet and forage preferences of the black-tailed jackrabbit (*Lepus californicus*) were studied by stomach content analysis to determine the degree of competition between cattle and jackrabbits on sandhill rangeland. Grasses were most important in the diet in early spring and summer. Forbs were important during summer and fall and shrubs were eaten in fall and winter. Competition for forage between jackrabbits and cattle was greatest in early spring and least in late fall and winter. Jackrabbits influence the longevity of reseeded forage stands and the secondary succession on old fields. A thorough knowledge of diet and forage preferences of jackrabbits permits the land manager to make better decisions for efficient range use.

The black-tailed jackrabbit is a common inhabitant of much of the western United States. It has been recognized as a pest on range and croplands and has been reported to compete with livestock for forage (Vorhies and Taylor, 1933; Arnold, 1942; Currie and Goodwin, 1966). The food habits of the black-tailed jackrabbit have been studied more intensively than those of other jackrabbits, but little is known about the seasonal diet of jackrabbits on sandhill rangelands. Previous observations on the study area in eastern Colorado indicated that rabbits ate some of the same species of plants that were consumed by cattle (Sanderson, 1959).

The objectives of this study were to determine the seasonal diet and food preferences of the black-tailed jackrabbit on sandhill rangeland and to relate this information to the diet of cattle grazing on the same pastures.

Methods

Field studies were conducted at the Eastern Colorado Range Station, 17 miles north of Akron, Washington County, Colorado. The climate of the area is semiarid with an average annual precipitation of about 15 inches, most of which comes as rain during the growing season. The terrain is predominately dune type with many small depressions. Range sites vary from the "deep sand" sites in the sandhills to the "sandy plains" sites where the topography is more nearly level and the soil is slightly heavier.

The vegetation of the study area is dominated by blue grama (*Bouteloua gracilis*), prairie sandreed (*Calamovilfa longifolia*), and needleandthread (*Stipa comata*). On the heavier soils western wheatgrass (*Agropyron smithii*) forms an important portion of the vegetation. Grasses make up about 90% of the total vegetation. Sand sagebrush (*Artemisia filifolia*) is the most abundant shrub, and summer cypress (*Kochia scoparia*), wooly indianwheat (*Plantago purshii*) and scarlet globemallow (*Sphaeralcea coccinea*) are common forbs. Many species of forbs occur in the area, but each comprises only a small part of the total vegetation. A detailed description of the study area is given by Reppert (1960).

Reclaimed blowouts and old fields on the Station support a variety of seeded and volunteer species, including alfalfa (*Medicago sativa*), yellow sweetclover (*Melilotus officinalis*) and white sweetclover (*Melilotus alba*). Several alfalfa hay fields, fenced to exclude cattle but not jackrabbits, have been established near the center of the Station.

The diet of wild black-tailed jackrabbits was studied from September 1965, through November 1966. A total of 250 rabbits were collected for stomach analysis. Ten samples, each consisting of 25 animals, were collected at approximately monthly intervals during the spring and summer and at bimonthly intervals during the fall and winter. Jackrabbits were usually killed during the late evening hours or at night using a shotgun and a spotlight. The stomachs were removed and frozen within a few hours after collection. An attempt was made to collect the rabbits in proportion to their relative numbers from all parts of the Station.

The contents of each stomach were washed, mixed in warm water, and placed on absorbent paper to dry. The dried material was ground in a Wiley laboratory mill over a 20 mesh screen. Ground stomach contents were washed again over a 200 mesh screen to insure mixing and to remove dirt and very small plant fragments. One microscope slide was prepared from a sample of the contents of each stomach, according to procedures outlined by Bear and Hansen (1966).

Tissue of identified plants collected on the study area was prepared and mounted on microscope slides. Plant species in the stomach samples were identified by comparing the epidermal tissue of food material with known plant material on reference slides (Davies, 1959; Croker, 1959; Brusven and Mulkern, 1960; Storr, 1961).

The percentage of each food item in the diet was estimated by examining 20 systematically located fields on each stomach slide with a binocular compound microscope at 125 power magnification. The species present in each microscope field were recorded. Average frequency percentages were computed for all species present in the composite sample of 25 jackrabbits (500 fields). The frequency percentages were then converted to density per field (Fracker and Brischle, 1944) and percent composition of each food item was calculated for the sample.

As an aid in determining food preferences, botanical composition was taken at each kill site using the step-point method described by Evans and Love (1957). Twenty-five points at pace intervals were read in the cardinal directions from the kill site, thus 100 points were located at each site.

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[1] Adapted from a thesis submitted as partial fulfillment of requirements for the M.S. degree at Colorado State University. Published with approval of the Director, Colorado Agricultural Experiment Station, as Scientific Paper No. 1228.

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Table 1. Seasonal botanical composition (mean percentage) of the most abundant plants on areas where jackrabbits were collected.

Plants	Fall	Winter	Spring	Summer
Grasses and grass-like plants:				
Agropyron smithii	4	7	13	7
Andropogon hallii	<1	1	<1	<1
Aristida longiseta	1	<1	<1	<1
Bouteloua gracilis	55	55	52	46
Bromus sp.	<1	—	2	<1
Buchloe dactyloides	1	2	<1	3
Carex heliophila	2	1	3	3
Calamovilfa longifolia	9	12	4	11
Festuca octoflora	—	—	7	2
Sporobolus cryptandrus	5	3	1	4
Stipa comata	4	7	6	6
Forbs:				
Artemisia ludoviciana	<1	<1	<1	<1
Conyza canadensis	<1	<1	2	<1
Eriogonum annuum	<1	<1	<1	<1
Kochia scoparia	6	2	<1	1
Plantago purshii	<1	1	<1	1
Sphaeralcea coccinea	<1	<1	<1	<1
Shrubs:				
Artemisia filifolia	2	3	2	2
Opuntia humifusa	<1	<1	<1	<1

Botanical composition of the feeding areas was determined for all but the one sample that was taken when the ground was covered with snow. A summary of the botanical composition of the areas where jackrabbits were killed is presented in Table 1. Food preference indices were determined by dividing the mean percent composition of that species in the diet by the mean percent composition that plant comprised in the feeding areas.

Results

The diet of the black-tailed jackrabbit in the study area followed definite seasonal trends that were influenced by forage maturity and availability (Fig. 1, Table 2). A total of 41 species of plants were identified in the diet. Fifteen species, each comprising at least 1%, accounted for 86% of the yearly diet (Table 3).

Grasses

Although grasses comprised approximately 89% of the botanical composition of the study area, they made up only 50% of the yearly diet of the jackrabbit. Grasses were eaten most frequently during early spring and summer.

Western wheatgrass was the most important plant in the diet. It comprised 22% of the yearly diet and occurred in 72% of the stomachs examined (Table 3). It was eaten throughout the year but was most important in late fall and early spring. The fall regrowth of this grass provided green forage during the winter season when most plants were dormant, and it was one of the first grasses

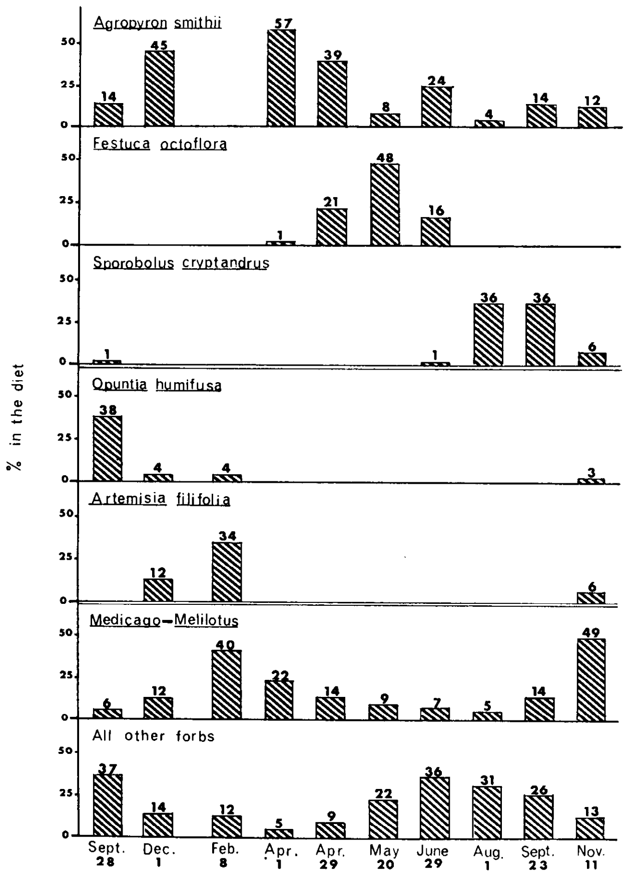

Fig. 1. Mean percent composition of most important food items in diet of the black-tailed jackrabbit from September 1965, through November 1966.

to initiate growth in the spring. Western wheatgrass constituted 45% of the diet in December and 57% of the diet in early April (Fig. 1, Table 2). It was eaten in but minor amounts throughout the summer.

Sixweeks fescue (*Festuca octoflora*), an annual grass, was a major component of the diet during the latter part of April, May, and early June. The seed heads of this grass were heavily utilized in late May, when it comprised 48% of the diet (Fig. 1, Table 2). Only small amounts of this grass were eaten during the remainder of the year. Sixweeks fescue made up 8% of the yearly diet and occurred in 28% of the stomachs analyzed (Table 3).

The diet contained 36% sand dropseed (*Sporobolus cryptandrus*) in August and September, although it was seldom eaten during other parts of the year. Jackrabbits ate the leaf sheaths surrounding the inflorescences and the seeds were common in the stomach contents and in the feces. Sand dropseed was 8% of the yearly diet and occurred in 28% of the stomachs examined.

Needleandthread grass was important for only a short period in early spring. This grass comprised 11% of the diet on April 29 but was eaten in

Table 2. Species composition (mean percent of food items) in monthly diet of the black-tailed jackrabbit.

Plants	Sept 28	Dec 1	Feb 8	Apr 1	Apr 29	May 20	June 29	Aug 1	Sept 23	Nov 11
Grasses:										
Agropyron smithii	14	45	<1	57	39	8	24	4	14	12
Festuca octoflora	<1	<1	—	1	21	48	16	—	—	<1
Sporobolus cryptandrus	1	<1	—	—	—	<1	1	36	36	6
Stipa comata	<1	3	—	7	11	6	1	<1	1	3
Calamovilfa longifolia	<1	—	<1	—	<1	4	6	10	2	<1
Bromus sp.	—	7	<1	4	2	2	1	—	<1	3
Bouteloua gracilis	<1	<1	<1	<1	<1	<1	3	4	1	—
Other grasses	<1	<1	4	3	2	<1	4	7	2	<1
Unidentified grasses	<1	<1	<1	<1	<1	—	<1	2	1	<1
Total grasses	18	57	7	72	77	69	57	63	57	24
Forbs:										
Medicago-Melilotus	6	12	40	22	14	9	7	5	14	49
Kochia scoparia	2	<1	8	<1	2	4	6	11	1	5
Physalis sp.	11	2	—	—	—	—	1	5	11	5
Chenopodium album	13	2	<1	—	—	—	<1	<1	—	—
Plantago purshii	<1	<1	—	<1	<1	4	9	—	—	<1
Eriogonum annuum	2	5	—	—	—	—	<1	<1	2	1
Other forbs	4	2	<1	3	4	11	12	9	6	—
Unidentified forbs	4	2	3	1	2	3	7	5	6	2
Total forbs	43	26	52	27	23	31	43	36	40	62
Shrubs:										
Opuntia humifusa	38	4	4	<1	—	—	—	—	<1	3
Artemisia filifolia	—	12	34	—	—	—	—	—	—	6
Other shrubs	—	1	2	—	—	—	—	—	—	—
Total shrubs	38	17	40	<1	—	—	—	—	<1	9
Seeds	1	<1	2	—	—	—	—	<1	4	5

smaller amounts during the remainder of the study (Table 2). Although needleandthread occurred in 28% of the stomachs examined, it made up only 3% of the yearly diet (Table 3).

Prairie sandreed was eaten mainly in late spring and summer, although very small amounts were eaten at other seasons. This grass was 10% of the diet of jackrabbits in early August. It comprised 2% of the yearly diet and occurred in 24% of the stomachs examined.

Blue grama and cheatgrass brome (*Bromus tectorum*) were the other grasses that made up at least 1% of the yearly diet. Grasses and grass-like plants that constituted less than 1% of the yearly diet included: *Andropogon hallii, Buchloe dactyloides, Carex heliophila, Distichlis stricta,* and *Sorghum vulgare.*

Forbs

Roughly 9% of the vegetation on the study area was forbs, but they made up 39% of the yearly diet of the black-tailed jackrabbit. Forbs were eaten most frequently during summer and early fall.

Alfalfa was the second most important food item in the diet. It made up 18% of the yearly diet and occurred in 52% of the stomachs examined (Table 3). Rabbits ate alfalfa throughout the year, but it was most important in late fall, winter and early spring. This forb comprised 40% of the diet in February when the ground was covered with snow and was 49% of the diet in November 1966 (Fig. 1, Table 2). When snow covered the vegetation on the study area, jackrabbits ate alfalfa hay that had been fed to cattle and they dug through the snow to obtain green growth near the bases of the alfalfa plants.

Alfalfa, as used in this paper, includes yellow sweetclover and white sweetclover as well as alfalfa. The diagnostic characters of these species were so similar that all were recorded as alfalfa. In most cases, alfalfa was probably the major component of the group.

Summer cypress constituted a part of the diet in all seasons although it was most important in February when snow covered the shorter vegetation and from May through August when it was green and succulent. This forb comprised 11% of the diet in August (Table 2). It accounted for 4% of the yearly diet and occurred in 36% of the stomachs examined (Table 3).

Groundcherry (*Physalis* sp.) was preferred during late summer and fall but was not eaten during winter or spring. This plant comprised 11% of the diet in September 1965 and 1966. The leaves were eaten in minor amounts, but the fruits were relished and eaten as long as they were available. Groundcherry constituted 4% of the yearly diet and occurred in 28% of the stomachs examined.

Table 3. Occurrence and composition (in percent) of food items in yearly diet of the black-tailed jackrabbit.

Plants	Occurrence	Composition
Agropyron smithii	72	22
Medicago-Melilotus	52	18
Kochia scoparia	36	4
Festuca octoflora	28	8
Sporobolus cryptandrus	28	8
Physalis sp.	28	4
Stipa comata	28	3
Opuntia humifusa	24	5
Calamovilfa longifolia	24	2
Artemisia filifolia	20	5
Bromus sp.	20	2
Chenopodium album	12	2
Plantago purshii	12	1
Eriogonum annuum	8	1
Bouteloua gracilis	5	1
Unidentified forbs	56	4
Seeds	20	1

Lambsquarters (*Chenopodium album*) made up 13% of the diet in September 1965, but decreased to 2% by December 1965 (Table 2). During the remainder of the study it was eaten infrequently and in small amounts. It was 2% of the yearly diet and occurred in 12% of the stomachs examined.

The diet contained 9% of wooly indianwheat in late June although it was eaten only in very small amounts during the rest of the year. This forb comprised 1% of the yearly diet and occurred in 12% of the stomachs examined.

Annual buckwheat (*Eriogonum annuum*) was the only other forb that made up at least 1% of the yearly diet, but the following forbs were eaten in amounts less than 1% of the yearly diet: *Artemisia ludoviciana*, *Astragalus* sp., *Asclepias* sp., *Conyza canadensis*, *Cryptantha* sp., *Descurainia* sp., *Erigeron* sp., *Evolvulus nuttallianus*, *Gaura coccinea*, *Lepidium densiflorum*, *Mentzelia nuda*, *Portulaca* sp., *Psoralea tenuiflora*, *Salsola kali*, *Sophora sericea*, *Sphaeralcea coccinea*, *Tradescantia occidentalis*, and *Tribulus terrestris*.

Shrubs

Shrubs comprised roughly 2% of the vegetation on the study area and were 10% of the yearly diet of the jackrabbit. They were most important in the fall and winter.

Pricklypear was the most important food item in September 1965, when it was 38% of the diet (Fig. 1, Table 2). It was eaten mainly in the fall and winter, but utilization of this species decreased after September. The ripe fruits were relished and were eaten whenever they were available, whereas the pads were eaten in lesser amounts. Pricklypear comprised 5% of the yearly diet and occurred in 24% of the stomachs analyzed (Table 3).

Sand sagebrush was eaten during late fall and winter. This shrub was first detected in the stomach contents in December 1965, when it constituted 12% of the diet. It accounted for 34% of the food eaten in February when snow covered most of the vegetation on the study area. This shrub was not eaten during the spring or summer but appeared in the diet again early in November 1966. The yearly diet included 5% sand sagebrush which occurred in 20% of the stomachs examined.

Soapweed (*Yucca glauca*) eaten in very small amounts, was the only other shrub to appear in the stomach contents.

Seeds

Seeds appeared in the stomach contents primarily during the fall and comprised 4% of the diet in September 1966 (Table 2). They made up 1% of the yearly diet and occurred in 20% of the stomachs analyzed.

Discussion

Diet

Only two plants served as staple foods for black-tailed jackrabbits, although many other plants were eaten seasonally or in small amounts. The staples, western wheatgrass and alfalfa, were eaten throughout the year and showed similar trends of importance in the diet (Fig. 1). Preference for the green regrowth of these plants was high during seasons when most of the vegetation was dormant or dead and was low when other green grasses and forbs were plentiful.

After forbs in the sandhill pastures matured and became unpalatable, jackrabbits shifted their feeding activities to an area along a draw where western wheatgrass was a common component of the vegetation. Most jackrabbits that were collected in late fall and winter had been feeding in these areas or in alfalfa fields that bordered the draw. Utilization of alfalfa fields was most apparent in February when snow covered the short vegetation and was least apparent in the spring and summer when rabbits probably fed on sweetclover and alfalfa in old fields and on other forbs and grasses in the native pastures. The amounts of western wheatgrass and alfalfa in the diet decreased after the spring period, and they were replaced by species that have their maximum growth in the summer.

The apparent importance of alfalfa in the diet of the jackrabbit was influenced by the sampling method. Each sample was made up of some jackrabbits that had access to alfalfa and some whose home range probably did not include a source of alfalfa. As a result, most samples included a few jackrabbits that had eaten almost entirely alfalfa

Table 4. Jackrabbits with more than and less than 50% alfalfa[1] in the diet on all sampling dates.

Sampling dates	More than 50% alfalfa		Less than 50% alfalfa	
	No. of animals	Percent alfalfa	No. of animals	Percent alfalfa
September 28	3	92	22	6
December 1	6	77	19	4
February 8	14	65	11	12
April 1	8	71	17	5
April 29	4	68	21	8
May 20	4	66	21	4
June 29	3	63	22	3
August 1	1	60	24	3
September 23	3	84	22	8
November 11	15	88	10	5

[1] Alfalfa includes white sweetclover, yellow sweetclover as well as alfalfa.

and a larger number that had eaten alfalfa in small amounts or not at all (Table 4).

About 60% of the yearly diet of the jackrabbit was made up of plants that were eaten in small amounts or were preferred only at a particular time of the year. Seasonal foods were usually available in the preferred stage of maturity for short periods. Sixweeks fescue, while it was in a green vegetative stage, was the second most important item in the diet in late April. Utilization of this grass more than doubled after it had developed an inflorescence, making it the most important constituent of the diet in late May. It became unpalatable and disappeared from the diet in August. Sand dropseed was eaten in large amounts only after it had flowered, and utilization decreased sharply before November when it had matured and the seed had shattered. Pricklypear and groundcherry were relished only when their fruits were ripe in late summer and fall. Sand sagebrush was preferred and eaten only after its leaves began to fall in November. Currie and Goodwin (1966) reported a similar trend on utilization of big sagebrush in Utah. Blue grama and prairie sandreed were preferred only during the summer, although they were the two most abundant plants and were available throughout the year.

The diet of jackrabbits on the study area appeared to be influenced by the changing availability of some plants. Vorhies and Taylor (1933) indicated that the availability of food materials has much to do with feeding habits of jackrabbits. In September 1965, both lambsquarters and pricklypear were consumed in large amounts, but in September 1966, lambsquarters was not eaten and pricklypear was eaten only in small amounts. Lambsquarters, an annual, was plentiful in the summer of 1965, whereas it was seldom observed in the pastures in 1966. Pricklypear plants were laden with fruits and appeared vigorous in September 1965, but by December the pads had shriveled and remained in this condition until the study was terminated in November 1966. Few fruits were produced in September 1966, which probably accounted for the small amount of this plant in the diet at that time. To get an accurate estimate of the plants eaten by jackrabbits, their diets should be investigated over a period of several years.

Preference

The preference for a plant species shown by jackrabbits seemed to be governed by the kinds, the quantity and the condition of the plants present (Bear and Hansen, 1966). Hayden (1966) suggested that the selection of food material in desert areas was strongly influenced by the environment and the necessity of maintaining a water balance. Succulent grasses and forbs were preferred by jackrabbits during my study. Seasonal preferences for certain plants also could have been influenced by the amount of energy the plant yielded to the animal. Although no energy determinations were made, rabbits may have been harvesting high energy foods when they consumed the seeds of sixweeks fescue and sand dropseed and the fruits of groundcherry and pricklypear.

Preference indices, computed for the most common food items, varied throughout the year for each species. Forbs were more highly preferred than were grasses, and seasonally important foods received higher preference indices than those plants eaten in all seasons. The preference index for western wheatgrass varied from 6.5 in December 1965, to 0.8 in August 1966. Preference indices for some of the seasonally important foods at the peak of their utilization was: lambsquarters, 131.0; pricklypear, 94.5; annual buckwheat, 27.5; groundcherry, 26.5; sixweeks fescue, 6.9; sand dropseed, 6.6; prairie sandreed, 0.7; and blue grama, less than 0.1.

Because jackrabbits probably move over a large area while feeding, preference indices are only an approximate measure of true preference. Botanical composition of the vegetation was taken only at the kill site, and it was possible that the jackrabbit had eaten elsewhere.

Grazing Relationships

Competition.—Seasonal diets of cattle have been investigated on the Eastern Colorado Range Station (Dahl, unpublished data) and Reppert (1960). Both found that blue grama, prairie sandreed, and needleandthread comprised most of the yearly diet of cattle. Western wheatgrass and sunsedge (*Carex heliophila*) formed an important part of the diet in early spring. Sand dropseed, sand bluestem (*Andropogon hallii*), and forbs were eaten in smaller amounts in summer.

Competition for food between jackrabbits and cattle was greatest in early spring when both animals preferred green forage. Western wheatgrass, needleandthread, and sunsedge initiated growth early and were preferred by both classes of animals. At this time of the year green forage was at a premium and any consumer that removed it was competing with cattle.

Although jackrabbits and cattle ate some of the same species during the summer, they did not eat them in similar proportions. Cattle ate large amounts of blue grama, prairie sandreed, and sand bluestem, whereas jackrabbits ate mostly forbs and sand dropseed.

Competition was probably slight during fall and winter when cattle ate needleandthread and blue grama and jackrabbits relied on western wheatgrass, forbs, and shrubs.

Effects on rangeland.—Jackrabbits probably influence secondary succession on old fields and denuded ranges and decrease the longevity of reseeded forage stands on rangelands. Brown (1947) reported that over a period of 6 months jackrabbits deposited 12.75 lb/acre of sand dropseed seed in fecal pellets on an abandoned field. He also found that the digestive processes of the jackrabbit increased the viability of the seed from 4.2% to 31.3%. The feasibility of using grass–alfalfa mixtures on reseeded rangelands was investigated at the Eastern Colorado Range Station (Dahl et al., 1967). Sand dropseed invaded the reseeded pastures and increased as the amount of intermediate wheatgrass (*Agropyron intermedium*) decreased. Data presented in the present paper indicate that alfalfa, sand dropseed, and possibly intermediate wheatgrass (not distinguished from western wheatgrass) are preferred foods of the jackrabbit. Perhaps jackrabbits concentrated on areas seeded with a grass–alfalfa mixture and disseminated sand dropseed seed while feeding, thus contributing to the invasion of the species.

Conclusions

The major foods in the diet of the black-tailed jackrabbit were western wheatgrass, alfalfa, sixweeks fescue, sand dropseed, pricklypear, and sand sagebrush. The diet followed definite seasonal trends that were influenced by forage maturity and availability. Grasses made up 50% of the yearly diet and were most frequently eaten during early spring and summer. Forbs constituted 30% of the yearly diet and were preferred during summer and early fall. Shrubs were 10% of the yearly diet and were eaten primarily during fall and winter. Forbs were preferred over grasses and seasonally important foods received higher preference indices than those that were eaten in all seasons.

Competition for food between jackrabbits and cattle was greatest in early spring when both animals preferred green forage. At other times they ate some of the same foods but not in the same proportions, so competition was not great for the plants that were preferred by cattle.

Jackrabbits probably decrease the longevity of reseeded forage stands on rangelands and influence secondary succession on old fields and denuded ranges. When a grass–alfalfa mixture is used to reseed rangelands, it is possible that jackrabbits concentrate on seeded areas and disseminate the seeds of less desirable grasses and forbs while feeding, thus contributing to the invasion of these species.

LITERATURE CITED

Arnold, J. F. 1942. Forage consumption and preferences of experimentally fed Arizona and antelope jackrabbits. Arizona Agr. Exp. Sta. Tech. Bull. 98. 86 p.

Bear, G. D., and R. M. Hansen. 1966. Food habits, growth and reproduction of white-tailed jackrabbits in southern Colorado. Colorado Agr. Exp. Sta. Tech. Bull. 90. 59 p.

Brown, L. H. 1947. Coaction of jackrabbit, cottontail, and vegetation in a mixed prairie. Kansas Acad. Sci., Trans. 50:28–44.

Brusven, M. A., and G. M. Mulkern. 1960. The use of epidermal characteristics for the identification of plants recovered in fragmentary condition from the crops of grasshoppers. North Dakota Agr. Exp. Sta. Res. Rep. No. 3. 11 p.

Croker, B. H. 1959. A method of estimating the botanical composition of the diet of sheep. New Zealand J. Agr. Res. 2:72–85.

Currie, P. O., and D. L. Goodwin. 1966. Consumption of forage by black-tailed jackrabbits on salt-desert ranges of Utah. J. Wildl. Manage. 30:304–311.

Dahl, B. E., A. C. Everson, J. J. Norris, and A. H. Denham. 1967. Grass–alfalfa mixtures for grazing in eastern Colorado. Colorado Exp. Sta. Colo. State Univ. Tech. Bull. 529-S. 25 p.

Davies, I. 1959. The use of epidermal characteristics for the identification of grasses in the leafy stage. Brit. Grassland Soc. J. 14:7–16.

Evans, R. A., and R. M. Love. 1957. The step-point method of sampling—a practical tool in range research. J. Range Manage. 13:58–65.

Fracker, S. B., and J. A. Brischle. 1944. Measuring the local distribution of Ribes. Ecology 25:283–303.

Hayden, P. 1966. Food habits of black-tailed jackrabbits in southern Nevada. J. Mammal. 47:42–46.

Reppert, J. N. 1960. Forage preference and grazing habits of cattle at the Eastern Colorado Range Station. J. Range Manage. 13:58–65.

Sanderson, H. R. 1959. Relationships between jackrabbit use and availability of forage on native sandhill range. M.S. Thesis, Colorado State Univ., Fort Collins. 85 p.

Storr, G. M. 1961. Microscopic analysis of feces, a technique for ascertaining the diet of herbivorous mammals. Austral. J. Biol. Sci. 14:157–164.

Vorhies, C. T., and W. P. Taylor. 1933. The life histories and ecology of jackrabbits, *Lepus alleni* and *Lepus californicus* ssp., in relation to grazing in Arizona. Arizona Agr. Exp. Sta. Tech. Bull. 49:471–587.

Sagebrush Reinvasion as Affected by some Environmental Influences[1]

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Highlight

Five chemically sprayed and 15 plowed and seeded areas in southwestern Montana were examined to determine the influence of several environmental factors on big sagebrush reinvasion. Sagebrush surviving the treatments was found to be the most important factor related to reinvasion. Plowing near or after sagebrush seed maturation resulted in heavy reinfestation of seeded stands. Sagebrush adjacent to treated areas was of no practical importance as a seed source for reinvasion. Non-sagebrush vegetation, slope, erosion, soil texture, and precipitation were seldom related to sagebrush reinvasion. Northwest exposures favored reinvasion.

Large acreages of big sagebrush (*Artemisia tridentata*) have been treated by various control methods in the Intermountain region. Successful reduction of sagebrush densities has resulted in increased grass production. Two common methods of sagebrush removal are chemical spraying and plowing. Spraying has the advantage of not disturbing the soil but is successful only when ample desirable grasses are present to assume dominance. Plowing usually requires seeding. Unfortunately, big sagebrush reinvades many treated areas.

Observers generally agree that intensive grazing has resulted in increased density and distribution of sagebrush (Lommasson, 1946; Frischknecht and Plummer, 1955; and others).

Beneficial results of control measures are often temporary due to rapid reinvasion following initial stand reductions (Lommasson, 1947; Bleak and Miller, 1955; Frischknecht and Plummer, 1955; and others).

Seed source is the primary question in sagebrush re-establishment. Mueggler (1956) concluded that wind-borne seed was restricted to within a few hundred feet of the treatment edges, and that residual seed was the greater source for reinvasion on burned areas in Idaho. The maximum distance of seed dissemination by wind was found to be about 33 m by Goodwin (1956) who also indicated that morphological characteristics of sagebrush seed allowed adherence to passing objects upon contact. Frischknecht and Plummer (1955) stated that seed was transported to a 45-acre site by wind and to some extent by animals. Lommasson (1946) and Bleak and Miller (1955) concluded that sagebrush reinvasion resulted from seed produced by plants surviving eradication.

Sagebrush seed production and subsequent potential re-establishment vary with date of mechanical eradication. Bleak and Miller (1955) found spring eradication resulted in low sagebrush kills with the remaining plants becoming prolific seed producers. Pechanec et al. (1944) and Bleak and Miller (1955) stated that fall eradication after seed set scattered the seed and prepared a good seed bed.

Many studies have concluded that seeded grass stands cannot become established unless the competitive effects of mature sagebrush are reduced (Pechanec et al., 1944; Blaisdell, 1949). Once perennial grasses are established, however, young sagebrush seedlings tend to become excluded (Pechanec et al., 1944). Beetle (1960) observed that grasses were more likely to establish when a litter layer was present than were sagebrush seedlings. Robertson (1947) reported mature sagebrush plants contributed to sagebrush seedling establishment since the areas under the shrubs were void of grasses.

Years favorable for natural sagebrush seedling establishment come at irregular intervals (Blaisdell, 1949). Bleak and Miller (1955) stated that available moisture was a primary factor. Lommasson (1946, 1947) found that above normal precipitation during the year of establishment as well as in following years enhanced seedling survival. Opposing this, Beetle (1960) stated drought gave an advantage to sagebrush seedlings, whereas adequate moisture was advantageous to grasses.

To shed further light on the problem of reinvasion, the following environmental and biological factors were examined on 20 treated areas in southwestern Montana: (1) effectiveness of initial sagebrush kill; (2) time of treatment in relation to sagebrush maturity; (3) influence of wind-borne seed; (4) competition with non-sagebrush vegetation; (5) yearly precipitation regimes; and (6) surface soil texture, erosion class, slope, and exposure.

Experimental Area and Procedure

Field research was conducted in southwestern Montana, mostly within 50 air miles of Dillon. Fifteen plowed and

[1] This investigation was conducted as part of Western Regional Research Project W-25 and published as Journal Series No. 840, Montana Agricultural Experiment Station. Research was completed by the senior author in partial fulfillment of the M.S. degree, Montana State University. Appreciation is expressed to personnel of the Dillon District, Bureau of Land Management, for historical information and maps. Grateful acknowledgment is also given to Dr. James T. Nichols, South Dakota State University, for his critique and suggestions on the manuscript.

Table 1. Average number of sagebrush per square meter in 5 sprayed areas and 15 plowed and seeded areas, Beaverhead County, Montana, 1965. Earliest year of sagebrush establishment for each location is the first growing season following eradication. Reinvaded sagebrush are listed by year of establishment.

Location	Sagebrush plants present in 1965 by year of establishment									Plants surviving eradication[1]	Total plants[1]	Total plants estab. after treatment[1]	Total plants less 1965 establishment[1]	Total plants estab. after treatment less 1965 establishment[1]
	1957	1958	1959	1960	1961	1962	1963	1964	1965					
Sprayed areas														
Coyote Flats			0.3	0.2	0.5	0.2	1.2	1.8	6.5	0.2	10.8	10.7	4.4	4.2
Reservoir Creek						T	T	T	0.3	0.1	0.5	0.4	0.2	0.1
Muddy Creek								0.4	0.4	0.2	1.0	0.8	0.6	0.4
Badger Pass								0.2	0.6	0.2	1.0	0.8	0.4	0.2
Bannack								0.1	0.1	0.3	0.6	0.2	0.3	0.1
Plowed & seeded areas														
Coyote Flat	2.3	0.5	0.5	0.3	0.2	0.1	T	T	0.1	0.1	5.3	5.2	5.2	5.1
PHW	1.8	0.5	0.7	0.4	0.4	0.1	0.2	0.9	1.1	0.3	6.3	6.0	5.2	4.9
Exchange		T	T	0.0	T	T	T	T	T	0.2	0.3	0.2	0.3	0.1
Hughes		0.1	0.0	T	T	T	T	0.1	0.1	0.2	0.5	0.4	0.4	0.3
Brenner			T	T	T	T	T	0.0	T	0.1	0.2	0.1	0.2	0.1
Mansfield			0.3	T	T	T	T	T	0.4	0.2	1.0	0.8	0.6	0.4
Rape Creek				0.1	T	0.1	0.3	0.4	0.8	0.3	1.9	1.7	1.1	0.8
Chinatown					T	T	1.1	1.6	4.2	0.2	7.1	6.9	2.8	2.7
Holland						T	0.1	0.2	3.8	0.3	4.4	4.1	0.6	0.3
Marchesseau						0.3	0.4	0.9	11.9	0.6	14.1	13.5	2.1	1.6
Junction							0.1	0.1	0.2	0.2	0.6	0.4	0.4	0.2
Rock Creek							0.3	0.2	1.1	0.3	2.0	1.6	0.9	0.5
Taylor Creek							T	T	8.3	0.3	8.6	8.3	0.3	T
Cottonwood Creek									3.8	0.4	4.2	3.8	0.4	0.0
Trail Creek									0.4	0.7	1.1	0.4	0.7	0.0

[1] Apparent discrepancies due to rounding error.
"T" = 0.01 to 0.05 plants per square meter.

seeded locations and five sprayed locations, totaling 28,681 acres were examined in 1965. Treatment dates were from 1957 to 1964.

Most sprayed areas occupy steeply rolling to mountainous foothill sites whereas the plowed areas are on gentler topography. The upland soils are mostly Aridisols (Brown, Solochak, and Solonetz) and Mollisols (Chestnut and Chernozem). The normally calcareous soils have A and B horizons with diverse depth and physical characteristics. Calcium carbonate deposits on upturned stones indicate shallow moisture penetration.

Over a 15-year period, precipitation at the Dillon airport ranged from 6.55 to 12.35, with an average of 9.59 inches. April, May, and June received over 50% of the annual precipitation. Isothermal lines drawn in 1961 indicate that most of the experimental sites are in the 8 to 12 inch annual precipitation zone. The growing season averages 88 days. The wide climatic extremes often are intensified by wind and exposure.

The native vegetation near the study areas is dominated by a big sagebrush—bluebunch wheatgrass (*Agropyron spicatum*) aspect. Associated shrubs are rabbitbrush (*Chrysothamnus* spp.) and three-tip sagebrush (*Artemisia tripartita*). Associated perennial grasses include Idaho fescue (*Festuca idahoensis*), Sandberg bluegrass (*Poa secunda*), needleandthread (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), and western wheatgrass (*Agropyron smithii*). The most common forbs are the mat-type phlox (*Phlox* spp.) and lupines (*Lupinus* spp.).

Paired plots were placed at predetermined regular intervals along transects 150 m in length and at least 50 m apart. Transects used to test whether reinvasion came from outside the areas were designated "regression transects," and originated at and perpendicular to treatment edges with potential sagebrush seed sources. Other transects located within the treatment area were designated "interior transects."

Two types of plots (hence the term "paired plots") were used in sampling. One plot was one meter square and the other was circular with a radius of one meter, both with the same center.

All sagebrush plants within the square-meter plot were counted and aged by ring counts (Ferguson, 1964). Sagebrush plants established before the treatment within the circular plot were counted and designated as mature plants capable of seed production even though some were not producing seed at the time of the study. Mature plants were counted when foliage was present within the vertical projection of the circular plot boundaries.

Each pair of plots (for both regression and interior transects) had the following information recorded: surface soil texture (Dyksterhuis, 1964); direction of land exposure, with eight exposure classes; slope as determined with a hand level; and one of five erosion classes ranging from "none," with no soil movement and a vegetational litter cover of 80% within the square plot, to "severe rill," the precursor of active gullying. Basal cover of vegetation by

Table 2. Correlation coefficients between mature (treatment surviving) sagebrush and various age classes of reinvaded sagebrush.

Location	Associated degrees of freedom	Year in which reinvaded sagebrush became established									
		1957	1958	1959	1960	1961	1962	1963	1964	1965	Sum
Sprayed areas											
Coyote Flats	110			.248**	.092	.048	–.009	.039	.107	.021	.064
Reservoir Creek	615						.362**	.002	.096	.072	.090
Muddy Creek	305								.420**	.266**	.379**
Badger Pass	225								.483**	.284**	.382**
Bannack	225								.006	.084	.043
Plowed and seeded areas											
Coyote Flat	445	.089*	.088	.062	.052	.046	.333**	.055	–.033	.028	.124**
PHW	185	–.152*	.031	.067	.018	.185**	.105	.030	.157*	.140*	.139*
Exchange	380		.255**	.115*	.064	.051	.096	.097	.153**	.072	.200**
Hughes	265		.028	.000	.090	.069	.127*	.267**	.172*	.148*	.276**
Brenner	265			.065	–.021	.034	.076	.142*	.139*	.093	.164*
Mansfield	730			.005	.075	.111**	.086*	.148**	.106**	.148**	.172**
Rape Creek	300				.104	.053	.150**	.205**	.239**	.338**	.330**
Chinatown	570					.031	.090*	.166**	.253**	.368**	.367**
Holland	545						.334**	.351**	.194**	.151**	.184**
Marchesseau	480						.172**	.132**	.032	.214**	.216**
Junction	265							.180**	.152**	.038	.097
Rock Creek	185							.154*	.141*	.206**	.233**
Taylor Creek	550							.275**	.112**	.380**	.383**
Cottonwood Creek	225									.160*	.160*
Trail Creek	300									.120*	.120*

** Indicates significance at the 1% level.
* Indicates significance at the 5% level.

species was recorded along one edge of the meter square plot frame.

Field data were recorded on Port-a-punch cards and transferred to standard 80-column IBM cards. Standard mathematical and statistical procedures were used to evaluate the results.

Results and Discussion

Sagebrush age classes are shown in Table 1. From 0.1 to 0.7 sagebrush plants/m² survived the eradication treatments. There was no statistically significant difference between survival on areas that were sprayed and on areas that were plowed and seeded to grass.

Sagebrush plants established following sagebrush control activities varied widely among and within locations (Table 1). With few exceptions, there were more seedlings of 1965 germination (the year of the study) than any other year. This indicates a marked mortality of new seedlings before the second growing season. The column titled, "Total Plants Less 1965 Establishment" gives the best estimate of the number of sagebrush plants which may be expected to remain in an area. The last column, "Total Plants Established after Treatment, Less 1965 Establishment," is the best estimate of re-establishment of sagebrush.

Effectiveness of Initial Sagebrush Kill.—Re-established brush was found in association with mature brush in all but one of the treatment areas (Table 2). In 13 of the 20 locations, seedlings germinating in 1965 were significantly correlated with the mature brush, although the correlations were fairly low. Sagebrush plants germinating in 1964 likewise were significantly correlated with mature sagebrush in 13 of the 20 locations. Ten of these locations were the same as those having significant correlations for the 1965 seedlings. Ten locations had significant correlations for plants germinating in 1963 and eight for plants germinating in 1962. Plants germinating in earlier years showed few significant correlations with mature sagebrush.

Of the five chemically sprayed locations, the Muddy Creek and Badger Pass spray areas showed significant positive correlations for the two years since treatment. Six of the plowed and seeded locations lacked significant positive correlations in the first year after treatment. Five of these had significant positive correlations in later years.

It is concluded that unkilled sagebrush is the major cause of reinvasion. The generally low correlation values for all locations and years indicate that as long as there is some limited number of mature sagebrush plants present to provide seed, additional mature shrubs will not affect reinvasion. The lack of significant correlations for young plants over four years old indicates that factors affecting plant survival are of primary importance as the plants grow older.

Table 3. Regression coefficients of three study areas to determine whether sagebrush reinvaded brush control areas from adjacent sagebrush stands.

Reseeding area	Age Class	b value
Chinatown		
	Mature (treatment surviving)	–.0069**
	Reinvaded brush[1]	
	1961	–.0005*
	1962	–.0006*
	1963	–.0261**
	1964	–.0284**
	1965	–.0682**
Marchesseau		
	Mature (treatment surviving)	.0036
	Reinvaded brush[1]	
	1962	.0007
	1963	–.0016
	1964	–.0068*
	1965	–.0352
Taylor Creek		
	Mature (treatment surviving)	–.0018
	Reinvaded brush[1]	
	1963	.0003
	1964	–.0002
	1965	.0942**

* Indicates significance at the 5% level (one-tailed test).
** Indicates significance at the 1% level (one-tailed test).
[1] Years 1961 to 1965 represent plants present in 1965 by year of establishment.

Time of Treatment in Relation to Sagebrush Maturity.—Four of the plowed and seeded areas (Coyote Flat, Marchesseau, Cottonwood Creek, and Trail Creek) were believed plowed in late autumn after sagebrush seed maturation. The first year re-established sagebrush plants averaged 2.3, 0.3, 3.8, and 0.4 plants/m^2 respectively (Table 1). The exceptionally high early re-establishment rates likely resulted from a scattering of the new sagebrush seed crop throughout the freshly prepared seedbed. The reduced competition following plowing further served to insure high rates of early brush re-establishment. The practice of mechanically removing sagebrush in the autumn after seed maturation appears to assure severe reinfestation of the treated areas.

Wind-borne Seed.—Eight of the study locations were adjacent to sagebrush stands suitable for studying the influence of wind-borne seed on reinvasion. Table 3 lists three of the locations and their corresponding regression coefficients. Of the eight areas, only the Chinatown Reseeding had consistently significant and, generally speaking, slightly higher negative values than the other locations. Even these values for seedlings probably do not indicate seed movement into the treated area from the periphery. The mature plants (potential sources of seed) within the Chinatown Reseeding likewise had a negative value, indicating decreasing densities of unkilled brush from the edge inward.

Prevailing wind direction was not considered in evaluating wind-borne seed. Even though this is the case, it is felt that sagebrush adjacent to such large areas is of no practical importance as a seed source for reinvasion.

Influence of Non-sagebrush Vegetation on Reinvasion.—Basal intercept of live vegetation varied from 0.6 to 3.4%. In all of the correlations examined, only four of 95 were significant, and these were positive. With the exceptions of these four, no trend was found for either positive or negative correlations. Negative correlations would have indicated non-sagebrush vegetation was instrumental in preventing sagebrush re-establishment and positive correlations the reverse. The only conclusion which can be reached is that sagebrush re-establishment was not influenced by other vegetation.

Precipitation.—Studies in southwestern Montana have shown that sagebrush seed germinated in the spring as soon as temperatures became sufficiently warm (Mont. Agr. Exp. Sta., Progress Reports, 1961–64). In these studies, precipitation never limited germination. Temperature appeared to control germination, but the summer survival of the seedlings was thought to be limited by precipitation.

With this in mind, June to July, May to October, and annual precipitation patterns were studied to determine whether differences in precipitation accounted for differential reinvasion rates. Three study locations were selected for examining precipitation–reinvasion relationships. These were among the first treated and consequently best suited for regression analyses due to adequate sample size (determined by number of years since the treatment). In addition to the analyses of the three individual areas, all plowed locations and all 20 locations were considered collectively. The results of the regression analyses were non-significant in all cases.

Although these results indicate no relationship between precipitation and reinvasion rates, the possibility should not be discounted. It is possible that the proper precipitation data combination was not used. Perhaps an interaction of factors, including precipitation, is involved.

Effect of Soil and Topographic Characteristics.—The influence of each of these factors was tested only where major differences in a factor occurred within a treatment area.

Soil texture was significantly related to the re-establishment of big sagebrush in two of the seven areas where soil textures varied. In these two areas, the highest reinvasion rate was found on silty soil. Since reinvasion rates in relation to soil texture were not frequently found, it is concluded that soil texture was not well related to reinvasion rate.

Significant differences in sagebrush re-establishment among erosion classes were found within three of 17 locations, but the relationships were not the same among these locations. It is concluded that erosion severity is not related to sagebrush re-establishment.

In nine treatment areas re-established sagebrush varied significantly with respect to exposure. The northwest exposures generally were more favorable for re-establishment than south exposures.

Twelve areas were tested to determine if a relationship existed between percent slope and sagebrush re-establishment. Only two areas indicated that a relationship existed, with more sagebrush found on steeper slopes. Since 10 of these areas showed no relationship, percent slope cannot be considered an important factor.

LITERATURE CITED

BEETLE, A. A. 1960. A study of sagebrush—the section *Tridentatae* of *Artemisia*. Wyo. Agr. Expt. Sta. Bull. 368. 83 p.

BLAISDELL, JAMES P. 1949. Competition between sagebrush seedlings and reseeded grasses. Ecology 30:512–519.

BLEAK, A. T., AND WARREN G. MILLER. 1955. Sagebrush seedling production as related to the time of mechanical eradication. J. Range Manage. 8:66–69.

DYKSTERHUIS, E. J. 1964. Technicians' Guide, Part II, E. U.S. Dept. Agr., Soil Conserv. Serv. 4 p.

FERGUSON, CHARLES WESLEY. 1964. Annual rings in big sagebrush. The Univ. Ariz. Press, Tucson, Ariz. 95 p.

FRISCHKNECHT, NEIL C., AND A. PERRY PLUMMER. 1955. A comparison of seeded grasses under grazing and protection on a mountain brush burn. J. Range Manage. 8: 170–175.

GOODWIN, DUWAYNE LEROY. 1956. Autecological studies of *Artemisia tridentata* Nutt. Ph.D. Thesis. Wash. State Coll. Summary, p. 64–67.

LOMMASSON, T. 1946. Transition of sagebrush, *Artemisia tridentata*, on high mountain rangeland in southwestern Montana, 1915–1945. U.S. Forest Serv., Region 1, Missoula, Mont. Range Manage. No. 4. 7 p.

LOMMASSON, T. 1947. Transition of sagebrush, *Artemisia tridentata*, on semiarid foothills of the upper Missouri River valley following burning. U.S. Forest Serv., Region 1, Missoula, Mont. Range Manage. No. 6. 2 p.

MONTANA AGRICULTURAL EXPERIMENT STATION. 1961–64. Annual progress reports—contributing project to Regional Project W-25—ecology and improvement of brush infested range.

MUEGGLER, WALTER F. 1956. Is sagebrush seed residual in the soil of burns or is it wind-borne? U.S. Forest Serv., Intermountain Forest and Range Expt. Sta. Res. Note No. 35. 10 p.

PECHANEC, JOSEPH F., A. PERRY PLUMMER, JOSEPH H. ROBERTSON, AND A. C. HULL, JR. 1944. Eradication of big sagebrush (*Artemisia tridentata*). U.S. Forest Serv., Intermountain Forest and Range Expt. Sta. Res. Paper No. 10. 23 p.

ROBERTSON, JOSEPH H. 1947. Responses of range grasses to different intensities of competition with sagebrush (*Artemisia tridentata* Nutt.). Ecology 28:1–16.

Preplanting Treatment to Hasten Germination and Emergence of Grass Seed[1]

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Highlight

Seeds in the crested wheatgrass complex were placed under conditions favorable for germination for periods of 10 to 90 hr, superficially dried, and then planted on a greenhouse bench. The most effective treatment was at 63 F for 60 to 70 hr. Seedlings resulting from this treatment emerged about 40 hr ahead of untreated seeds. The study suggests that if field tests yield similar results, pretreatment of seed may contribute towards greater success in range seeding.

[1] Cooperative investigation by the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Utah Agricultural Experiment Station.

Many seeding failures have occurred when unfavorable conditions have developed subsequent to planting. Hot drying winds, unexpectedly low temperatures, or rain that briefly wets the surface and causes the soil to crust, are a few conditions that damage range seedings. Failures in this category should be reduced if practices could be employed that would hasten emergence.

McKee (1935) conducted vernalization experiments with grass seeds. He reported that ". . . in the case of grasses and certain legumes, seed that have been slightly sprouted and again dried will start into growth quicker than unsprouted seeds." Chippendale (1934) states that ". . . although the soaking of grass seeds was formerly carried out frequently by farmers, this procedure is not applied in modern agriculture." He reported that under conditions favorable for the growth and development of plants, many species "derive extremely little benefit from previous soaking in water," but that "the benefit from presoaking was enhanced as the conditions for establishment deteriorated." No reports have been found in the literature in

Table 1. Percent emergence on September 9 and 10 from seeds planted on greenhouse bench September 6. Means of 3 replications.

Hours treated	September 9 Treatment temp. Control	40 F	63 F	82 F	September 10 Treatment temp. Control	40 F	63 F	82 F
0	0				5			
10		0	0	0		19	15	28
20		0	1	11		23	36	57
30		0	6	5		33	48	53
40		0	21	19		37	61	57
50		0	38	16		37	71	52
60		3	10	8		44	53	60
70		1	21	10		51	67	55
80		6	48	16		44	79	64
90		9	33	16		52	63	61
Avg.		2 c[1]	20 a	11 b		38 b	55 a	54 a

[1] Duncan's multiple range test indicated significant differences at the 1% level for September 9 ranging from 11.0 for adjacent values to 13.3 where the two extremes are compared. For September 10 these differences were 15.3 to 18.6, respectively. For each date, different letters following averages indicate significance at the 1% level.

which presoaked seeds have been used to enhance establishment of grass on arid range land, however.

In the present study seeds of grasses in the crested wheatgrass complex, were "treated" by being exposed to moisture for various periods of time and brought to various stages of germination before planting. The objective was to determine if emergence could then be hastened.

Materials and Methods

Shallow plastic boxes with self-sealing lids to maintain high humidity were used. In each box a scattered single layer of seeds was placed on a wet paper towel resting on a wet germination blotter.

In the first study nine treatments are reported. They range from 10 to 90 hr, at 10-hr intervals. Each treatment was carried out at 40, 63, and 82 F. In the second study there were six treatments ranging from 40 to 90 hr at 10-hr intervals. These were all at 63 F.

The beginning time of treatment was so scheduled that all periods ended on the morning of the same day. At the termination of each treatment, external moisture was removed from the seeds by blowing warm air over them for 2 min. The seeds were then weighed and the numbers to be planted were counted out and wrapped in small sheets of aluminum foil to prevent further dehydration. In the second study, however, some seeds from one source were not rapid-dried, to determine what effect, if any, the rapid drying might have on emergence. Greenhouse plantings were completed the same day, although the seeds may have been held in the aluminum foil several hours. Rows were spaced 3 inches apart and seeds were uniformly covered with 0.5 inch of soil. The first planting was in 3 replications of 50 seeds/row. A single source of commercial crested wheatgrass *Agropyron desertorum* was used. The second planting was in 4 replications of 25 seeds each. Seeds of *Agropyron* from six sources were used. Following each planting, the soil was kept moist and emergence counts were made daily.

Results and Conclusions

Effect of treatment temperature and duration.—Seeds treated in the first study were planted September 6. Table 1 records percentage emergence on September 9 and 10. The data are quite variable, but the following conclusions appear warranted.

1. Emergence was hastened by the treatment at all temperatures and durations.
2. Seeds treated at 40 F were slower to emerge than those treated at 63 or 82 F.
3. Most of the increased emergence from treatment at 63 or 82 F had been achieved by 50 hr, but the data were far from consistent.
4. Emergence on September 9 for seeds treated at 63 F was greater than for those treated at 82 F, but again the data were far from consistent.

By September 16 all treated as well as untreated seeds had shown satisfactory emergence. Seeds planted dry had emerged 91.5%. Seeds treated for different periods of time had emerged 88 to 94% and those treated at different temperatures 89 to 91%.

Effect of seed source.—Seeds treated in the second study were from six different sources. They were planted October 8. Table 2 records percentage emergence on October 11. The following conclusions appear warranted from these data.

1. Emergence of each seed source was hastened by the treatment.
2. Seed sources differed markedly in emergence rate.
3. Seeds subjected to drying after treatments that lasted 80 or 90 hr were slower to emerge than non-dried seeds. The final emergence was also lower.
4. Seed source 5 was low in viability compared with all other lots.
5. Although seed sources did not all respond alike, treatments lasting 60 to 70 hr appeared to be slightly better, on the average, than those of shorter or longer duration.

Time gained by treatment.—Time gained by treatment was determined by interpolation, after plotting the rate of emergence of dry seeds. In the

Table 2. Percent emergence on October 11 from seeds treated at 63 F and planted on greenhouse bench October 8, 67 hours earlier. Each value is an average of 4 replications.[1]

Hours treated	Source[2] 01[3]	1	2	3	4	5	6	Average
0	0	0	8	0	0	0	0	1
40	29[4]	28	37	86	74	4	41	43c
50	43	40	59	84	70	11	53	51abc
60	53	38	42	86	76	13	61	53ab
70	68	58	42	78	79	10	59	56a
80	74	43	42	71	61	10	51	50abc
90	67	53	45	66	54	5	38	47bc
Average	56 c	43 d	44 d	78 a	69 b	9 e	50 cd	50

[1] The 4th replication, which remained in place three more days had 74 to 92% emergence for different sources, except source 5 which was 41%, and 69 to 83% for different treatments, the 40-, 80-, and 90-hour treatments being somewhat lower than 50 to 70 hours.

[2] (1) Commercial Nordan grown in Northern Utah in 1965 (used also for 1st study); (2) certified Nordan from North Dakota, 1965 seed; (3) induced tetraploid *A. cristatum* × *A. desertorum* (from D. R. Dewey); (4) Summit F. C. 38332; (5) commercial Fairway F. C. 38561; (6) Nebraska 3576 Fairway.

[3] 01 designates seeds of source 1 that were not exposed to the 2-minute drying treatment. Otherwise for each treatment they were directly comparable to source 1.

[4] Duncan's multiple range test indicated significant differences at the 1% level at 20.3 for adjacent values to 25.4 where the two extremes are compared. Within each set of averages, those not having a letter in common differ significantly at the 1% level.

first study, the 63 F treatment 88 hr after planting is presented in Table 3. The following conclusions appear warranted.

1. There was a progressive time gain, following pre-treatment, of 3 to 44 hr, as treatment time increased from 10 to 50 hr.

2. Time gain, for treatments beyond 50 hr, was erratic, which suggests injury or other operating factors.

In the second study, comparable emergence time was determined for 67 hr after planting. The data are presented in Table 4. The following conclusions appear warranted.

1. Pretreatment of 70 hr gave maximum gain.

2. The range of 60 to 70 hr pretreatment appeared superior to either 40 or 90 hr.

3. Seed sources differed in response.

4. The 2-minute warm air drying slowed emergence when treatments lasted 60 hr or more (compare 1 and 01, Table 4).

Discussion

The studies reported in this paper will require extensive field testing. They suggest that seeds which have been allowed to absorb water for 2 to 3 days, at near room temperatures, produce seedlings which can emerge from the soil in less time than dry seeds. If the same relations hold under field conditions, soaking seeds could be the decisive factor between success and failure. The results obtained suggest one means of overcoming some of the hazards involved in range seeding and lowering the incidence of seedling failure.

If the time between planting and emergence can be reduced, it follows that conditions existing at the time of planting will be a better indicator of subsequent emergence. The probability of satisfactory emergence of a seeding might then be predicted with greater accuracy from moisture available in the soil at the time of planting.

The time gained by pretreatment, reported in Tables 3 and 4, was never sufficient to offset the actual treatment time. For example, the 50-hr treatment (Table 4) yielded a gain of 41 hr, but the seeds had been wet 50 hr, and 6 hr lapsed between the end of the 50-hr treatment and planting. Even if it is assumed that the superficial drying stopped growth, there is a loss of 9 hr for treated

Table 3. Percent emergence of treated seeds at 63 F, 88 hours after planting in the first study and hours required for seeds planted dry to reach same emergence, by interpolation.

Hours treated	Emergence 88 hours	Equal emergence for dry seeds	Pretreatment gain
0	5		
10	15	91	3
20	36	101	13
30	48	109	21
40	61	121	33
50	71	132	44
60	53	113	25
70	67	126	38
80	79	154	66
90	63	123	35

Table 4. Hours required for untreated seeds to reach the emergence recorded for treated seeds 67 hours after planting in the second study, by interpolation.[1]

Hours treated	Source[2] 01	1	2	3	4	5	6	Average hours	Gain hours
40	80	79	84	128	97	101	105	96	29
50	101	99	113	122	95	121	105	108	41
60	108	97	99	128	98	125	114	110	43
70	126	113	102	110	102	122	112	112	45
80	132	101	99	100	91	119	103	106	39
90	122	108	102	95	90	101	93	102	35
Avg. hours	112	100	100	114	97	115	105	105	39
Avg. gain hours	45	33	33	47	30	48	38	38	

[1] The 40-, 50-, 60-, 70-, 80-, and 90-hour treatments began 45, 56, 67, 80, 90, and 98 hours, respectively before planting.

[2] For identity of sources see footnote 2, Table 2.

seeds compared to those put dry into the soil. This suggests that moist soil on the greenhouse bench was a more favorable environment than the plastic boxes with the moisture and temperature provided in the laboratory. Whether a more favorable pretreatment environment can be found remains to be determined, as well as the effect that it will have on subsequent seedling development.

Surface-drying of the treated seeds may be essential to their successful planting through drills in common use. Drying seeds treated 60 hr or longer delayed emergence compared with wet seed. However, most of the advantage from pretreatment persisted.

LITERATURE CITED

CHIPPENDALE, H. G. 1934. The effect of soaking in water on the "seeds" of some *Gramineae*. Ann. Appl. Biol. 21: 225–232.

McKEE, R. 1935. Vernalization experiments with forage crops. U.S. Dept. Agric. circular 377. 12 p.

Carbohydrate Reserves of Sand Reedgrass under Different Grazing Intensities[1]

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Highlight

Stored carbohydrates of sand reedgrass increased from a low in late May and early June to a maximum in late September and early October. Starch was the major stored carbohydrate. The concentration of starch in the roots decreased slightly with increased grazing intensity. The results of this study combined with information on the morphological development, extent of root system, and other physiological aspects of sand reedgrass can be used in developing grazing management systems for sand reedgrass.

Sand reedgrass (*Calamovilfa longifolia*), a tall, sod-forming, warm-season grass with large, spreading rhizomes, is one of the prominent plants in the sandhills vegetation of northeastern Colorado. Sand reedgrass is a preferred or "sought-after" species by cattle only during May and early June, but, because it is abundant, it is a major component of cattle diets throughout the summer months. This plant decreases under heavy summer grazing (Dahl and Norris, 1965). Branson (1953) pointed out the importance of position of apical meristem and ratio of vegetative to reproductive stems in the response of a grass to grazing. The results of a study by Dahl[3] at the Eastern Colorado Range Station showed that apical meristem of reproductive shoots of sand reedgrass remained below the soil surface until June, shoot apices of vegetative stems remained below or near the soil surface throughout the growing season and were not subject to removal by grazing. There were approximately twice as many vegetative stems as reproductive stems. Therefore, the level of reserve carbohydrates may be a more important factor in the reaction of sand reedgrass to heavy grazing than position of apical meristem.

Reserve carbohydrates are those carbohydrates that are alternately accumulated and utilized by the plant during the growth cycle. Sucrose, fructosans, and starch are the most important reserve carbohydrates with glucose and fructose less significant. These carbohydrates are stored in the roots, rhizomes, stem bases, and corm-like organs of grasses. Carbohydrate reserves are used for initiation of growth in the spring, for regrowth following defoliation, and for respiration during the winter. Defoliation of a grass generally reduces the carbohydrate reserves. The degree of reduction depends on the frequency, intensity, and time of foliage removal (Weinmann, 1952; Troughton, 1957; Cook, 1966; Everson, 1966).

The objectives of this study were to determine seasonal trend, constituents (starch and soluble carbohydrates), and concentrations of the reserve carbohydrates in the roots and rhizomes of sand reedgrass as affected by grazing intensity. Basic knowledge of this plus morphological information are essential in developing grazing management systems that will utilize this species and its associates in the most efficient manner.

Methods and Materials

The study was conducted at the Eastern Colorado Range Station near Akron, in the sandhills of the northeastern part of the state. The climate is semi-arid and is characterized by hot summers; mild, dry autumns; cold winters; and moist, cool springs. The average annual precipitation is about 15 inches with most falling as rain during the growing season (Dahl et al., 1967). Reppert (1960) gives a detailed description of the station.

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[1] Adapted from a thesis submitted in partial fulfillment of the requirements for the M.S. degree in Range Science at Colorado State University under the direction of Dr. J. J. Norris and Dr. Bill E. Dahl. Published with approval of the Director of the Colorado Agricultural Experiment Station as Scientific Series Paper No. 1220.

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[3] Results of an unpublished study in 1961 and 1962 on the position of apical meristem of sand reedgrass by Bill E. Dahl, formerly Assistant Range Conservationist, Eastern Colorado Range Station, Akron, Colorado. Results on file at ECRS.

The study area was on deep sand range sites in two moderately grazed pastures, two heavily grazed pastures, and three exclosures. Vegetation on these areas is composed primarily of sand reedgrass, blue grama (*Boutelous gracilis*), needleandthread (*Stipa comata*), and sand sagebrush (*artemisia filifolia*). The soils are Blakeland loamy sand and Valentine sand. Stocking rates averaged about 1.0 and 0.7 acre/yearling steer-month for moderate and heavy grazing, respectively. The pastures were grazed at these intensities from about May 1 to October 1 during the years 1955 through 1966. Exclosures were not grazed by livestock.

Samples of roots and rhizomes were collected on 17 dates from July 1965 to November 1966. Sampling intervals varied from two weeks to several months. Samples were collected more frequently in the spring and early summer to determine when the reserves were at their lowest point and when storage began. After this period, samples were collected according to the following phenological stages: 1.) anthesis (early and late anthesis in 1965), 2.) seed in soft dough stage and, 3.) seeds mature. The last sample of the calendar year was taken in November after the plants became dormant. The first sample of the following year was taken in March before plants began growth.

To determine the effect of repeated foliage removal on the reserve carbohydrates, an area of sand reedgrass about 15 ft square was mowed repeatedly to a stubble height of 1 inch or less in 1966. The plants were not allowed to reach a height over 6 to 8 inches in the early part of the growing season and were kept below 3 to 4 inches during the remainder of the growing season. This plot was sampled on the same dates as the other study areas.

At each sampling date, several groups of plants in similar phenological development were selected in each pasture and exclosure. A representative sample of the roots and rhizomes of these plants was obtained by removing a sod approximately 12 inches square and 10 inches deep from each group. Soil was shaken from the roots and rhizomes and the plant tops were removed. Samples were collected from the same general areas on each sampling date.

Sods taken in a given pasture were composited. Also, sods taken from the exclosures in one heavy intensity pasture and the moderate intensity pasture were combined. The sample from the other exclosure was used as the replicate.

The composited samples were washed with water to remove any remaining soil. Roots and rhizomes were separated, ground with a hand-operated meat grinder, weighed, and placed in separate jars containing a measured amount of 80% ethanol (50 ml of 80% ethanol/g of oven-dry plant material). A portion of each sample was used to determine oven-dry weight. About 2 hr elapsed between removal of the sod and when the plant parts were placed in the ethanol. The material in ethanol was macerated with a Waring Blendor, filtered, and stored in a freezer until it could be chemically analyzed. The residue was oven-dried, ground through a 40-mesh screen, and sealed in jars.

The filtrate was analyzed for soluble carbohydrates by the anthrone reagent method (Johnson et al., 1964; Everson, 1966). Starch was extracted from the residue with perchloric acid (Pucher et al., 1948; Everson, 1966). Starch content was then determined by the anthrone reagent method. The concentration of carbohydrates was expressed as mg/g of oven-dry plant method.

Ascending paper chromatography was used to separate

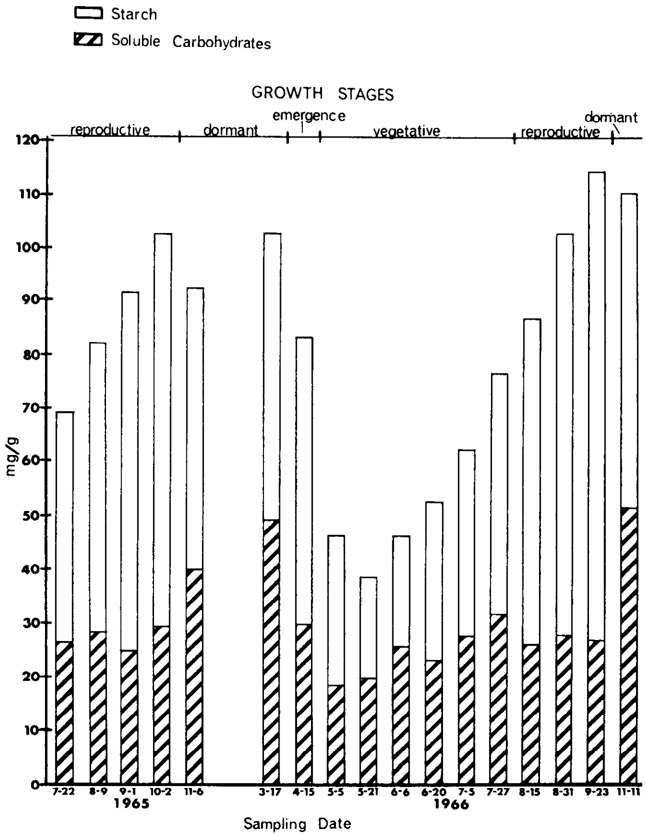

FIG. 1. Seasonal trend of reserve carbohydrate concentration (mg/g of oven dry roots and rhizomes) in sand reedgrass.

and identify the constituents of the soluble carbohydrate fraction (Olson[4]). Solvents used were n-butanol–acetic acid–water (40 : 10 : 19) and ethyl acetate–acetic acid–water (6 : 3 : 2). Aniline hydrogen phthalate and p-anisidine hydrochloride were used as color developers. Chromatograms were run in duplicate; one in each solvent. Glucose, fructose, and sucrose standards were run on each chromatogram to aid in identifying the spots of respective carbohydrates.

The data for each sampling date were analyzed statistically by split-plot analysis of variance. Least significant difference and smallest significant range were used to evaluate the reason for significant interactions. Data from all dates combined were analyzed similarly, thus, adding a split over time.

Results and Discussion

Seasonal Trend.—Fig. 1 shows that total carbohydrate concentration of the underground plant parts followed the typical U-shaped seasonal trend referred to by numerous workers (Cook, 1966). Carbohydrates were being accumulated when the first samples were collected in July 1965. The reserves increased to a peak in early October. They decreased after the beginning of dormancy, but were still at high levels just before new growth started in the spring of 1966. With initiation of

[4] Olson, G. G. 1963. Paper chromatography–anthrone determination of sugars. M.S. Thesis. Colorado State Univ., Fort Collins. 62 p.

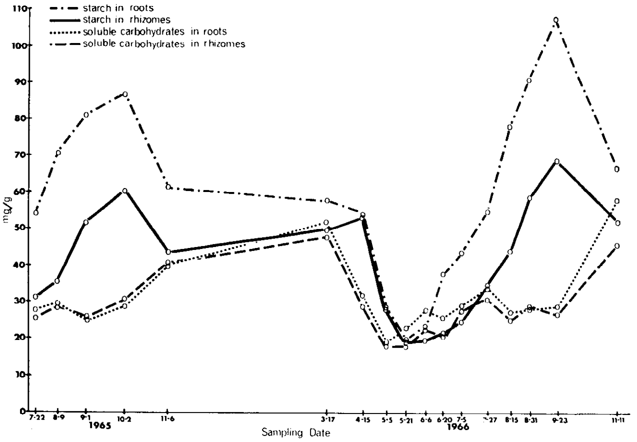

FIG. 2. Carbohydrate concentration (mg/g of oven dry plant material) in roots and rhizomes of sand reedgrass.

growth, reserves declined rapidly. The lowest concentration occurred on May 21. Thereafter, carbohydrate content increased steadily and the trend for the remainder of the growing season was similar to that of 1965.

The seasonal trend shows that accumulation of reserve carbohydrates in sand reedgrass begins early in the growing season. This agrees with the observation made by Hyder and Sneva (1959) that plants with a high proportion of vegetative stems, short internodes, and basal leafiness replenish reserves rapidly. In sand reedgrass, the carbohydrates began accumulating concurrently with the most rapid elongation of leaves and the greatest increase in dry weight. This indicated that sufficient leaf area was present by June 6 to provide photosynthate in excess of the plant demands for carbohydrates in respiration and growth.

The carbohydrate concentration was greater in the spring before growth began than the preceding fall after plants had become dormant. This may have been due to experimental error or to soluble carbohydrates being translocated from the stem bases to the roots and rhizomes after sampling was completed in the fall.

Throughout most of the growing season the starch content was significantly higher than the content of soluble carbohydrates. However, their concentrations were similar before the initiation of growth in the spring; when reserves were at their lowest point; when storage began; and after the plants were dormant in 1966. Soluble carbohydrate concentration was relatively constant throughout the growing season, but was higher during dormancy as a result of the conversion of starch to soluble carbohydrates at low temperature. The starch concentration fluctuated throughout the sampling period (Fig. 1). Thus, the seasonal variation of total reserve carbohydrates was the result of fluctuations in the starch content. The variability of the starch content and the relatively constant soluble carbohydrate concentration during the growing season resulted in a significant constituents–dates interaction.

Starch is the major stored carbohydrate of sand reedgrass. However, the soluble carbohydrates are the most readily available for use by the plants. The constancy of the concentration of these soluble carbohydrates throughout the growing season may indicate that they serve as the translocatable portion of the reserve carbohydrates. This relatively consistent concentration may also indicate that an equilibrium exists between the concentration of starch and soluble carbohydrates. The starch is apparently converted to soluble carbohydrates when the concentration of soluble carbohydrates is low, and the soluble carbohydrates are converted to starch when the concentration of soluble carbohydrates becomes high.

Underground Plant Parts.—Roots had a significantly higher concentration of total carbohydrates than the rhizomes from late June through November (Fig. 2). Total carbohydrate concentration in the roots was similar to the concentration in the rhizomes during initial spring growth. Because the carbohydrate concentration was greater in the roots for only part of the year, a significant plant parts–dates interaction resulted.

Soluble carbohydrate concentrations were similar in both roots and rhizomes throughout the year. However, the starch content was significantly higher in the roots during the periods when carbohydrates were being accumulated. A significant plant parts–constituents interaction resulted on these dates and for the whole experiment because of this higher starch concentration in the roots. Because the starch concentration was similar in roots and rhizomes for the early portion of the growing season and then became greater in the roots, a significant plant parts–constituents–dates interaction resulted (Fig. 2). This may indicate that starch is depleted at about the same rate from both roots and rhizomes, but that accumulation begins first in the roots.

Effect of grazing.—Only two dates, June 6, and August 15, 1966, showed a significant difference in carbohydrate concentration due to grazing treatment (Fig. 3). On June 6 the grazed plants had a higher concentration of carbohydrate reserves than the ungrazed plants. Plants in the exclosures began growth later than the grazed plants probably because the soils were cooler and wetter under the thick litter cover in the exclosures. On June 6 the carbohydrate reserves of the ungrazed plants were at the low point for the season, while the grazed plants had begun to replenish their reserves. Ungrazed and moderately grazed plants had a significantly higher carbohydrate concentration than heavily grazed plants on August 15. This differ-

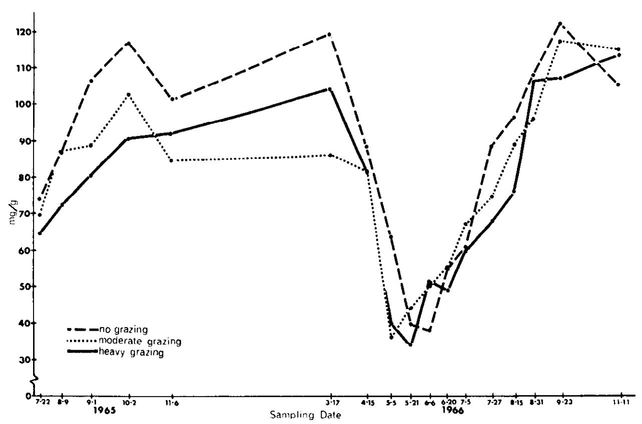

FIG. 3. Reserve carbohydrate concentration (mg/g of oven dry roots and rhizomes) of sand reedgrass under three intensities of grazing.

ence may be due to an apparent lag in the accumulation of reserve carbohydrates in the heavily grazed plants.

For all dates combined, a significantly higher concentration of carbohydrates occurred in the ungrazed plants. The ungrazed plants had a mean carbohydrate concentration of 86 mg/g while moderately grazed plants had 79 mg/g and heavily grazed plants had 75 mg/g. The concentration of reserve carbohydrates in the ungrazed plants was somewhat higher than in the grazed plants throughout most of the study period (Fig. 3). Although the concentration was not significantly higher for most of the individual dates, the cumulative effect when all dates were combined resulted in the significant difference.

The data from all dates combined have a significant grazing–constituents interaction because the starch concentration was lower in the underground parts of heavily grazed plants (45 mg/g) than in moderately grazed plants (50 mg/g). Also, starch concentration was lower in moderately grazed plants than in ungrazed plants (56 mg/g), whereas the soluble carbohydrates remained relatively constant in all grazing treatments and in both roots and rhizomes. The lower starch concentration occurred only in the roots of these plants, so a grazing—plant parts—constituents interaction also resulted. The lower starch content in the roots may indicate that an increase in grazing intensity reduces leaf area, which in turn reduces photosynthate production and starch accumulation. The biological significance of the small difference in concentration of starch in plants grazed at different intensities is uncertain.

Grazing intensity studies have shown generally that as intensity of grazing increased the root system was reduced. If the root systems of heavily grazed sand reedgrass plants have been reduced, then the total amount of reserve carbohydrates would be less than in the moderately grazed or ungrazed plants. This would account for the reduction in amount of sand reedgrass under heavy grazing. However, the size of the root system of sand reedgrass under different grazing intensities has not been studied. Research on the size of the root system is needed to complement the information on the concentration of reserve carbohydrates.

Effect of Repeated Foliage Removal.—Starch concentration of the underground parts of repeatedly mowed plants was as low as 7 mg/g on August 15, while plants from the other treatments averaged 61 mg/g. After the plants were dormant, the starch concentration was 14 mg/g on the mowed area and 58 mg/g on the other areas. The lowest concentration of soluble carbohydrates was 4 mg/g on August 31 for the mowed area, while the other areas averaged 28 mg/g. The mowed plants had a soluble carbohydrate concentration of 6 mg/g after dormancy, and the the other plants averaged 52 mg/g.

Cattle seek out early growth and regrowth of sand reedgrass. This would be the period when reserves are declining. If cattle graze the early growth and then graze the lush regrowth, as could be the case under heavy grazing, a situation similar to the repeatedly mowed area (but not as intensive) may result. Carbohydrate reserves are required for the initiation of growth when little or no photosynthetic tissue is present. The critical level of reserve carbohydrates needed for survival is not known.

Constituents.—Paper chromatograms of soluble carbohydrates in the roots and rhizomes for all sampling dates showed that glucose, fructose, and sucrose were the constituents of the soluble carbohydrate fraction. Carbohydrates in the residue were primarily starches. These constituents were the same as those found in the reserve carbohydrates of switch cane (*Arundinaria tecta*), a warm season grass morphologically similar to sand reedgrass (Lindahl et al., 1949). The carbohydrate reserves of big bluestem (*Andropogon gerardi*), another grass morphologically similar to sand reedgrass, were composed of similar carbohydrates, but had, in addition, a considerable amount of fructosan (Crockett[5]).

Chromatograms of samples collected in November showed two additional unidentified carbohydrates believed to be di- or tri-saccharides. These carbohydrates were probably intermediaries in the transformation of starch to sucrose and monosaccharides. The conversion of starch to soluble carbohydrates occurs when the temperature is near or below freezing.

[5] Crockett, J. J. 1960. Effects of intensity of clipping on three grasses from grazed and ungrazed areas in west-central Kansas. M.S. Thesis. Fort Hays State Coll., Fort Hays, Kansas. 68 p.

Paper chromatograms showed that the soluble carbohydrates in samples from the mowed area from August 15 to the end of the sampling period had one carbohydrate in addition to those found in samples from the other areas; the additional carbohydrate had a R_F value similar to the one reported for xylose (Lederer and Lederer, 1957). Xylose is a primary constituent of hemicellulose. Therefore, the presence of xylose in the soluble carbohydrates of plants with reserves maintained at a low level (near 20 mg/g) for about two months may indicate that hemicellulose was being broken down to provide energy for the plant.

Conclusions

Total carbohydrate concentration of sand reedgrass followed the typical U-shaped seasonal trend with reserves declining during early growth, then accumulating throughout the remainder of the growing season. The seasonal trend was due to fluctuations in the starch concentration, thus, starch was considered to be the major stored carbohydrate. The soluble carbohydrate concentration remained relatively constant throughout the growing season, and for this reason they were believed to be important as translocatable carbohydrates and as the most readily available carbohydrates for use by the plants.

The roots and rhizomes had similar concentrations of soluble carbohydrates throughout the year, but starch concentration was higher in the roots during the period when carbohydrates were accumulating. This may indicate that accumulation begins first in the roots.

The effect of grazing on the concentration of total carbohydrates was not significant for most of the sampling dates. For all dates combined there was a significant grazing effect. This effect was due to a higher concentration of starch in the roots of ungrazed plants than in the roots of moderately grazed plants and a higher starch concentration in the roots of moderately grazed plants than in the roots of heavily grazed plants. This may be due to a reduction of photosynthetic tissue with increased grazing intensity which apparently results in reduced starch accumulation in the roots.

The constituents of the soluble carbohydrate fraction from the roots and rhizomes for all dates were glucose, fructose, and sucrose. Roots and rhizomes taken from the repeatedly mowed area had an additional carbohydrate after the reserves were maintained at a low level for about two months. The additional carbohydrate was believed to be xylose. This may indicate that hemicellulose was being broken down to furnish simple carbohydrates for use by the plants.

Management implications cannot be concluded from this study. However, these findings combined with information on the morphological development, extent of root system, and other physiological aspects of sand reedgrass can be used in developing grazing management systems for sand reedgrass.

Future studies on carbohydrate reserves should be designed to determine the critical level of reserve carbohydrates needed for survival. Also, morphological studies should be conducted along with carbohydrate reserve studies to determine if a morphological factor may be limiting rather than the level of carbohydrate reserves when plants are heavily defoliated.

LITERATURE CITED

Branson, F. A. 1953. Two new factors affecting resistance of grasses to grazing. J. Range Manage. 6:165–171.

Cook, C. W. 1966. Carbohydrate reserves in plants. Utah Agr. Exp. Sta. Utah Resources Series 31. 47 p.

Dahl, B. E., and J. J. Norris. 1965. The effect of grazing intensity on native sandhill ranges. Colorado Agr. Exp. Sta. PR 162. 2 p.

Dahl, B. E., A. C. Everson, J. J. Norris, and A. H. Denham. 1967. Grass–alfalfa mixtures for grazing in eastern Colorado. Colorado Agr. Exp. Sta. Bull. *In Press*.

Everson, A. C. 1966. Effects of frequent clipping at different stubble heights on western wheatgrass (*Agropyron smithii*, Rydb.). Agron. J. 58:33–35.

Hyder, D. N., and F. A. Sneva. 1959. Growth and carbohydrate trends in crested wheatgrass. J. Range Manage. 12:271–276.

Johnson, G., C. Lambert, D. K. Johnson, and S. G. Sunderwirth. 1964. Colorimetric determination of glucose, fructose, and sucrose in plant materials using a combination of enzymatic and chemical methods. J. Agr. and Food Chem. 12:216–219.

Lederer, E., and M. Lederer. 1957. Carbohydrates. 4. Paper chromatography of sugars, p. 245–259. *In* E. Lederer and M. Lederer, Chromatography; a review of principles and applications. Elsevier Publishing Co. New York.

Lindahl, I., R. E. Davis, and W. O. Shepherd. 1949. The application of the total available carbohydrate method to the study of carbohydrate reserves of switch cane (*Arundinaria tecta*). Plant Physiol. 24: 285–294.

Pucher, G. W., C. S. Leavenworth, and H. B. Vickery. 1948. Determination of starch in plant tissues. Anal. Chem. 20:850–853.

Reppert, J. N. 1960. Forage preference and grazing habits of cattle at the Eastern Colorado Range Station. J. Range Manage. 13:58–65.

Troughton, A. 1957. Chemical composition, p. 49–68. *In* A. Troughton, The underground organs of herbage grasses. Commonwealth Bur. Pastures and Field Crops Bull. 44.

Weinmann, H. 1952. Carbohydrate reserves in grasses, p. 655–660. *In* Proc. VI Int. Grassland Congr., Penn. State College.

Seasonal Grazing of Crested Wheatgrass by Cattle

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Highlight

Thirty-six pastures of crested wheatgrass were grazed in early spring plus early fall; late spring; all spring; early summer; late summer; early fall; and late fall. Summer and fall treatments included grazing with and without supplement. Yearlings made substantial gains in all seasons except during late fall when they lost weight. They finished the entire grazing period with an average gain of 224 lb. Calves gained 249 lb. Yearlings and calves did as well on crested wheatgrass as on forest range, and supplementation provided no additional gain. Cows on supplement gained 125 lb as compared to 50 lb for non-supplemented cows. In years with no fall regrowth, second grazing of crested wheatgrass without supplement produced daily gains in early fall equal to those for single grazing with supplement.

Due to reductions of permitted livestock on the higher summer ranges, it is important for some owners to obtain new sources of feed supply for the summer months. Crested wheatgrass has been used extensively on lower ranges for spring and fall grazing although it has been considered inferior to other grasses during the summer (Sarvis, 1941; Williams and Post, 1945; Barnes and Nelson, 1950; Cook et al., 1956).

The purpose of this study was: (1) to determine if crested wheatgrass was a dependable source of forage for cattle from April to December; and (2) to determine the merits of feeding a protein supplement to cattle grazing crested wheatgrass during summer and fall, combined with regular spring grazing. The data covers a four-year period from 1961 to 1964.

A preliminary report by Harris et al. (1965) showed that cows responded well to seasonal grazing of crested wheatgrass from April through mid-December when supplemented with 0.34 kg (0.75 lb) of protein supplement daily. Yearlings and calves made good gains throughout the season without supplement.

Literature relative to supplementing cattle on crested wheatgrass was scarce at the outset of this experiment; however, Wallace et al. (1963) have since reported work done with yearling cattle. The yearlings were supplemented with barley, cottonseed meal, and salt, alone and in various combinations, while grazing crested wheatgrass on a two-year study. Both energy and protein supplementation resulted in significant gains over the two-year period, while salt in combination with cottonseed meal showed less response than cottonseed meal alone.

Experimental Area and Procedure

The Benmore experimental area is located in southeastern Tooele County within a belt commonly considered as spring–fall range in the Intermountain region. The elevation is approximately 5,800 ft (1,768 m), and the average annual precipitation is about 12 inches (30 cm). Soils are mainly clay loams, generally with small amounts of gravel in some locations. This area, now under the jurisdiction of the Forest Service, was marginal dry farm land purchased in 1934 by the federal government. Thirty-two hundred acres were set aside as an experimental area from which pastures were fenced and seeded to grass. Water was piped to each pasture in the late 1930's.

The grass stands are now approximately 25 years old. At present, crested wheatgrass, including both fairway wheatgrass (*Agropyron cristatum*) and the so-called "standard" crested wheatgrass (*A. desertorum*), make up about 95% of the forage, with minor amounts of western wheatgrass (*A. smithii*), bulbous bluegrass (*Poa bulbosa*), cheatgrass (*Bromus tectorum*), squirreltail grass (*Sitanion histrix*), and several forbs. Big sagebrush (*Artemisia tridentata*) and rubber rabbitbrush (*Chrysothamnus nauseousus*) are present in varying amounts but were seldom eaten by cattle in the experimental pastures.

For the experiment, 36 pastures were divided into 3 blocks (replicates) of 12 pastures per block for grazing at different seasons as shown in Fig. 1. Treatments were: early spring plus early fall; late spring; all spring; early summer; late summer; early fall; and late fall. All of the summer and fall treatments included grazing with supplement and grazing without supplement.

All pastures were 50 acres each, except the ones grazed all spring and late spring; these pastures were 100 acres in size. Two yearlings and about 10 cow-and-calf pairs were allotted at random to each of the 50-acre pastures, while the 100-acre pastures received about twice the number of animals in keeping with predetermined stocking rates. Animals were shifted to new pastures at the beginning of each season, excepting that the three pastures grazed in early spring were also grazed in early fall. Cattle in the "all spring" treatment were shifted to the mountain range (National Forest) during the summer.

Utilization of the grasses was 60 to 70%. Animals were weighed individually after an overnight shrink in the corral before being placed in, or taken out of, a pasture. Cattle of Hereford breeding were provided by the Vernon Cattlemen's Association.

During summer and fall, half of the yearlings and lactating cows received in portable mangers the equivalent of 0.34 kg/day of a protein supplement on Monday, Wednesday, and Friday. The other half received no supplement. The supplement had the following percentage composition:

Soybean meal, solvent extracted, 44% protein	88.2%
Calcium phosphate, dibasic	10.8%
Trace mineral salt	1.0%

Each 0.34 kg of supplement supplied 75% of the daily requirement of phosphorus.

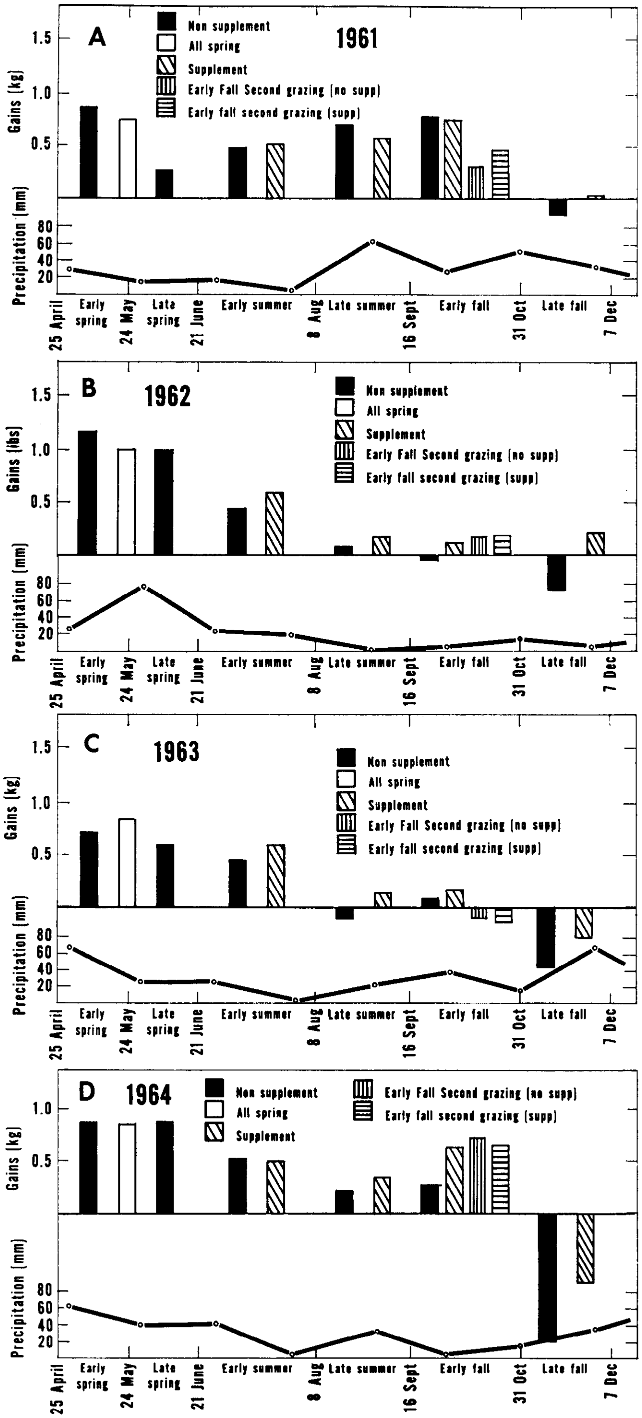

FIG. 1. Average daily gains for three classes of cattle grazing crested wheatgrass at various seasons of the year for four years (A) 1961 (B) 1962 (C) 1963 (D) 1964 and precipitation data for the same period.

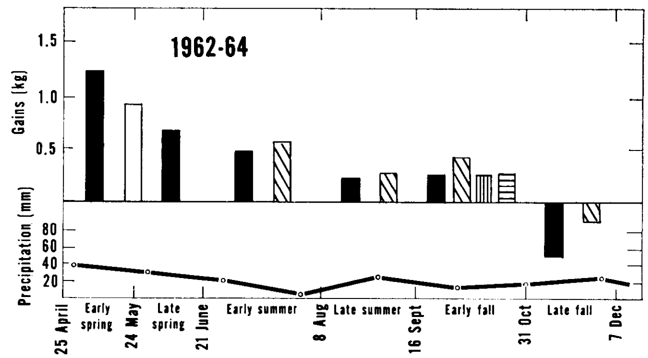

FIG. 2. Average daily gains for three classes of cattle grazing crested wheatgrass at various seasons of the year for four years (1962–64) and precipitation data for the same period.

All animals received rock salt during the spring periods, while during the summer and fall periods they received crushed salt in one side of a self feeder and one part trace mineral salt and one part calcium phosphate, dibasic, in the other half of the feeder.

Bulls were admitted to the pastures at the beginning of the late spring period. At the end of this period, part of the cattle were moved to the mountainous summer range (forest) south of the pastures. These cattle were rounded up and weighed at the beginning of the early fall period to provide data for comparison of pasture gains with gains made on the higher summer range.

Results

Average yearly daily gains per period and precipitation data for the corresponding periods are shown in Fig. 1. Animal gains varied as a function of available green forage, this in turn being affected by the precipitation, except during late fall which was beyond the growing season. Variations during the grazing seasons for the four years were large enough to warrant discussion by year.

Daily gains in summer and fall averaged highest during 1961, probably for two reasons. Late spring gains were low because of reduced growth of grass, so fairly high subsequent gains were possible. A total of 3.31 inches (8.4 cm) of rain fell during August, resulting in considerable late summer and fall green regrowth of grass. Secondly, the animals were removed from the late-fall treatment on November 23, due to heavy snows. Since the cattle generally lost weight during late fall, weight losses were minimized by this comparatively early removal.

During 1962, gains were relatively high in the spring periods. Little rain fell during the remainder of the grazing season and no fall regrowth occurred. With less green forage available, the effects of protein supplement were more pronounced, especially during the late fall when the cattle receiving supplements continued to gain at a rate of 0.21 kg/day while animals not supplemented lost weight.

Gains for 1963 were basically the same as for the previous year, although spring gains were slightly lower. The effects of supplement were more pronounced early in the season due to the dryness of the year. There was enough moisture during September to produce some regrowth, which resulted in a slight increase in gains for early fall over the previous year. A heavy fog blanketed the area for about a month during the late fall period of 1963

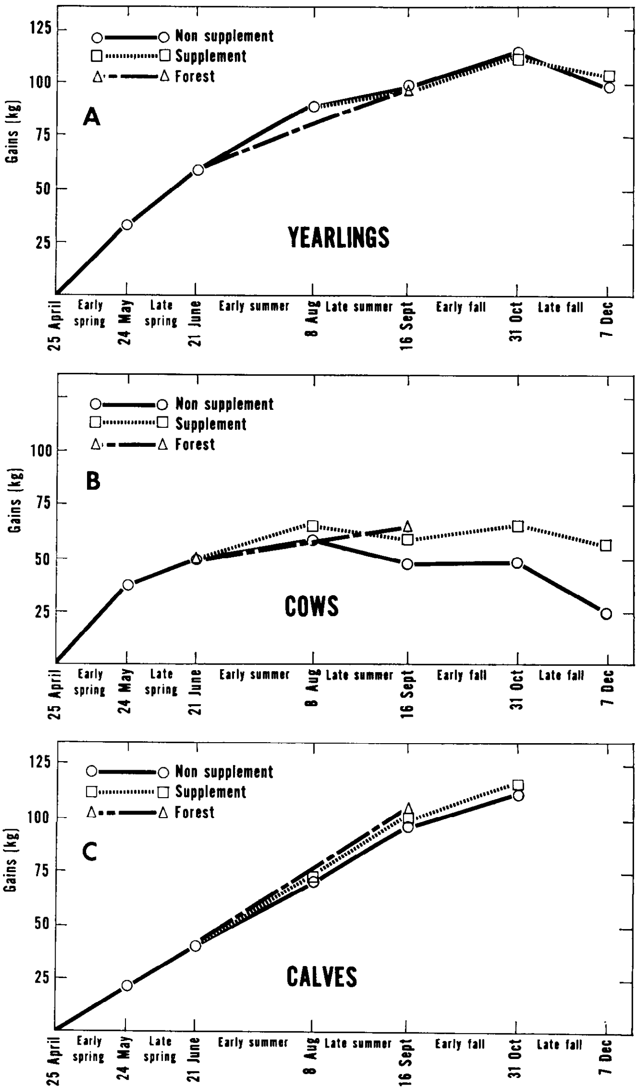

FIG. 3. Cumulative average gain (kg/animal) for three classes of cattle grazing crested wheatgrass at various seasons of the year for (A) yearlings, (B) cows, and (C) calves. Some animals on crested wheatgrass received supplement; others did not. Part of these animals were compared for the summer season with cattle on the National Forest.

reducing the daytime temperatures considerably. This may be one reason for the increased weight loss during that period.

Fairly high gains for the spring periods were made during 1964. Even though summer moisture was not sufficient to produce regrowth, possibly enough total growth was made during spring to sustain the substantial gain during summer and early fall. During late fall of 1964, cold weather and above-normal amounts of snow covering the feed caused the extreme loss in weight for that period.

Pastures that were grazed twice (early spring and again in early fall) provided slight additional gains upon second grazing in 1962 and 1964 compared to pastures grazed only in early fall. In these two years, early fall gains for second grazing without supplement equaled or exceeded gains for single grazing with supplement. These years were dry wherein no summer or fall regrowth was produced. On the other hand, during the years of late summer and fall regrowth (1961 and 1963) early fall gains were higher for single grazing than for second grazing. The four-year average of gains made by the three classes of cattle during second grazing showed no significant response to supplementation (Fig. 2).

FIG. 4. Cattle in good condition on September 30 have grazed on crested wheatgrass since April 20. They received protein supplement during summer and fall. (Yearling in right foreground—cows and calves beyond.)

Cumulative gain (average per animal over a 4-year period) is shown in Fig. 3. The weight profile for each of the three classes of animals is portrayed over all grazing seasons. In addition, weights of the cattle grazing the forest area are compared to weights of animals on crested wheatgrass with and without supplement.

Yearlings and calves showed no significant differences among supplemented, non-supplemented, or forest-grazed animals. The cows tended to push yearlings away from the manger, which may account for the fact that yearlings did not respond to the supplement. The calves gained at a consistent rate through all seasons, making an average gain of 113 kg (249 lb) by the time they were sold near the end of early fall. The yearlings finished the entire grazing period with an average gain of 102 kg (224 lb) after losing slightly during late fall.

Cows made a significant response ($P < .05$) to supplement, finishing the entire season with an overall weight gain of 57 kg (125 lb) compared to 23 kg (50 lb) gain for non-supplemented cows. Summer gains made by cows receiving supplement on crested wheatgrass were essentially the same as those made by cows on the mountain range. These animals were in good condition until storms and cold weather hit in November (Fig. 4).

Gain per acre averaged highest for late spring

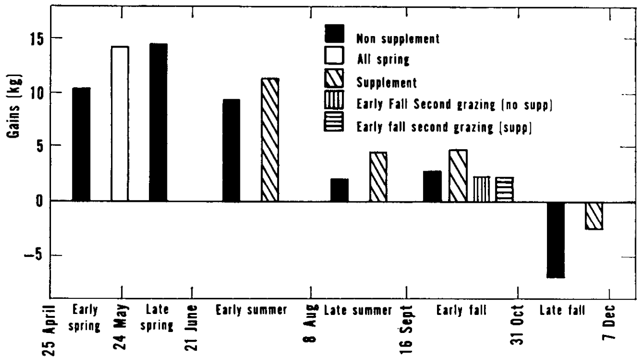

FIG. 5. Total gain per acre for the cattle grazing crested wheatgrass at various seasons of the year.

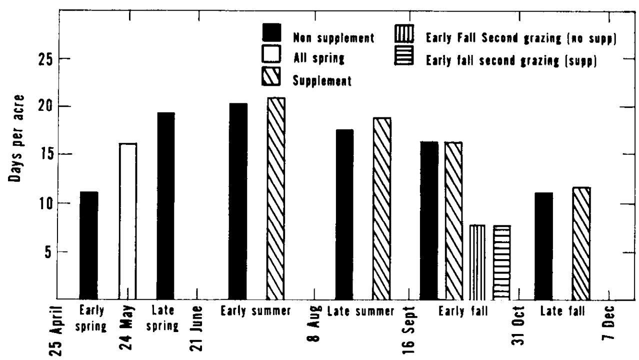

FIG. 6. Animal days per acre for three classes of cattle grazing crested wheatgrass at various seasons of the year.

and all spring grazing (Fig. 5). This corresponds to the period of maximum green forage. Substantial gains were also made during early summer. Excluding second grazing, average gains were slightly over 4.5 kg (9.92 lb)/acre during late summer and early fall for cattle receiving supplement, while cattle without supplement gained only about half this amount; these differences were significant ($P < .05$). Considering that cold, stormy weather contributes to high weight losses in late fall, it would probably be well to terminate grazing on crested wheatgrass ahead of late fall storms. This would depend upon past management patterns. Cattle at Benmore wanted to "go home" when heavy snowstorms occurred in November. Heavy snowstorms caused early termination of grazing in certain years. Otherwise it was Dec. 15.

Fig. 6 portrays the average stocking rates for the various seasons. In pastures where the grazing capacity was not reduced by big sagebrush, the stocking level in early spring averaged about 5 acres/cow month, not considering calves. At this rate, cows with suckling calves ate the grass about as fast as it grew. Again in early fall the stocking level on pastures that had been grazed previously in early spring averaged about 5 acres/cow month. Thus, the total grazing capacity of these pastures was about 2.5 acres/cow month which was about equal to that of pastures in the other treatments. The only difference was that half the capacity was taken in early spring and the other half in early fall, rather than in one period.

As the grass matured, cows became more selective of the areas grazed and the parts of plants they desired to graze. In the spring, utilization of grass in small swales and depressions averaged about 5% heavier than on small ridges and flat areas. Utilization continued equally heavy in the swales in all seasons, but it became lighter on ridges and flats as the seasons progressed. By late fall, utilization of grass in swales and depressions was about 15% heavier than that on the ridges and flats.

In summer and fall, grass around rabbitbrush plants was utilized heavily, like that in swales and depressions. Since rabbitbrush was not detrimental to grass yields under conditions existing at Benmore (Frischknecht, 1963), it appeared that the presence of rabbitbrush enhanced the crested wheatgrass for late summer and fall grazing. In late summer and fall, cows ate mainly seedheads on the dry grass on ridges and flats. The nutritive quality of seedheads was undoubtedly superior to that of the dry stems.

Summary and Conclusions

Thirty-six pastures of crested wheatgrass were divided into 3 blocks (replications) of 12 pastures each. The treatments were: early spring plus early fall; late spring; all spring; early summer; late summer; early fall; and late fall. All of the summer and fall treatments included grazing with supplement and grazing without supplement. Cow and calf pairs and yearlings were randomly allotted to the pastures. The supplemented cattle received the equivalent of 0.34 kg of protein supplement daily in three feedings per week. Salt and calcium phosphate, dibasic one part, and salt one part were also supplied free choice. During the summer, part of the cattle were moved to the adjacent mountain range (elevation 1,981 to 2,438 m) for comparisons of gains on the higher native range and those on crested wheatgrass.

Yearlings made substantial gains in all seasons except during late fall when they lost weight slightly. They finished the entire grazing period with an average gain of 102 kg. Calves gained at a constant rate, finishing in October with an average gain of 113 kg. It may be concluded that yearlings and calves did as well on crested wheatgrass as on the forest range, and supplementation provided no additional gain. Cows showed the only significant response to the supplement of the three classes, making an average gain of 57 kg, as compared to about 23 kg for non-supplemented cows. Cows on the higher range made comparable gains to cows receiving supplement on crested wheatgrass.

In years when there was no fall regrowth, second grazing of crested wheatgrass without supplement produced daily gains in early fall equal to those for single grazing with supplement. In years of fall regrowth, early fall gains were higher for single grazing than second grazing. Except for second grazing, gain per acre in summer and fall was significantly higher ($P < .05$) in pastures where supplement was fed than where it was not fed.

LITERATURE CITED

BARNES, O. L., AND A. L. NELSON. 1950. Dryland pastures for the Great Plains. Wyo. Agr. Exp. Sta. Bull. 302. 30 p.

COOK, C. WAYNE, L. A. STODDART, AND LORIN E. HARRIS. 1956. Comparative nutritive value and palatability of some introduced and native forage plants for spring and summer grazing. Utah Agr. Exp. Sta. Bull. 385. 39 p.

FRISCHKNECHT, NEIL C. 1963. Contrasting effects of big sagebrush and rabbitbrush on production of crested wheatgrass. J. Range Manage. 16:72–74.

HARRIS, LORIN E., NEIL C. FRISCHKNECHT, AND EARL M. SUDWEEKS. 1965. Extended grazing of crested wheatgrass by cattle. Utah Agr. Exp. Sta. Farm and Home Sci. 26(1): 14–17.

SARVIS, J. T. 1941. Grazing investigations on the Northern Great Plains. N. Dak. Agr. Exp. Sta. Bull. 308. 110 p.

WALLACE, JOE D., FARRIS HUBBERT, JR., AND R. J. RALEIGH. 1963. The response of yearling cattle on crested wheatgrass pasture to energy, protein and sodium supplementation. J. Range Manage. 16:1–5.

WILLIAMS, RALPH M., AND A. H. POST. 1945. Dryland pasture experiments at the central Montana Branch Station, Moccasin, Montana. Mont. Agr. Exp. Sta. Bull. 431. 31 p.

Forage Ratings for Deer and Cattle on the Welder Wildlife Refuge[1]

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Highlight

Forage preferences of white-tailed deer and cattle on the Welder Wildlife Refuge in South Texas were determined by relating availability, percent utilization, and percent frequency of use of each plant species utilized by deer or cattle. Overall forage ratings showed that though both animals were grazers, deer preferred forbs and cattle preferred grasses. Selection of forage by both deer and cattle varied with the seasonal availability and palatability of the forage. Seasonal forage ratings showed that few species of the many utilized made up 50% of the forage ratings for deer and cattle. On clay soils, deer utilized all browse species present, while cattle utilized little browse. Four perennial grasses made up most of the preferences of cattle. During the winter, grass and grass seed heads were highly utilized by deer. Forbs were the most important deer forage class on sandy soils. Grasses made up about 25% of the total preference rating of deer in fall and winter on the sand. Cattle utilized forbs more in spring and summer, but utilized grasses more in the fall and winter.

The extent of competition for forage between livestock and big game is a major area of concern in range and wildlife management. Therefore, a basic need in land management is to determine the food habits of the animals present and to determine the extent to which their diets overlap.

Some work has been done on the food habits of cattle and white-tailed deer in South Texas. Davis (1952) used rumen contents in a study of deer–cattle competition and "animal equivalence." By comparing deer rumen weights to cattle rumen weights, he found that 13 deer ate as much as one steer. Seasonal changes in the availability of vegetation of each forage class caused changes in the carrying capacity of a range. Chamrad (1966) found that the deer on the Welder Wildlife Refuge were grazers rather than browsers during winter and spring, with almost 90% of their diet being herbaceous plants. Forbs made up 67% of the diet, grasses 22%, and browse 5%. During his study the food habits of the deer followed the phenology of the vegetation and fluctuated with forage availability.

In the present study the seasonal plant preferences of white-tailed deer and cattle were determined on the Welder Wildlife Refuge by relating availability of forage to utilization and frequency of use of each plant by each class of animal.

Study Area and Procedures

This study was conducted on the Welder Wildlife Refuge, located near Corpus Christi in South Texas. The climate of the area is mild, with warm temperatures throughout the year. Mean temperatures are around 55 F in January and 84 F in July. Average annual rainfall for the area is about 30 inches. Monthly rainfall patterns show peaks in spring and fall. Vegetative growth follows these rainfall peaks closely. The soils of the Refuge have been described as dark, calcareous to neutral clays and clay loams, with areas of eolian sand along the Aransas River (Box, 1961).

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The Welder Refuge is in the southern part of the Gulf Prairies and Marshes Vegetational Area (Gould, 1962). Fifteen distinct plant communities have been described on the Refuge (Box and Chamrad, 1966). For this study, areas representative of the major plant communities were selected. These communities and the major species found in each are listed below.

Major species of the "Mesquite–buffalograss Community" are mesquite (*Prosopis glandulosa* Torr.) with infrequent mottes of chaparral (species to be enumerated below), buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), silver bluestem (*Andropogon saccharoides* Swartz var. *longipaniculata* Gould), spike bristlegrass (*Setaria leucopila* (Scribn. and Merr.) K. Schum.), Roemer threeawn (*Aristida roemeriana* Scheele), filly panic (*Panicum filipes* Scribn.), Texas wintergrass (*Stipa leucotricha* Trin. and Rupr.), vine mesquite (*Panicum obtusum* HBK), tridens (*Tridens* spp.), sawtooth frogfruit (*Phyla incisa* Small), prairie coneflower (*Ratibida columnaris* (Sims) D. Don.), western ragweed (*Ambrosia psilostachya* DC), Texas broomweed (*Xanthocephalum texanum* (DC) Shinners), and other grasses and forbs.

Vegetation of the "Chaparral–bristlegrass Community" consists of chaparral species such as huisache (*Acacia farnesiana* (L) Willd.), blackbrush acacia (*Acacia rigidula* Benth.), agarito (*Berberis trifoliolata* Moric.), granjeno (*Celtis pallida* Torr.), brasil (*Condalia obovata* Hook), lotebush (*Condalia obtusifolia* (Hook) Weberb.), Mexican persimmon (*Diospiros texana* Scheele), mesquite prickly ash (*Zanthoxylum fagara* (L) Sarg.), and others. Grass and forb species are similar to those of the Mesquite–buffalograss Community.

Major plant species of the "Bunchgrass–annual Forb Community" are grasses such as seacoast bluestem (*Andropogon scoparius* Michx. var. *littoralis* (Nash) Hithc.), southern sandbur (*Cenchrus echinatus* L), hooded windmillgrass (*Chloris cucullata* Busch.), Pan American balsamscale (*Elyonurus trypsacoides* Humb. and Bonpl.), fall witchgrass (*Leptoloma cognatum* (Schult) Chase), thin paspalum (*Paspalum setaceum* Michx.), sandhill bristlegrass (*Setaria firmula* (Hitchc. and Chase) Pilger), and others; and forbs such as camphorweed (*Heterotheca latifolia* Buckl.), sunflower (*Helianthus debilis* Nutt. var. *cucumerifolius* Torr. and Gray), sawtooth frogfruit, wild buckwheat (*Eriogonum multiflorum* Benth.), croton (*Croton* spp.), skunk daisy (*Ximenisia encelioides* Cav.), and others.

Vegetation of the "Live oak–chaparral Community" consists of live oak (*Quercus virginiana* Mill.) chaparral, and herbaceous vegetation similar to that of the Bunchgrass–annual Forb Community.

Forage ratings were developed for the major plants by relating availability of forage to utilization and frequency of use by deer and cattle on each community. Preference values were calculated for each plant by multiplying percent utilization by percent frequency of use (Dwyer, 1961). Forage ratings, or relative forage values, were developed by multiplying the preference value by percent cover of each plant (Box and Powell, 1965). All percentages were used as whole numbers in computations. Plants that occurred in trace amounts (less than 1%) were considered to make up less than 0.5% of the cover, as this was the accuracy to which cover was measured. Methods of calculation are as follows:

Preference value = % utilization × % frequency of use

Forage rating = preference value × % cover

During the summers of 1965 and 1966, utilization surveys were made at six different locations in the major plant communities using existing cattle exclosures. Two other cattle exclosures were constructed on typical areas, and used during fall, winter, spring, and summer. The exclosures allowed deer free access to vegetation inside the exclosure, but eliminated cattle utilization. Utilization surveys were made both inside and outside each exclosure. By subtracting utilization by deer from that by deer and cattle, utilization by cattle was obtained. No attempt was made to remove the influences of grazing rodents, rabbits, and other small mammals on utilization.

Percent frequency of use was determined by examination of 25 plants of each species present in the study location. Percent utilization was determined by estimating the amount of each plant removed. Each plant was placed in a utilization category as follows: (1) 1–20% utilization, (2) 21–40%, (3) 41–60%, (4) 61–80%, and (5) 81–90%. At least five 300-ft transects were randomly established across each survey area. At intervals of 10 steps along each transect, five plant species nearest the toe of the right foot were examined.

Plant availability was determined by two methods. Point frame analysis was used to determine cover of herbaceous vegetation (Rader and Ratliff, 1962). The line intercept method was used to determine percent cover of woody vegetation (Canfield, 1941). Sampling of the major species was within 10% of the mean.

To facilitate discussion of results, percentages of preference were calculated for forage classes by dividing the total of all preference values for each area at each date into the total preference value for the forage class. Plant communities were combined as to soil type, i.e., clay areas—Mesquite–buffalograss Community and Chaparral–bristlegrass Community, and sand areas—Bunchgrass–annual Forb Community and Live oak–chaparral Community.

Results and Discussion

Relative percentages of browse, forbs, and grasses in deer and cattle preferences were determined for each season of the year from the preference values (Table 1). Deer preferences varied with the condition and abundance of the forage. The forage preferences of cattle followed the trends in the condition and availability of the vegetation much as did the preferences of deer.

Forage ratings were arranged in order of importance for each date of data collection, and only

Table 1. Seasonal fluctuations of forage classes[1] in the preferences of deer and cattle, in percent of total preference.

	Summer			Fall			Winter			Spring			Yearlong Average		
	B	F	G	B	F	G	B	F	G	B	F	G	B	F	G
Clay soils															
Deer	24	71	5	7	66	27	4	59	37	1	65	34	13	69	18
Cattle	8	14	78	12	12	76	4	11	85	0	42	58	6	19	75
Sandy Soils															
Deer	–	99	1	–	83	17	–	98	2	–	99	1	–	92	8
Cattle	–	81	19	–	13	87	–	16	84	–	72	28	–	53	47

[1] B = Brush; F = Forbs; G = Grass.

Table 2. Forage Ratings[1] for species in the upper 50% of forage ratings for deer and cattle on clay soils.

Species	June 1965 Deer	June 1965 Cattle	Nov. 1965 Deer	Nov. 1965 Cattle	Jan. 1966 Deer	Jan. 1966 Cattle	Apr. 1966 Deer	Apr. 1966 Cattle	June 1966 Deer	June 1966 Cattle
Browse										
Acacia farnesiana	938		1968		2296		164		2296	
Acacia rigidula	270		2922		797		0		531	
Prosopis glandulosa	1141		223		0		446		2232	
Other browse	3727		270		0		0		1476	
Forbs										
Ambrosia psilostachya	560		4792		3862		1978		6048	
Coreopsis cardaminaefolia	180		–		–		3694		342	
Oenothera speciosa	480		416		672		7296		360	
Ratibida columnaris var. *pulcherrima*	3951		2688		2128		7113		1082	
Other forbs	2516		2367		345		367		3140	
Grasses										
Andropogon saccharoides var. *longipaniculata*	960	4240	2268	1780	2128	236	152	0	160	13160
Andropogon scoparius var. *littoralis*	2160	8160	4600	19520	4464	30464	0	10718	3296	61800
Buchloe dactyloides		1900		4028		3579		1532		2728
Eriochloa sericea	60		600		4800		426		1344	
Setaria leucopila	0	8120	3072	2720	3800	5000	80	0	816	1149
Stipa leuchtricha	0		250		1114		3344		0	

[1] Qualitative ranking: 0–500 = low, 500–1000 = moderate, 1000–3000 = high, and 3000+ = very high. Blank spaces indicate the plant was not in the upper 50% of the ratings for the animal. Dashes indicate the plant was not growing at that season.

those plants in the upper 50% of the ratings were chosen for discussion (Tables 2 and 3). Although the species listed made up 50% of the total forage rating, over 150 species made up the remaining 50% of the ratings. Thus the importance of one plant or class of plants should not be overemphasized.

Deer utilized all browse species present on the clay at some time during the year (Table 2). The most frequently and heavily utilized browse species were huisache, blackbrush acacia, and mesquite. Forbs were the most important deer forage class on the clay. Perennial forbs made up most of the deer's forage except during spring when there was an abundance of palatable annuals. Grasses were most important during winter and

Table 3. Forage ratings[1] for species in the upper 50% of forage ratings for deer and cattle on sandy soils.

Species	June 1965 Deer	June 1965 Cattle	Nov. 1965 Deer	Nov. 1965 Cattle	Jan. 1966 Deer	Jan. 1966 Cattle	Apr. 1966 Deer	Apr. 1966 Cattle	June 1966 Deer	June 1966 Cattle
Forbs										
Amblyolepsis setigera	–	–	0	–	1360	–	1760	1220	–	0
Commelina erecta	1344		200		–		–		520	
Helianthus debilis		13760		–		–		416		450
Heterotheca latifolia	574	2330	3798	2100	0	–	10080	0	7000	6540
Linum alatum	1480		–		–		280		2000	
Oenothera lacinata	1320		–		–		1600		1300	
Phyla incisa	168		1200		900		0		1540	
Ratibida columnaris var. *pulcherrima*	–		240		–		4900		4200	
Rudbeckia hirta	–		–		–		–		5924	
Sphaeralcea lindheimeri	70		30		1526		96		308	
Verbena halei	1002		280		1047		340		208	
Other forbs	1170	–	370	–	568	–	1363	1745	1229	0
Grasses										
Andropogon scoparius var. *littoralis*	2660	35720	1248	10080	315	28100	672	1820	600	12800
Brachiaria ciliatissima		9840		0		0		0		1860
Chenchrus echinatus	400	34800	1120	1350	0	170	0	40	180	840
Paspalum setaceum	2240		1228		0		448		390	
Setaria firmula		12563		6730		704		0		1536
Other grasses	–	–	2700	0	330	–	0	2272	–	–

[1] Qualitative ranking: 0–500 = low, 500–1000 = moderate, 1000–3000 = high, and 3000+ = very high. Blank spaces indicate the plant was not in the upper 50% of the ratings for the animal. Dashes indicate the plant was not growing at that season.

spring. During these two seasons five grasses, silver bluestem, seacoast bluestem, Texas cupgrass, spike bristlegrass, and Texas wintergrass were in the upper 50% of the deer's forage ratings. During the early winter, grass seed heads were the main portion of the plant being eaten. Chamrad (1966) also found that grasses made up a high percentage of the Refuge deer's diet during the winter.

Four perennial grasses made up 50% of the preferences of cattle on the clay (Table 2). In order of decreasing importance these grasses ranked as follows: seacoast bluestem, silver bluestem, spike bristlegrass, and buffalograss.

More annual species were utilized by deer on the sand than on the clay. Forbs were the most important deer forage class on the sand (Table 3). Only three grasses, seacoast bluestem, southern sandbur, and thin paspalum, were in the upper 50% of deer forage ratings.

Three species of forbs and four species of grasses made up most of the upper 50% of the forage ratings for cattle on the sand (Table 3). Grasses were more important than forbs to cattle on the sand. As on the clay, seacoast bluestem was the highest ranked forage for cattle.

Forage ratings can be a useful tool for managing rangelands by indicating the best forage for each class of animal under given conditions.

LITERATURE CITED

Box, T. W. 1961. Relationships between plants and soils of four range plant communities in South Texas. Ecology 42:794–810.

Box, T. W., and A. D. Chamrad. 1966. Plant communities of the Welder Wildlife Refuge. Contrib. 5, Series B. Welder Wildlife Foundation, Sinton, Texas. 28 p.

Box, T. W. and J. Powell. 1965. Brush management techniques for improved forage values in South Texas. Trans. N. Am. Wildl. Conf. 30:285–296.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. J. Forestry 9: 388–394.

Chamrad, A. D. 1966. Winter and spring food habits of the white-tailed deer on the Welder Wildlife Refuge. M.S. Thesis. Texas Technological College, Lubbock. 181 p.

Davis, R. B. 1952. The use of rumen contents data in a study of deer–cattle competition and "animal equivalence." Trans. N. Am. Wildl. Conf. 17:448–458.

Dwyer, D. D. 1961. Activities and grazing behavior of cows with calves in Northern Osage County, Oklahoma. Okla. Agr. Exp. Sta. Bull. 588. 61 p.

Gould, F. W. 1962. Texas plants—A checklist and ecological summary. Tex. Agr. Exp. Sta. MP-585. 112 p.

Rader, L., and R. D. Ratliff. 1962. A new idea in point frames. J. Range Manage. 15:182–183.

Forage Moisture Variations on Mountain Summer Range[1]

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Highlight

Diurnal and seasonal differences, as well as site features of slope aspect and shading, were found to be significant variables related to forage moisture content on a mountain summer range in northern Utah. These variations, if ignored in range analysis, can have considerable practical consequence. Therefore, improvements on wet to dry-weight conversion factors have been suggested.

Forage dry-matter data are essential in determining range production. However, time and facilities are rarely available for samples to be regularly dried during range analyses. As a result, empirical formulae have been adopted by American land managing agencies to derive estimates of dry weights from green forage. An example of such guidelines is given in Table 1. The suggested conversion factors allow for adjustments for different growth forms and growth stages of the plant materials. In the case of browse, leaf texture is con-

Table 1. Agency conversion factors.[1] Air-dry weights expressed as percent of green weight.

Growth form	Growth stage or leaf texture	Air-dry percentage
A. Grasses and sedges	Just before heading	25–30
	Headed out	35–40
	After bloom	45–50
	Seed maturity and past	55–80
B. Forbs	Very lush	15–20
	Flowering	20–25
	Seed time	30–35
C. Browse	Lush leaves (snowberry)	30–40
	Fibrous leaves (oak) and *Purshia*	35–45
	Rabbitbrush and sagebrush	40–60

[1]Extracted from Exhibit 93.3-B, R-4 Range Analysis Handbook, Forest Service, U.S.D.A., 1966.

[1] Research supported in part by the Agency for International Development. Presented at the Twentieth Annual Meeting, American Society of Range Management, Seattle, Washington, February 13–16, 1967. Journal Paper No. 703, Utah Agric. Exp. Sta.

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Table 2. Percent vegetation cover–exposure relationships in the study area.

Species	Exposures							
	South		West		East		North	
	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded
Trees								
Populus tremuloides		85		65		50		70
Pseudotsuga menziesii								10
Total		85		65		50		80
Shrubs								
Symphoricarpos vaccinoides	22	1	32	3	12	4	18	1
Artemisia tridentata	8		4	10	1			
Prunus virginiana	1	13	2	17		8	4	
Chrysothamnus viscidiflorus			4		2			
Rosa woodsii		2	1	1	1	5	1	1
Amelanchier alnifolia		1	1	9		5	4	15
Minor shrubs[1]	2	1		15	1		2	
Total	33	18	44	45	26	23	29	17
Forbs								
Solidago lepida	4		1					
Viguiera multiflora	3	1			1	1		
Lupinus caudatus	1	3	1	1		1	1	
Thalictrum fendleri			9		6	1	5	
Lathyrus pauciflorus		4	1	2	3	14		6
Geranium fremontii		1	2	2	1	3	1	
Smilacina stellata				4				
Delphinium occidentale						1	9	
Senecio integerrimus							4	
Minor forbs	13	8	5	5	9	7	8	7
Total	21	17	10	23	14	33	24	18
Grasses								
Poa pratensis	3	35	17	20	5	6	9	7
Elymus cinereus	12	2		1	5			
Agropyron spicatum	2	4						
Agropyron subsecundum		7		2	7	3	6	2
Bromus marginatus		6		5	2	11	22	23
Arrhenatherum elatius						4	2	1
Minor grasses				1	3	4	1	3
Total	17	54	17	29	22	28	40	36

[1] Minor species contributed less than 2% cover on any given slope(s).

sidered. These factors, although widely used, have no known research backing. In fact, very little literature on the subject of forage moisture variation under rangeland conditions exists.

The earliest investigations of moisture in herbage were made by agricultural chemists concerned primarily with nutritional studies. Salisbury (1848) is credited with the first such analysis; he reported variations of moisture content in two varieties of corn. Atwater (1869) observed different moisture contents in timothy cut at different growth stages. The first bulletin on grass analyses which recognized moisture variations as a result of differences in growth stages was written by Richardson (1889). The effect of time-of-day of clipping on herbage moisture was first reported by Vinal and McKee (1916).

Whitman (1941) reported a gradual decrease in water content of prairie grasses with growth advancement. The day and night rhythm in range forage plants was studied by Stoddart (1935). He found the lowest levels of plant moisture content occurred during afternoons. The importance of time of clipping was re-established by Curtis (1944), who reported higher moisture percentages in morning and lower values in afternoons. The significance of moisture variations during the day, however, continued to be questioned (Dexter, 1945; Jameson and Thomas, 1956).

We suspected that in addition to the phenological and growth form differences in herbage moisture recognized in agency formulae, it was possible that diurnal variation in the plant material itself and the environmental effects of slope aspect and shading would prove to be significant considerations in areas of dissected topography. Therefore, a study was designed to evaluate these elements of herbage moisture variation on a typical Intermountain summer range.

Methods

The study area is near the Tony Grove Guard Station, Cache National Forest, Utah. The study plots were in the Douglas-fir (*Pseudotsuga menziesii*)[3] climatic climax zone of the Wasatch Mountains at elevations of 6,200 to 6,800 ft. Relatively little of the area is covered by the climax dominant since topography, soils, and disturbance greatly influence the present vegetation. Abbreviated percent vegetation cover–exposure relationships are given in Table 2. Values are separate estimates of cover for trees, shrubs, grasses, and forbs on plots.

The plots on westerly exposures occur in sheep summer range, all the other plots are included in cattle summer range. Wildlife browsing is common in all areas.

The experimental area lies in a 25-inch annual precipitation zone. Most of the precipitation is in the form of snow. Summers are usually dry with less than 6 inches of rainfall. July is the hottest month with maximum temperatures between 85 F and 95 F common, at 1 ft above the ground on southern slopes.

The bedrock is largely limestone. A Miocene erosional cycle deposited an irregular pebble and cobble conglomerate (the Wasatch Formation) over the limestone. The northern aspect sites were scoured by several glaciers during the Pleistocene.

Southern slopes are convex but eastern, western, and northern exposures are concave. Southern slopes average 35%, whereas both westerly and northerly exposures have average slopes of 38%. Easterly exposures slope 23%, on the average.

The texture of upper soil horizons on unshaded sites varies from loam to silt loam with loam predominating. The shaded subplot soils are uniformly silt loams. The soils of northern exposures are deep loams derived from glacial till. These soils have adequate soil aeration and excellent water holding capacity. On eastern, western, and southern aspects the soils have developed from Wasatch Conglomerate. These soils are shallow and rich in clay and silt. Tight clays in deeper strata are suggestive of slow permeability, poor aeration, and limited productivity.

Since no species occurred on all slopes in the open and under shade (Table 2), the data were considered by growth form rather than species. Moreover, under field conditions, aspect, shade, time-of-day, and season cannot be isolated as single-factor effects. Factor complexes are involved in determining the moisture content of a given sample of range forage. Nevertheless, certain patterns of variation can be related to different effective environments on the different sites at various times and such data can be used to test the validity of procedures such as those suggested in Table 1.

During the summer of 1964, a pilot study was made to determine statistically acceptable sample sizes and replications. Samples of 25, 50, 100, and 200 g of forage were collected at various sites, at different times of day, throughout the season. Three 25 g samples yielded data within 5% of the true dry weight mean. Twelve fenced plots were laid out in 1965, three on each aspect; north, south, east, and west. Every plot consisted of one subplot in shade of natural tree growth and the other exposed to direct sunlight. Each subplot contained 66 units 1 × 6 ft each with alternate units available for clipping. On every clipping day, 2 plots 1 × 4 ft each were randomly selected and clipped leaving a 1-ft buffer on all sides. Every clipping consisted of 2 sampling operations: one in the forenoon (9 to 11 AM) and the other the same afternoon (2 to 4 PM). Twelve clippings were made at weekly intervals, excepting the last interval which was 2 weeks. The clippings commenced in the third week of June and ended the second week of September 1965, thus covering the entire grazing season. Herbaceous plants were clipped to within 1 inch of the ground surface. In the case of woody plants, however, only current year's twig growth was clipped. The clipped material was separated into three growth forms, i.e., grass and grass-like plants, forbs, and shrubs. Each sample was weighed immediately. In the evening, the samples were taken to Logan and dried in an oven at 80 C for 24 hr.

When the field season was over the samples were placed under uniform room conditions. The dry samples absorbed moisture hygroscopically and were weighed again when they acquired constant weight. The difference between the dry weight and green weight was taken as the weight of moisture and was expressed as percent of dry weight. These procedures were designed to correspond in principle with the air-dry forage-weight method generally used in arriving at management decisions.

An analysis of vegetation on all experimental plots was carried out to determine floristic composition, cover value, and relative species abundance. At every clipping, the phenological stage of clipped species and weather conditions were also recorded.

Analysis of variance of data of this factorial design allowed the effects of the various factors to be separated statistically. Magnitude of the effects of aspect, shade, time-of-day, season, and their interactions have thus been obtained.

Results

Moisture in plants is dynamic and variable. Nevertheless, moisture content of forage is amenable to some generalizations. For instance, forbs usually contained more moisture than grasses. Grasses were consistently wetter than shrubs. However, the necessity of separating growth forms in dry-weight computations is widely recognized. The other features in our experimental design were the ones which have generally been ignored by other workers.

Aspect.—After pooling data collected at all times, at all sites, and analyzing in regard to aspect (Table 3), we found that aspect was, by far, the most important factor-complex relating to differences in plant moisture content. The analyses of variance indicated that the northerly slopes were highly significantly[4] different in moisture content from the remaining slopes for all three growth forms. The northern exposures always possessed plants with

[3] Nomenclature follows Holmgren (1965).

[4] "Significant" implies statistical significance at the 0.05 level of probability. "Highly significant" indicates statistical significance at the 0.01 level.

Table 3. Average moisture content (percent of dry weight) of different growth forms related to aspect.

Growth form	Aspects North	South	East	West
Grasses	252	152	171	179
Forbs	362	251	279	284
Shrubs	177	159	163	155

the maximum moisture content. Duncan's multiple-range test indicated that the moisture differential between the eastern, western, and southern slopes was not statistically significant for forbs and shrubs. For grasses the eastern exposures did not differ significantly from westerly exposures. However, samples from southern plots contained significantly different amounts of moisture from those on the eastern and western exposures. Table 3 demonstrates that aspect alone can account for a difference of up to 111% mean moisture content in herbaceous vegetation. For shrubs the variation could range up to 22%.

Shade.—A similar analysis of the pooled data showed the increase in moisture, due to the total effects of shade, could be of the average order of 72, 69, and 27% for forbs, grasses, and shrubs, respectively. (Table 4). Shade was evidently more effective in modifying moisture in herbaceous than woody plants. Nevertheless, the variation in moisture content related to shade was highly significant for all three growth forms.

Time-of-day.—Average forenoon moisture values were invariably and highly significantly different from those for the afternoon. The decline in moisture by afternoon in forbs, grasses, and shrubs was of the magnitude of 26, 20, and 11%, respectively. (Table 5).

Seasonal Variation.—Seasonal variation as a factor effecting forage moisture was highly significant. Duncan's multiple-range test indicated that at least the first four and twelfth clippings all differed

Table 4. Average moisture content (percent of dry weight) of different growth forms, on various aspects related to shade.

Growth form	Shade	Aspects N	S	E	W	Additional moisture under shade N	S	E	W	Overall
Grasses	Shaded	291	179	209	215	78	53	76	72	69
	Unshaded	213	126	133	143					
Forbs	Shaded	407	295	305	314	89	89	51	61	72
	Unshaded	318	206	254	253					
Shrubs	Shaded	191	171	177	169	27	24	28	27	27
	Unshaded	164	147	149	142					

Table 5. Average moisture content (percent of dry weight) of different growth forms related to time-of-day of clipping.

Growth form	Time-of-day	Aspects N	S	E	W	Additional moisture in forenoon N	S	E	W	Overall
Grasses	AM	264	159	183	188	24	13	24	18	20
	PM	240	146	159	170					
Forbs	AM	376	262	292	298	27	23	25	28	26
	PM	349	239	267	270					
Shrubs	AM	183	164	170	161	11	10	14	11	11
	PM	172	154	156	150					

significantly from the other clippings within each growth form in moisture content (Fig. 1). The fifth through eleventh clippings did not have as pronounced differences. Forbs underwent the steepest relative decline with the highest initial moisture content and greatest loss (215%) through the season. Grasses showed an intermediate initial content and an intermediate rate of decline with a loss of 122% over the season. A gradual decline of 82% was registered for shrubs during the season. Shrubs had the least moisture content in the first clipping.

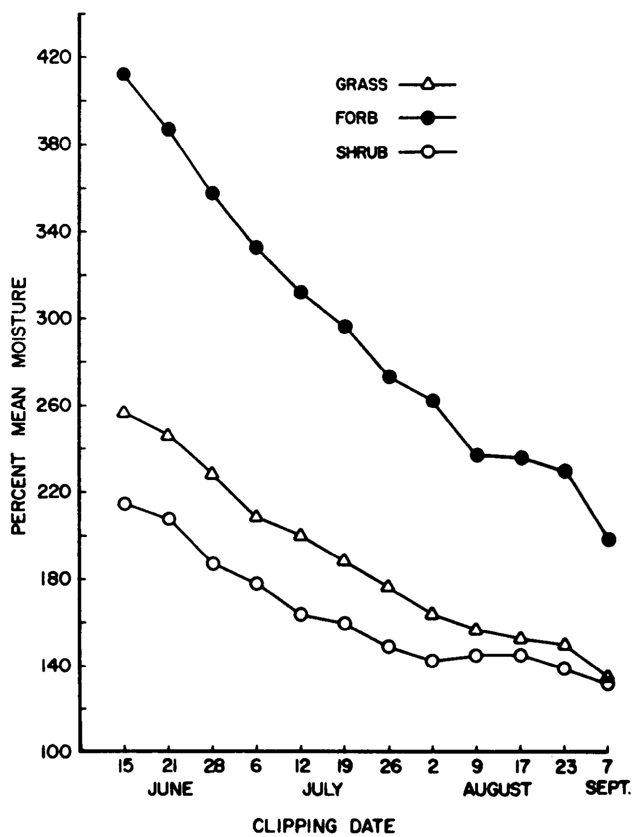

FIG. 1. Moisture variations in different growth forms over the season.

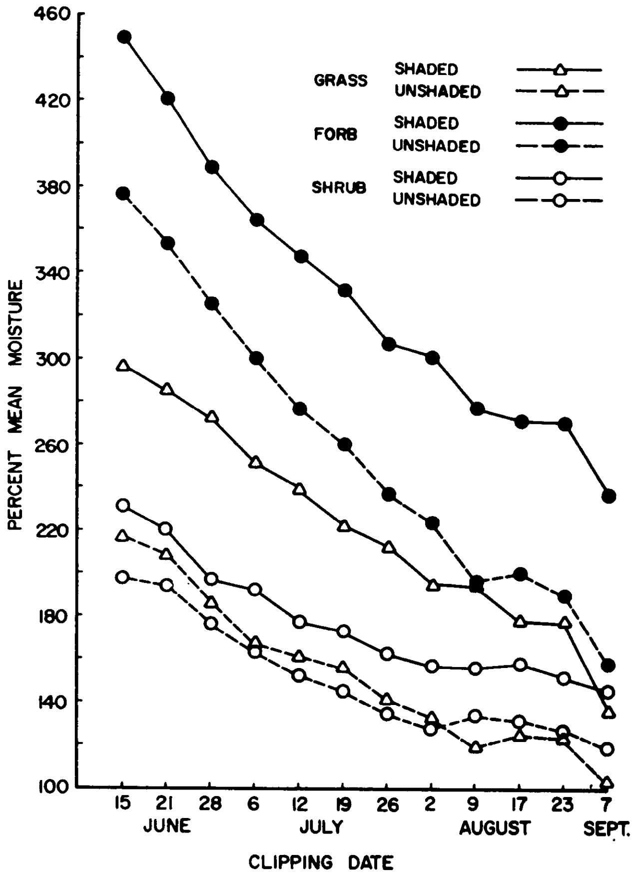

FIG. 2. Moisture variations in different growth forms over the season as affected by shade or lack of shade.

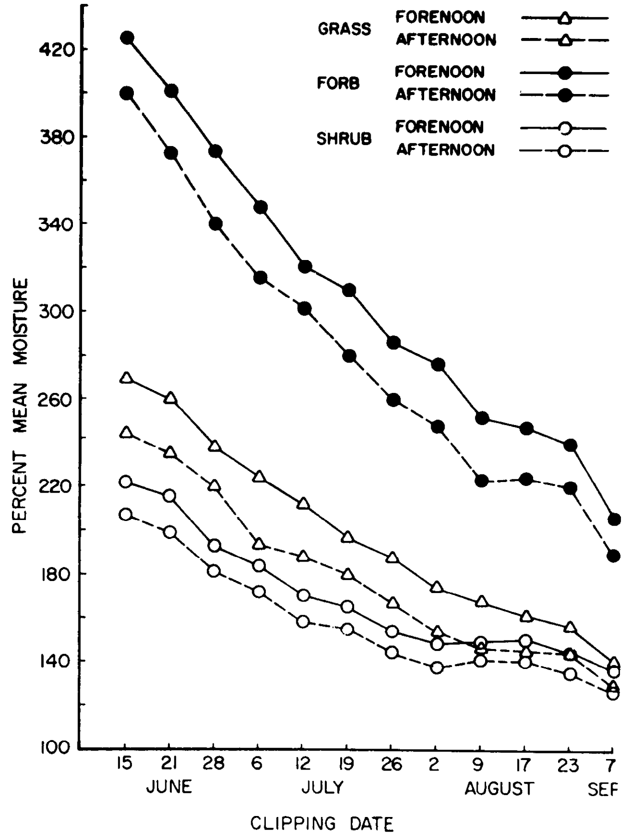

FIG. 3. Moisture variations in different growth forms over the season as affected by time-of-day of clipping.

Interactions.—Besides the ecological features of aspect, shade, time-of-day, and season which had highly significant relationships to forage moisture content, the following interactions were also found to be highly significant.

1. Grasses: (a) Shade × time-of-day, (b) Aspect × season, (c) Shade × clippings, and (d) Aspect × shade × season.

2. Forbs: (a) Aspect × season, and (b) Aspect × shade × season.

3. Shrubs: (a) Shade × time-of-day, and (b) Aspect × season. In addition the aspect × shade × time-of-day interaction was significant.

Some of these interactions can be illustrated here. For instance, aspect × shade interactions are shown in Table 4. Samples from the four exposures showed different moisture content with and without shade. Grasses and shrubs from the southern exposures showed the minimum differences under the two situations. Maximum variation for grasses was found on northern exposures.

Aspect × time-of-day interactions are illustrated in Table 5. Forage samples from the four aspects reacted differently with respect to the time-of-day when they were collected. The minimal values for moisture content in all three growth forms came invariably from the afternoon samples collected from southern exposures. Maximum values came invariably from morning clippings taken on northern slopes.

Shade expressed itself even in clippings made during the forenoon and afternoon of the same day. Shaded and unshaded conditions accounted for an average of 13, 2, and 4% of the overall variation in water content of grasses, forbs and shrubs, respectively. The higher moisture content under shade persisted throughout the season (Fig. 2). Among shrubs the difference was 33% in the initial clipping, and shrank to 26% in the final clipping. Grasses had an initial difference of 79% but decreased to 43% at the end of the season. Forbs showed little interaction of this type with 73% additional moisture at the first clipping increasing to 78% at the last clipping.

Differences between the forenoon and afternoon forage moisture persisted throughout the growing season (Fig. 3) with the differential being consistently greatest for forbs, intermediate for grasses, and least for shrubs. The seasonal decrease of moisture was most pronounced for forbs. Grasses showed less rapid loss of moisture than forbs but a faster rate than the strikingly slow rate of decline of moisture in shrubs.

The average moisture content of the three growth forms at most clipping dates differed significantly on different aspects. Southern slopes showed the lowest moisture values, most of the time, for all three growth forms. In the final clippings however, the minimal values occurred on eastern slopes for herbaceous plants but western slopes for shrubs. The northern aspects consistently had higher moisture values for grasses and forbs. Shrubs from the northern slopes generally contained more moisture than those on other aspects.

In the first clipping, the maximal value for shrubs (average of northern aspects) was 129% of the minimal value (average of southern aspects). The corresponding ratios for grasses and forbs were 212% and 171%, respectively. In the final clipping the maximal to minimal ratios were 156, 135, and 127% for grasses, forbs, and shrubs, respectively.

Discussion

The pattern of moisture contents observed is caused by a complex of biological and environmental differences contributing to each set of data. Different species of different abundance and phenology occur on the various aspects under shaded and unshaded conditions. Major differences in species occurrence and abundance are itemized in Table 2. Phenological development of all species was generally earliest on the southern aspects and progressively later on west, east, and north slopes. Phenology, as well as species composition, was affected by shade or lack of it. Moisture content was also related to the date and time-of-day clippings took place. The major environmental complex influencing the results was obviously aspect orientation of the sites to solar radiation. Forage moisture content can be directly or indirectly related to different energy budgets (Kozlowski, 1964).

However, it was not our purpose to discuss causation. Rather, since the study area is a summer range similar to those for which many range conservationists collect range analysis data, we have attempted to apply our findings to improving the overgeneralizations or "rules of thumb" found in Table 1.

There is some indication of significant species and even intraspecific herbage moisture differences, however, the plot approach has limited such inferences. Although time-of-day was highly significant statistically, this consideration is relatively less important than aspect or shade and could be ignored along with species differences in the immediate improvement of factors for estimating dry weights from green plant material in non-research applications.

Suggested simplified conversion factors for deriving dry weights in the study area are set out in Table 6. The basis for these factors is the actual weights of forenoon clippings in the study area. Although such considerations would be expected to apply in principle to many range types, the recommendations made here are limited to mid-elevation mountain summer ranges in northern Utah.

Table 6. Improved green weight to air-dry weight conversion factors, in percent.

Aspect	Phenological stage[1]	Grass U[2]	Grass S[2]	Forbs U	Forbs S	Shrubs U	Shrubs S
North	Just before heading	24	20	18	16	31	—
	Headed out	31	25	25	19	33	31
	After bloom	—	—	—	—	—	36
East	Just before heading	32	28	22	20	34	—
	Headed out	40	33	24	22	36	36
	After bloom	—	—	—	—	—	41
South	Just before heading	39	35	27	22	35	38
	Headed out	44	38	—	23	40	38
	After bloom	—	—	—	—	—	41
West	Just before heading	40	24	22	23	37	32
	Headed out	45	31	23	25	40	34
	After bloom	—	—	—	—	—	40

[1] "Just before heading" rows refer to the "very lush" category for forbs and "lush leaf" stage for shrubs in Table 1. "Headed out" refers to "flowering" for forbs and shrubs. "After bloom" refers to "seed time" for forbs and shrubs.
[2] U = Unshaded; S = Shaded.

The omissions in Table 6 result from lack of data for all phenological stages on all plots. The data were collected in a year when conditions were wetter than average. The 1965 precipitation total was 32.53 inches as compared to a long term average of 25.44 inches. Even more important, the 7.70 inches of rain between mid-June and mid-September was 37% higher than the long term average of 5.64 inches (A. Richardson, personal communication). Annual variations, although unstudied, are also likely to be important in analyses of herbage moisture.

A comparison of the factors in Table 6 with some formula values used by land managing agencies (Table 1) is made below with suggestions for improvement. Grasses and sedges: The agency formula values of 25 to 30% dry matter "just before heading" hold well for unshaded northern and eastern aspects. But for southern and western aspects a factor of 35 to 40% would give closer estimates. Likewise the agency formula values are close for shaded eastern and western grasses. On shaded northerly and southerly aspects, however, the conversion factors should be increased or decreased by 5%, respectively, to improve estimates.

The agency formula value for "headed out" grasses gives a fair dry-weight approximation for unshaded grasses on eastern, southern, and western aspects. However, for unshaded northerly grasses a reduced conversion factor of 30 to 35% would

Table 7. Grazing capacity of one net forage acre calculated by agency and improved formulae.

Growth form / Shading / Phenological stage / Aspect	Derived AUMs	
	Improved formula	Agency formula
Grass		
Shaded		
Preheading:		
West and East[1]	2.5	2.5
South	3.0	2.5
North	2.0	2.5
Headed Out:		
East, South, and West	3.0	4.0
North	2.5	4.0
Unshaded		
Preheading:		
North and East	2.5	2.5
South and West	3.5	2.5
Headed Out:		
East, South, and West	4.0	4.0
North	3.0	4.0
Shaded and Unshaded		
After Bloom:		
West and South	3.5	5.5
Forbs		
Unshaded		
Very Lush Stage:		
South	1.6	1.0
Shrubs		
Shaded and Unshaded		
Sagebrush	0.9	1.1

[1] Aspects were grouped when less than 5% differences in correction factors between aspects were indicated.

yield more reliable dry weight approximations. This factor also applies to shaded grasses on easterly, southerly, and westerly aspects. For shaded northern aspects, a further reduction by 5% would improve accuracy.

The phenological stages for grasses in Table 6 refer to the most abundant species except for shaded southerly and unshaded westerly slopes where the most abundant species is Kentucky bluegrass (*Poa pratensis*). This grass presented a special problem since it was past seed maturity on these slopes before its associates headed out. A conversion factor of 35 to 45% rather than 55 to 80% would allow a more accurate estimate of its dry weight after seed maturity, irrespective of aspect and light conditions. After bluegrass, bearded wheatgrass (*Agropyron subsecundum*) was the second most abundant species. Hence the data refers to the bearded wheatgrass in the two instances.

Forbs: The formula values are sufficiently close to actual values except for southern aspects. The unshaded southern forbs would yield closer values with a higher conversion factor of 25 to 30%.

Shrubs: The values given in Table 1 for browse species are generally adequate, except for sagebrush. The agency formula value of 40 to 60% exaggerates its dry weight estimates. Including sagebrush in the second browse category of "fibrous leaves and *Purshia*" (conversion factor, 35 to 45%) would keep sagebrush estimates closer to actual weights recorded.

Some effects of the suggested formulae modifications on grazing capacity computations are illustrated in Table 7. For simplicity, net utilizable green forage of 6,000, 4,000, and 1,300 lb/acre of grass, forb, and shrub growth, respectively, has been assumed. Actual production and composition varied with aspect, shading, and season; however, the sampling design did not adequately account for these quantitative differences. The importance of variable moisture on actual range analysis computations will exceed these assumed values because variation in production adds to the variations illustrated here. The estimated dry weights have been derived by multiplying assumed green weights by the lowest value in the conversion factor range relating to that growth form and phenological stage. For instance, in deriving dry weights of green grasses in the stage "just before heading" the agency formula conversion factor is 25 to 30%. The lowest value in the conversion range, i.e., 25% has been used in the table for agency formula derived AUMs. Likewise for AUMs calculated with improved conversion factors suggested by this research the lowest value has been used, e.g., 35% in case of unshaded grass in the "just before heading" stage on southern and western aspects ($6{,}000 \text{ lb} \times 0.35 = 2{,}100$ lb air-dry forage). The lowest-factor rule has been substituted with the middle factor in case of shrubs where the range of conversion was wide. For instance, in the case of sagebrush the agency formula factors range from 40 to 60% and improved factors range from 35 to 45%. Accordingly, dry matter estimates in Table 7 have been derived by multiplying green weights by 50% and 40% to obtain agency formula and improved formula-derived AUMs, respectively.

Table 7 further shows that, in a grass sward in the stage "just before heading," for every 2.5 AUMs computed by the agency formula, the AUMs could vary from 2 to 3 AUMs computed by the improved conversion factor. Likewise in the "headed out" stage the agency formula gives 4 AUMs. However, the AUMs computed with the improved conversion factor range from 2.5 to 4. The most striking differences are presented by western aspects where the most abundant species is Kentucky bluegrass. This grass is in the stage of "seed maturity and past" when grazing capacity estimates are commonly made. For every 5.5 AUMs derived by the agency formula for this grass, (which means practically all the available herbaceous forage on the western aspects), the value should be only 3.5

AUM. These discrepancies in AUMs, when calculated to apply to extensive acreages, could mean substantial loss in AUMs or serious overgrazing.

Forbs and shrubs indicated less striking variations. Only the unshaded forbs on southern aspects resulted in a 0.6 AUM difference over and above every AUM derived by the agency formula. The agency formulae gave slightly higher values than our improved formulae for sagebrush.

LITERATURE CITED

ATWATER, W. O. 1869. On the proximate composition of several varieties of American maize. Amer. J. Sci. 149: 352–360.

CURTIS, O. F. 1944. The food content of forage crops as influenced by the time of day at which they were cut. J. Agron. 36:401–416.

DEXTER, S. T. 1945. The yield and sugar content of alfalfa cut at various times of day and sugar content of hay after various methods of drying. J. Agron. 37:394–399.

HOLMGREN, A. H. 1965. Handbook of the vascular plants of the northern Wasatch. Lithotype Printing Co. San Francisco. 202 p.

JAMESON, D. A., AND G. W. THOMAS. 1956. Time of day as a consideration in grass clipping experiments. J. Range Manage. 9:98–99.

RICHARDSON, C. 1889. The agricultural grasses and forage plants of the U.S.A.–the chemical composition of grasses. U.S.D.A. Spec. Bull. 133–137.

SALISBURY, J. H. 1849. History and chemical investigation of maize or Indian corn. 1848. Reprinted in book form by C. Van Benthuysen, Albany, New York. 206 p.

STODDART, L. A. 1935. Osmotic pressure and water content of prairie plants. Plant Physiol. 10:661–680.

VINAL, H. N., and R. MCKEE. 1916. Moisture content and shrinkage of forage and the relation of these factors to the accuracy of experimental data. U.S.D.A. Bull., 353. 21 p.

WHITMAN, W. C. 1941. Seasonal changes in bound water content of some prairie grasses. Bot. Gaz. 103: 38–63.

Maturity Studies with Western Wheatgrass[1]

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Highlight

Leaf class (number of leaves per plant) and cutting date were considered as indices of maturity of western wheatgrass. Although some early-season effects of leaf class could be demonstrated, cutting date was a better measure of stage of maturity. Cutting date but not leaf class was shown to affect plant fractions and chemical components. The upper portion of the plant was more digestible than the basal portion. No digestibility effect was demonstrated for topographic location or leaf class. Leaf blades removed from plants under heavy grazing were more digestible in vitro than those from lightly-grazed pastures, probably because of later emergence or shorter height.

The nutritional value of a forage appears to be greatly influenced by factors which either cause or accompany plant maturity. The relationship of lignification to maturity and plant digestibility has been extensively studied (Crampton and Maynard, 1938; Patton and Gieseker, 1942; Steppler, 1951; Kamstra et al., 1958; Sullivan, 1959). Much less emphasis has been given to the effect of range site, range condition, and relative plant size on lignification, digestibility, and animal utilization. For such studies a method of determining plant maturity becomes necessary. The usual definition of maturity stage by reference to boot, flowering, or seed stalk production cannot be used consistently with range grasses because many of them produce seed only during favorable years. This is especially true of grasses such as western wheatgrass (*Agropyron smithii* Rydb.), which are not dependent upon seed for reproduction.

This paper considers leaf class and cutting date as indicators of stage of maturity as measured by in vitro cellulose digestibility. The effect of age of tissue on in vitro cellulose digestibility was studied by analyzing upper and lower portions of the plant separately. Individual leaves also were separated according to time of development and analyzed separately.

Experimental

The sampling areas for the 1961 collections of western wheatgrass were located at the Cottonwood Range Field Station 75 miles east of Rapid City. In 1962 additional areas were sampled at the Cottonwood Range Field Station, the Antelope Range 15 miles southeast of Buffalo, and a small prairie area seven miles west of Pierre. Table 1 provides additional information relative to the 1962 collection areas.

In Vitro Cellulose Digestibility.—Sample collections of western wheatgrass were made in 1961 from clayey upland in lightly and heavily grazed pastures in good and poor range condition, respectively, at the Cottonwood Range Field Station. The samples were hand-cut by leaf class (number of leaves per plant) from temporary exclosures on May 11, June 9, and July 14. The leaves were removed from the stem and numbered from the bottom leaf. Sam-

[1] Published with the approval of the Director of the South Dakota Agricultural Experiment Station as Publication No. 786 of the Journal Series.

Table 1. Description of range collection areas for westernwheatgrass.[1]

Item	Antelope Range		Cottonwood Range Field Station		Pierre
Precipitation (in.)					
Ave. annual	13.1		15.1		16.0
Growing season (Apr.–Sept.)					
1961	—		9.9		—
1962	11.8		11.4		18.4
Topographic position	upland	run-in	upland	run-in	upland
Range soil group[2]	silty	overflow	clayey	overflow	shallow clay
Range condition[2]	good	good	good	excellent	excellent
	fair	fair	poor	poor	—

[1] There were two replications in each range condition class in each range soil group at each location.
[2] Range site and range condition were classified according to Soil Conservation Service (1961).

ples were forced-air dried at 65 C, ground to 40 mesh, and stored at –20 C until used.

In 1962 collections were made on June 10, July 9, August 6, and September 12 at the Cottonwood Range Field Station, Antelope Range, and near Pierre. The collections at Antelope Range and Cottonwood were made by leaf and height classes from uplands and run-in sites in high and low range condition. Collections at Pierre were from an upland in high range condition only. The samples were taken in conjunction with a height–weight relationship study of western wheatgrass not reported here. The joint usage of these samples limited the amount of sample available. The sample preparation was similar to the 1961 collections; however, the leaves were not separated from the stems.

In vitro cellulose digestibility was determined on composite samples of blades within leaf classes within grazing rates at all cutting dates in 1961. Cellulose digestibility was determined on 1962 collections where sample size permitted. These 48-hr in vitro cellulose digestibility determinations were made according to the method of Kamstra et al. (1958). The preliminary cellulose values necessary for in vitro cellulose digestibility were determined by the method of Crampton and Maynard (1938).

Plant Components.—Additional collections of western wheatgrass for a plant component study were made in 1962 from a clayey upland in good range condition deferred for winter grazing at the Cottonwood Range Field Station. Samples were collected on June 11, July 9, August 8, and September 9 according to leaf class. These collections were used in a study of the effect of cutting date and leaf class on hemicellulose sugars and other plant components. All samples were forced-air dried at 65 C, ground to 40 mesh, and stored at –20 C until used. Holocellulose was prepared by the method of Whistler et al. (1948) using 5 g samples of forage. The cellulose and hemicellulose separation from holocellulose and the acid hydrolysis of hemicellulose to free sugars and subsequent separation on Whatman number 1 filter paper followed the procedures of Myrhe and Smith (1960). The sugars were located by spraying the paper with aniline hydrogen phthalate (Patridge, 1948). Relative amounts of each sugar were measured by a Photovolt Densitometer (Model 425) directly from the chromatograph after development. Protein and ash were determined by the method of the A.O.A.C. (1960). Lignin was determined by the method of Patton (1943).

Results and Discussion

Effect of Cutting Date, Grazing Rate, and Blade Position on In Vitro Cellulose Digestibility.—The digestibility of blades 2 and 3 from three-leaved plants cut May 11, 1961 from temporary exclosures in heavily grazed pastures in poor range condition and lightly grazed pastures in good range condition at Cottonwood were compared with the same blade positions on four-leaved plants cut from the same areas on June 9 (Fig. 1). Blades from the May cutting were more digestible than those from June (67.8 vs. 34.9%, $P < .01$). Blades from heavily grazed pastures were more digestible than those from lightly grazed pastures (56.4 vs. 46.4%, $P < .05$). The reason for this difference may be that the plants in heavy grazing emerged later and were thus younger or that they were smaller and thus contained less structural material. The younger leaf blade 3 was more digestible than the older leaf blade 2 (60.4 vs. 42.3%, $P < .01$). The mean squares for interaction were small and were not significant (standard error of the mean, 4.4%).

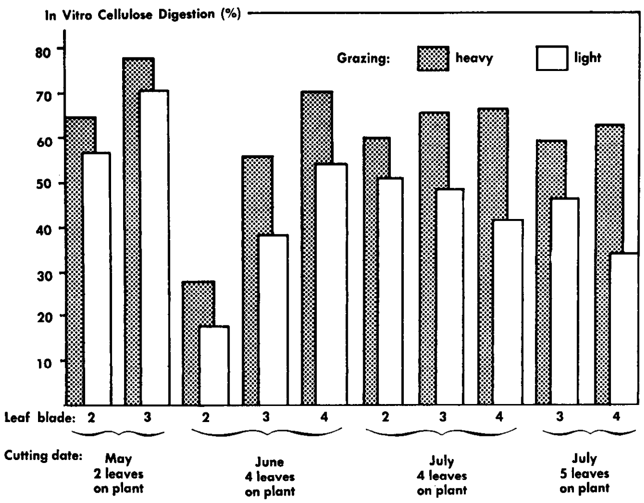

FIG. 1. Comparison of the in vitro cellulose digestibility of western wheatgrass leaf blades collected by leaf classes, cutting dates, and grazing rates.

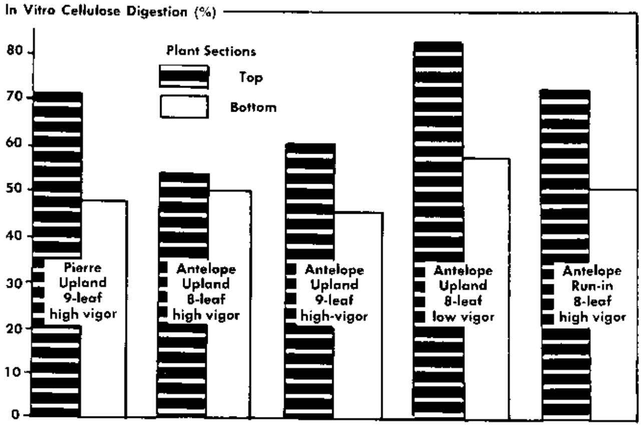

FIG. 2. Comparisons of the in vitro cellulose digestibility of western wheatgrass plant sections collected by vigor class and location during one cutting date (August 6, 1962).

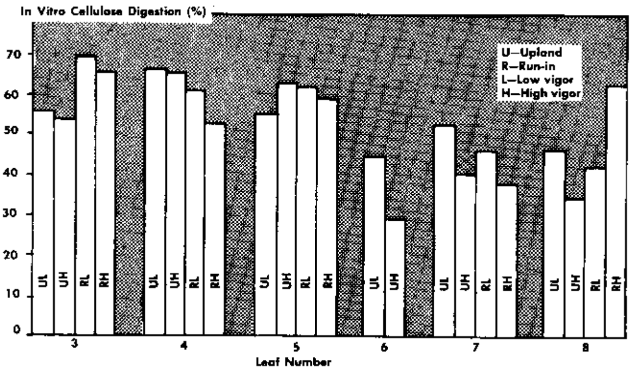

FIG. 3. Comparison of the in vitro cellulose digestibility of western wheatgrass plants collected by leaf and vigor classes from the Antelope Range Field Station on July 9 (leaf no. 3, 4, and 5) and September 12, 1962 (leaf no. 6, 7, and 8).

The digestibility of blades 2, 3, and 4 cut from four-leaved plants in heavy and light grazing at Cottonwood July 9 were compared with the same blade positions from five-leaved plants cut on the same areas at the same date (Fig. 1). A missing value was calculated for blade 2, five-leaved plant, poor range condition (heavy grazing), replication 2 by the method described by Snedecor (1956). Values for blade 2, five-leaved plants are not shown. The range condition × blade interaction was highly significant ($P < .01$). In heavy grazing the younger leaves were more digestible, whereas in light grazing the youngest leaf was least digestible. This difference may have been due to death of the terminal shoot which was observed on some plants in light grazing. The cause of death of these terminal shoots was not determined. Blades from heavy grazing were more digestible than those from light grazing (57.2 vs. 44.3%, $P < .01$). Blades from leaf class five plants appeared to be more digestible than those from leaf class four (55.5 vs. 45.9%). This difference was significant ($P < .01$) when tested with the pooled error term, but was not significant when tested with the rep x treatment interaction with only 1 degree of freedom for treatment and 1 for error. Likewise, the two younger leaf blades, 3 and 4, (51.2 and 55.2%, respectively) appeared to be more digestible than older leaf blade 2 (45.8%). While these differences were significant ($P < .05$) when tested with the pooled error term, they were not significant ($P < .01$) when tested with the rep x treatment interaction with 2 degrees of freedom for treatment and 2 for error. More than two replications were clearly needed to adequately test the leaf class and leaf blade effects. In general, the younger and smaller plants or plant parts were more digestible than other and larger plants or plant parts.

Effect of Plant Portion on In Vitro Cellulose Digestibility.—The digestibility of the top halves of plants cut from shallow clay uplands near Pierre in excellent range condition and from uplands and run-in locations at Antelope Range in August, 1962 were compared with the bottom half of the same plants (Fig. 2). The tops were more digestible than the basal portion (68.5 vs. 50.5%, $P < .05$). The standard error of the mean was 3.9%. Grazing livestock generally select the upper portion of western wheatgrass plants, especially later in the season.

Effect of Range Site, Range Condition, Sampling Date, and Leaf Class on In Vitro Cellulose Digestibility.—The digestibility of western wheatgrass vigor classes separated into leaf numbers is shown in Fig. 3. Leaf numbers 3, 4, and 5 were collected on July 9 and leaf numbers 6, 7, and 8 were collected on September 12, 1962, from the Antelope Station. Least square means were 60.8% for July and 43.3% for September ($P < .01$). Differences due to topographic position, range condition, and leaf number were not significant. None of the two-factor interactions were significant. When digestibility of western wheatgrass plants from the same topography, source, vigor class, and leaf numbers was compared by cutting date, the plants became progressively less digestible from June 10 to September 12 (Fig. 4).

Comparison of Carbohydrate Composition, Lignin, Protein, and Ash by Cutting Date and Leaf Class.—With cutting date as the measure of maturity, lignin and cellulose increased, whereas protein and ash decreased as the plants matured. The lignin content approached a value equal to approximately half the cellulose as the growing season progressed (Fig. 5). The only indication that number of leaves per plant was a measure of plant maturity appeared in the June collection. In this collection protein decreased and lignin increased as number of leaves on the plant increased. As such a trend did not appear in any subsequent col-

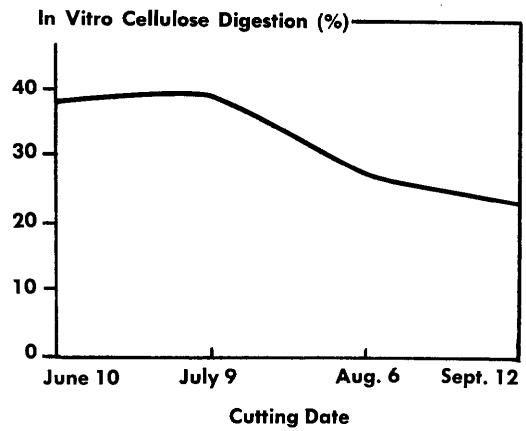

FIG. 4. Comparison of the in vitro cellulose digestibility of western wheatgrass at different cutting dates collected from the same location, vigor class, and with one leaf class (5 leaves/plant).

lection, the data for Fig. 5 were pooled for leaf classes from each collection. The yield of holocellulose and hemicellulose was higher in July than at other dates. This agrees with the results of Routley and Sullivan (1958) for grass holocellulose. Their work suggested that grass in the flowering stage was higher in holocellulose yield than at the boot stage. Western wheatgrass usually flowers during the third or fourth week of June if flowers are produced. Cellulose also increased in July, which is consistent with the findings of Phillip et al. (1954), who noted an increase in both true and natural cellulose up to the flowering stage in some grasses. The relative proportion of cellulose to hemicellulose did not change markedly with plant maturity (Tomlin et al., 1965).

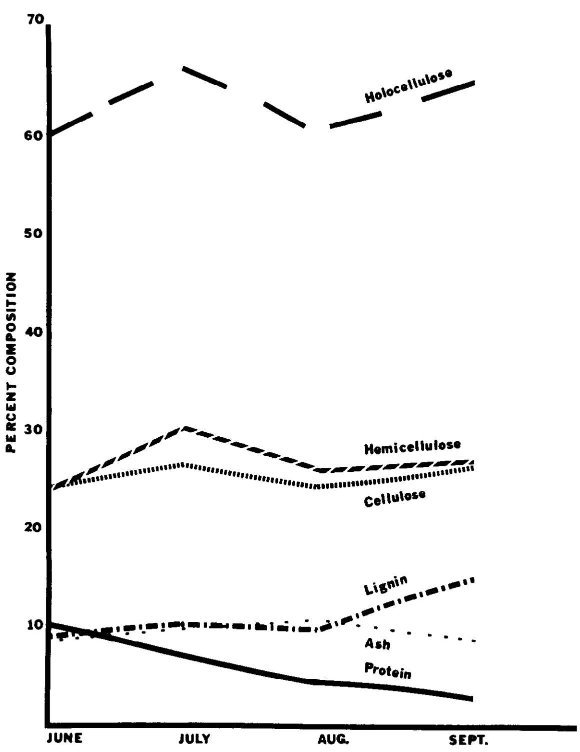

FIG. 5. Chemical components of western wheatgrass at different cutting dates.

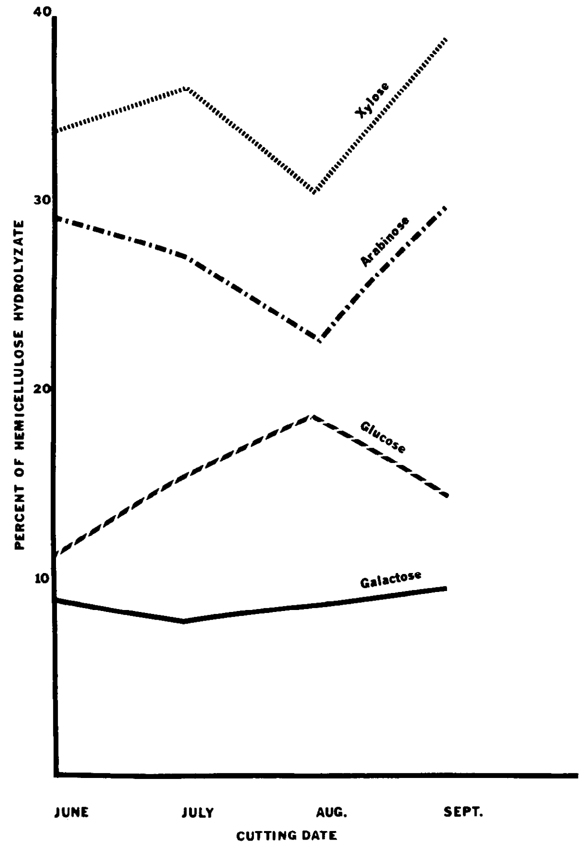

FIG. 6. Neutral sugar components of western wheatgrass at different cutting dates.

Comparison of Neutral Sugar Components of Hemicellulose by Cutting Date and Leaf Class.—The neutral sugar components of western wheatgrass hemicellulose were found to be xylose, arabinose, glucose, galactose, and trace amounts of rhamnose at all cutting dates (Fig. 6). Sullivan et al. (1960) noted the presence of minor amounts of rhamnose in the hemicellulose fraction of several grasses. No consistent effect of leaf class on sugar content was noted and similar values resulted when each sugar was totaled for all cutting dates by leaf class. For example, xylose was shown to comprise 34.5, 35.5, 35.5, and 34.8% of the total sugars with 5, 6, 7, and 8 leaved plants, respectively. As indicated in Fig. 6, the quantity of individual sugars was affected by cutting date, however, the same sugars were present in all collections. The same hemicellulose sugars were also present in each leaf class. Xylose was the principal sugar in all preparations followed by arabinose, glucose, and galactose. The amount of arabinose in western wheatgrass hemicellulose decreased while glucose increased until the August collection, after which arabinose increased and glucose decreased. Routley and Sullivan (1958) noted a similar decrease in the glucose content of hemicellulose of stems and leaves of brome grass during maturation. Sullivan et al. (1960) showed this loss of glucose with maturation in several other grasses. The levels of galactose did not appear to be greatly affected by cutting date or leaf class. Xylose has been shown to be the main structural chain of the hemicellulose moiety of forage (Myhre and Smith, 1960) and in this study changes in xylose closely corresponded to changes in arabinose. This suggests that arabinose may be important as a structural component. However, no direct relationship between the content of neutral sugars and palatability to grazing livestock has been shown as yet.

LITERATURE CITED

A.O.A.C. 1960. Official Methods of Analysis (9th ed.). Association of Official Agricultural Chemists. Washington, D.C. 832 p.

Crampton, E. W., and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15:383.

Kamstra, L. D., A. G. Moxon, and O. G. Bentley. 1958. The effect of stage of maturity and lignification on the digestion of cellulose in forage plants by rumen microorganisms *in vitro*. J. Animal Sci. 17:199.

Myhre, D. V., and F. Smith. 1960. Constitution of the hemicellulose of alfalfa (*Medicago sativa*). Hydrolysis of hemicellulose and identification of neutral and acidic components. Agr. and Food Chem. 8:359.

Patton, A. R., and L. Gieseker. 1942. Seasonal changes in the lignin and cellulose content of some Montana grasses. J. Animal Sci. 1:22.

Patton, A. R. 1943. Seasonal changes in the lignin and cellulose content of some Montana grasses. J. Animal Sci. 2:59.

Partridge, S. M. 1948. Filter-paper partition chromatography of sugars. I. General description and application of the qualitative analysis of sugars in apple juice, egg white and foetal blood of sheep. Biochem. J. 42:238.

Phillips, T. G., J. T. Sullivan, M. E. Loughlin, and V. G. Sprague. 1954. Chemical composition of some forage grasses. I. Changes with plant maturity. Agron. J. 46:361.

Routley, D. G., and J. T. Sullivan. 1958. The isolation and analysis of hemicelluloses of brome grass. Agr. and Food Chem. 6:687.

Snedecor, G. W. 1956. Statistical Methods (5th ed.). 310 p.

Soil Conservation Service. 1961. Technical guide for South Dakota. Mimeo.

Steppler, H. A. 1951. Pasture studies (XXXI) lignification studies with various grass species. Scientific Agriculture 41:1.

Sullivan, J. T. 1959. A rapid method for the determination of acid-insoluble lignin in forages and its relation to digestibility. J. Animal Sci. 18:1292.

Sullivan, J. T., T. G. Phillips, and D. G. Routley. 1960. Water-soluble hemicelluloses of grass holocellulose. Agr. and Food Chem. 8:152.

Tomlin, D. G., R. R. Johnson, and B. A. Dehority.1965. Relationship of lignification to *in vitro* cellulose digestibility of grasses and legumes. J. Animal Sci. 24:161.

Whistler, R. L., J. Bachrach, and D. R. Bowman. 1948. Preparation and properties of corn cob holocellulose. Arch. Biochem. and Biophys. 19:25.

Tolerance of Subclover, Rose clover, Hardinggrass, and Orchardgrass to 2,4-D

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Highlight

Species commonly used to seed California rangelands were sprayed with varying rates of the alkanolamine salt of 2,4-D at a number of vegetative growth stages in two different years. Subclover, hardinggrass, and orchardgrass were not permanently damaged by rates up to 2.0 lb/acre at any of the growth stages tested. Rose clover was tolerant of up to 0.5 lb/acre if sprayed at the proper growth stage but yields were frequently reduced by even low rates at other growth stages.

Much of the range improvement in the grasslands of cismontane California below 3,000 ft elevation involves the seeding of subclover (*Trifolium subterraneum* L.), rose clover (*T. hirtum* All.), and hardinggrass (*Phalaris tuberosa* L. var. *stenoptera* (Hack.) Hitchc.). These plants are sown alone or in mixtures to replace the well established, but less productive, annual vegetation. The resident annuals produce an abundance of seed and invariably result in an extremely weedy seedbed in spite of the best preparation. Although many of these annual weeds are grasses, the weeds in a new seeding on a seedbed prepared by cultivation are often predominantly broadleaves. Common among these are mustard (*Brassica* spp.), radish (*Raphanus* spp.), yellow star thistle (*Centaurea solstitialis* L.), filaree (*Erodium* spp.), and fiddleneck (*Amsinckia* spp.). There is a need for a selective herbicide to control these weeds.

The reaction of rose clover to 2,4-D (2,4-dichlorophenoxyacetic acid) was demonstrated by Williams and Leonard (1959). Both the propylene glycol butyl ether ester of 2,4-D and the alkanolamine salt of 2,4-D, applied at the rosette, early bud, and early bloom stages, caused significant reduc-

Table 1. Stage of growth at times of 2,4-D application.[1]

Experiment	Spraying date	Rose Clover	Subclover	Hardinggrass	Orchardgrass
First	1/29/65	1 trifoliate leaf	1 trifoliate leaf		
	2/26/65	5 to 6 leaves, 2–3 inch rosette	6 to 8 leaves, 1.5 inch rosette		
	3/9/65	10 to 20 leaves, 3 inch rosette	6 to 12 leaves, 3 inch rosette		
	4/1/65	vegetative—10 inch rosette	vegetative—10 inch rosette		
Second	12/8/65	unifoliate leaf	unifoliate leaf	2nd leaf just starting	1.5 leaves
	1/10/66	1.5 trifoliate leaves	1 to 2 trifoliate leaves, 1 inch rosette	1 inch, 3 leaves	1 inch, 3 leaves
	2/11/66	5 leaves, 2.5 inch rosette	5 leaves, 2.5 inch rosette	2 to 3 inches, 5 leaves, tillering	2 inches, 1 to 3 tillers
	3/2/66	3 to 4 inch rosette	3 to 4 inch rosette	4 to 6 inches, tillered	2 inches, tillered

[1] Linear measurements refer to diameter of rosettes in clovers and leaf lengths in grasses.

tions in forage and seed production of rose clover. Ormrod et al. (1960a, 1960b) found subclover was more tolerant to 2,4-D ester than were rose and crimson clovers (*T. incarnatum* L.). Treatment in the early flowering or bud stage produced significant reductions in both forage and seed yield of all three clovers.

The application of paraquat (1,1′-dimethyl-4,4′-bypyridinium) removed grassy weeds from rose and subclover (Kay, 1964), but cannot be used when hardinggrass occurs in the mixture. Fiddleneck can be killed with bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) without damage to the clovers or seeded grasses (Kay, 1967).

Two formulations and a number of rates of 2,4-DB (4-(2,4-dichlorophenoxy) butyric acid) were tested under cultivated conditions (Kay, 1963), on rose clover, subclover, and crimson clover at four to six growth stages varying from one trifoliate leaf to early ripe. Herbage yields, seed yields, and seed quality were for the most part unaffected by either formulation at the spraying dates which normally would be used for weed control. However, trials under range conditions showed 2,4-DB to be an ineffective weed killer. While some species were controlled, others seemed to be totally unaffected. These results have prompted another look at 2,4-D amine because of its broader weed-control spectrum. Hardinggrass was also included in one trial because of past reports (unpublished) that 2,4-D cannot be safely used with hardinggrass in the seedling stage. Palestine orchardgrass (*Dactylis glomerata* L.) was also included in one trial because of its popularity in range seeding.

Methods and Materials

Two separate trials were conducted on successive years (1964–65 and 1965–66). Both studies were on the Agronomy Farm at Davis (50 ft elevation). Rose clover and subclover were seeded in separate rows 36 inches apart before the first fall rain. The alkanolamine salt of 2,4-D (2,4-D amine—Dow Formula 40) was applied at four growth stages in each experiment (Table 1) at rates from ⅛ to 2.0 lb/acre. No surfactant was added; however, there may have been some present in the 2,4-D formulation. Spray treatments were applied to one row of each species at the same time, using a logarithmic sprayer (Yates and Ashton, 1960) with a half distance of 28 ft, spraying 43 gpa in the first experiment and 49 gpa in the second. Rows of hardinggrass and Palestine orchardgrass were also included in the second trial. Each treatment was replicated four times in a split plot design. Weeds were controlled by tillage and hand hoeing when soil moisture conditions permitted.

Clover yields were measured by clipping to ground level 8 ft of row centered over the half distance for the treatments listed. Samples were air dried before weighing. Seedling heights of hardinggrass and orchardgrass were measured on March 10, and on May 11 plants were rated on a 1 to 10 scale for damage from spraying. Clover seed yields were measured from selected treatments in the first experiment only.

Results and Discussion

Rainfall during the two experiments was very different. The 1964–65 growing season was very close to "normal" for the area. Total annual rainfall was 18.56 inches (slightly above normal) and well distributed throughout the growing season. Forage yields were typical for the area. By contrast the 1965–66 season received only 11.41 inches with a very dry spring. The last effective rainfall occurred on February 23, 1966. Forage yields were about 25% of the previous year (Fig. 1 and 2).

Both rose clover and subclover reacted to spraying with varying degrees of epinasty and strapped and cupped leaves. However, in many cases the

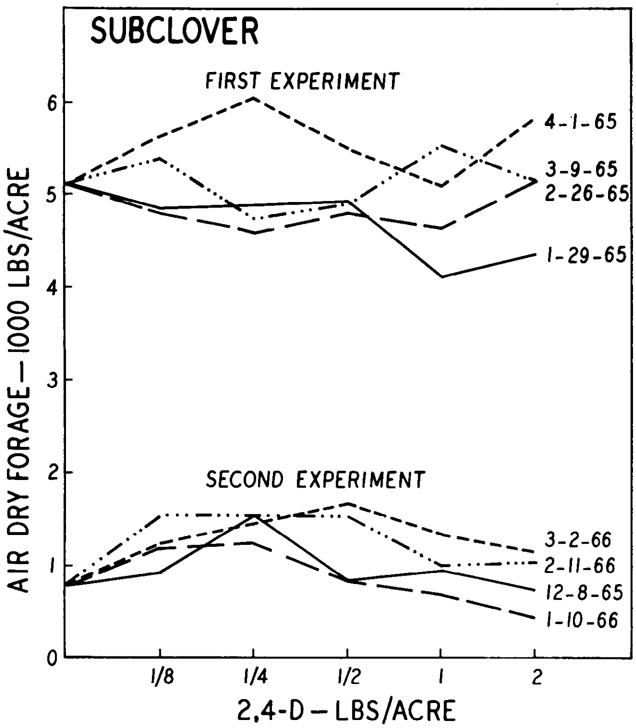

Fig. 1. Effects of varying rates of 2,4-D at four growth stages on forage production of subclover.

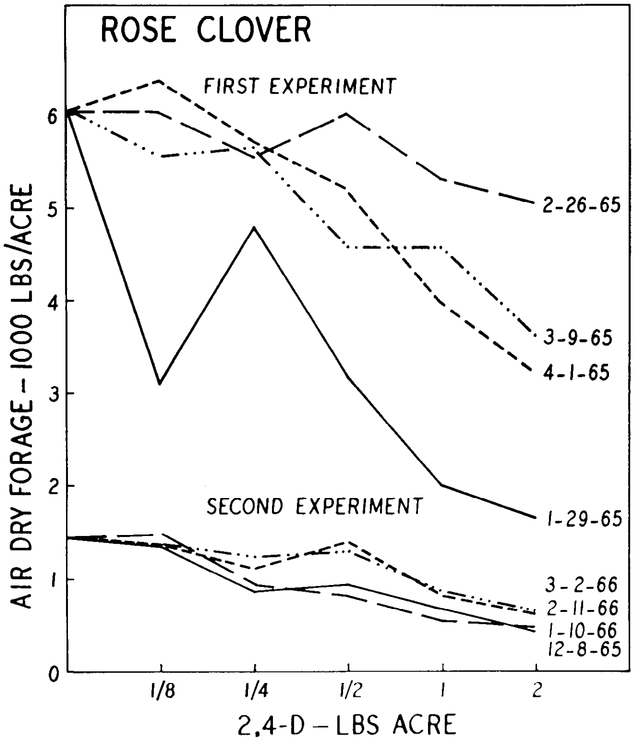

Fig. 2. Effects of varying rates of 2,4-D at four growth stages on forage production of rose clover.

plants completely recovered. There was no significant difference in forage or seed yields of subclover from any rates of 2,4-D at any of the growth stages in the first experiment (Fig. 1 and Table 2). In the second experiment forage yields were reduced at the .05 level of significance only by the 2-lb rate at the second growth stage. Yields were actually increased by many treatments because of the early weed control before tillage.

Rose clover was more severely damaged than subclover. In the first experiment, differences due to 2,4-D rates, growth stages, and the interaction of rates times growth stages were all significant at the .01 level. Forage yields were reduced by the 2-lb rate at all growth stages, and by the 1.0-lb rate at all but the second growth stage (Fig. 2). The first spraying date produced the greatest damage. Yields were reduced by all rates at this date.

Table 2. Effect of 2,4-D treatments on seed yields (lb/acre), first experiment.

Treatment date	2,4-D—lb/acre			
	Subclover		Rose clover	
	0.5	2.0	0.5	2.0
1/29/65	800	660	510	250
2/26/65	790	860	1080	880
3/9/65	800	810	820	640
4/1/65	780	870	642	460
Check	830		1050	

Results of the second experiment were very similar. Again, rose clover forage yields were reduced at all growth stages by the 2.0-lb rate, and by the 1.0-lb rate at the first two growth stages.

With the exception of the earliest growth stage 0.5 lb of 2,4-D was safely used on rose clover. Severe leaf deformations occurred at these rates, but the plants recovered to a degree that would be termed satisfactory under range conditions. Also, under range conditions weeds would intercept much of the 2,4-D and the clover would receive a much lower dosage. Seed production would be more than adequate to regenerate the species the following year.

However, 2,4-D cannot be safely used on rose clover grown for seed. Seed yields were significantly reduced by both the 0.5 and 2.0-lb rates at all but the second spraying date (Table 2). Seed yield was reduced 50–75% by some treatments. Yield reductions from the 2.0-lb rate were not significantly greater than at the 0.5-lb rate.

Spraying at the second growth stage of the first experiment (5 to 6 leaves) produced far less damage to either forage or seed yield of rose clover than spraying immediately before or after. However, this temporary immunity appears to be of little value in making a recommendation, as the following spraying, 11 days later, produced severe damage. The "safe" spraying occurred at the beginning of a period of very rapid growth. The tolerance may be correlated with this growth rate rather than the size of the plant, because plants sprayed at a similar size the following year did not show this tolerance.

Hardinggrass and Palestine orchardgrass were not damaged at any of the combinations of rates and growth stages tested. There were no differences in seedling height or other damage symptoms. The first two applications were followed by a very wet fog the following night which probably resulted in some runoff from the sprayed plants to the root zone. Still, no mortality was noted.

The results of these trials indicate that 2,4-D may have a much more prominent place in controlling weeds in range seedings than had been supposed earlier. The experiments by Williams and Leonard (1959) showed severe damage to rose clover by rates of 2,4-D amine as low as 0.75 lb/acre. However, most of their applications were made at later growth stages to coincide with brush control practices rather than control of herbaceous weeds. Also the damage they measured using amine in the 2-inch rosette stage would not prohibit the use of 2,4-D. Ormrod et al. (1960a, 1960b) tested only the less selective ester formulation and again sprayed at later growth stages than would be used for herbaceous weeds.

In view of the results reported here it seems safe to use the alkanolamine salt of 2,4-D on subclover, hardinggrass, and orchardgrass at rates as high as 2 lb/acre to control herbaceous range weeds in new seedings. Normally spraying would be done at 0.5 to 1.0 lb/acre when the weeds are small. Up to 0.5 lb/acre could also be used on rose clover grown for forage recognizing that moderate damage will result to the clover. Moderate damage in the seeding year is preferable to a seeding failure due to weed competition.

LITERATURE CITED

Kay, Burgess L. 1963. Effects of 4-(2,4-DB) and dalapon on three annual trifoliums. Weeds 11:195–198.

Kay, Burgess L. 1964. Paraquat for selective control of range weeds. Weeds 12:192–194.

Kay, Burgess L. 1967. Bromoxynil on rose clover, subclover, hardinggrass and Palestine orchardgrass. Research progress report. Western Weed Control Conf., p. 14–15.

Ormrod, D. P., and W. A. Williams. 1960a. Vegetative and reproductive growth response of three trifolium species to 2,4-D. Agron. J. 52:229–234.

Ormrod, D. P., W. A. Williams, and B. L. Kay. 1960b. Growth responses of three annual clovers to treatments with 2,4-D. Parts I and II. California Agr. 14(7 and 8): 7–8, 6–7.

Williams, W. A., and O. A. Leonard. 1959. Effect of 2,4-D on growth, seed production, and seed viability of an annual reseeding clover. Agron. J. 51:383–387.

Yates, W. E., and F. M. Ashton. 1960. Logarithmic dosage sprayer. Agr. Eng. 41:436–438, 442.

Ranching in Panama[1]

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Highlight

Grass and cattle are an important part of Panama agriculture. Ninety percent of all grassland contains one or more introduced grasses. Brush control, fire control, and improvement in grass and livestock management are major problems. Cattle are grown and finished for market on grass. Low calf crops, disease and parasites, poor dry season feed conditions, and low-quality animals result in a generally low beef production per cow. Improved grazing practices and sound livestock management will result in higher calf crops and increased beef yields. Potential exists for a sound and economically profitable ranching enterprise.

La Ganaderia en Panama

Resumen

Los pastizales y el ganado son una parte muy importante de la agricultura de Panamá. El 90% de las tierras de pastoreo contienen una ó más especies de gramíneas introducidas. El combate de arbustivas, el control de las quemas, y el mejoramiento tanto de las plantas forrajeras como del ganado son de los problemas más importantes.

El ganado se cría y se engorda para el mercado en los potreros. Los bajos porcentajes de parición, las enfermedades y los parásitos, el bajo valor nutritivo de los forrajes durante las épocas de sequía, y los animales de calidad inferior traen como consecuencia, por lo general, una baja producción por vaca. Mayores porcentajes de parición y aumentos en el rendimiento de carne podrán lograrse mediante prácticas de pastoreo mejoradas y un manejo adecuado del ganado.

La ganadería en Panamá ofrece un buen potencial para establecer empresas remunerativas.

Panama is best known as the narrow strip of land which connects the two Americas, and as the location of the strategic Panama Canal which makes events in this area of worldwide importance. Panama is a small country some 400 miles long and 40 to 150 miles wide. It is bisected by a mountain chain only about 200 ft high at the lowest point, rising to 11,000 ft at the high point near the Costa Rica boundary. Temperatures are tropical except where elevations act to moderate the heat. Precipitation is from 1,000 to 5,000 mm annually, with a dry season of 100 to 130 days. Rainfall is adequate

[1] Information compiled by the author while employed by International Engineering Co., San Francisco, California, servicing the Agrarian Reform Project in Panama.

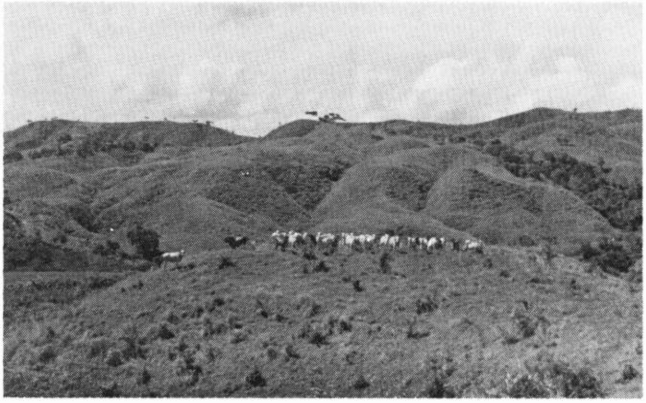

FIG. 1. Much of the grazing land in Panama is on steep slopes, where forage production is often high. Cattle graze readily on very steep lands.

to abundant in the wet season and drouth is frequently severe in the dry season. Precipitation is higher on the Atlantic slopes but this discussion is limited to the populated areas along the Pacific slopes and the vicinity of the Canal.

Cattle in Panama are grown and finished on grass with little or no supplemental feed. Grass is a major land use but a considerable percentage of it is derived from tropical savannah and from clearing tropical forest. Much of the land is not suited to crops and cultivation but is maintained in satisfactory condition in either forest or grass when supported by correct practices (Fig. 1).

Cattle and grassland not only provide a sound land use but also provide employment and subsistence for comparatively large numbers of people, as well as an important contribution to the national economy.

The Pacific coast has always been the principal area of habitation. The alternating wet and dry seasons offer a much more pleasant and healthful climate and well-adapted to production and harvesting of crops.

Ecology

Considerable variation occurs in rainfall and temperature and there is a corresponding variation in soil and vegetation. Space does not permit a complete treatment of the area ecology but it is evident that the natural or climax vegetation is determined by the length and severity of the dry season as well as by the amount of precipitation. Tropical forest is the most extensive plant formation with variations from a low but dense scrub, to a tall four-story rain forest, although the rain forest is outside the area of this discussion for the most part. There is no question that plant cover has been greatly influenced by man in the inhabited sections and many plants now found are indicators of man's treatment rather than an index of natural vegetation. Some species, of which a scrub tree, *Curatella americana*[2], is the best example, prefer open sun and are resistant to fire, grazing, and other acts of man. These are now apparent dominants in localities where such plants would not occur in the natural vegetation. Precipitation of about 2,500 mm produces tropical forest with a dry season of 100 to 120 days.

There appears to be adequate basis for accepting savannah as the natural vegetation on upland soils in the 1,000 to 2,500 mm zone of precipitation where the dry season is severe. The deep alluvial soils have a forest climax in the most arid climate found in Panama.

The savannah vegetation is typical tropical savannah. *Curatella americana* is probably the most common scrub tree, often called sandpaper tree because of the large rough leaves, but is called chumico locally. *Anacardium occidentale* or Cashew nut, *Brysonima crassfolia* or nance, and a number of other xerophytic species are common. Xerophytes are represented in grasses and sedges by one or more species of such genera as *Trachypogon, Muhlenbergia, Aristida, Andropogon, Paspalum, Scleria, Bulbostylis,* and many others.

Seeding of exotics, brush control, and other treatments are applied on grassland regardless of original plant cover, and most grassland has scrub brush in the cover. Consequently the boundary between true forest and savannah is essentially of academic interest except as a question of competition of land use arises. The land suitable for cultivation is limited, the relative competitive position of cropland and other uses is not to be explored here but obviously cultivation is a high priority use when soil and topography are suitable. An extensive area of savannah and scrub forest is more useful and productive in grass than in trees except under intensive treatment not found in current tree culture practice in Panama. Both forest and grassland use are suitable uses for resource conservation when supported by correct treatment.

Native Grazing Plants

Some of the native grasses are excellent forage but many of the dominants are coarse harsh bunchgrasses of low palatability. Representative dominants on good upland sites are *Andropogon bicornis, A. angustatus, Paspalum virgatum, Panicum grande, Manisuris aurita, Setaria tenax.* The dominants on shallow arid sites include *Trachypogon secundus, Andropogon leucostachys, Axonopus aureus, Muhlenbergis emersleyii, Paspalum humboldtianum, Aristida tincta.* Wet land dominants include *Paspalum virgatum* and numerous sedges

[2] Identification of grasses and forbs principally by Florida State University, with a limited number by the author after Swallen (1943). Tree identification by Forestry Division of Panama Dept. of Agriculture.

and rushes. The habitats of these grasses are intermixed and overlap into both wetter and drier sites. Some species of *Paspalum* are common intermediate grasses. *P. plicatulum* is the most important of these and grows on practically all sites but is seldom a dominant on a sizable area.

There is an important understory of shorter grasses that fill in the interstices even on arid sites. Density is normally very high on all sites and any openings in the grass cover are a sign of depletion. Understory grasses are often stoloniferous or rhizomatous or both. *Axonopus compressus* and *Homolepis aturensis* are the most common on all but the very wet and very dry sites. Other common grasses are *Paspalum notatum, P. multicaule, P. conjugatum, P. pilosum, P. microstachyum, Panicum polygonatum,* and *Erogrostis maypurensis. Bouteloua repens* and *Axonopus purpusii* are common on arid sites and often form a sod under misuse, providing good grazing but low in productivity.

Sedges occur frequently on all sites. *Dichromena cilatus* (ojo del gato) is the most frequent and grows in all grassland but has little grazing value. *Cyperus, Fimbristylis,* and *Rynchospora* are common genera. *Bulbostylis* and *Scleria* are usual on arid and sandy sites. *Eleocharis* and *Equisetum* are frequent on wet land sites.

Shrubs and forbs do not make a significant part of the plant population in high condition grassland. *Mimosa albida* is a small creeping shrub that is nearly always present in grassland and may increase under misuse. It is sometimes grazed and is considered toxic. Species of *Heliconia* and *Sida* are shrubs 4 to 10 ft tall which readily invade grassland when there is any appreciable loss of the tall grass. When these shrub species gain a foothold they usually overtop the grass, and become dominant unless checked. These are nurse cover for trees and other shrubs and often eliminate grass. The land reverts to brush of doubtful value although good forest will reclaim favorable sites rapidly.

Introduced Grasses

Questionable value of many native dominants led to early efforts to improve the forage by introducing better grasses. Remarkable success has been achieved and much improvement in forage quality and yields has been obtained from exotics that have been established. Earliest introductions date back more than a half century in some localities. Some of the same species are major components of grasslands in neighboring Costa Rica and may be the source of the seed. The use of improved seedings is more recent in other sections of the country and has occurred in the past 25 years.

Melinis minutiflora (calingueiro or molasses grass), one of the first introductions, thrives in intermediate elevations and is a dominant on steep hills including areas too rough for grazing. It is fairly good forage but does not endure heavy trampling well.

FIG. 2. Faragua (*Hyparrhenia rufa*) is the most important grass in Panama. It is a tall grass readily attaining heights of 6 to 9 ft.

Panicum purpurascens (Para grass) is widely used on low, wet lands. It is six to ten ft tall and produces heavy yields. It is good forage and well suited for land too wet for most good forage plants.

Panicum maximum (Indiana or Guinea grass) is a tall coarse grass well adapted to deep soils and requires good moisture situations. It is reasonably good forage but the large coarse bunch presents a utilization problem.

Hyparrhenia rufa (called faragua in Panama or jaragua in most of Latin America) is a tall high-yielding grass adapted to shallow soil in all but the most arid situations in Panama (Fig. 2). It is the most widely used grass in the country and is the backbone of the grazing industry. It has problems in use but is reasonably good forage.

Pennisetum purpureum (elephant grass or Napier) is a good performer but requires abundant moisture to produce well and is not well adapted to the most arid lands in Panama.

Pennisetum clandestinum (Kikuyu) is the only sod grass of the exotics. It is adapted to elevations of 4,000 ft and higher and is the most common grass in the limited area of high elevation grazing land.

Digitaria decumbens (Pangola) is a recent introduction, but is very popular. It is palatable, yields well, and is high in protein. It is demanding in its requirements for moisture and fertile soil and must be regarded as restricted in its adaptation. It is essentially a cultivated grass.

A number of other grasses are now used in limited acreages and in a few localities. Still others are in process of trial and show promise. All those in use have important limitations but also have decided advantages and may be expected to be in common use for the foreseeable future.

It is too early to evaluate exotics in relation to native grass. Some as faragua, calinguiero, and Kikuyu have demonstrated ability to invade adjacent native stands under a variety of conditions. This is of perhaps less importance than in many places because most grassland, whether from natural grassland, savannah, or developed by clearing forest, has been seeded. Seeding is not difficult and stands are normally fairly easy to establish. Census reports indicate 90% of the grazing land in use has been seeded to one or more exotic species. The same understory of short and intermediate grasses is present, or develops in a short time, on land seeded to exotics as is found on good condition native grassland. A dense stand of exotics is not susceptible to invasion by brush in any quantity and will remain dominant as long as it is given correct use. Brush will invade the more susceptible areas where there is even a brief period of overuse.

Brush and Fire

Natives hacked away at brush and forest and burned it to make fields for crops for centuries. A few years of crops followed by abandonment brought a return of the forest and a renewal of the soil resources. A much more frequent and intensive application of cut and burn brings grassland and this has occurred in parts of Panama. The process is aided by seeding but undesirable brush species are not destroyed by this process. Topgrowth may be killed but rootsprouting follows and brush maintains its foothold. Recutting is necessary at intervals, followed by fire to destroy the residues. Some brush may be reduced on the surface by fire without cutting but the two processes are applied together for satisfactory control. This is a laborious and expensive operation, but where brush is a problem; failure to apply control means that any brush present will overtop the grass and soon becomes dominant.

Cutting well below the soil surface probably will eradicate the brush but rocky terrain and lack of suitable equipment prevent widespread application of this method. Chemicals offer the most promising results but require much more trial work to be effective.

Grassland is burned frequently in much of the country. Whether it is grazed appears to make little difference and custom must be considered as the basic reason for much burning. Fire is helpful in disposing of the residues which accumulate and some believe it helpful to grass. Organic residues in burned materials are released and are readily used by new growth; they are as readily carried away by erosion which always take toll after a fire.

A few more advanced and successful ranchers do not practice burning. The Department of Agriculture has started to work on the problem and has issued regulations which represent progress, although these are not nearly adequate for the needs. There is need for appraisals of values, detriments, alternatives, and a program of research and mass education to deal with the problem of fire.

Grazing Management

Correct use of grass is a problem here as in other areas of the world where range and pasture grazing is applied. Overgrazing is common and sometimes severe, although there is much grassland that is not subjected to heavy grazing. There is a surprisingly good understanding of correct use by the local users including many of the small operators.

Tall grass is very susceptible to depletion by any type of misuse. Continuous grazing will require maintenance of a height of 20 inches of ungrazed residue. This is conducive to spot use and is difficult to maintain when needs for dry season reserves and variation in growth rates are considered. Rotation grazing is a practical solution and the only one that has been developed to date. Many ranchers prefer to permit a height growth of about four ft, followed by grazing the stubble as short as practical depending on the species. With this system natural seeding will usually be adequate and the plant vigor is maintained.

A short grass cover is not only much less productive but is difficult to maintain because when there is adequate light near the ground, invasion of undesirable plants is serious.

Grazing lands are productive and carrying capacity is high. The national census shows an animal unit population of a grazing animal on a little less than a hectare (2.48 acres). A cow per hectare is a widely quoted rule of thumb. Normal upland tall grass with 80 inches rainfall will support a cow/ha with proper grazing use; 1.25 ha may be needed on the lowest rainfall and on poor soils. A sizable acreage of mountain grassland is of no significant value for grazing because of rugged terrain and low quality forage. Wetland in Para grass, fertilized Pangola, and grasses on high rainfall mountain land or irrigated land may support three to four animals/ha.

Ranch improvements are usually modest. Fences are nearly always adequate to carry out a rotation grazing plan and to permit good livestock management, although not always located to take advantage of terrain for good distribution of grazing. Cropland is not always fenced and poses a problem in control. The ephemeral nature of cropping practices in areas of slash and burn and abandonment in a few years increases the difficulty of protecting cropland.

Many do not have title to the land occupied and

FIG. 3. Steers fattening on Pangola grass on alluvial land in the dry season. Moisture is adequate here for good growth of this very palatable grass.

occasionally conflicts arise. Ownership is a major problem in many localities where people have occupied the land for generations without title. Ef forts are now being made to correct this situation to transfer title to legitimate users.

Livestock water is not a problem in the wet season but is a major deficiency in many localities in the dry season, often resulting in moving animals considerable distances to find water. Grazing land is at a premium along permanent streams and over-grazing is a frequent result of scarce water supplies. In much of the area the solution is in wells or surface ponds which would be entirely adequate for the relatively short period of inadequate stock water.

There is little or no difficulty in distribution of grazing on the steep slopes common in Panama. Cattle seem to like the steep hills because of better air drainage resulting in lower temperatures and less insect pest activity. Soils on steep slopes are younger and may have a more favorable mineral content and there may be other factors.

Livestock Operations

The first Spanish settlers introduced cattle in the savannahs and added grazing acreage by clearing forests, making use of negro slaves and native slaves as labor. Ranching quickly became the principal agricultural activity. However, ranching was virtually static for centuries and livestock production at the turn of the century was low and quality of feed and animals was poor. Numbers of cattle have increased steadily from about 60,000 in 1903 to approximately 1,000,000 in 1965. Important factors in growth of cattle raising are increase in market demand, introduction of better forage grasses, improvement in breeding animals, and developments in disease and parasite control.

Cattle are grown and finished on grass (Fig. 3). The normal age of marketing is 30 to 36 months at 900 to 1,100 lb. Prices are controlled by the Federal Government and premature slaughter of lightweight unfinished cattle is discouraged by penalty prices.

Cattle are predominantly Brahman breeding but the crossbred Santa Gertrudis and Brangus are fairly common. There are a number of good purebred herds and the quality is improving rapidly in the commercial herds. There is room for a great deal of further herd improvement but quality is adequate for much better production than is now achieved.

Dairy production is locally important in some sections. Brown Swiss, Red Sindi, and Holstein breeding is usual for the dairy cattle. There are some well-managed dairies and many beef producers milk cows to supplement income and to provide employment for the labor force. Milk trucks have routes along most of the all-weather roads to collect milk. The surplus is processed as evaporated milk.

Herd improvement, higher calf crops, disease and parasite control, rigid culling of old and inferior animals, and correction of forage and nutritional deficiencies are some of the needs to achieve higher production per breeding cow and effect a needed improvement in the profit margins.

Calf crops are usually 50% or less with a few exceptions. Actual death loss varies but is relatively high. Loss from effects of parasites is greater than is usually recognized.

Breeding cows suffer from poor nutrition in the dry season and do not breed regularly as a result. An adequate supply of grass is important but does not solve this problem, because the dry grass is deficient in nutritive qualities. It can be solved by stored feed as hay or by green forage on irrigated or wet land. Many ranches have no wet lands of consequence for reserves and hay making is not practiced although it has definite possibilities. A controlled breeding season to drop calves at the end of the dry season or beginning of the wet season and weaning calves early in the dry season to enable cows to be carried through the dry season with the lowest demands on them will do much to correct the problem.

Mineral deficiencies are severe in much of the country. Phosphorous or calcium or both are lacking in most areas with the possible exception of some of the mountain grazing lands. Mineral feeding is a high-cost cash outlay many hesitate to incur but is showing excellent results on a few ranches which supply the needed minerals. Summing up, adequate grass of the best quality possible with reserves for the dry season, controlled breeding seasons, and weaning calves on schedule will result in more regular breeding cows and increased calf crops.

Protein deficiencies occur but do not prevent high production. Imported protein feeds are too expensive to be feasible for general use. Legumes have not been developed to supply the need and native legumes are generally unpalatable.

Disease and parasites are virtually always serious problems where there are moist conditions in the tropics and the severity of the problem is not always recognized. Death loss is not severe except for outbreaks that occasionally occur. Loss in condition and in animal health and well being is less evident but is probably equally serious. The development in use of antibiotics and control measures for both disease and parasites makes it possible and feasible to correct problems in animal health. A few progressive ranchers have demonstrated the advantages of improved sanitation.

The application of improved husbandry practices together with rigid culling and a program of herd improvement will undoubtedly increase calf crops, reduce losses, and result in a much more vigorous and faster gaining herd and better performance by animals. The market yields of beef and milk can be increased tremendously. A program of mechanical and chemical brush control will greatly reduce the cost of treatment and lead to a reasonably permanent control.

Technical aid and sometimes financial help is a particular deficiency for small ranchers. Too often aid that has been available has been concentrated on large operators who are sometimes better able to respond but who also have less need for assistance. Progress is too often measured by mechanized operations and criteria suitable for a much more advanced agriculture than the present farms of Panama can be expected to handle. Native ranchers have acquired a surprising knowledge of the principles of grazing management and are eager to learn, although handicapped by local fears and prejudices. Specialists in grazing management are one important need that has been overlooked thus far. Both the land and its people have a potential for a much higher level of production if given correct direction.

BIBLIOGRAPHY

Anderson, Chas. L. 1911. Old Panama and Castillo del Oro. North River Press. New York.

Bennett, H. H. 1929. Soil reconnaissance of the Panama Canal Zone and Contiguous Territory. U.S. Dep. Agri. Tech. Bull. 94. 46 p.

Guzman, Lewis E. 1956. Farming and farm lands in Panama. Univ. of Chicago Press. Chicago, Ill.

Holdridge, L. R., and Gerardo Budowski. 1956. Report of an ecological survey of the Republic of Panama. Caribbean Forester 17:92–110.

Johnson, I. M. 1949. Botany of San Jose Island. Lancaster Press, Lancaster, Penn.

Lothrop, Samuel. 1937. Archeology of Central Panama. Peabody Papers, Part 2, Harvard Univ. Press, Cambridge, Mass.

Maddox, Thos. J., Jr. 1945. Agriculture in Panama, present and potential. Inst. Interamerican Affairs, U.S. State Dep. 45 p.

Quesada, Luisa E. Directoria, Censos Nacionales de 1960. Republic of Panama. Panama City.

Servicio Interamericano de Cooperacion Agricola en Panama. 1958. Agriculture in Panama. Division Natural Resources, Panama Dept. of Agriculture.

Standley, Paul C. 1928. Flora of the Panama Canal Zone. U.S. Nat. Herb. Washington, D.C. 416 p.

Swallen, Jason R. 1943. Grasses of Panama. Annals of the Missouri Bot. Garden. 30(2) St. Louis, Mo. 390 p.

Stryker, M. M. 1952. Soil and land investigation in Panama. Office of Foreign Agricultural Relations, U.S. Dep. Agri. Washington, D.C. 60 p.

Two New Journal Features

Did you notice our new Journal feature in the May issue, p. 185–187? It is called "Viewpoints," a section for the statement of individual views on subjects of interest to range men—statements more complete than a simple letter to the Editor, but without the formal status of an Editorial. Editorial Board member "Hoop" Hooper suggested the idea. Your reactions are solicited.

The ASRM Board of Directors approved inclusion of a "Resumen en Espanol" for selected Journal papers, starting with this July issue; see p. 242 and 255. Initial translations prepared by Dr. Martin H. Gonzalez, of the Mexico Section in Chihuahua.

—*R. S. Campbell,* Editor

Rates of Seeding Rambler Alfalfa with Dryland Pasture Grasses

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Highlight

Rambler alfalfa, crested wheatgrass, and Russian wild ryegrass were combined to give five rates of seeding. These rates were achieved by mixing 0.25, 0.5, 1.0, 1.5, and 2.0 lb of the alfalfa with 3 lb of seed of each grass and seeding the mixtures at these rates per acre. In four of the seven harvest years the mixture seeded at 1 lb/acre of alfalfa significantly outyielded those seeded at 0.25 and 0.5 lb/acre, however, there was no difference in yield between the three highest rates of seeding treatments. Increasing the seeding rate of alfalfa resulted in increased plant density of the mixture by increasing the alfalfa component while not affecting the density of the grass component. It was concluded that the creeping-rooted Rambler alfalfa need not be seeded at a rate exceeding 1.0 lb/acre when grown in combination with grass for dryland forage production.

The creeping-rooted alfalfa variety Rambler (*Medicago media* Pers.) was developed especially for use in the dry prairie plains of Canada (Heinrichs and Bolton, 1958; Heinrichs, 1954). Heinrichs, in discussing the agricultural possibilities of creeping-rooted alfalfas, suggested that more agronomic research would be required before the true value of the creeping-rooted character could be assessed.

The excellent winterhardiness of Rambler has been demonstrated in several Canadian studies (Ashford and Heinrichs, 1967; Heinrichs and Bolton, 1958; Heinrichs, 1963; Heinrichs et al., 1960). The superior persistence of Rambler over other alfalfa varieties when grown in competition with grasses over a period of dry years has also been shown (Kilcher and Heinrichs, 1966; Kilcher et al., 1966; Kilcher and Heinrichs, 1966).

This study was undertaken to determine the minimum rate at which Rambler alfalfa may be seeded in pasture mixture with crested wheatgrass (*Agropyron cristatum* L.) and Russian wild ryegrass (*Elymus junceus* Fisch.) without sacrificing yield.

Materials and Methods

Rambler alfalfa seed was mixed in increasing amounts with a fixed amount of grass seed to provide five rates of seeding. In lb/acre the mixture seeding rates were 6.25, 6.5, 7.0, 7.5, and 8.0. Each rate treatment contained 3 lb/acre of Russian wild ryegrass and of crested wheatgrass. Thus, grass made up a fixed 6 lb/acre amount within each treatment with the remainder being alfalfa seed. Alfalfa was therefore included at 0.25, 0.5, 1.0, 1.5, and 2.0 lb/acre. In number of seeds the ratio of alfalfa to grass in the five rate treatments was approximately 1 : 20, 1 : 10, 1 : 5, 1 : 3, and 1 : 2.

The test was seeded in 1955 on a dryland, fallow, clay–loam soil at Swift Current, Saskatchewan. Plot sizes were 6 × 30 ft with interrow spacings of 12 inches. The design of the test was a random block with 6 replications.

Data were obtained in 1956 and continued for 6 successive years thereafter. They included 2 cuttings a year for dry matter yield determinations and yearly estimates of stand and composition as determined by the point quadrat method. The cuttings were made during the first half of June and during the latter part of July or early in August, whereas estimates of stands were determined in May of each year. Recovery and regrowth after the second cutting were never sufficient to warrant taking a third cutting.

Results and Discussion

Dry Matter Yield.—Dry matter yields and year-to-year variation in yields were typical for grass–alfalfa mixtures grown in the semiarid brown soil region of the Canadian Prairies (Clark and Heinrichs, 1957; Kilcher and Heinrichs, 1966). In four of seven years mixtures containing 1.0 lb/acre of alfalfa produced significantly (P = .05) higher seasonal D.M. yields than treatments having less alfalfa (Table 1). However, there was no further increase in yields at the alfalfa rates higher than 1.0 lb/acre. The 7-year annual average yield advantage from the 1.0 lb/acre of alfalfa was 38% greater than that from the treatment containing 0.25 lb/acre of alfalfa and 26% greater than the one containing 0.5 lb/acre of alfalfa.

The increased yields from the treatment containing 1.0 lb/acre of alfalfa seemed more marked in

Table 1. Seasonal grass–alfalfa mixture yields (lb/acre) from two cuttings in each of seven years.[1]

Seeding rate treatment lb/ac	Annual dry matter yields							
	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	7-yr av
6 grass + 0.25 alf.	1771	755	366	774	846	373	607	784
6 grass + 0.5 alf.	1841	801	413	899	978	428	656	860
6 grass + 1 alf.	2562	909	511	1159	1128	407	905	1082
6 grass + 1.5 alf.	2473	820	491	1192	1132	458	783	1050
6 grass + 2 alf.	2562	750	488	1053	1116	401	749	1017
Mean	1362	808	454	1016	1014	414	741	886
D value (P = .05)	640	N.S.	142	249	230	N.S.	N.S.	237
S.E.M. %	11.1	12.7	13.1	9.4	10.4	17.1	15.2	6.1

[1] Annual precipitation for each of the 7 years 1956 to 1962, inclusive, was 13.2, 11.8, 11.5, 14.0, 12.4, 8.9, and 13.2 inches.

Table 2. Comparisons between first and second cuttings for yield advantages of mixture containing 1 lb/acre of alfalfa.

	Relative yield[1]	
Year	First cutting	Second cutting
1956	129	151
1957	114	122
1958	122	137
1959	121	152
1960	119	132
1961	108	129
1962	143	131
Mean	122	136

[1]Relative yield of mixture having 1 lb/acre alfalfa as percent of mixtures having less alfalfa.

the second cut (Table 2). Second cut from grass–alfalfa mixtures is traditionally richer in alfalfa than from the first cut since the deeper rooted legume is better able to recover and grow. This probably explains why the treatments containing a higher proportion of alfalfa show an increased yield benefit in second cuttings.

Basal Cover and Composition.—The basal ground cover of the grass component was virtually unaffected by differences in alfalfa seeding rates (Table 3). On the other hand, the different seeding rates of alfalfa did result in notable differences in the basal ground cover of the legume, particularly between the 0.25, 0.5, and 1.0 lb/acre levels (Fig. 1). Above the 1.0 lb/acre rate the differences in alfalfa ground cover were small. A similar relationship between treatments was measured for the percent composition of alfalfa within each mixture (Fig. 2).

It was concluded that where Rambler alfalfa is grown with adapted dryland grasses in the semiarid region of the more northerly part of the Northern Great Plains it should be included at a rate not less than 1.0 lb/acre, and that there is little or no advantage in seeding it at higher rates.

Table 3. Relative basal ground cover of the grass component (in percent) throughout the test years.

Seeding rate treatment lb/ac	Year						
	1st	2nd	3rd	4th	5th	6th	7th
6 grass + 0.25 alf.	5.0	12.1	20.4	19.4	23.6	22.2	21.5
6 grass + 0.5 alf.	5.4	10.1	19.3	18.2	24.0	22.8	21.6
6 grass + 1 alf.	5.2	12.6	19.0	18.9	23.6	22.5	21.9
6 grass + 1.5 alf.	4.8	11.6	19.6	19.0	23.8	22.0	21.0
6 grass + 2 alf.	4.3	9.9	19.9	18.6	22.2	21.6	20.0
Mean	4.9	11.3	19.6	18.8	23.4	22.2	21.2
D value (P = .05)	1.0	2.4	N.S.	N.S.	N.S.	N.S.	N.S.

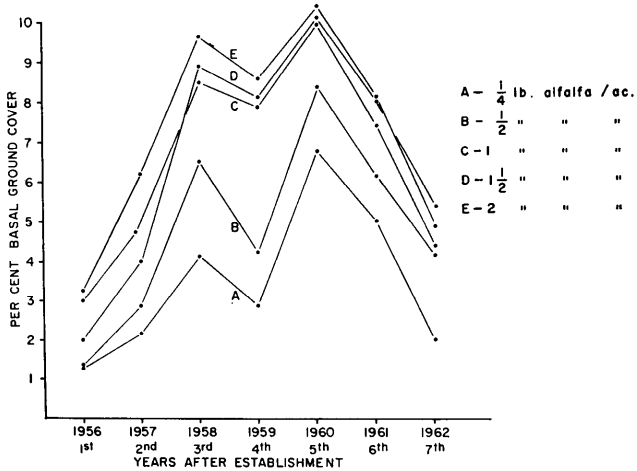

FIG. 1. Relationship of ground cover of Rambler alfalfa and rate of seeding.

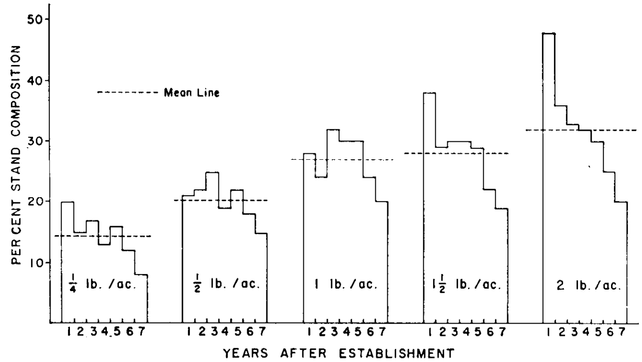

FIG. 2. Percent of total stand made up of Rambler alfalfa as influenced by seeding rate.

LITERATURE CITED

ASHFORD, R., AND D. H. HEINRICHS. 1967. Grazing trial of alfalfa varieties and observations on bloat. J. Range Manage. 20:152–153.

CLARK, K. W., AND D. H. HEINRICHS. 1957. Grass–legume mixture trials. Can. Dep. Agr. Proc. Bull. 29 p.

HEINRICHS, D. H., AND J. L. BOLTON. 1958. Rambler alfalfa. Can. Dep. Agr. Publ. 1030. 15 p.

HEINRICHS, D. H. 1954. Developing creeping-rooted alfalfa for pasture. Can. J. Plant Sci. 34:269–280.

HEINRICHS, D. H. 1963. Creeping alfalfas. Advances in Agronomy. V. Academic Press, Inc. New York. P. 317–337.

HEINRICHS, D. H., J. E. TROELSEN, AND K. W. CLARK. 1960. Winterhardiness evaluation in alfalfa. Can. J. Plant Sci. 40:638–644.

KILCHER, M. R., AND D. H. HEINRICHS. 1966. Persistence of alfalfas in mixture with grasses in a semiarid region. Can. J. Plant Sci. 46:163–167.

KILCHER, M. R., K. W. CLARK, AND D. H. HEINRICHS. 1966. Dryland grass–alfalfa mixture yields and influence of associates on one another. Can. J. Plant Sci. 46:279–284.

KILCHER, M. R., AND D. H. HEINRICHS. 1966. Performance of some grass–alfalfa mixtures in southwestern Saskatchewan during drought years. Can. J. Plant Sci. 46:177–184.

The Effects of Fire on Seed Germination[1]

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Highlight

Fire is characteristically used in the pineywoods of the Southeast to produce repetitive abundant stands of native legumes. However, results are frequently erratic and unpredictable. Seed germination results following simulated fire conditions are presented. Results show dry heat ineffective in increasing germination, whereas moist heat greatly increased both germination rate and total germination of some species of seed.

Terms such as "fire climax" and "fire species" have been used to describe plant communities in the Southeastern part of the United States for a long time. Probably one of the best known "fire communities" is the pine–wiregrass–legume association common in the Georgia–Florida flatwoods.

Although the use of fire as a land management tool has undergone periods of severe criticism—sometimes justifiable—the last 20 to 30 years of research have made necessary a rather drastic reorientation of our ideas about fire as an ecological factor. Odum (1953) stated: "It is now evident that fire should be considered not a minor or abnormal factor but a major factor which in many regions is, and has been for centuries, almost a part of the normal climate." Classic works concerning the ecological effects of fire are those by Ahlgren in Minnesota; Biswell and Sampson in California; Bruce, Chapman, Garren, Stoddard, Green, and Wahlenberg in the South; Weaver in the Ponderosa country of the West; Lutz in Alaska; and Little in the pine barren region of New Jersey, plus many others. However, references dealing with the specific effects of fire on such a basic part of the plant kingdom as a seed are few.

The authors have to date found works by Hofmann (1925), Wright (1931), Stone and Juhren (1951), and Went et al. (1952) concerning the effects of fire on seed of woody species. There is a definite lack of published information on the effects of fire on the germination of seed from the native herbaceous plants which are so vital to our southeastern range and wildlife resources. Therefore, in 1964, the Forest Service, cooperating with the Virginia Polytechnic Institute and the International Paper Company, began a program of research to determine the effects of fire on several of the more important range and wildlife food plants found in the Southeastern Coastal Plain flatwoods, with particular emphasis on *Cassia nictitans* and *C. fasciculata*.

Recently, Martin and Cushwa (1966) presented results from laboratory experiments concerning the effect of heat and moisture on native legume seed germination. The present report uses this material for background information, and summarizes results from current experiments.

Field Conditions

Let us review "normal" field conditions and some possible effects of fire on seed, as stated by Martin and Cushwa (1966). Generally, burns conducted specifically for the purpose of increasing legume flora are done in open stands of slash and longleaf pine shortly after a rain, when the surface fuel will readily carry fire and the lower fuel layers are still quite moist (Stoddard, 1931, 1961).

With this in mind, we might consider several possible effects of fire in bringing about a regeneration of these plants. First, the effect might be considered as a manipulation of growing conditions. This could be merely an improved seedbed that allows the seed a better chance to germinate and root in a favorable mineral soil. Second, the effect could be to change the environment of the seed or plant chemically. A third possibility would be changes in the biotic environment, either by reducing competition for light, nutrients, and water; or by inhibiting factors exuded from organisms; or by reducing seed and seedling destruction by various organisms. A fourth possibility could be the direct effect of fire on the seed—that is, changing the temperature and moisture conditions of the seed during the fire.

We know, for example, that temperatures in the upper soil layers during prescribed burns in the "pineywoods" of the South rarely exceed 300 F and that the increased temperature is of short duration, being in the range of from 2 to 4 minutes (Heyward, 1938).

Moisture conditions in litter and upper soil layers during prescribed burns in this pine ecosystem are not available. However, one could speculate that because water is one of the main products of thermal degradation and combustion of woody fuels (Uggla, 1958), and because burning is usually done when subfuels are moist, some water vapor produced from either of these sources could be expected to diffuse downward due to vapor pressure gradients and condense on cooler objects, such

[1] Presented at Twentieth Annual Meeting, American Society of Range Management, Seattle, Washington, February 16, 1967.

as a seed, thus changing both the temperature and moisture conditions of the seed. At least part of the legume seed population stored in the fuel and upper soil layers are "macrobiotic" hard seed (Rampton and Ching, 1966) which, because of either physical or physiological dormancy, are viable but have not and will not germinate until conditions are altered. The condition of hard seed in legumes in general is widely recognized (Mayer and Poljakoff-Mayber, 1963; Fordham, 1965; Kawatake et al., 1955; Koller and Neghi, 1966; Amen, 1963), but not well understood; however, generally a physiological dormancy would be a factor within the embryo itself, whereas a physical dormancy would be a factor within the seedcoat. Also, it may be possible for a seed to have both physiological and physical dormancy, and the embryo and seedcoat may be intermingled in dormancies.

Assuming that high temperatures during a fire actually break dormancy or increase the rate of germination or overall germination, generally at low temperatures a given species of seed would have a relatively constant germination percentage. As temperature is increased, a range would finally be encountered where dormancy factors were broken, resulting in an increase in germination percentage. Following this, as temperature continues to increase, a plateau of relatively constant high germination would be expected, and finally there is a rather sharp decrease until no germination whatever occurs because of the lethal effects of high temperatures. We might otherwise state the null hypothesis as—no increased germination occurs due to increasing temperature.

Cassia nictitans was the species used in our early experiments for several reasons. First, it is one of the more important quail food plants in the Southeast (Stoddard, 1931), and therefore, knowledge of fire effects on this seed would be most useful in prescribing proper burning conditions. Second, the wide distribution and abundance of this plant reduces the problem of obtaining experimental material. Third, it is an annual plant and therefore depends entirely on seed as a means of propagation. Fourth, it produces hard seed which remain dormant and viable for long periods of time.

Methods and Results

Our first experiments involved four minutes exposure of *Cassia nictitans* seed to different temperature treatments in the dry atmosphere of a modified laboratory oven. These treatments had no significant effect on germination (Table 1). Also, germination was usually eliminated by four minutes exposure to dry heat treatments above 100 C.

Next, we scarified seed by soaking them in concentrated sulfuric acid for 25 minutes at room temperature and others in water to 70 C for 30 minutes. We also mechanically scarified seed by rubbing them with sandpaper. Seed exposed to these three treatments exhibited increased germination. Therefore, it follows that germination was enhanced by scarification, possibly by increasing the permeability to water and gases. It would seem possible that fire might affect dormancy by altering the seedcoat chemically, as in the acid treatment, or physically, through dissolution or hydration as might have occurred in both the acid and hot-water treatments. Either of these treatments would have affected the outer-most layer of the seedcoat, the same layer affected by mechanical scarification.

Table 1. Average response (percent germination) of *Cassia nictitans* seed to different treatments.

Treatment	Age of seed: Collected fall 1963; tested summer 1965	Collected fall 1965; tested winter 1966	Collected fall 1965; tested summer 1966
Control (no treat.)	58	12	44
Soaked in H_2SO_4, 25 min	99	—	71
Soaked in H_2O at 70°C, 30 min	95	—	93
Mechanical abrasion	92	—	77
Dry Heat (Temp. °C)			
45	35	9	9
60	—	7	11
70	—	5	19
80	38	7	26
90	32	24	19
100	3	27	0
110	0	0	0
Moist Heat (Temp. °C)			
45	—	6	39
60	78	15	85
70	86	34	98
72.5	—	—	97
75	—	80	96
77.5	—	92	98
80	93	99	95
82.5	—	98	96
85	—	98	94
90	39	96	74
92.5	—	—	43
95	—	—	1
98.4	2	45	2

In order to determine if fire affected the seedcoat chemically, some seed were placed in ashes from pine-needle fires and others were moistened with water percolated through these ashes. Neither of these treatments, however, resulted in any increased germination, indicating that a chemical scarification could not be expected from fire.

Seed heated at 80 C in an atmosphere saturated with water vapor exhibited an extremely high germination rate and cumulative germination—up to 75% germination 3 days after treatment and greater

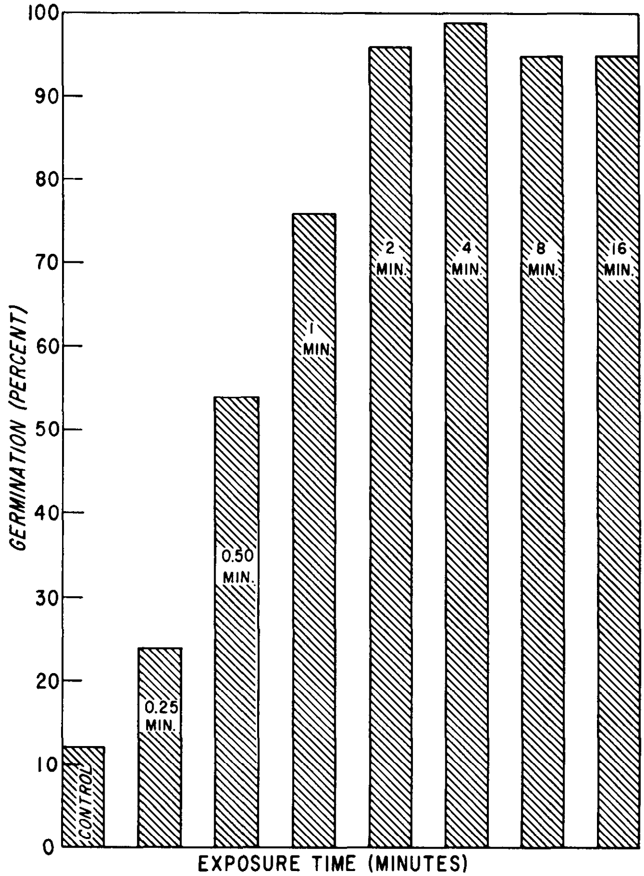

FIG. 1. Effect of varying time in a saturated atmosphere at a constant temperature of 80 C on germination of *Cassia nictitans* seed.

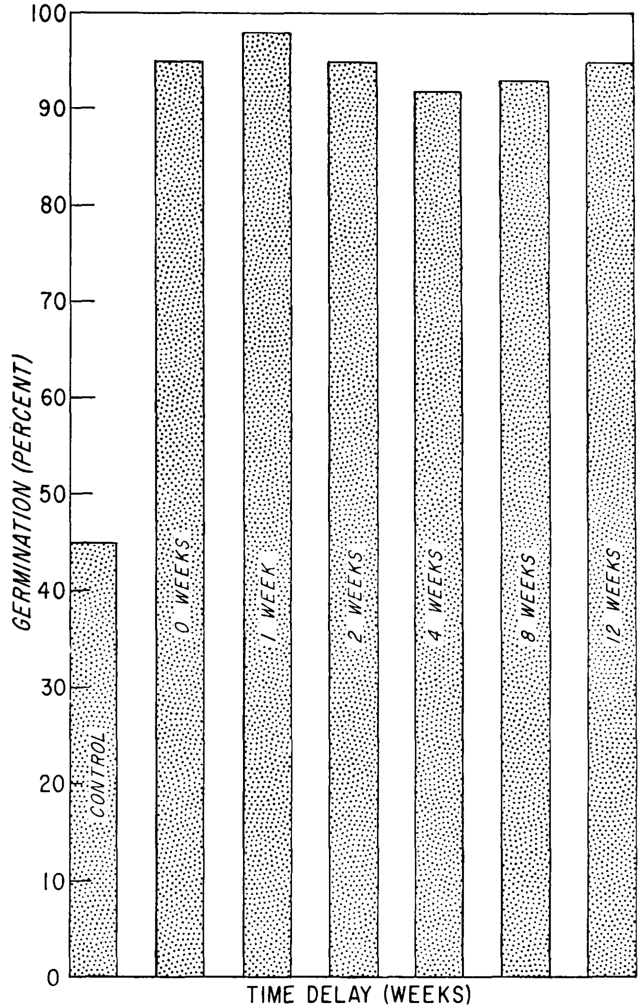

FIG. 2. The effect on germination of withholding moisture for varying time periods after *Cassia nictitans* seed were exposed to a moist-heat treatment at 80 C for four minutes.

than 95% cumulative germination. In all succeeding experiments, *Cassia nictitans* seed responded to the moist-heat treatments, the degree of response depending on seed population, age, temperature, and duration of treatment, and post-treatment delay (Table 1 and Fig. 1 and 2). There is a tendency for germination rate following moist-heat treatment to increase with the age of the seed, but cumulative germination does not change appreciably (Table 1).

In order to see how period of exposure to temperature treatments affected germination rate, we used moist heat at 80 C and varied the period from 15 seconds to 16 minutes. Cumulative germination increased with heating time up to 2 minutes, with no decrease for 16 minutes exposure. Germination rate increased for heating times up to 4 minutes exposure, but remained relatively constant for longer exposures (Fig. 1).

What is the effectiveness of moist-heat treatments if, following a fire, seed remain dry for various periods of time before sufficient moisture for germination is available? We withheld moisture up to 12 weeks following treatment, allowing seed to dry in the laboratory. The greatest effect was an increased *rate* of germination in the first three to seven days following wetting. This was noticeable up to an 8-week delay; 12-weeks' delay, however, seemed to decrease the early germination rate. There were no apparent differences in cumulative germination whether or not a delay period was used (Fig. 2).

The effects of hot water and a saturated atmosphere on seedcoat appearance have been demonstrated by light microscopy. Not only is the overall seedcoat appearance altered, but there are also striking changes in pre-treatment "dimpled" areas of the seedcoat; following treatment, these stand out as "elevated dimples." This suggests that some of the seedcoat material was removed during treatment. Exposing seed for four minutes in water at 80 C removed a highly hydrated material that had about the same volume as the seed, but amounted to only slightly over three % of the total dry weight of a seed. This material can be precipitated by ethyl alcohol. Although its exact nature is not

Table 2. Average response (percent germination) of legume seed treated during the winter 1966–67.

Species	Control No Treatment	Moist heat (Temperature °C)						Dry heat (Temperature °C)						
		45	60	70	80	90	98	45	60	70	80	90	100	110
*Lespedeza intermixta**	73	75	76	78	42	4	0	83	78	80	86	68	3	0
*Lespedeza daurica**	36	33	49	56	56	0	0	41	42	39	49	63	0	–
*Lespedeza cyrtobotrya**	27	59	72	87	69	19	1	63	83	83	84	89	0	0
*Lespedeza cuneata**	88	86	85	91	27	0	0	93	83	90	89	83	2	0
*Lespedeza virgata**	59	65	61	40	34	1	0	59	60	63	60	57	0	0
*Lespedeza japonica**	80	85	87	88	56	0	0	85	88	89	93	91	0	0
Lespedeza daurica var. *schimidae**	56	57	63	78	66	1	0	58	58	67	71	71	0	0
*Lespedeza capitata**	70	76	76	75	65	3	1	79	78	80	77	79	0	0
*Lespedeza hedysaroides**	40	31	56	69	60	0	1	35	49	58	72	86	0	0
*Lespedeza tomentosa**	31	30	51	48	25	4	0	30	53	61	50	63	0	0
*Lespedeza bicolor**	64	62	68	69	35	0	1	65	69	68	66	54	0	0
Cassia aspera	34	39	40	44	44	67	24	38	37	38	42	37	20	0

* Seed supplied and identified by Dr. A. F. Clewell, Assistant Professor of Botany, Florida State University, Tallahassee, Florida.

known, Tookey and Jones (1965) indicated that the seed of *Cassia fasciculata* contain 23% galactomannans. From the *Cassia nictitans* seedcoat material we removed, preliminary results indicate a molecular weight of about 200,000 by gel filtration and 17,000 to 100,000 by ultracentrifuging, depending on assumptions of the molecular configurations. The structure of the molecule, as well as the basic carbohydrate units, has yet to be determined.

Discussion

So far our results have some puzzling aspects. For example, *Cassia aspera*, a species closely resembling *Cassia nictitans* but confined to the more temperate environment of South Florida, responded relatively well to temperature treatments (Table 2). However, *Cassia fasciculata*, which commonly grows with *Cassia nictitans* but is confined to more open situations, has responded poorly to moist and dry heat treatments. Foote and Jackobs (1966) reported no difficulty in obtaining germination of seed from this species collected in Illinois. Because our heat treatments failed to induce germination of *Cassia fasciculata* seed, we are now testing the effect of stratification on germination. Recently, we exposed *Cassia fasciculata* seed to a temperature of 2 C for one week in a refrigerator, and then exposed these stratified seed to a moist-heat treatment for four minutes at 80 C. Results look promising; seven days following both stratification and scarification treatments, seed were germinating.

We have also conducted experiments to determine the effect of temperature treatments on the germination of 13 species of *Lespedeza*, 3 species of *Desmodium*, and 1 species of *Galactia* (Tables 2 and 3), all of which are common plants in the fire ecosystem of the Southeast.

Recently, we exposed palmetto (*Serenoa repens*) and razorsedge (*Scleria muhlenbergii*) seed to a variety of moist and dry temperature treatments plus mechanical abrasion and acid treatments. To date we have been unable to obtain any germination. Hilmon[2] (personal correspondence 1967) obtained germination of palmetto seed by two

[2] Range Scientist, U.S.D.A., Forest Service, Southeastern Forest Experiment Station, Fort Myers, Florida.

Table 3. Average response (percent germination) of legume seed treated during the summer of 1966.

Species	Control No Treatment	Moist heat (Temperature °C)						Dry heat (Temperature °C)						
		45	60	70	80	90	98	45	60	70	80	90	100	110
Cassia fasciculata	0	1	1	1	2	3	0	1	0	0	1	1	0	0
Desmodium ciliare	97	97	100	100	75	0	0	97	97	97	70	4	0	0
Desmodium cuspidatum	76	72	69	77	81	29	0	73	79	79	78	20	0	0
Desmodium fernaldii	91	90	90	91	92	26	0	88	89	91	91	15	0	0
Galactia volubilis	12	4	16	16	16	32	12	20	12	16	24	8	0	0
*Lespedeza bicolor**	4	44	76	68	92	84	88	44	68	80	100	100	0	0
*Lespedeza hirta**	4	6	7	7	18	32	15	3	3	6	10	51	0	0
Lespedeza hirta var. *curtissii**	2	5	3	4	16	7	0	1	2	3	17	3	0	0

* Seed supplied and identified by Dr. A. F. Clewell, Assistant Professor of Botany, Florida State University, Tallahassee, Florida.

methods: (a) By removing the micropyle cover and exposing the endosperm to moisture, and (b) by increasing the oxygen pressure. Also, he was able to germinate *Scleria* seed taken from quail crops.

In summary, our work is still in the developmental stages. Nonetheless, we feel that we have been able to create a situation in the laboratory which closely resembles field burning conditions. But we have not been able to prove this, mainly because of the complexity of the time, temperature, and moisture relationships during a burn.

We have installed a field study designed to bracket these variables, and hopefully we will emerge with an evaluation prescription for conditions which will enable a land manager to manipulate vegetation through the use of fire. In addition, we are examining the chemical composition and physical structure of seedcoat materials in order to understand better the role of fire in propagating these species.

LITERATURE CITED

AHLGREN, I. F., AND C. E. AHLGREN. 1960. Ecological effects of forest fires. Bot. Rev. 26:483–533.

AMEN, R. D. 1963. The concept of seed dormancy. Amer. Sci. 51(4):408–424.

BISWELL, H. H. 1963. Research in wildland fire ecology in California. 2nd Tall Timbers Fire Ecol. Conf. Proc., p. 63–97.

BRUCE, D. 1959. Effect of low competition on longleaf pine seedling growth. Soc. Amer. Forest. Proc. 1958:151–154.

CHAPMAN, H. H. 1952. The place of fire in the ecology of pines. Bartonia 26:39–44.

FOOTE, L. E., AND J. A. JACKOBS. 1966. Response of partridgepea (*Cassia fasciculata* Michx.) and Korean Lespedeza (*Lespedeza stipulacea* L.) to differences in soil types, phosphorus fertilization, and plant populations. Agron. J. 58:419–423.

FORDHAM, A. J. 1965. Germination of woody legume seed with impermeable seedcoats. Arnoldia 25(1):1–8.

GARREN, K. H. 1943. Effects of fire on vegetation of the southeastern United States. Bot. Rev. 9:617–654.

GREEN, S. W. 1935. Effect of annual grass fires on organic matter and other constituents of virgin longleaf pine soils. J. Agr. Res. 50:809–822.

HEYWARD, F. 1938. Soil temperatures during forest fires in the longleaf pine region. J. Forest. 36:478–491.

HOFMANN, J. V. 1925. Laboratory tests on effect of heat on seeds of noble and silver fir, western white pine, and Douglas fir. J. Agr. Res. 31:197–199.

KAWATAKE, M., K. TAKIZAWA, AND M. KATAYAMA. 1955. Studies on the developmental processes of hard seed of some legumes. Dev. Plant Breed. and Cult. Bull. 30:177–182, 193–202 Takai-Kinki.

KOLLER, D., AND M. NEGHI. 1966. Germination of seed of desert plants. Dep. of Bot., Hebrew Univ., Jerusalem, Israel. 180 p.

LITTLE, S., AND E. B. MOORE. 1953. The ecological role of prescribed burns in the pine–oak forests of southern New Jersey. Ecology 30:223–233.

LUTZ, H. J. 1956. Ecological effects of forest fires in the interior of Alaska. U.S. Dep. Agr. Tech. Bull. 1133:121.

MARTIN, R. E., AND C. T. CUSHWA. 1966. Effects of heat and moisture on leguminous seed. 5th Tall Timbers Fire Ecol. Conf. Proc., Tallahassee, Florida.

MAYER, A. M., AND POLJAKOFF-MAYBER. 1963. The germination of seed. The Macmillan Co., New York. 236 p.

ODUM, E. P. 1953. Fundamentals of ecology. W. B. Saunders Company, Philadelphia. 384 p.

RAMPTON, H. H., AND TE MAY CHING. 1966. Longevity and dormancy in seed of several cool-season grasses and legumes buried in soil. Agron. J. 58:220–223.

SAMPSON, A. W. 1952. Range management principles and practices. John Wiley & Sons, Inc., New York. 570 p.

STODDARD, H. L. 1931. The bobwhite quail. Charles Scribner's Sons. 559 p.

STODDARD, H. L. 1961. The cooperative quail study association. Misc. Pub. No. 1. Tall Timbers Res. Sta., Tallahassee, Florida. 500 p.

STONE, E. C., AND G. JUHREN. 1951. The effects of fire on the germination of seed of *Rhus ovata* (Wats.). Amer. J. Bot. 38:368–372.

TOOKEY, H. L., AND Q. JONES. 1965. New sources of water-soluble seed gums. J. Econ. Bot. 19(2):165–174.

UGGLA, E. 1958. Ecological effects of fire on North Swedish Forests. Univ. Uppsala, Inst. of Plant Ecol. 18 p.

WAHLENBERG, W. G. 1935. Effect of fire and grazing on soil properties and the natural reproduction of longleaf pine. J. Forest. 33:331–338.

WEAVER, H. 1959. Effects of burning on range forage values in the ponderosa pine forests. Soc. Amer. Forest. Proc. 1958:212–215.

WENT, F. W., G. JUHREN, AND M. C. JUHREN. 1952. Fire and biotic factors affecting germination. Ecology 33:351–364.

WRIGHT, E. 1931. The effect of high temperatures on seed germination. J. Forest. 29:679–687.

Adjusting Cattle Numbers to Fluctuating Forage Production with Statistical Decision Theory

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Highlight

Statistical decision theory offers northern Nevada cattle producers an opportunity to increase their income by aiding in making adjustments in livestock numbers according to expected forage production. It is necessary for cattlemen to determine the number of cattle to carry through the winter before knowledge of forage supply for the coming year is available. Statistical decision theory provides a simple tool whereby ranchers may use observed information on precipitation to select the appropriate number of cattle to be wintered. Ninety-five years of weather data were used to evaluate this technique under ranch conditions in northern Nevada. Results indicate that statistical decision theory offers promise as a technique for maximizing the long-run average income of ranchers while making provision for protection of the range resource.

Como Ajustar el Numero de Animales a las Fluctuaciones en la Produccion Forrajera—una Aplicacion de la Teoria de Decision Estadistica

Resumen

Para ejemplificar este modelo bajo probabilidades a priori y a posteriori, se empleó una operación combinada de pié de cría (venta de crías al destete) y de pié de cría—engorda (venta de crías como añojos). Esta organización tiene muy buena flexibilidad para ajustarse a niveles de producción forrajera tanto abajo como arriba de lo normal. Por lo tanto, el valor del modelo expuesto fué más bien limitado para este sistema. El modelo resultó de mayor valor bajo el sistema menos flexible de una operación pié de cría.

Aunque los aumentos en los ingresos fueron modestos con el modelo, la técnica ofrece ciertas promesas para trabajar en este campo. La técnica puede aparecer complicada al principio, pero es más bien simple. Los resultados pueden presentarse en una forma sencilla, como aparecen en el cuadro 6, para aquellos no interesados en profundizarse en suposiciones y mayores datos.

Este modelo fué desarrollado para ayudar a los ganaderos a utilizar los reducidos datos disponibles en el otoño con el fin de predecir la cantidad de forraje disponible para el año siguiente. El modelo está planeado simplemente para tratar de obtener los máximos ingresos a largo plazo. Podría modificarse fácilmente para reflejar otras cosas tales como diferentes grados de utilización de forraje aceptable, niveles de ingreso mímimo anual, ó cualquier otra medida de importancia en el manejo del recurso pastizal. Esta es otra herramienta que puede ayudar al ganadero a aumentar sus ingresos y a la vez sirve para mejorar la utilización de un pastizal.

Cattlemen and range scientists are continually faced with the problem of adjusting stocking rates to fluctuating forage production. Currie and Peterson (1966), Houston and Woodward (1966), Reed and Peterson (1961), and several others have published research on this problem. Numerous "rules-of-thumb" have been advanced to aid decision makers in resolving this problem. Stoddart and Smith (1943) mention several in their text. Recent developments in the field of statistical decision theory may offer some new insights into this traditional problem. This study was designed to examine the usefulness of statistical decision theory in specifying adjustments in response to an uncertain forage supply in the sagebrush–grass range area of northern Nevada.

Annual fluctuations in forage production in this area are due primarily to fluctuations in precipitation. If future precipitation were known with certainty, it would be a simple matter for producers to adjust their operation to future forage supply. However, future precipitation is rather uncertain. Statistical decision theory was employed in an attempt to develop a procedure utilizing observable precipitation to predict future precipitation. From the precipitation prediction future forage production may be estimated, thereby facilitating adjustment of livestock numbers. The model developed in this study maximizes the weighted average of possible incomes for ranchers. A restraint preventing range use in excess of current year's production was imposed to prevent deterioration of the range.

Method of Analysis

The formal theory used was Bayesian statistics. A nontechnical presentation of the method may be found in Chernoff and Moses (1959). The more mathematically inclined may prefer works by Luce and Raiffa (1957) or Schlaifer (1959).

A ranch situation capable of running 400 cows under a conventional cow–calf system in normal years was synthesized to represent a typical set of feed resources found in northern Nevada. Three basic livestock systems were fitted to this feed base: (1) a strict cow–calf system, (2) a combination cow–calf and cow–yearling system, and (3) a strict cow–yearling system. Cow numbers were adjusted under each system so that production and consumption of forage would be equal for a "normal" year.

Monthly precipitation data from the Elko, Ne-

[1] Present Address: Dr. Rogers is now with the Department of Agricultural Economics, Washington State University, Pullman, and Mr. Peacock is farming in Reedley, California.

Table 1. Frequencies of three precipitation levels.

Level	Amount (inches)	Years observed	*A priori* probability
Below normal	0 to 5.99	21	.221
Normal	6.0 to 10.99	57	.600
Above normal	11 or more	17	.179

vada weather station were obtained for 95 years (1870–1965). Three levels of precipitation were established. Median annual precipitation was 8.5 inches and served as the base for establishing the average feed resource for the ranch. A "below normal" level was established at 5 inches and an "above normal" level at 12 inches of precipitation. Frequencies for these precipitations are shown in Table 1. The forage production equation developed by Sneva and Hyder (1962) was used to estimate forage under the "below" and "above" normal years.[2]

Although ranchers have selected one of the basic livestock systems (i.e., cow–calf, combination, or cow–yearling), additional adjustments may be made within each system as forage supply fluctuates. Four such alternatives were assumed to exist: (1) sell all calves, (2) sell one-half and retain one-half of the calves, (3) keep all the calves, and (4) sell some of the cow-herd in addition to selling all the calves. Selection of an alternative depends upon the rancher's expectation of precipitation for the coming year. This decision must be made in the fall when annual precipitation is still an unknown.

The analysis to this point includes three possible precipitation levels, three livestock systems, and four possible actions within each system. This yields 36 possible outcomes. Income data from research by Peacock (1967) were used in evaluating the usefulness of this technique. In order to simplify the presentation, income data are shown only

[2] This forage estimating equation has not been validated for northern Nevada conditions. Therefore, forage yields for "above" and "below" normal precipitation years may be subject to some error. Readers are cautioned to view this work only as a demonstration of the application of the technique.

Table 2. Net ranch income for combination livestock system under three precipitation levels and four actions.

Action	Level: Below normal	Normal	Above normal
Sell all calves	– $5,324	$4,626	$ 7,102
Sell one-half calves	– 5,516	8,242	10,128
Keep all calves	– 6,260	6,115	14,482
Sell-down cows	– 1,614	1,159	3,145

for a 362 cow combination cow–calf and cow–yearling system (Table 2).

The 95 years of weather data were examined to determine the relationship between observed July through October precipitation and total precipitation for the year. It is necessary to develop *a posteriori* probabilities which are the conditional probabilities of the three levels of precipitation given that a particular level of July through October precipitation is observed on November 1. Table 3 illustrates the derivation of these *a posteriori* probabilities by Bayes' formula,

$$P(\Theta/Z) = \frac{P(\Theta)\,P(Z/\Theta)}{P(Z)}.$$

Detailed procedures for calculation of these probabilities may be found in Luce and Raiffa (1967). The following gives a brief explanation of the calculations appearing in Table 3. For example, the conditional probability figures appearing in the "below normal" precipitation year of Section I were calculated in the following manner. Below normal precipitation occurred in 21 of the 95 years of recorded weather data. In 17 of these 21 years less than one inch of precipitation was observed by November 1 (Z_1), while in the remaining 4 years between 1 and 1.99 inches were observed by November 1 (Z_2). Therefore given that a below normal precipitation year actually occurred, the conditional probability of observing less than one inch of precipitation by November 1 was .810, that of observing between 1.0 and 1.99 inches was .190, and there was zero probability of observing 2 or more inches of precipitation. Con-

Table 3. Determination of *a posteriori* probabilities of total precipitation based on observed precipitation, November 1.

Total precip. (Θ)	I. Conditional probabilities P(Z/Θ) — Observed precip., Nov. 1 (in.): 0–.99	1–1.99	2–2.99	3–3.99	Over 4	*A priori* probabilities P(Θ)	II. Joint probabilities P(Θ) P(Z/Θ) — Observed precip., Nov. 1 (in.): 0–.99	1–1.99	2–2.99	3–3.99	Over 4	III. *A posteriori* probabilities $P(\Theta/Z) = \frac{P(\Theta)\,P(Z/\Theta)}{P(Z)}$ — Observed precip., Nov. 1 (in.): 0–.99	1–1.99	2–2.99	3–3.99	Over 4
Below normal	.810	.190				.221	.1790	.0420				.4720	.1288			
Normal	.316	.368	.228	.053	.035	.600	.1896	.2208	.1368	.0318	.0210	.500	.6733	.7647	.6011	.3328
Above normal	.059	.353	.235	.118	.235	.179	.0106	.0632	.0421	.0211	.0421	.0280	.1939	.2353	.3989	.6672
						P(Z)	.3792	.3260	.1789	.0529	.0631					

Table 4. Expected value of action for combination system with 2 to 2.99 inches of observed precipitation.

Precipitation	Net ranch income: Sell all calves	Sell one-half calves	Keep all calves	Sell down cows	*A posteriori* probabilities
Below normal	–$5,324	–$5,516	–$6,260	–$1,614	.0000
Normal	4,626	8,242	6,115	1,159	.7647
Above normal	7,102	10,128	14,482	3,045	.2353
Expected value	$5,209	$8,686	$8,084	$1,603	1.0000

ditional probabilities for normal and above normal precipitation levels were derived similarly. The *a priori* probabilities shown in Table 3 are merely the percentage of years that each precipitation level occurred over the 95-year period.

The joint probabilities shown in Section II of Table 3 are simply an intermediate step needed to derive the *a posteriori* probabilities. These joint probabilities are the product of two distributions. The conditional probabilities shown in Section I are multiplied by the values appearing in the vector of *a priori* probabilities. As an example, the figure .1790 appearing in the upper left-hand corner of the joint probabilities section was obtained as the product: $.810 \times .221 = .1790$. The P(Z) row is simply the sum of values appearing in the columns of the joint probabilities section.

The *a posteriori* probabilities are then derived according to Bayes' formula as shown in Section III of Table 3. This involves dividing each element in the joint probability matrix by the corresponding value in the P(Z) row. As an example, the figure .4720 appearing in the upper left-hand corner of Section III was obtained as the quotient of the fraction, .1790/.3792.

The *a posteriori* probabilities are then used by the decision maker in determining which action will maximize his weighted average net ranch income. A simplified example is shown in Table 4 considering only the 2 to 2.99 inch observed precipitation column. Income figures from Table 2 are multiplied by the respective *a posteriori* probability value (Section III, Table 3) for that precipitation level. As an example, $5,209 under "sell all calves" (Table 4) was calculated as: $(-5{,}324)\ (0) + (4{,}626)\ (.7647) + (7{,}102)\ (.2353) = 5{,}209$.

It can be seen from Table 4 that a rancher observing between 2 and 2.99 inches of rainfall by November 1 should decide to sell one-half of his calves and winter over the other one-half if he wishes to maximize his long-run average profit. Table 4 is easily expanded to calculate expected values for the other observed levels of precipitation.

Results

The payoff matrix for the combination livestock system using only *a priori* or long-run averages is shown in Table 5. As would be expected, the profit maximizing strategy, yielding $5,539 net ranch income, is indicated under sell one-half the calves and winter over one-half the calves.

The question of concern is whether the average income level obtained with use of only *a priori* probabilities can be increased with the decision model. If so, the rancher will have an increased income and the range will benefit from less overgrazing in low precipitation years. The decision theory payoff matrix using *a posteriori* probabilities is shown in Table 6.

Table 6. Net ranch incomes (dollars) with *a posteriori* probabilities.

Observed precip. Nov. 1 (inches)	Net ranch income ($): Sell all calves	Sell one-half calves	Keep all calves	Sell down cows
0 to 0.99	1	1,801	508	97
1 to 1.99	3,824	6,836	6,144	1,167
2 to 2.99	5,209	8,686	8,084	1,603
3 to 3.99	5,614	8,994	9,453	1,912
4 or more	6,278	9,500	11,697	2,418

Table 5. Net ranch incomes with *a priori* probabilities.

Precipitation	Net ranch income: Sell all calves	Sell one-half calves	Keep all calves	Sell down cows	*A priori* probabilities
Below normal	–$5,324	–$5,516	–$6,260	–$1,614	.221
Normal	4,624	8,242	6,115	1,159	.600
Above normal	7,102	10,128	14,482	3,045	.179
Expected income	$2,869	$5,539	$4,878	$ 883	1.000

The underlined figures indicate the correct action for each observed level of July through October precipitation. A mixed strategy is indicated. The basic action selling one-half and keeping one-half the calves is indicated for November 1 precipitation levels up to three inches. If three or more inches of precipitation are observed by November 1, the rancher should keep all his calves over the winter. The long-run expected value of this strategy is $5,704, an average increase of $162 for a ranch running approximately 362 cows. This is obtained by multiplying the underlined values by the appropriate P(Z) value shown as the bottom line in Section II of Table 3: i.e., (1,801) (.3792) + (6,836) (.3260) + (8,686) (.1789) + (9,453) (.0529) + (11,697) (.0631) = 5,704. The same model applied to the basic cow–calf system increased annual income $286.

Conclusions

A combination cow–calf and cow–yearling system was indicated using both the *a priori* and *a posteriori* probabilities. Such a combination livestock system has considerable inherent flexibility for adjustment to both below and above normal forage supplies. Therefore, increases in income with use of statistical decision theory were rather small for the combination cow–calf and cow–yearling system. The model was of greater value under the less flexible cow–calf system.

Although increases in income were modest, the technique offers some promise as a method for making decisions concerning adjustments of cattle numbers. The procedure as presented in this article may appear complicated at first exposure but is rather easily developed when broken down into separate steps. Results applicable for a particular area could be presented in a simple form (e.g., such as Table 6) for those not interested in the underlying assumptions and data.

This research was conducted to determine whether statistical decision theory might be useful in assisting ranchers to use precipitation data available to them in the fall for predicting forage for the following year. The model sought simply to maximize long-run expected income. It could be easily modified to reflect such things as different rates of acceptable forage utilization, minimum annual income levels, or other measures of importance in managing the range resource. Statistical decision theory, employing Bayesian statistics, is another tool which may help increase rancher income while serving to improve range utilization.

LITERATURE CITED

Chernoff, H., and L. E. Moses. 1959. Elementary decision theory. John Wiley, New York. 364 p.

Currie, P. O., and G. Peterson. 1966. Using growing-season precipitation to predict crested wheatgrass yields. J. Range Manage. 19:284–288.

Dean, G. W., A. J. Finch, and J. A. Petit, Jr. 1966. Economic strategies for foothill beef cattle ranchers. Calif. Agr. Exp. Sta. Bull. 824. 48 p.

Houston, Walter R., and R. R. Woodward. 1966. Effects of stocking rates on range vegetation and beef cattle production in Northern Great Plains. U.S. Dep. Agr. Tech. Bull. No. 1357. 58 p.

Luce, R. D., and H. Raiffa. 1957. Games and decisions. John Wiley, New York. 509 p.

Peacock, Walter S., III. 1967. An application of statistical decision theory to adjustments on northeastern Nevada livestock ranches. Unpublished Master's thesis, University of Nevada. 96 p.

Reed, M. J., and R. A. Peterson. 1961. Vegetation, soils, and cattle responses to stocking and grazing on Northern Great Plains range. U.S. Dep. Agr. Tech. Bull. No. 1252. 79 p.

Schlaifer, R. 1951. Probability and statistics for business decisions. McGraw-Hill, New York. 732 p.

Sneva, F. A., and D. N. Hyder. 1962. Estimating herbage production on semiarid ranges in the Intermountain Region. J. Range Manage. 15:88–93.

Stoddart, Laurence A., and Arthur D. Smith. 1943. Range management. McGraw-Hill, New York. 547 p.

A. W. Sampson Portrait

Mrs. A. W. Sampson graciously has permitted the California Section to have reproductions made of a recent portrait of Sammy. These are 8 × 10, mat finish, suitable for framing. The pose is different from that in the picture which appeared in the November 1967 issue of the Journal. Copies are available at $2.00 each. Write to Mert Reed, P. O. Box 245, Berkeley, California 94701.

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Growth and Yield of Legumes in Mixtures with Grasses on a Mountain Range[1]

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Highlight

Nine legumes, including three strains of variegated alfalfa, were planted in mixture with each of four grasses in the fall of 1950. Alfalfa A-169 was the most productive legume. In 1965 it yielded 100 lb/acre, about 35% more than cicer milkvetch or Ladak alfalfa and 160 lb/acre more than sickle milkvetch or Rhizoma alfalfa. Siberian alfalfa was clearly inferior to all the above. Flat pea, birdsfoot trefoil, and perennial vetch disappeared from the plots early in the study. Intermediate and crested wheatgrasses were more productive than smooth brome, both in combination with legumes and as pure stands. The highest yielding plots in 1965 were those originally sown to mountain brome. This short-lived grass afforded less competition to the legumes which became well established prior to invasion by crested and intermediate wheatgrass or smooth brome grass. The use of a legume with the grass, on the average, increased production by 144 lb/acre.

The need for suitable legumes for mountain rangelands has been stressed by many workers, including Hafenrichter et al. (1949), Plummer et al. (1955), and Keller (1959), but plantings have not been encouraging. This paper presents results from a range planting made in central Utah to determine the best legumes for planting in grass–legume mixture and to determine the effects of the plant association on relative yield of grasses and legumes.

Area, Species, and Methods

The study was conducted on a small terrace in the mountain brush type in central Utah locally known as Majors Flat. It is at an elevation of 7,100 ft on the Manti–LaSal National Forest. The soil is a productive silt loam of limestone origin. Average annual precipitation during the study was 17.8 inches.

Native vegetation consists primarily of big sagebrush (*Artemisia tridentata* Nutt.) interspersed with small patches of gambel oak (*Quercus gambelii* Nutt.) and mountain snowberry (*Symphoricarpos oreophilus* A. Gray). A few remnants of bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith), Indian ricegrass (*Oryzopsis hymenoides* (Roem. & Schult.) Ricker), and lupine (*Lupinus* sp.) persist under the shrubs. Cheatgrass (*Bromus tectorum* L.) and other annuals are abundant in the openings.

All vegetation was removed by burning, plowing, and grubbing, and a good seedbed was prepared during the spring and summer of 1950. The plots were seeded in the fall. The experimental design was a randomized split plot with four replications. Four grasses, crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult.), intermediate wheatgrass (*A. intermedium* (Host) Beauv.), smooth brome (*Bromus inermis* Leyss.), and mountain bromegrass (*B. marginatus* Nees) constituted the main plots. Nine legumes, including three varieties of variegated alfalfa (*Medicago sativa* L.), A-169, Ladak, and Rhizoma; Siberian alfalfa (*M. falcata* L.); cicer milkvetch (*Astragalus cicer* L.); sickle milkvetch (*A. falcatus* Lam.); birdsfoot trefoil (*Lotus corniculatus* L.); flat pea (*Lathyrus sylvestris* L.); and perennial vetch (*Vicia tenuifolia* Roth) constituted the subplots. Each main plot contained 27 parallel rows 10 ft long spaced 20 inches apart and was sown to one grass. Superimposed on the main plot were nine subplots each consisting of three of the main plot rows sown to one legume. Both grasses and legumes were seeded at 8 lb/acre, the seed was covered 0.5 inch, and the soil was firmed. A specific inoculant was worked into the soil for all rows seeded to birdsfoot trefoil.

Plant numbers and estimated herbage productions were taken in 1951, 1952, and 1953. Pocket gophers were controlled by poisioning from 1951 to 1953, but the area was open to natural grazing until 1957. Early in 1957 any remaining herbage from previous years was removed from the area; pocket gophers were trapped and poisoned; and a rabbit, deer, and livestock exclosure was constructed. Plot ratings were made in 1957, 1958, 1961, and 1965. In 1957 and 1965 all legume plants were counted and clipped. Grass plots were rated and yields were determined by total clipping in 1957. In 1965 only a portion of each plot was clipped. Air-dry weights were taken on all forage samples, and oven-dry weights were taken on selected samples.

Results and Discussion

Climatic conditions were favorable for seed germination and seedling emergence in the spring of 1951. All grass stands rated by the method of Hull (1954) were good to excellent and estimated production averaged 1,380, 1,330, 630, and 375 lb/acre for crested wheatgrass, intermediate wheatgrass, mountain brome, and smooth brome, respectively. Fair to excellent stands of seedling legumes were obtained, but legume seedling mortality was high after the residual soil moisture had been depleted. By late July 1951, the legume plants remaining in the crested wheatgrass and intermediate wheatgrass plots rated poor to fair, with an average of .8 and 1.9 plants/ft of row. Legume plants remaining in the mountain brome and smooth brome plots rated fair with an average of 1.3 and 1.4 plants/ft of row.

All grass species thrived. Estimated production in 1952 was 3,160, 3,220, 1,920, and 2,420 lb/acre for crested wheatgrass, intermediate wheatgrass,

[1] Research conducted by the Crops Research Division, Agricultural Research Service in cooperation with the U.S. Forest Service, U.S. Department of Agriculture and the Utah Agricultural Experiment Station, Logan. Utah Agricultural Experiment Station Journal Paper 714. Thanks go to A. P. Plummer of the Intermountain Forest and Range Experiment Station, U.S. Forest Service, and E. James Koch, Biometrical Services, Agricultural Research Service.

FIG. 1. Left, crested wheatgrass maintained the original rows. Right, the rhizomatous intermediate wheatgrass filled in the interspaces between the rows.

mountain brome, and smooth brome, respectively. Cicer milkvetch, alfalfa A-169, Ladak, and Rhizoma made the best showing in mixture with the four grasses. Estimated legume production was 55, 40, 125, and 130 lb/acre when grown with crested wheatgrass, intermediate wheatgrass, mountain bromegrass or smooth bromegrass, respectively. This low herbage production by the legumes in their second growing season was attributed to rapid soil moisture depletion and partial shading in the seedling year by the more rapidly developing grasses.

All grasses maintained stand ratings in 1953, but average production was only 73, 88, 57, and 91%, respectively, of the 1952 yield of crested wheatgrass, intermediate wheatgrass, mountain brome, and smooth brome. All of the flat-pea plants and most of the perennial vetch plants perished prior to late summer of 1953. Mortality of the birdsfoot trefoil and Siberian alfalfa was high, especially in mixture with the two wheatgrasses. Other legumes maintained fair ratings. Estimated production for all legumes varied from 90 lb/acre in mixture with intermediate wheatgrass to 370 lb/acre in mixture with mountain brome.

Table 1. Mean dry-weight yield in pounds/acre of grasses in combination with six legumes and in the absence of legumes, 1965. Each mixture is the mean of 24. Each yield for grass alone is the mean of 12.

Mixture	Mountain brome[1]	Crested wheat	Intermediate wheat	Smooth brome	Mean
Grass fraction	723	808	918	501	737
Legume fraction	390	244	108	248	247
Total yield	1113	1052	1026	749	984
Grass alone[2]	883	867	914	678	835
Advantage of mixture	230	185	112	71	144

[1] Mountain brome being short-lived had nearly disappeared from the plots and the grass present consisted of associated species which had invaded.

[2] From plots originally seeded to grass in combination with flat pea, birdsfoot trefoil, or perennial vetch, none of which persisted.

During the period 1954 to 1961, crested wheatgrass, intermediate wheatgrass, and smooth brome maintained full stand ratings. They also completely replaced the mountain bromegrass which had died prior to 1961. Crested wheatgrass maintained the original rows (Fig. 1), and invaded open adjacent areas by natural seeding. By 1965 the rhizomatous grasses had made limited ingress into most of the adjoining plots, especially the crested wheatgrass plots. The number of legumes decreased from 1954 to 1965. Most of this legume mortality was attributed to pocket gopher activity, although the area was poisoned each year.

Legume composition and herbage production were determined in 1957 and 1965. Grass and legume composition in these years were similar except that the plots originally sown to mountain brome were least productive in 1957 and most productive in 1965. Total yields on intermediate and crested wheatgrasses were similar in both years. Smooth brome plots were the lowest yielders in 1965.

Analysis of the grass yields (Duncan, 1955) shows significance at the 5% level for grasses, but no difference for legumes in 1957. Both grass and legume yields were significant in 1965. There were no significant differences in the grass yields in 1957 because of the planting of legumes, but significant differences were found by 1965. Tables 1 and 2 summarize yields for grass and legumes, respectively.

Since three of the legumes had no production, they were omitted from analysis. In these analyses, grass and legume yields were significant, but the

Table 2. Mean dry-weight yield in pounds/acre of legumes in combination with four grasses, 1965. Each value is a mean of 16.

	A-169	Cicer	Ladak	Sickle	Rhizoma	Siberian	Mean
Grass	699	768	720	784	688	784	737
Legume	390	287	290	213	230	74	247
Total yield	1059	1055	1010	997	918	858	984

grass × legume interactions were not significant. Averaging the four grasses in mixture with the legume, alfalfa A-169, yielded highest in both 1957 and 1965, although cicer milkvetch and Ladak yields were not significantly less either year.

Legume yields were smallest when planted with intermediate wheatgrass and largest when planted with the short-lived mountain bromegrass. Legume production in mixture with crested wheatgrass or smooth bromegrass were similar. The use of a legume with the grass, on the average, increased production 144 lb/acre. On the invaded plots initially seeded to mountain brome, the average gain from legumes was 230 lb/acre. The crested wheatgrass plots benefited by 185 lb from the presence of legumes while intermediate wheatgrass benefited 112 lb and smooth brome 71 lb.

Negative correlations of .207 and .245 were found between the legume and grass yields in 1957 and 1965. This indication of competition effect between the established legumes and grasses is significant, but it is not an adequate indication of the severe competition which occurred during the seedling year and later establishment period. Most of the variegated alfalfa and milkvetch herbage was produced by a few relatively large plants. This indicates that once established these legumes can successfully compete with the grasses on this site. Procedures could be devised which would provide for legume establishment before the grasses were planted.

Other varieties of alfalfa may be equal to or superior for range plantings with grasses. Later alfalfa plantings at this location have usually demonstrated that Nomad, A-169, Ladak, Sevelera, and Rhizoma have maintained stand ratings and have been relatively productive. Nomad and A-169 were damaged less by pocket gophers than the other varieties. Rambler alfalfa was not included in these early range plantings, but should persist in mixture with grass (Heinrichs and Bolton, 1958) and be equally resistant to pocket gopher damage.

LITERATURE CITED

DUNCAN, D. B. 1955. Multiple range and multiple F-tests. Biometrics 11:1–42.

HAFENRICHTER, A. L., L. A. MULLEN, AND R. L. BROWN. 1949. Grasses and legumes for soil conservation in the Pacific Northwest. U.S. Dep. Agr. Misc. Pub. 678. 56 p.

HEINRICHS, D. H., AND J. L. BOLTON. 1958. Rambler alfalfa. Canada Dep. of Agr. Pub. 1030. 15 p.

HULL, A. C., JR. 1954. Rating seeded stands on experimental range plots. J. Range Manage. 7:122–124.

KELLER, WESLEY. 1959. Breeding improved forage plants for western ranges. Grasslands, Am. Ass. Advance. Sci. 335–344.

PLUMMER, A. P., A. C. HULL, JR., G. STEWART, AND J. H. ROBERTSON. 1955. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. U.S. Dep. Agr. Handbook No. 71. 73 p.

Juniper Extract and Deficient Aeration Effects on Germination of Six Range Species[1]

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Highlight

Juniper foliage extract significantly decreased seed germination for three of six range species tested. Deficient aeration severely decreased germination for two species and completely inhibited germination of the other four.

Field observations have indicated that plant species and varieties most resistent to inhibitors from juniper, and to poor aeration, might be most likely to succeed on heavy clay soils previously occupied by juniper. For this reason we investigated the effects of Utah juniper (*Juniperus osteosperma* (Torr.) Little) foliage extract and deficient aeration on seed germination of 6 species important for range seeding in the pinyon–juniper woodland.

Suppression of understory vegetation by juniper is a common phenomenon that occurs over many thousands of acres in Arizona and New Mexico (Arnold et al., 1964). The effect is most pronounced on heavy clay soils, particularly those which are poorly drained and poorly aerated (Jameson, 1965). Jameson (1961) found that both aqueous and alcohol extracts of leaves and herbaceous stems from Utah, alligator, and one-seed juniper inhibited growth of wheat radicles in germinating seed. Jameson (1965) hypothesized that there was an accumulation of phytotoxins from juniper leaves under conditions of poor aeration and drainage. In later work with vegetation consisting mainly of pinyon, juniper, and an understory of blue grama, Jameson (1966) concluded that tree litter rather than competition for moisture and nutrients was the reason for the absence of blue grama under the tree canopies.

Johnsen (1962) found that water extracts from old litter, recent litter, and fresh foliage of one-seed juniper had little effect on the germination of blue grama caryopses. In later work Johnsen (unpublished data[2]) grew blue grama in pots with mixtures of soil and foliage litter from Utah, alligator, and one-seed juniper, and he observed no significant effects on seedling emergence or growth. In other work, however, he found that both soil adjacent to juniper roots and groundup roots mixed with potting soil inhibited leaf growth of blue grama, sideoats grama, and wheat. Alligator juniper exerted the greatest effect and Utah juniper the least. Sideoats grama was the most sensitive species tested and blue grama the least.

Aeration effects on seed germination mainly result from the interaction of O_2 and CO_2. Hart and Berrie (1966) working with wild oats under different gaseous environments, found O_2 essential for germination and CO_2 also important. Three % CO_2, by volume, allowed germination in light whereas 20% CO_2 inhibited germination in both light and darkness at all O_2 concentrations. Dasberg et al. (1966) compared germination of 4 range grasses with wheat in atmospheres containing various concentrations of O_2 and CO_2. Wheat germination was relatively insensitive to concentrations of O_2 ranging from 0 to 21% and CO_2 from 0 to 15%. Response of the grasses was fairly uniform. They decreased in rate and final germination percentage with decreasing O_2 concentrations. Fifteen % CO_2 combined with 20% O_2 also decreased both the rate and final amount of germination, but these effects were much smaller than the O_2 effects. Any CO_2 depressing effects at lower O_2 concentrations were apparently masked by O_2 acting as the limiting factor.

Materials and Methods

We used a randomized complete block design consisting of 6 species, 3 treatments, and 4 replications. Species tested were Nordan crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult.), Luna pubescent wheatgrass (*A. trichophorum* (Link) Richt.), fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.) collected 20 miles south of Winslow, Arizona, sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) collected on the lower part of the Beaver Creek watershed south of Flagstaff, Arizona, Capitan blue grama (*B. gracilis* (HBK.) Lag. ex Steud.), and weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees).

Amounts of seed used were measured by weight and were based on previous germination tests in which number of viable seed per pound of seed matter had been determined. The following amounts per replication were used for the different species: Nordan crested wheatgrass 966.2 mg, Luna pubescent wheatgrass 1,265.9 mg, fourwing saltbush 1,765.7 mg, sideoats grama 866.1 mg, Capitan blue grama 866.0 mg, and weeping lovegrass 816.0 mg.

Untreated seed was germinated in petri dishes with one layer of filter paper under and another over the seed. Four cc of distilled water were used to wet the filter paper in each dish for the deficient aeration and the control treatments. The juniper extract treatment consisted of substituting 4 cc of extract for the distilled water.

Utah juniper extract was prepared from oven-dry leaves and herbaceous stems ground to pass through a 20-mesh screen. A light petroleum ether extraction was made for 3 hr to defat

[1] Contribution from the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Rocky Mountain Forest and Range Experiment Station and the University of Arizona, Agricultural Experiment Station.

[2] Johnsen, Thomas N., Jr., Research Agronomist, Crops Research Division, ARS, U.S.D.A., Flagstaff, Arizona.

the ground vegetation. Juniper leaves are waxy so that water extraction without preparatory treatment is difficult. Defatting is a standard laboratory procedure that greatly improves the efficiency of water extraction. The material was redried and then mixed with distilled water in the proportions of 3 g oven dry juniper to 100 ml of water. Finally the mixture was centrifuged, filtered, and the solid residue discarded. The juniper extract had a pH of 4.5. Tests using hydrochloric acid dilutions have shown that a pH as low as 2 is not detrimental to seed germination.

The deficient aeration treatment was accomplished by removing the petri dish covers and placing the bottoms with the seed into 2 desiccators. The desiccators were then flushed with CO_2 and the lids sealed on. No CO_2 measurements were made but O_2 readings taken with an oxygen meter on the desiccator atmospheres just before sealing showed slightly less than 5% O_2. Since approximately 75% of the O_2 was replaced we assumed an equal proportion of N_2 replacement, and calculated CO_2 concentration to be about 75%.

All treatments were germinated in 2 germinators. The petri dishes with the juniper extract and control treatments were stacked directly on the wire germinator shelves. The sealed desiccators with the CO_2 treated seed were also placed on wire shelves in the same germinators. Germinators were kept at room temperature which fluctuated from a diurnal maximum of 80 F to a nocturnal minimum of 60 F. Free water was kept in the bottoms of both the desiccators and the germinators to prevent the seed from drying out. Seed was germinated over a 72-hr period and then examined. Seeds were considered to have germinated and were counted as such when the radicle had ruptured the seed coat.

Data were analyzed by analysis of variance and the Duncan multiple range test.

Results and Discussion

Seed germination was affected by the Utah juniper extract with significant differences among the 6 species tested (Table 1). Blue grama, crested wheatgrass, and sideoats grama exhibited the greatest sensitivity to the inhibitors in the juniper extract as evidenced by a marked reduction in seed germination. Weeping lovegrass and pubescent wheatgrass were only slightly sensitive with small variations that were not significant. Seed germination of fourwing saltbush actually appeared to be stimulated by the juniper extract. The increase, however, was so variable that it was not significant.

The juniper extract favored heavy fungus growth, especially with seed of fourwing saltbush and pubescent wheatgrass. This growth appeared to destroy some of the seeds before they were able to start germinating and may have exerted a confounding influence on the results.

Deficient aeration decreased seed germination of all six species. Germination was 9.25% of the control for fourwing saltbush and 0.74% for blue grama. No germination occurred for seed of crested wheatgrass, pubescent wheatgrass, sideoats grama, and weeping lovegrass. The weeping lovegrass seed became transparent after it imbibed water. The embryo then appeared green and viable but without any sign of growth or of breaking through the seed coat.

With deficient aeration there was a complete absence of fungus on the moist filter paper in the petri dishes. This absence of growth was in strong contrast to the other 2 treatments, especially the juniper extract, where heavy fungus growth was prevalent.

The germination period was set at 72 hr so that only initial vigorous germination would be measured. Results, therefore, are influenced by effect of juniper extract and CO_2 on rate as well as amount of seed germination. Over a longer time period more seed probably would have germinated and changes in proportions of treated seed to control might have occurred.

No attempt was made to separate effects of O_2 and CO_2 on seed germination. Instead, extreme conditions of deficient aeration were simulated by reducing the O_2 and increasing the CO_2 concentrations. Then, the effect of this simulated condition on seed germination was determined. The interaction of deficient aeration with juniper phytotoxins was not investigated though it may be important for some range soils.

Caution should be exercised in extrapolating germination inhibition effects from laboratory to field conditions. Absorption or incubator characteristics could nullify or accentuate the action of the inhibitors under various conditions.

Table 1. Percent germination[1] of 6 range species as affected by Utah juniper extract and deficient aeration.[2]

Treatment	Blue grama	Crested wheatgrass	Sideoats grama	Weeping lovegrass	Pubescent wheatgrass	Fourwing saltbush
Utah juniper extract	28.54	32.38	60.36	90.17	102.71	134.08
Deficient aeration	0.74	0.00	0.00	0.00	0.00	9.25

[1] Percentage of the control for each species after a 72 hour germination period.
[2] Values underscored by the same line are not significantly different at the 5 percent level.

LITERATURE CITED

Arnold, Joseph F., Donald A. Jameson, and Elbert H. Reid. 1964. The pinyon–juniper type of Arizona: effects of grazing, fire, and tree control. U.S. Dep. Agr. Prod. Res. Rep. 84. 28 p.

Dasberg, S., H. Enoch, and D. Hillel. 1966. Effect of oxygen and carbon dioxide concentration on the germination of range grasses. Agron. J. 58:206–208.

Hart, J. W., and Alex M. M. Berrie. 1966. The germination of *Avena fatua* under different gaseous environments. Physiologia Plantarum 19:1020–1025.

Jameson, Donald A. 1961. Growth inhibitors in native plants of northern Arizona. U.S. Forest Serv., Rocky Mt. Forest and Range Exp. Sta. Res. Note No. 61. 2 p.

Jameson, Donald A. 1965. Reduction of understory grass growth by chemicals in litter of *Juniperus*. Proc. 16 An. Meet. A.I.B.S.

Jameson, Donald A. 1966. Pinyon–juniper litter reduces growth of blue grama. J. Range Manage. 19:214–217.

Johnsen, Thomas N., Jr. 1962. One-seed juniper invasion of northern Arizona. Ecol. Monog. 32:187–207.

Estimating Percentage Dry Weight in Diets Using a Microscopic Technique[1]

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Highlight

Percent composition by dry weight was accurately estimated for 15 mixtures of plants that are found in the diets of some herbivores. The mixtures were sampled by recording the frequency of occurrence of each species in 100 microscope fields using 125-power magnification, converting frequency to density, and calculating relative density as an estimate of percent composition by dry weight. Dry weight percentages were predicted directly from relative density. The microscopic technique reported in this paper would be an accurate means of determining the dry-weight composition of stomach samples, esophageal samples, rumen samples, and clipped herbage.

A rapid, reliable method for estimating plant species composition in the diets of herbivorous animals is needed. This need is emphasized by the variety of methods used for reporting diets (Norris, 1943; Torell, 1956; Reppert, 1960; Vaughan, 1967).

A problem encountered in the study of herbivore diets is the lack of a method that can be checked for accuracy. The technician needs a method that builds confidence in his own ability to estimate the composition of a diet. The procedure should be as simple as possible. Botanical analysis of the diet should accurately reflect both the plant species eaten and the amount of each that was eaten.

A microscopic technique for identification of plants eaten by herbivores that thoroughly masticate their food was described by Baumgartner and Martin (1939) and the technique was later refined by Dusi (1949). This basic technique has been employed frequently in recent years by numerous other researchers. However, no one has evaluated the accuracy of the technique for estimating dry-weight percentages of plants in the diets of herbivores.

The objective of this study was to determine if dry-weight composition of a mixture of grasses and forbs could be accurately estimated by a microscopic technique.

Methods and Materials

Samples that contained known amounts of grasses and forbs were artificially mixed. Four mixtures contained Arizona fescue (*Festuca arizonica*), mountain muhly (*Muhlenbergia montana*), Pennsylvania cinquefoil (*Potentilla pensylvanica*), and fringed sagewort (*Artemisia frigida*). Eleven mixtures included from two to four of the following species: western wheatgrass (*Agropyron smithii*), prairie sandreed (*Calamovilfa longifolia*), summercypress (*Kochia scoparia*), and alfalfa (*Medicago sativa*).

All plants used in the mixtures were actively growing when collected. The plant material was oven dried and ground over a one-mm screen to reduce all plant fragments to a uniform size. The mixtures were compounded of various combinations of species so no two samples were alike. The species and dry-weight composition of the mixtures were unknown to the authors until after the sample estimates were recorded. Mixtures were washed over a 200-mesh screen to insure mixing, to remove dirt, and to remove very small plant fragments. A small portion of the mixture was spread evenly and mounted on a microscope slide using Hertwig's Solution (Baumgartner and Martin, 1939) and Hoyer's Solution (Baker and Wharten, 1952). The slides were oven dried at 60 C. Five slides were prepared from each mixture.

Tissues of plants that were used in the mixtures were prepared and mounted on microscope slides in the same manner for study as reference material. Identification of each species in the mixtures was based on epidermal characteristics (Davies, 1959; Brusven and Mulkern, 1960; Storr, 1961). These workers found that epidermal characteristics of grasses and forbs were variable with different stages of maturity. Histological features such as size and shape of epidermal hairs, presence or absence of hairs, cell shapes, and crystals included in epidermal cells provided diagnostic characteristics for identification of forb species. Species of grasses were identified by the occurrence and position of such specialized epidermal cells as cork cells, silica cells, silico-suberose couples, and asperities. The size and shape of the guard and subsidiary cells of the stomata were also reliable diagnostic features.

The mixed samples were analyzed by examining five slide mounts of each mixture under a compound binocular microscope. Twenty locations were systematically observed on each slide. A location was considered as an area of the slide delineated by a microscope field using 125-power magnification. Only those fragments that were recognized as epidermal tissue (other than hairs) were recorded as positive evidence for the presence of a plant species at a location on the slide. Each species present for each location was recorded. Frequency percentages (number of fields that the species occurred in out of 100 locations) were tabulated for each species in the mixture. The frequency percentages were converted to particle density per field using a table developed by Fracker and Brischle (1944) and the relative density, expressed as a percentage, of each species in the mixture was calculated. The relative density of a species was used to estimate the percentage dry weight of that species in the mixture.

Regression equations that express the relationship between estimated percentage dry weight (X) and actual percentage dry weight (Y) were developed for three categories: grasses, forbs, and grass–forb combinations.

Results and Discussion

Prediction equations for grasses, forbs, and grass–forb combinations are shown in Fig. 1, 2, and 3. The ratio between estimated dry weight percentages (relative density) and actual dry weight percentages was approximately 1 : 1 for all three categories. Student's t-test showed that there was no significant difference ($P < .01$) between regression equations for grasses and forbs and that the calculated regression equations for grasses, forbs, and grass–forb combinations were not statistically different from the equation $Y = X$. Therefore, the percent composition based on dry weight of the mixtures could be predicted directly from the relative density.

For 11 of the 15 mixtures, the number of epidermal fragments of each species at a location was recorded in

[1] Published with the approval of the Director of the Colorado Agricultural Experiment Station as Scientific Series Paper No. 1230.

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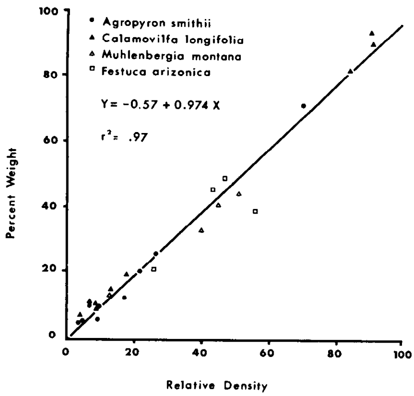

FIG. 1. Relationship of relative density to actual percent composition by weight for four grasses.

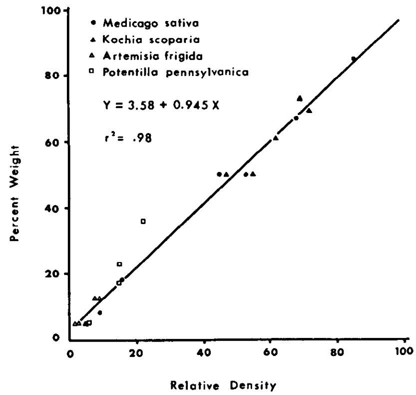

FIG. 2. Relationship of relative density to actual percent composition by weight for four forbs.

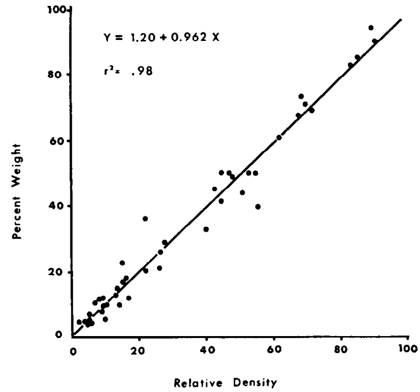

FIG. 3. Relationship of relative density to actual percent composition by weight for four grasses and four forbs.

addition to recording frequency. An estimate of the dry-weight percentages for each species was computed from the totals. A paired t-test showed no significant difference ($P < .01$) between the estimates obtained from the "particle count" technique and the "frequency conversion" technique. Either can be used with a similar degree of accuracy, but it is much easier and faster for the technician to determine if a species is present or absent than to count all recognizable fragments. The "frequency conversion" technique reported in this paper is recommended.

There are two requirements that must be met before frequency percentage can be converted to density (Curtis and McIntosh, 1950). The plant fragments must be distributed randomly over the slide, and the density of particles must be such that the most common species does not occur in more than 86% of the microscope fields. A random distribution can be attained by reducing the particles to a uniform size and thoroughly mixing them. A frequency of less than 86% for the most common species can be maintained by adjusting the amount of material mounted on the slide. This is done by trial and error until the technician becomes familiar with the material.

Storr (1961) and Heady and Van Dyne (1965) reported that weight per unit area of plant material is not consistent at different stages of maturity nor is it consistent from species to species. The 1 : 1 relationship between estimated dry-weight percentages and actual dry-weight percentages for the species used in this study may not be consistent with other species or at other stages of maturity. However, unless the plant parts in the diet being analyzed are grossly different from these in our studies, the added accuracy gained by using a prediction equation more complicated than $Y = X$ will probably not be worthwhile. If the specific gravity of a species or the phenological stage of a species is suspected of being different from that used in this study, the investigator can easily compound mixtures and develop regression equations for estimating dry-weight percentages.

The microscope technique reported in the present paper could also be used to determine the species composition of clipped herbage and the weights contributed by each species present. Thus, it should be possible to accurately estimate the yields of individual components in botanical studies.

LITERATURE CITED

BAKER, E. W., AND B. W. WHARTEN. 1952. An introduction to acarology. MacMillan Co., New York. 465 p.

BAUMGARTNER, L. L., AND A. C. MARTIN. 1939. Plant histology as an aid in squirrel food-habit studies. J. Wildl. Manage. 3:266–268.

BRUSVEN, M. A., AND G. M. MULKERN. 1960. The use of epidermal characteristics for the identification of plants recovered in fragmentary condition from the crops of grasshoppers. North Dakota Agr. Exp. Sta. Res. Rep. No. 3. 11 p.

CURTIS, J. T., AND R. P. MCINTOSH. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology 31:434–455.

DAVIES, I. 1959. The use of epidermal characteristics for the identification of grasses in the leafy stage. Brit. Grassland Soc. J. 14:7–16.

DUSI, J. L. 1949. Methods for the determination of food habits by plant microtechniques and histology and their application to cottontail rabbit food habits. J. Wildl. Manage. 13:295–298.

FRACKER, S. B., AND J. A. BRISCHLE. 1944. Measuring the local distribution of *Ribes*. Ecology 25:283–303.

HEADY, H. F., AND G. M. VAN DYNE. 1965. Prediction of weight composition from point samples on clipped herbage. J. Range Manage. 18:144–148.

NORRIS, J. J. 1943. Botanical analyses of stomach contents as a method of determining forage consumption of range sheep. Ecology 24:244–251.

REPPERT, J. N. 1960. Forage preference and grazing habits of cattle at the Eastern Colorado Range Station. J. Range Manage. 13:58–65.

STORR, G. M. 1961. Microscopic analysis of faeces, a technique for ascertaining the diet of herbivorous mammals. Austral. J. Biol. Sci. 14:157–164.

TORELL, D. T. 1956. Development of a point system for plant composition analyses of hand-clipped and fistula samples for nutrition studies, p. 2. In West. Regional Res. Proj., W-34, Annual Prog. Rep. California Agr. Exp. Sta.

VAUGHAN, T. A. 1967. Food habits of the northern pocket gopher on shortgrass prairie. Amer. Midland Natur. 77:176–189.

Apparent Sap Velocities in Big Sagebrush as Related to Nearby Environment[1]

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Highlight

Peak daily sap velocities were rather consistent throughout the year, and were always less than five cm/hr (average of five plants). A 30-variable multiple regression equation involving environmental parameters measured near plants accounted for only 54.05% of variability associated with apparent sap velocity measurements. Big sagebrush plants must, therefore, exert considerable physiological control of transpirational water losses.

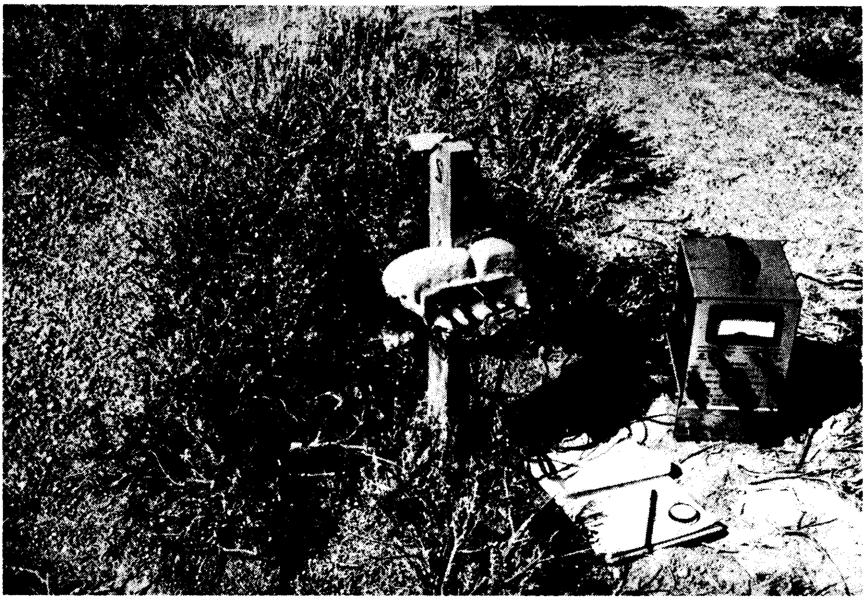

FIG. 1. Big sagebrush plant equipped for measuring sap flow velocities.

Ecology of semiarid plant species is probably influenced more by water relations than by anything else. The passive and physiological aspects of plant response to available moisture have not been studied extensively in the West, and especially with respect to big sagebrush (*Artemisia tridentata* Nutt.). Yet this particular plant occupies millions of acres of western rangeland and is used by many as an indicator plant for potential range rehabilitation measures, for estimating annual rainfall amounts, for visual determination of particular soil properties, etc. Certainly an understanding of the water relations of this species would greatly enhance our present knowledge of the niche this species occupies.

Transpiration is of interest in plant–water relationship studies. Not only total quantities, but also seasonal and daily losses are important and how these losses are modified through plant response to the environment.

One indicator that transpiration is occurring is velocity of the sap stream. In this paper, velocity of a heat pulse within a sagebrush as influenced by flow of sap was used to approximate apparent sap velocities. Heat pulse velocity, the technically correct term, is used interchangeably throughout this paper with sap velocity.

Study Area and Procedures

The study was undertaken in Eastgate Basin, located 120 miles east of Reno, Nevada. The Basin constitutes an area of about 220 mi^2 and is generally quite dry. Elevation varies from about 4,500 ft at the mouth of the basin to nearly 10,000 ft in the nearby Desatoya Mountains. Greasewood (*Sarcobatus vermiculatus* Hook.), shadscale (*Atriplex confertifolia* Torr. & Frem.), big sagebrush, pinyon–juniper (*Pinus monophylla* Torr. & Frem.—*Juniperus osteosperma* Torr.), and low sagebrush (*Artemisia arbuscula* Nutt.)—dominated communities are found in the basin. Average annual precipitation at 5,500 ft, the elevation of the study site, is 10 to 12 inches.

Soils on the sagebrush site were alluvial derived, with little or no profile development. Soil texture was sandy loam down to at least 36 inches, with gravel and some boulders present.

The study site is part of the *Artemisia tridentata/Bromus tectorum* L. community in the Basin as delineated by Heinze et al. (1965). Live shrub canopy coverage was about 25% and the slope a gentle 2 to 3%.

All sap velocities were measured by the heat-pulse technique of Marshall (1958), as modified by Swanson (1962, 1965). Marshall's theory was developed for non-porous woods (no vessels) and sagebrush wood is diffuse porous.

A 3-0-8 mm probe spacing was used, and probes were installed near the base of each sagebrush, one set per plant. Ferguson (1964) has discussed stem anatomy of big sagebrush, and probes were installed where reliable sap velocity readings were most likely to occur. A Medistor Model A-60C microvoltmeter was used as a null detector for temperature measurements. Five plants were measured each hour on 13 selected days during a year from before sunrise to after sunset (Fig. 1). Minimum detectable apparent sap velocity was 3 cm/hr.

Several environmental parameters were measured near the plants. Net radiation was measured with a Fritschen-type (Fritschen, 1963) net radiometer coupled to a Rustrak Model 88 6v battery-powered recorder. Wind was measured with a Stewart anemometer coupled to a Rustrak Model 88 24v battery-powered recorder. Temperatures were measured with Rustrak Model 1443 shielded nickle-wire sensors coupled to a multiple-input Rustrak Model 133 24v battery-powered recorder. Some canopy temperatures were measured with Weston Model 2261 thermometers. Soil moisture was measured with a Troxler Model 105 A Depth Moisture Probe to a depth of 4.5 ft.

The following parameters (in linear

[1] This study was initially financed by a grant from the Desert Research Institute Committee for Research Planning in the Life Sciences, University of Nevada. Additional support was received as a Grant-in-Aid of Research from Society of Sigma Xi. Both are gratefully acknowledged. Thanks also go to Mr. Steve Evermann, University of Nevada, for assistance in the field.

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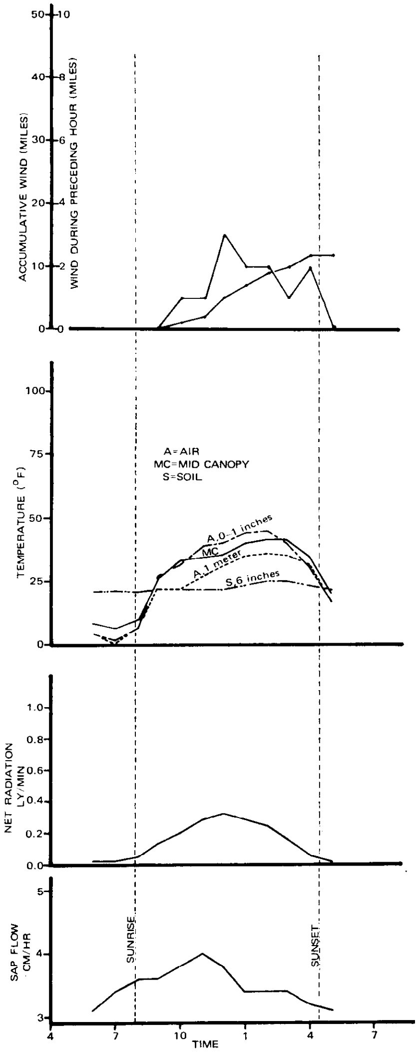

FIG. 2. Sap velocities (average of 5 plants) and selected environmental parameters on 1–17–67.

and quadratic form) were examined in a step-wise multiple regression analysis for their influence on sap movement:

- X_1 Temperature, top of sagebrush canopy
- X_2 Temperature, mid sagebrush canopy
- X_3 Temperature, bottom sagebrush canopy
- X_4 Temperature, 3-inch soil depth directly beneath sagebrush
- X_5 Temperature, air at 39.37-inch height in opening between plants
- X_6 Temperature, air at 6-inch height in opening between plants
- X_7 Temperature, air at 0 to 1-inch height in opening between plants

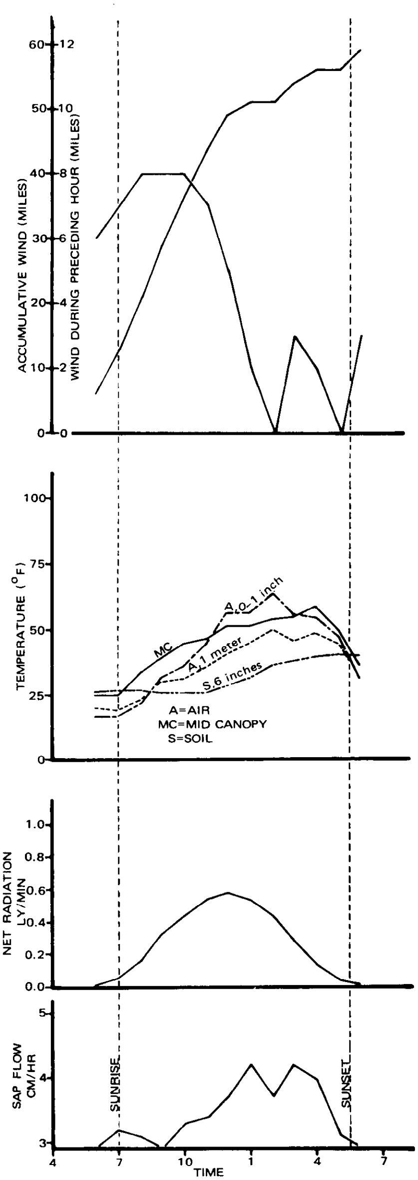

FIG. 3. Sap velocities (average of 5 plants) and selected environmental parameters on 3–7–67.

- X_8 Net Radiation, ly/min at 39.37-inch height
- X_9 Temperature, soil in opening between plants at 2-inch depth
- X_{10} Temperature, soil in opening between plants at 6-inch depth
- X_{11} Temperature, soil in opening between plants at 24-inch depth
- X_{12} Wind (miles) during preceding hour at 39.37-inch height
- X_{13} Accumulative wind (miles) at 39.37-inch height
- X_{14} Relative humidity at 12-inch height in opening between plants

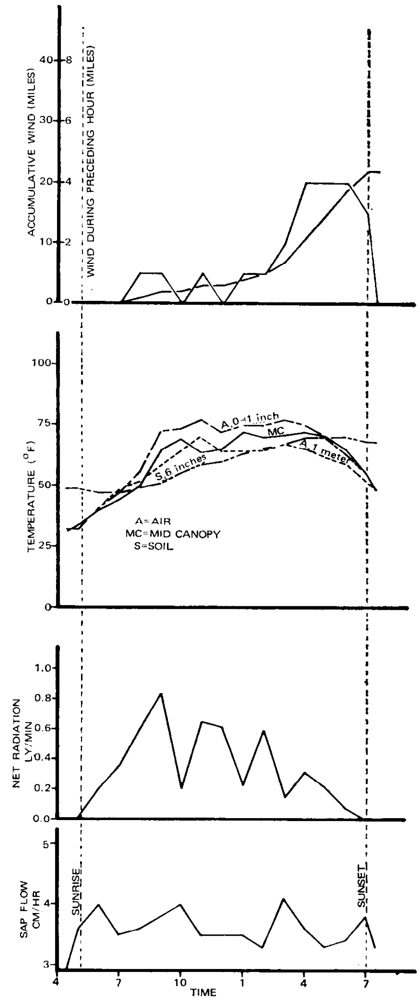

FIG. 4. Sap velocities (average of 5 plants) and selected environmental parameters on 6–14–67.

- X_{15} Relative humidity at 39.37-inch height in opening between plants

Soil moisture distribution in a four-foot soil profile on each sampling date is shown in Table 1. The more uniform the moisture distribution, the drier the profile. Moisture seldom penetrated greater than 30 inches on the study site.

Results and Discussion

Big sagebrush apparently exercises considerable physiological control of water loss. The 30-variable multiple regression equation explained only 54.05% of the variation associated with apparent sap velocities, and only 14 variables explained more than 1% each of measured variability. These vari-

Table 1. Soil moisture distribution (percent of total water by one foot increments) in four-foot soil profile on days when sap velocities were measured.

Date	Foot increments 0–1	1–2	2–3	3–4
9-21-66	29.1	23.4	24.1	23.4
10-5-66	26.3	24.6	24.6	24.5
10-19-66	25.2	25.2	25.2	24.4
10-25-66	25.4	24.6	25.4	24.6
11-23-66	25.7	24.8	24.8	24.7
12-15-66	35.0	21.9	21.9	21.2
1-17-67	35.0	21.9	21.9	21.2
2-8-67	44.3	22.7	16.5	16.5
2-28-67	37.0	24.6	20.0	18.4
3-7-67	37.0	24.5	20.0	18.5
3-21-67	42.1	23.1	17.4	17.4
4-8-67	44.7	22.9	16.2	16.2
6-13-67	24.5	28.2	24.5	22.8

ables, and their relative importance, are given below:

Variable	Variance Explained (Percent)
$(X_5)^2$	17.1
$(X_1)^2$	5.6
$(X_{14})^2$	5.3
X_9	4.3
$(X_{10})^2$	3.8
X_{13}	3.4
X_2	2.3
$(X_2)^2$	2.2
X_{14}	1.8
$(X_{11})^2$	1.5
X_{12}	1.4
$(X_2)^2$	1.2
X_8	1.2
$(X_9)^2$	1.1

The resulting empirical relationship is as follows:

$$\hat{Y} \cong f\left[\frac{(X_{11})^2 + (X_1)^2 + X_2 + (X_9)^2 + X_8 + X_{12} + X_{13} + X_{14}}{(X_2)^2 + (X_{14})^2 + (X_5)^2 + (X_{12})^2 + X_9 + (X_{10})^2}\right]$$

where $\hat{Y}$ is sap velocity.

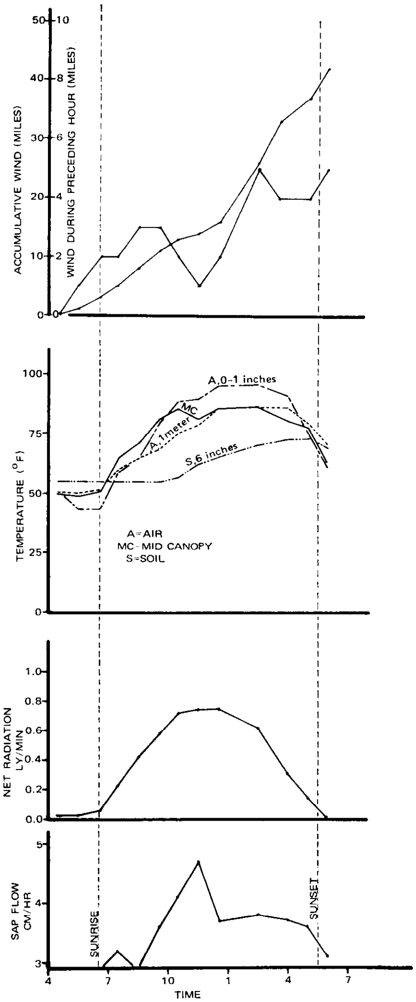

FIG. 5. Sap velocities (average of 5 plants) and selected environmental parameters on 9-21-67.

As previously noted, the analysis represents data from all seasons of the year. If data were analyzed on a seasonal basis, then above relationships could vary somewhat. Soil moisture, an important factor, would also influence the equation, if included.

Peak daily sap velocities were approximately the same, regardless of season (Fig. 2, 3, 4, 5). Average sap velocity for five plants never exceeded 5.0 cm/hr.

Similar sap-flow velocity patterns throughout the year should not infer equal volumes of water being transpired. Late in the summer when moisture is highly limiting, only a small portion of the stem is probably transporting water. However, during the spring soil moisture is readily available, and a greater cross-sectional area of the stem may be conducting water. Therefore, volume of water being transpired cannot be inferred from sap velocity, only time when transpiration is taking place. This study indicates that sagebrush may transpire at any time during the year, but variance associated with sap-velocity measurements could be only partially explained by surrounding measured environmental conditions. Physiological control is, therefore, at least one probable important unmeasured parameter in this study.

LITERATURE CITED

FERGUSON, C. W. 1964. Annual rings in big sagebrush. Univ. Arizona Press. 95 p.

HEINZE, D. H., P. T. TUELLER, AND R. E. ECKERT. 1965. Vegetation and soils of the Eastgate Watershed. Unpublished manuscript, Univ. of Nevada Agr. Exp. Sta. 60 p.

MARSHALL, D. C. 1958. Measurement of sap flow in conifers by heat transport. Plant Physiol. 33:385–396.

SWANSON, R. H. 1962. An instrument for detecting sap movement in woody plants. Forest Service, Rocky Mt. Forest & Range Exp. Sta. Paper 68. 16 p.

SWANSON, R. H. 1965. Appendices to seasonal course of transpiration of lodgepole pine and engelmann spruce. Proceedings, International Symposium on Forest Hydrology, Pennsylvania State University, August 29 to September 10, 1965.

Demarcation of Small Plots with Spring-Loaded Wires

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Highlight

Wires have some advantages over frames for delineating plot boundaries.

For repeated measurements of herbage on ungrazed study areas, boundaries of small, contiguous plots can conveniently be marked with wires held tight by springs. In a trial on Louisiana range this method proved superior to delineating plots with frames.

Each study area, 15.5 × 9.3 ft, was divided into 15 contiguous plots by spring-loaded, 18-gage, galvanized wires spaced 3.1 ft apart on both axes (Fig. 1). Springs were the kind commonly used on baby swings and doorstop chains: compression type, 6 × 7/8 inches, galvanized steel, with S-hook attached.

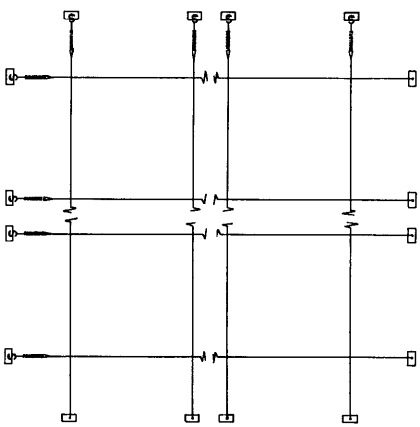


FIG. 1. Contiguous 3.1- × 3.1-ft plots demarked by tension wires.

FIG. 2. Spring installed and adjusted to about 25-lb tension.

Ends of wires were anchored by 2- × 4-inch wooden stakes 1 ft long, driven to within 3/4 inch of ground surface. To minimize interference with harvesting, stakes were put 2 ft outside the plots. A 20 d nail driven into the top of each stake provided a fastening point for the wire. One end of each wire was secured to the nail in a stake on one side of the study area. The other end was passed through the loop of a spring held by an S-hook to a nail in the stake on the opposite side of the area. The wire was tightened until the spring compressed to about half its length (Fig. 2). Securely wrapping the wire completed the installation. Tension on the wire was about 25 lb but could be increased to 45 or 50 lb by fully compressing the spring.

The six installations tested have proven highly satisfactory. Since old plant material was removed and plots were established before growth began, little herbage crossed under the wires. This, and the small diameter of the wire, made it easy to separate vegetation and to judge which plants grew on each plot. Consequently, time spent preparing to clip was far less than with frames. Loss of delineation during harvest was no problem, as it is when a frame is inadvertently moved, for tension automatically realigned the wires.

The technique is relatively costly where plots per location are few. A single plot, for example, requires four springs and eight stakes. For contiguous plots, material cost per unit diminishes as the number increases; blocks having an equal number of plots on each axis are most efficient. Expense can probably be reduced by substituting expansion springs for the compression type. Though subject to damage by overextension, these should work satisfactorily if installed with reasonable care.

Maximum length of wire for effectiveness depends largely on relief of the sample area. Surfaces of study sites were almost flat; hence, elevation and tension held wires clear of the ground. In trials with wires of various lengths, 25 to 30 lb of tension and 3/4-inch elevation proved adequate up to 30 ft. With tension increased to maximum, 55-ft wire sagged 1/2 inch. Since soil surface varied more than 1/4 inch, greater elevation or tension was needed to clear wires exceeding 50 ft.

Although the technique has been employed mainly on protected sites, one set of plots was grazed briefly by cattle without damage to wire installations. Thus, application on grazed range may prove feasible, provided wires are uniformly near the ground—probably less than 1 inch.

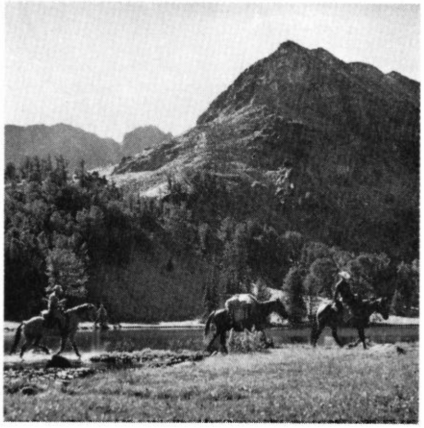
Recreation and Range Use

GEORGE R. WOLSTAD

Forest Service, U.S.D.A., Missoula, Montana.

The cover photo on this issue was adjudged grand champion at the 21st ASRM Annual Meeting in Albuquerque. The picture shows Ranger Blaine Tennis and his assistant, Bob Ketchingman, of the Ennis District on the Beaverhead National Forest in southwestern Montana, leaving Lower Echo Lake. This beautiful lake, teeming with rainbow trout, is south and east of Ennis in the Hilgard Peaks of the Madison Range. This wild and beautiful sub-alpine country is north and west of Yellowstone Park. Elevations run between 9,000 and 11,000 ft. Since this photo was taken in 1966, the Ennis District has been merged with the Madison District, headquarters at Ennis.

Domestic sheep at one time grazed here during the summer months but this practice has long since been discontinued. The cost of operation and the difficulty of finding suitable herders to go into such remote and relatively inaccessible areas have been largely responsible. In place of the sheep has come an ever increasing use by pack and saddle stock, largely by recreation users. The high elevation, the deep winter snows persisting from October until July, and the resulting short growing season all combine to render the vegetation very vulnerable to animal use. In addition to the use by domestic pack and saddle stock, there is a certain amount of use during the summer months by game. There are occasional elk, and mule deer and Bighorn sheep are common. These uses require such areas to be studied, range conditions evaluated, and plans made and supervised to use the forage resource in such a manner that the soil and vegetation, with due regard for the beauty and wilderness aspect, will be preserved.



Land managing agencies in the West are becoming increasingly aware of the need for study and management of the recreation-stock use of such areas. This work is being incorporated into the Range Allotment Analysis program. The task is formidable. The areas are usually remote and travel to and from them is slow. Effective field seasons are short. Management, after plans have been made, is difficult because of the difficulty of contacting the users and regulating the use with a minimum of restriction. Agencies recognize that users come to such areas purposely to avoid regulation and restriction. Therefore plans must be as broad as possible, still preserving the resource. Some areas are habitually heavily used and others, more remote, receive little or no use. This can usually be tied in with the presence or absence of an adequate trail system. Therefore, it is obvious that plans should also incorporate a program for development. Construction of new trails and improvement of existing ones must go hand-in-hand with the planned use of the forage. Ranger Tennis and his assistant were in the area making plans to begin such studies. A big part of the job is correlating with adjoining districts and units since recreationists obviously do not want to be hampered by unit boundaries any more than is absolutely necessary.

The small feed area in the photo is typical of many of the popular camping areas around the small lakes in the high Rockies. Users like to camp close to the shores of the lake and keep their animals picketed or hobbled close to camp. This means that forage tends to be over-used and vegetation damaged at the lakeshore while there may be other areas, farther from the lake, with abundant feed. Damage occurs not only to the grasses and forbs (flowers), but also to trees to which animals may have been tied, thus trampling out the roots. Any vegetation destroyed, at such high elevations, requires many years to replace. If damage is so great that soil is lost, it will not recover in our time.

Some areas have such limited vegetal growth or have been damaged to the extent no grazing can be permitted. In such cases, users must pack hay or concentrates. Fortunately, such areas are relatively few. Other areas may have sufficient forage that a given number of horse-days use may be permitted and any subsequent users must pack hay or pellets. Checking these areas to determine when the forage has been properly used and passing on this information to subsequent users is a big job for the District Ranger and his assistants in the Forest Service, as well as for the land managers in other agencies.

Though the days may be long and the work may be hard, it is tempered by the enjoyment of camping at such areas as this little lake. Blaine and Bob breakfasted well on trout caught from the lake the night before!

Vegetation at this particular lake is in good condition. The soil has adequate cover and has not been disturbed. Vegetation is characterized by high altitude bluegrasses, fescues, and sedges, along with geraniums, asters, paintbrushes, and other forbs which one would expect to find in the area. If studies reveal at a later date that noxious weeds and other plants not native to the area are invading, then management must be changed and remedial measures taken.

BOOK REVIEWS

The Geography of Soil. By Bryan T. Bunting. Aldine Publishing Company, Chicago, Illinois. 213 p. Rev. Ed. 1967. $5.00. (Paperbound $2.45.)

Written by a geographer using the literature and researches of soil science, this book is a practical, illustrated synthesis of the older and largely geographical concepts of the distribution and morphology of soil and new work concerned with the elaboration of soil forms. The author uses detailed examples and quantitative data to explain cause and effect relationships among such items as the interplay of erosional and use history and climatic changes to soil development. Especially interesting is the meshing of pioneer concepts of soil formation and classification, made available by recent translations of several major Russian works, with modern concepts of these phenomena. Consequently, a comprehensive bibliography is listed at the end of each chapter as well as a *Select Bibliography* at the end of the book.

Two major topics are discussed. The first eight chapters deal with Factors of Soil Formation. The last nine chapters discuss soil Description, Classification, and Nomenclature.

The fundamental hypothesis in the introductory chapter and emphasized in the succeeding seven chapters is that soil is a continuum, interdependent of the many factors influencing soil formation. The author stresses that the *monocyclic* or *climax* concept of soil formation is not the only possible interpretation. That soils are polycyclic in nature and origin; "Their orderly development—interrupted by changes of climate, . . . by abrupt intervention of geomorphic agents,—or burial by deposition of fresh material . . . ," may be the more logical approach to soil interpretation. Throughout these first eight chapters, the author integrates well by words and examples the formal processes of soil formation as well as the processes included in chemical weathering.

In Chapter 8 the author introduces American and European concepts of soil description, classification, and nomenclature. He makes a good attempt to meld the ideas of various classification schemes with the Seventh Approximation, which outlines classification of soils based on internal soil properties which either affect soil genesis, or result from it. The consequence is the presentation in the succeeding eight chapters of the results of modern national and international studies regarding soil classification, within the framework of Great Soil Groups, on a regional rather than a zonal basis.

The material in this book is presented in a manner whereby the student with even limited training in soil classification and geography can materially increase his knowledge and appreciation of soil. Anyone studying soils should have the book on his reference shelf.—*Richard S. Driscoll,* Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Wildflowers of the United States: Vol. I. The Northeastern States: Vol. II. The Southeastern States. Rickett, H. W. (Vol. I., Parts 1 and 2, x + 559 pages, illustrated, map; Vol. II., 1968, Parts 1 and 2, x + 688 pages, illustrated, map) McGraw-Hill Book Company, New York. $39.50 and $44.50, respectively.

These illustrated books on the wildflowers of the United States (excluding Alaska and Hawaii) are being prepared by the New York Botanical Garden. Rickett, the author, is assisted in this work by W. C. Steere, the General Editor and Director of the New York Botanical Garden, as well as six collaborators for Vol. I and eight collaborators for Vol. II. These large (about 10 × 13 inches) and colorful books are directed to the amateur with little or no botanical training as well as to the professional scientist in nonbotanical fields. Vol. I and II respectively covering the Northeastern states (bounded by Minnesota to Missouri to Virginia) and the Southeastern states (bounded by North Carolina to Arkansas across Southeastern Texas) will be followed by volumes on the Central Plains and Mountains (including the Rocky Mountains and the Great Basin), the Southwest, and the Pacific Northwest. Vol. III will be eagerly awaited by persons concerned primarily with rangelands and it should appear in the spring of 1969. Vol. IV and V are not yet begun, and probably they will not appear until 1971 at the earliest.

These books are well endowed with many excellent color photographs of the flowers as well as clear line drawings. Photographs have been supplied by a large number of persons and each is identified. Photographs from more than 50 persons were used in Vol. I and approximately twice this number in Vol. II. Each volume begins with an introduction concerning the names and identification of flowers. This material is duplicated in part between Vol. I and II and is accompanied by excellent line drawings of types of flower parts, fruits, leaves, and underground parts. Plants in Vol. I are grouped into 14 groups of families and in Vol. II into 15. A brief key is given to the group of plants and each volume contains an illustrated glossary. This introductory material comprises only a small part of these two volumes and most of the remainder of the two books is concerned with brief descriptions of the plant, line drawings, and excellent color photographs of the flowers. A feature of the descriptions of plants is that both Latin and common names are given. Vol. I contains more than 1,200 color photographs as well as 350 line drawings for some 1,700 species. Vol. II includes slightly less than 1,700 color photographs and more than 380 line drawings for some 1,900 species. Most of the color photographs are excellent and the few which lack somewhat in quality can be tolerated easily, especially by one who has attempted to photograph wildflowers. The textual discussion, the drawings, and the photographs relating to any one plant generally are located within a page or two of one another. The color prints are on the right-hand pages. The pages are of extra-heavy fine vellum paper; the books are bound in linen-finished buckram; each volume is published in two parts; and each volume is boxed in a durable library case.

In the context used in this series, wildflowers include what rangemen call forbs. Grasses, sedges, and most woody plants are not included. But many of the forbs are important as forage plants, as range indicators, and as increasingly important aesthetic resources. Many of the forbs illustrated in Vol. I occur in parts of the Northern Great Plains as well as in the Rockies. Many of the forbs in Vol. II, of course, are important on Southeastern rangelands. Therefore, Vol. I and II are valuable references for range managers and should be included in university and departmental libraries as well as libraries of research stations. Not many western range managers will feel it is possible to buy these excellent books for their personal libraries at the prices quoted. Yet, because of the clear line drawings and the large number of excellent color photographs, those who are interested in nature's beauty and enjoy studying wildflowers will find these books a bargain. The author, the New York Botanical Garden, and all the contributors to the development and funding of the efforts leading to these publications should be congratulated.—*George M. Van Dyne*, College of Forestry and Natural Resources, Colorado State University, Fort Collins.

VIEWPOINTS

Range Management and the Draft

In the matter of advancing the science and art of grazing land management, the American Society of Range Management has more than a little interest in the continued supply of well-trained range scientists. It should be, therefore, a matter of concern to the Society and the range management profession that present Selective Service regulations apparently will result in a very noticeable effect on this supply.

On February 15, 1968 the National Security Council advised the Director of Selective Service to end deferments of graduate students other than those now in the second or subsequent year of graduate study. In an attempt to assess the impact of the present draft rules on graduate study in 1968–69, a survey was conducted by the Scientific Manpower Commission (with which ASRM is affiliated) and the Council of Graduate Schools of the United States.

"Assessment of Graduate Enrollment" questionnaires were sent by SMC to the 279 member schools of the Council; usable data were returned by 122 of these graduate schools, including 13 of the 29 schools in the Range Management Education Council. SMC's analysis of these data indicate some startling possibilities with regard to next year's graduate programs; in summary—

1) the entering male enrollment in full time graduate school next year will be down 70% from the current school year

2) total enrollment (male and female) will fall 50% in the first year class, and 33% in the class of full time second year graduate students

3) veterans are expected to constitute only 6% of both the first and second year classes next year

4) by disciplines the anticipated percent of the normal number of first and second year male graduate students available for 1968–69 is:

Physics	30% and 61%
Chemistry	36% and 58%
Mathematics	40% and 62%
Biology	39% and 65%
Other Science	42% and 60%
Engineering	36% and 71%
Humanities	37% and 66%

There are no specific figures pertaining to graduate students in the range science or natural resources fields, but it is probably reasonable to assume their number will be off by about 40% to 60%. I have obtained from SMC copies of the original survey forms filed by the responding RMEC schools, but because of the design of the questionnaire no additional interpretations could be made beyond the initial analysis.

The important point, however, is that this survey does give substance to the criticism that current draft rules will disrupt normal professional education programs as well as withdrawing many persons from the economy who are already trained and now serving the nation in their profession (it is estimated that approximately 7,500 of this year's Ph.D.s will be subject to induction immediately after their degree is obtained). In addition to the problem of a drop in graduate student enrollment, both undergraduate and graduate programs will be affected by the shortage of teaching and research assistants.

With ever greater demands being made on the natural grazing lands, necessitating their more knowledgeable use and management, we cannot afford to be without a constant supply of range scientists with advanced training. But it now seems likely that the supply will be interrupted, and the full effect and seriousness of the problem may not be realized for several more years.

FRANCIS T. COLBERT

Progress in the Society

The following comments were extracted from the year-end "Report of Section Activities" made by ROBERT D. LIPPERT, *the 1967 President of the Kansas-Oklahoma Section.*

Speaking of progress . . . there remain many items of concern which must be considered if we are to measure progress in the future. Some of these items are:

1) *Membership:* Provide new incentives to obtain new members and to hold annual members until they become automatic perennials. Ranchers should constitute at least 50 percent of total membership.

2) *Accelerate Section Activities:* Recognize and define the need for expanded or new Section activities, then organize, plan, develop and carry out these programs by involving people, becoming involved and responding to assignments and individual responsibilities.

3) *Representation:* Each Section should have elected representation which would serve on National Board, committees, etc. This active representation is sorely needed. Section Chair-

men need direct participation in the formulation of policy and decisions, something more than merely being advisory to the advisors.

4) *Journal:* Consideration must be oriented toward making the Journal more interesting, informative and receptive to be read by more of the membership.

5) *Operating Funds:* Too much emphasis has been placed on the needs of additional funds nationally and too little toward the needs of the Sections to secure and maintain adequate, revolving operating funds to finance worthwhile projects within the Sections. Authorization and guidance are sorely needed.

6) *Active Committee Leadership:* A new look must be directed toward committee assignments, functions and responsibilities. We must utilize talents of the members, promote and pursue objectives under organized leadership of interested, active committee chairmen.

7) *National Nominations Committee:* Sections must develop members that have the potential for serving on national ASRM committees and as officers, whether elective or appointed. Not only must they have the qualifications, but also the experience . . . (of) participation in National meetings.

Leave Six for Pallbearers

Pre-industrial man, like any other animal, was closely dependent on the natural abundance of his surroundings. Through his adaptiveness and ability to reason, man has brought about industrialization and urbanization which have, in turn, lessened his dependence on and his subservience to nature's whims. Unlike other animals which had to undergo a great deal of *morphological, anatomical,* and *physiological* change to adapt to an ever-changing environment, man has grown to understand and use his accumulated knowledge of his environment, and is now able to transport parts of his environment through both time and space and survive without great changes.

Through expenditures of one or several forms of energy, man is able to concentrate other forms of energy or potential energy for his use. Agriculture is no exception. Crop yields have increased due to the concentrations of energy in producing a crop. That is, the sums of energy (man hours and machine hours) expended in building tractors and plows, manufacturing, distributing and applying fertilizers, selecting and producing hybrid seeds, are reflected in higher yields. Crop yields will continue to increase as man finds more ways of harnessing energy.

Range managers need to be more adaptive and strive to understand and use their accumulated knowledge of their environments. They should also be finding new ways of harnessing and concentrating energy to improve their working alliance with nature. However, tradition dictates that as soon as a "range man" starts to concentrate energy, he is no longer a "range man." He is classed as an agronomist or a "range farmer." There also is a tendency to associate the range manager image with that of a glorified cowboy.

Industrialization, urbanization, and wealth accumulation will increasingly become the characteristics of modern society. Range, as we now know it (a broad expanse), cannot long be expected to survive the inroads of modern society. In order to absorb the impact of these inroads, the range men must learn to use concentrations of energy upon the remaining rangelands and otherwise adapt his thinking to modern-day natural resource problems. The range manager has little chance of taking the concept of range management as he now knows it (domestic livestock on native range) through time. He is left with at least three alternatives: (1) transport it through space (perhaps to the moon); (2) adapt to a new environment (modern society) by undergoing morphological, anatomical or physiological change to cope better with his new environment; or (3) adopt a different philosophy of range management.

It is not very likely that the range manager's expertise will be needed on other planets in the near future. It is also doubtful that range managers will undergo change to fit better their environment. The only alternative is to develop a new expertise to match present-day problems. Arthur W. Sampson was studying deferment and rotation systems 50 years ago. How far have we come since then? Not very darn far. We are still doing grazing impact studies, still fiddling with rest-rotation. Thirty years ago salting was thought of as a tool in livestock distribution; fifteen years ago it was discounted. Now we are looking to the economics of salt placement again.

Range management must come up with real innovations, and apply these and other techniques to improve the domestic livestock industry. It must also expand into the areas of recreation, wildlife and watershed management.

Unless the present range philosophy is transported through space or the range manager undergoes some change or a new philosophy is evolved, the field of range management will die a slow, gruesome death. Hopefully, nature will be kind and leave six grand old men or their disciples to serve as pallbearers. Or, to put it more bluntly, hopefully nature will leave two pallbearers—there are only two handles on a garbage can.

This paper was designed to "get your dander up." We need your help and ideas to develop forcibly an expertise and a sphere of influence. We need to keep range management out of the garbage can. Can we count on your help? Your vocation is at stake!

JACK F. HOOPER

Department of Range Science
Utah State University
Logan, Utah

WITH THE SECTIONS

East Africa Section Field Day at Kekopey Ranch. Host Arthur Cole (back to camera, pointing) and W. R. Chapline (center, white shirt and camera).

East Africa

The First Annual meeting of the East Africa Section was held on June 4 at Headquarters, East Africa Agriculture and Forestry Research Organisation, Muguga, Kenya. Included on the program was **Dr. Gene Payne** (formerly at Bozeman, Montana) who spoke on range management training at Egerton College. Dr. Alister McKay, staff member of EAAFRO, discussed food habits and nutrition of cattle.

Two new Section officers, elected last March, were installed at the June 4 meeting: **Arthur Cole**, President, and **John Kenyon**, Council Member. Arrangements were made for a field tour of Richard Percival's POTHA Ranch, near Machakos, on September 23, 1968.

Last March 18 ASRM members and their guests attended a Section Field Day at Mr. and Mrs. Arthur Cole's Kekopey Ranch, Gilgil, Kenya. **W. R. Chapline**, range management consultant for USDA who is currently on a world tour, was present for this event and submitted the following report:

"It was indeed a pleasure to be on hand for the second field day of the East Africa Section of ASRM. It is an active organisation of both ranchers and scientific personnel. About 100 members and guests attended the first field tour on October 25, 1967 and about 50 were present on this second tour. The Section has adopted a policy of inviting only those genuinely interested in range management and good potential members.

"The March 18, 1968 field tour was held at Kekopey Farm in the Rift Valley, near Gilgil, Kenya. This farm, or ranch, covers 43,000 acres, of which 33,000 have been developed for intensive utilization. Elevations vary from 5,900 to 7,500 feet. Rainfall averages 24 inches annually, but has been as low as 15. It comes in two rainy seasons with dry periods between. The ranch supports 4,500 beef and 250 Guernsey dairy cattle. Mr. and Mrs. Arthur Cole, the owners and managers, are a great team. Through good range management and hard work they have developed a very efficient operation.

"The range is a savannah type with an overstory primarily of Leleshwa (*Tarchonanthus camphoratus*) and *Acacia* sp. The understory is composed of scattered low shrubs and a good soil cover of indigenous grasses, some legumes, and other forbs. The developed part of the ranch is divided into 85 pastures with 170 miles of fencing. Water is provided in each pasture by 37 miles of pipeline from a large spring originating high on the eastern escarpment of the Rift. Most of these pastures contain about 250 acres, and where the bush has been cleared will carry approximately 100 animal units for six months of grazing. They are then rested for six months. No pasture is grazed at the same season within a two-year period. With this type of grazing management most of the native grasses give way to star grass (*Cynodon dactylon*) which is a prolific producer of good forage in the area.

"The dairy herd has its own series of pastures near the headquarters. Sixty acres have been developed recently for sprinkler irrigation. Up to the present time the dairy herd has been used primarily for milk for the 80 or so farm workers and their families. This is furnished free—four pints for each worker daily and additional amounts for children. With irrigation the dairy herd will be increased and permit a commercial whole milk and cream operation.

"A Santa Gertrudis herd of 46 breeding cows and heifers is maintained to provide bulls for cross breeding on Boran cows at another ranch and to build up an improved Santa Gertrudis herd. The Boran, which resembles the Brahma, is a popular breed developed in Kenya from indigenous cattle.

"The Commercial herd is largely crossbred Boran-Shorthorn, which combines the hardiness of the Boran and the greater milk supply of the Shorthorn. Boran bulls are generally used with that herd. Calf crops average well above 90 percent while losses are about ½ of 1 percent. Bulls are with the cows practically yearlong. If a cow does not breed in 14 months she goes to the butcher. Ordinarily each bull serves 60 cows but if the cow herd (mob) is larger than 60, two bulls are used.

"Each month's calves and their mothers are separated from the various breeding mobs and put into a fresh, ungrazed pasture to form a new mob with calves of uniform age. The calves are usually weaned when they are about eight months of age and put in a rested, ungrazed pasture.

"The top 10 percent of the heifers are retained for breeding herd replacements. The bottom end goes to the butcher and the balance are bred and sold to other ranchers for their breeding herds, bringing a much better price than as butcher stock.

"Steers are usually grown out to 3 or 4 years of age. By then they are fully grown and go to market grass fat. The owners expect that faster maturing steers will result from their improved breeding program. Steers from the other ranch are brought down at about 3 years of age and fattened for about one year on the good star grass range, moving to fresh pasture after about 6 months.

"Most of the ranch was originally covered by a heavy stand of bush, and clearing was a major problem. If Leleshwa is cleared by hand, it costs from 60 to 120 Kenya shillings (about $8.40 to $16.80) per acre. Gyramowings of the remaining smaller bushes cost 10 shillings per acre for the first mowing and 4 shillings per acre for the second. Recently Mr. Cole has been getting land cleared at very little cost by local charcoal "burners," operating under contracts. The "burners" clear all wood and dig up the stumps; in return they use the wood for making charcoal. Yields of 2,000 bags per acre are obtained from heavy bush stands. Supervision is obtained by holding one man of a 10-man team responsible for a good finished job before the crew is allowed to start clearing a new area.

"There are a great many game animals on the ranch including several thousand impala, 500 or more eland, and countless numbers of Thompson gazelle and Chandler reedbuck. There also are many Cape buffalo, zebra, and hartebeest. Some controlled hunting is permitted on private land under Kenya laws whenever such game animals get so numerous as to compete with domestic stock for forage.

"I believe the East Africa Section has a real bright future. It is serving a vital need in this area."

Colorado

The Colorado Section's summer field meeting was scheduled for June 19 at the Tom Lasater ranch near Matheson. **Don Smith** and **Carleton Fonte** were in charge of the program, which had the theme "Working with Nature." The Lasater operation is unique in many respects, and a full report of this meeting (to appear in a later issue) should prove highly interesting.

Colorado now boasts of having four Past-Presidents on its membership roster: **C. Wayne Cook**, **Fred Kennedy**, **C. H. Wasser**, and **Donald F. Hervey**.

Wildlife Management Seminar: California Section President Robert H. Blanford studies rabbit population with assistance of Bunny Cecile.

California

Last February 2 the Bay Area Chapter of the California Section held its meeting at the San Francisco Playboy Club, thanks to Key Holder **Mert J. Reed**. Appropriately, perhaps, **Dr. Harold Biswell** presented a slide talk on "Fire Control and Use."

Robert Buttery was elected Chapter Chairman to succeed **Roche D. Bush**, and **Robert S. MacLaughlan** was elected Secretary-Treasurer.

Kansas–Oklahoma

June 7 and 8 were the dates of the Section's Summer Meeting, held at Medicine Lodge, Kansas. The program and tour were planned and supervised by **Victor Griswold**, **Norman Schlesener**, and **Ray Brown**. Three ranches were to be visited on the tour: the Herb Gress ranch (loamy upland and shallow prairie range sites), the Jim Louker ranch (eroded red clay and red shale range sites), and the Ted Chapin ranch (sandy lowland, loamy lowland, sandy, and sub-irrigated range sites).

The following letter appeared in the May issue of the Kansas–Oklahoma Section Newsletter, and it is worth repeating here. The correspondent, John Bozarth, is a student at Kansas State University and was the Section's representative to the Youth Range Forum at the Albuquerque meeting.

Dear Members of the Kansas–Oklahoma Section, ASRM:

I would like to take this opportunity to thank the Kansas–Oklahoma Section of the American Society of Range Management for sponsoring my trip to the Youth Forum at the National Meeting in Albuquerque.

The trip was one of the most rewarding experiences of my life. There were delegates there from Canada to Texas. Each Section presented a talk on its local youth range camp, and a talk on range management practices in its area. I thought the talks about range management practices in each section were particularly interesting. Almost every section had slides of the rangeland in its particular area and told of some of the particular problems they had. These problems varied from the bogs of Canada to the mesquite of the Southwest. The Youth Forum group was small enough that it didn't take long to get acquainted with the other delegates and the week proved to be one of the most enjoyable of my life.

I thought the Forum was well organized. I attended several of the talks presented to the delegation at large and I thought most of these were interesting and informative. Thanks again for one of the most memorable experiences of my life.

Sincerely,
John Bozarth

Idaho

Livestock, wildlife, timber, recreation, soil, water, people—all facets of natural resource management were discussed and emphasized at the annual meeting of the Idaho Section held last November 27–28. The theme of the meeting was summarized by **William Meiners** in his statement, "Range management in its fullest concept . . . is the key to multiple use on western rangelands."

Awards presented at the annual meeting included the following: President's Award for Arts, **John A. Pierce**, Rancher, Malta; President's Award for Science, **Lee A. Sharp**, University of Idaho, Moscow. **Ralph Samson**, Boise, was presented a Citation Award for his outstanding work in youth education and as leader of the Alpine Youth Conservation Camp. A Citation Award also went to **Rick Royer** as top delegate to the Alpine Youth Conservation Camp. **Jerry Reese**, student at the University of Idaho, was awarded the Section's $100 Scholarship.

From left to right, Walt Parmeter (SCSA), Sen. McGovern (with new hat), and Ralph Cline (ASRM).

Robert Rowan (right), chairman of Nevada's Awards Committee, presents the Range-Man-of-the-Year Award to Dean M. Sachs.

South Dakota

The 1967 annual meeting of the South Dakota Section was held last October 18–20 at Rapid City in conjunction with the South Dakota Chapter of the Soil Conservation Society of America. Harold Cooper, SCS State Conservationist from Wyoming presented the keynote address, "Protecting Our Environment." The banquet speaker was Senator George McGovern (D-S. Dak.), who was ceremoniously presented with a new hat by **Ralph Cline** (ASRM) and Walt Parmeter (SCSA).

South Dakota's "Range Man of the Year" award went to **A. J. Barta**, a rancher whose headquarters lies just east of Buffalo Gap in Custer County. Starting with 35 dairy cows on overgrazed range in the Dirty Thirties, the Barta family has expanded its operations to 1,000 cows on ranches in South Dakota and Montana. Mr. Barta has converted all of the old cropland on his ranch to forage: native range, tame pasture, or alfalfa. His ranching program easily carries through dry years without overtaxing the resources; it is an operation that is frequently used to demonstrate various aspects of good ranch and range management.

On July 12 the South Dakota Section was to sponsor a "Public Lands and Livestock Use" tour at the Vincent and Chester Crago ranch near Belle Fourche. A tour of the A. J. Barta ranch, Buffalo Gap, is scheduled for August 16.

Nebraska

The 1968 Nebraska Range Camp will be held August 4th to 9th at Curtis, utilizing the facilities of the University of Nebraska's School of Technical Agriculture.

Previously held at the State 4-H Camp at Halsey, the decision to change the location of the Range Camp resulted primarily from scheduling conflicts at the former site. The facilities at Curtis appear to be well adapted to the needs.

The program and format of the Nebraska Range Camp emphasize range forage, range livestock, and ranching. However, effort will be made this year to make the program as well suited to young people from eastern Nebraska as it is to those from the western part of the State. Consideration also is being given to the feasibility of students in the production agriculture curriculum participating in the Range Camp program. The Range Camp fee remains at $30 for 1968.

Nevada

Elko was the site of the annual winter meeting of the Nevada Section, held on January 9–10, where **Dean M. Sachs** was honored as Nevada Range-Man-of-the-Year. Sachs received his BS degree from the University of Idaho in 1935, and was employed by the Forest Service and Soil Conservation Service before joining the Grazing Service in Nevada in 1940. From 1950 until his retirement last November he served as BLM Range Conservationist in the Elko district; in this capacity he was largely responsible for district improvement programs which included the seeding of 332,000 acres, 1,700 miles of fencing, sagebrush spraying on 10,000 acres, and 356 water developments.

The eighth annual Nevada Range Camp for Boys was to be held June 10–15 on the Santa Rosa District of the Humboldt National Forest. June 20–21 were the dates of the Section's annual summer tour which started from Ely. Additional information about these events will appear in a future issue of the Journal.

Pacific Northwest

The Wallowa area of northeastern Oregon was the location of the Section's Summer Tour scheduled for June 24–25. Traveling by bus from Enterprise, the group was to spend the two days visiting several ranches and observing what Boise Cascade is doing on the management of its timberlands. A detailed report of this tour will be featured in a subsequent issue.

NEWS AND NOTES

XI International Grassland Congress

The XI International Grassland Congress will be held at Surfers Paradise, Queensland, Australia, April 13–23, 1970. Sixteen general sessions will be devoted to scientific papers grouped into the following sections:

Section I	Natural Grasslands and Woodlands
Section II	Land Development with Sown Pastures for Animal Production
Section III	Providing New and Improved Pasture and Forage Plants for Increased Animal Production
Section IV	Nutrient Requirements of Pasture and Forage Plants and Soil Fertility
Section V	Physiology of Pasture and Forage Plants
Section VI	Pasture and Forage Production and Ecology
Section VII	Pastures and Forages in Animal Nutrition
Section VIII	Management and Use of Pastures and Forage Crops
Section IX	Training of Grassland Research Workers

In addition there will be six sessions devoted to plenary symposia on selected topics.

Delegates are invited to submit papers for inclusion in the Congress. Authors of papers are requested to submit two copies of a synopsis (100–200 words) not later than October 1, 1968. The Program Committee reserves the right to refuse any paper which cannot be fitted into the program. Three copies of the final manuscript—maximum permissible length of 2,000 words—must be submitted on or before March 1, 1969.

A number of tours will be arranged for both before and after the Congress. They have been designed to enable members to visit temperate, sub-tropical, and tropical areas of Australia and to see grassland research and pastoral industry in these areas. Two post-Congress tours of New Zealand grassland districts are also included.

Several ASRM members have participated in past Congresses, and in the present instance there are numerous excellent opportunities for rangemen to appear. Anyone interested in participating in the Congress, or who would like further information, may write to The Congress Secretary, XI International Grassland Congress, 372 Albert Street, East Melbourne, Victoria, Australia 3002.

Box to Australia

Dr. Thadis W. Box, director of Texas Tech's International Center for Arid and Semi-Arid Land Studies, recently spent three weeks in Australia meeting with scientists from the Commonwealth Scientific and Industrial Research Organization, government officials, cattlemen's association leaders, and others.

The purpose of the visit was to make a preliminary feasibility study of central Australia's agricultural potential. Dr. Box noted that almost three-fourths of the continent is in the arid zone, and has been devoted to extensive pastoral enterprises. However, apparent reserves of underground water offer a possibility of developing more intensive agriculture in certain areas.

One of the major points outlined in Dr. Box's report is the development of irrigated pastures to stabilize the livestock industry.

The study was sponsored by the Magellan Petroleum Corporation, and was suggested when it reported the find of a major fresh water aquifer during development of its Mereenie Gas Field.

Outdoor Recreation

Emphasizing the increasing recreational use of natural lands, The Wilderness Society has announced the schedules of 35 wilderness trips for the 1968 season. These popular trips—involving riding, walking, backpacking, and canoeing—range in locale from southern Arizona to Alaska, and from Minnesota to the Cascades.

Range Committee

At its annual meeting last year the Florida Association of Soil and Water Conservation Districts created a standing committee on range. A primary objective of the committee is to create a greater awareness among landowners and the general public of the importance and potential of Florida's native grasses and the multiple use of natural lands. Included on the six-member rancher committee is **John Hunt**, manager of the Rainbow Ranch. Mr. Hunt also is a member of Polk SCD Board of Supervisors.

Fire Ecology Conference

The 7th Annual Fire Ecology Conference, sponsored by the Tall Timbers Research Station, Tallahassee, was held on March 14–15. **E. V. Komarek, Sr.** presided as conference chairman and also spoke on "Lightning and Fire Ecology—North America."

Of primary interest to the Tall Timbers Station are the influence of fire on the environment and the application of fire in land management. Many of the papers presented at the conference had special reference to the influence of fire on grasslands and grazing animals.

Other ASRM members in attendance included **William H. Moore, Ralph Hughes,** and **Lewis L. Yarlett.**

ATB

A new member of ASRM, **Dr. Thomas R. Soderstrom**, is also the Executive Director of The Association for Tropical Biology, Smithsonian Institution, Washington, D. C.

Organized in 1963, one of the aims of the Association has been to bring attention to different tropical regions of the world, and to bring members together by holding symposia in these regions. The first symposium, held in 1966 in Belém, Brazil, focused on the biology of the Amazon Basin. In the planning stages are symposia covering tropical areas in Hawaii, Colombia, Argentina, Asia, and Africa.

Team Approach to Reclaim Texas Rangeland

The invasion of brush over 88 million acres (82 percent) of Texas rangelands presents a major economic threat to the state. Reclamation of this lost grassland is the goal of a noxious brush and weed control team composed of Texas Tech, Texas A&M, Abilene Christian College, Sul Ross State College, Southwest Texas State College, Texas A&I University, USDA, and the Instituto Nacional de Tecnologia Agropecuaria in Argentina. Private companies and organizations are providing guidance and assistance, while several ranches have agreed to support research on their lands.

Dean Gerald W. Thomas of Texas Tech's School of Agriculture has primary responsibility for the program. **Dr. Thadis Box** is coordinator of research and **Dr. Joseph L. Schuster** is project leader of the brush control program.

Range scientists will carry on the major portion of the research, cooperating with the Departments of Agricultural Engineering, Agricultural Economics, and Entomology. Biological, mechanical, and chemical control methods are being explored as well as the use of fire as a tool in reducing brush competition. Economic studies will explore cost-benefit ratios for various control methods, and land management studies will emphasize follow-up control practices.

People

R. S. Campbell, Editor of the *Journal of Range Management,* presented the paper "Manipulating Biotic Factors in the Southern Forest Environment" at the 17th Annual Forestry Symposium at Louisiana State University on April 10–11.

Formerly a staff officer on the Sawtooth NF, *Reed C. Christensen* is now with the Division of Watershed Management, Region IV, Ogden, Utah.

SCS range conservationist *Gary R. Evans* has been transferred to Pocatello, Idaho. *Lew L. Pence,* who was at Pocatello, has been moved to Buhl.

Francis J. Ezernack has assumed the duties of Work Unit Conservationist at Lake Charles, La., while *Jack R. Cutshall* is WUC at DeRidder.

Ken R. Genz, range conservationist on the Toiyabe NF has been selected by the Intermountain Region to evaluate the quality and usefulness of all Parker Three-Step range condition and trend studies within the Region.

Willard D. Graves, SCS range conservationist from Littleton, Colorado, has retired after 30 years of service.

Ralph H. Hughes presented a paper entitled "Effects of Simulated Cattle Grazing in Young Slash Pine Plantations" at a recent meeting of the Florida Academy of Science.

Founder and long-time head of the Ona (Florida) Range Cattle Experiment Station, *Dr. W. G. Kirk* retired on June 30.

Dr. A. Starker Leopold, chief scientist of the National Park Service, has been appointed to the faculty of the School of Forestry and Conservation, University of California, Berkeley. Dr. Leopold's appointments in UC's Department of Zoology and Museum of Vertebrate Zoology will continue, but he will shift the focus of his programs to the School of Forestry and Conservation.

Retiring after more than 30 years with the Forest Service in South Dakota and Colorado is *Robert O. Lewis,* range and wildlife staff officer on the Routt NF.

Les A. McKenzie has been transferred by the SCS from Ely, Nev. to Cedarville, Calif.

The 1965 president of the Idaho Section, *Ralph S. Samson,* has been appointed as Assistant State Land Commissioner in Idaho.

After more than 41 years of service, *George K. Stephenson* retired from the Forest Service last April 20. He was Assistant Director of the Southern Forest Experiment Station, New Orleans.

Dr. Gerald W. Thomas, interim Executive Vice-President of Texas Tech, attended the third hemispheric conference of the Partners of the Alliance in Lima, Peru, March 31–April 3.

Jack F. Wilson, the 1966 president of the Idaho Section, is now BLM District Manager in Riverside, California.

Leaford C. Windle is manager of the SCS Plant Materials Center, Los Lunas, New Mexico.

Additional PLLRC Contract Awards

A contract award in the amount of $97,640 has been made by the Public Land Law Review Commission to study the development, management, and use of water resources on public lands. This study will cover policies involving water originating on and flowing across the public lands, including a review of the reservation doctrine of Federal water rights.

Contractors for the legal section of this study are Charles F. Wheatley, Jr., Washington, D.C., and Charles E. Corker of the University of Washington. The resources study requirements will be accomplished by Thomas N. Stetson and Daniel J. Reed, consulting engineers.

The University of Virginia has been awarded a $69,875 contract to study the rulemaking and adjudication procedures of Federal public land management agencies.

The PLLRC's study program will cover 34 subjects comprised of all aspects of public land management and resource use. Sixteen studies have been assigned to date. On completion of the studies, the Commission will recommend disposal and retention policies designed to enable the general public to realize the maximum benefit from its public lands.

Norris, Gonzalez in USSR

Dr. Jonathan J. Norris, formerly with Colorado State University and now with FAO in Rome, and **Dr. Martin H. Gonzalez,** Rancho Experimental La Campana, Chihuahua, were part of a seminar which recently spent several weeks studying the arid rangelands of central Asia. Sponsored by FAO and under the leadership of Dr. Norris, the group worked from Tashkent and Samarkand (Uzbek SSR), and from Ashkhabad (Turkmen SSR). The group later visited the Plant Materials Center in Leningrad and also spent some time in Moscow. The two ASRM participants are preparing a detailed report of the seminar which will appear in a future issue of the Journal.

No Sheep

There will be no sheep permittees on the Malheur NF in 1968, the first year sheep have been absent from the forest since its establishment in 1908. Peak numbers were reached in 1921 when 87,481 head were authorized; cattle numbers also reached a peak the same year with 36,090 permitted head. In 1967 permits were issued for 3,900 sheep and 20,157 cattle.

SOCIETY BUSINESS

Sciential Committees

For several years previous the Society has had annually a committee called "Cooperation with Scientific Organizations," which was composed of ASRM members who also were members of various other organizations, and who were designated as ASRM's representative to these other societies or associations (e.g., *Society of American Foresters, American Society of Agronomy, Ecological Society of America). The list of representatives was long and grew longer each year, and usually these representatives had no definite assignment or specified liaison duties.*

For 1968, President Dyksterhuis has reorganized the previous committee structure in this general area by (1) replacing the old "Cooperation with Scientific Organizations" committee with a committee on "Cooperation with Interdisciplinary *Organizations," and (2) establishing a group of 15 Sciential Committees (see J. Range Manage. 21:193–194, May 1968).*

The former is composed of the ASRM representatives to only the broad interdisciplinary groups (e.g., *American Association for the Advancement of Science) with which the Society* itself *is directly affiliated.*

The Sciential Committees, on the other hand, are unique in concept, and their purpose and functions are spelled out by President E. J. Dyksterhuis *in the following paragraphs; these comments constitute the charge made to the committeemen appointed to serve on the various Sciential Committees.*

It is anticipated that activities of sciential committees will result in Society publications within one to three years. Meanwhile articles and symposia are in order; but, the first major objective is thin 9 × 6 inch, paper-bound *summary reviews of principles and problems* with selected bibliography or citations, possibly including a limited number of schematic diagrams, tables, or simple maps with the whole suitable for study in our and related disciplines and for about two lecture assignments for third- or fourth-year college students. First publications from these committees will be titled like the names of these committees; to be published by ASRM, and distributed from the Executive Secretary's office. Authorship may be joint up to three names, or by assignment of segments with one name as Editor (for reference purposes) and with others named within the publication.

These committees will include our delegates to other groups of scientists in societies with whom we share an interest (*e.g.,* American Society of Agronomy, National Watershed Congress, American Society of Animal Sciences). Our delegate is authorized to receive mail for this purpose addressed as follows:

American Society of Range Management
____(Name)____, Delegate
____(Address)____

Our official delegate shall report for the ASRM to and from the allied discipline. He shall have wide latitude for independently representing the ASRM within the scientific field of his assignment. Any matters coming to his attention that may affect ASRM policy, tend to confound rangelands with timberlands, croplands, or barren deserts, or tend to confound volunteer native pastures of nonarable lands with cultured (tame) pastures of arable lands shall promptly be brought to the attention of the ASRM.

Our goals are (1) recognition of rangeland as a *unique* and vast natural resource; (2) the organization of knowledge concerning this resource; and (3) recognition that rangemen by training and experience are also well qualified to deal with problems and management of *native haylands* and of *native pasture lands* and of *grazable timber lands.* All of these have complex mixtures of perennials that volunteer; with vegetation varying more in response to grazing or cutting coactions than to practices associated with cultured pastures.

We shall at all times openly recognize that problems and treatments of cultured (tame) pastures are finally best specified by agronomists, and that problems and treatments of grazable timberlands are best specified by foresters, though we must often have a grazing and a conservation interest in such lands and, therefore, seek to collaborate within the limits of this interest and of our specialized knowledge.

The charges to seven of these committees contain additional clarification —*Rangeland Biometeorology*: First publication of this committee to point up uniqueness of rangeland climates worldwide, showing gradations of natural vegetation with gradients in environment between barren deserts and timberlands in temperate and tropical zones plus gradations, between permanent snow and ice through tundra and alpine vegetation to timberlands in arctic zones. To include center-spread map of the world's rangelands classified as Desert Scrub, Steppe, Prairie, and Tree-Savanna, plus major areas of Tundra, Alpine, and Coastal Marsh rangelands.

Rangeland Genotypes: For artificially re-establishing the dominant taxons of natural rangeland cover as related to climate and soil.

Rangeland Livestock: Animal science and husbandry *as conditioned* by rangeland grazing.

Rangeland Roadsides: And similar, generally ungrazed, situations best managed for permanent *natural rangeland vegetation.*

Rangeland Shrubs: Maximum measurements and other features.

Cultured Pastures of Arable Lands to Complement Range Seasonally: This committee can do much to foster widespread understanding of differences between (a) *cultured (tame) pastures* composed of domesticated-native or introduced strains, generally in pure seedings or simple mixtures, generally requiring periodic renovation, fertilization and/or irrigation for sustained high production and, therefore, generally economic through decades only on lands with relatively little hazard of droughts, damaging runoff, wind or water erosion, and increased salinity or alkalinity, and (b) *range* composed of complex mixtures of local strains in many species that volunteer on natural grazing lands, with vegetation generally following a predictable course of degeneration or secondary succession, the latter tending toward a climax type of cover suitable for natural pasture which, though usually producing far less than cultured pastures, may nonetheless produce at less cost per unit of animal product because of lower land and maintenance costs.

Native Pasture Lands of Farms and Forest Climates: Generally *nonarable* lands, including lands in forest climates without potential for tree growth of timberland life-form because of *edaphic* limitations.

Members with knowledge of useful material for any chairman of a sciential committee will find mail addresses in the May 1968 issue. The chairman of the Rangeland Recreation committee, not shown in that list, is L. D. Love, P. O. Box 252, Sedona, Arizona 86336.

Membership

Each year just prior to printing the address labels for the May issue of the *Journal of Range Management,* all members who have not paid their dues for the current year are suspended. This year there were 869 suspensions (19.3 percent of the gross membership), leaving us with a net paid membership of 3,627 as of May 10. (In addition there was a total of 652 paid subscribers—domestic and foreign—for a total paid circulation of 4,279.)

The following figures (all as of May 10 for the year indicated) show how we stand in comparison to previous years.

Year	Percent suspended	Net membership after suspensions
1968	19	3,627
1967	13	3,881
1966	15	3,706
1965	16	3,463
1964	13	3,197
1963	14	3,059

It really isn't possible to tell what proportion of this year's net loss in members results from the increase in dues. There also was a dues increase for 1965 and, although the percentage of suspensions jumped, there still was a net membership gain of 266 over the previous year.

Dropouts occur for various reasons. It is known that last year a high proportion of the more than 600 suspensions was among retired members. Hence, it is possible that the present dues increase resulted in even more people in this category following the dropout route.

But dropouts which result from a lack of interest are a more serious problem. Local activities of the kind that provide stimulation of the members is the best antidote for this, so considered effort ought to be made to promote and sustain wide individual participation in Chapter and Section affairs. As Robert Lippert has said elsewhere in this issue (VIEWPOINTS), we need "to hold annual members until they become automatic perennials."

Normally quite a few of the suspended members reinstate, and in those instances where Section membership chairmen have sent a reminder to their delinquent members, the results have been noticeable.

We are planning for and anticipating a good membership campaign this fall. And you, the individual member, can do the most to make it successful: what about the fellow next to you—has he joined? Ask him.

1969 Annual Meeting

A preliminary report from Alex Johnston, chairman of the Program Committee for the 22nd Annual Meeting, indicates that the response to the call for papers has been good.

Scheduled for February 10–14, 1969 at the Palliser Hotel in Calgary, Alberta, the program tentatively lists the following session topics:

- Rangeland North of the Forty-Ninth
- Rangeland Hydrology
- Northern Range and Pasture Production
- Environmental Factors Relating to Northern Range Cattle
- Grazing Systems
- Range Production
- Marketing
- Range Improvement

Tentative arrangements have been investigated in regard to tours to show wintering of cows and calves, and fattening of cattle under winter conditions. Mr. Johnston stresses that any such tours will be made in heated buses travelling on first class roads, and bringing outdoor Arctic gear will not be necessary.

The Calgary meeting will be more than good in all respects, so plan now to attend. Watch for more detailed information in the September and November issues of the Journal.

Move to Denver

As everyone in the Society probably knows by this time, the Executive Secretary's office is to be relocated in Denver. Accordingly, plans have been made to close the office in Portland on July 31, and—with a little luck—be open for business in Denver on Monday, August 5.

Effective **August 1, 1968** the mailing address of the American Society of Range Management will be **2120 South Birch Street, Denver, Colorado 80222.**

Publications For Sale

Glossary of Terms Used in Range Management .... 50¢ single copy; 35¢ in lots of 25 or more

Index, Vols. 1–10 inc., Journal of Range Management .... $1.00 each

Abstracts of Papers presented at Annual Meetings .... $1.00 each

Available for the following years:

1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968

Enclose check or money order payable to American Society of Range Management, P. O. Box 13302, Portland, Oregon 97213. Be sure to include zip code in your address.