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[RE] = Resumen en Espanol por Ing. Edmundo L. Aguirre, ITESM, Monterrey, N. L., Mexico.

Cover Photo—Fodder tree planted in earthen tube on sand dune in Thal, Pakistan.
See article by Ch. M. Anwar Khan, page 316.

Soil Moisture and Temperature Changes Following Sagebrush Control[1]

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Highlight

Soil moisture and temperature were measured for a five-year period on a mesic foothill grassland and on an arid cold desert shrub-type in western Wyoming. Herbage production increased on both the arid and mesic sites following the sagebrush and grazing control treatment with the greatest increase occurring on the mesic site. Average annual soil temperature was greatest at the arid site and was warmest in the shrub-dominated areas at both sites. Soil moisture recharge during the spring period was greatest at the mesic site under the non-use treatment but at the arid site grazing treatment did not significantly influence moisture accumulation. Under the shrub control treatment, soil moisture recharge was little influenced at the mesic site and at the arid site greatest soil moisture recharge occurred in the non-controlled shrub area. Soil moisture withdrawal was similar at both the arid and mesic sites in that the least amounts of moisture were taken from the soil under the grazed and non-controlled shrub treatments. Soil moisture accumulation during the spring period was greatest at the mesic site from 24 to 60 inches below the soil surface and the greatest values occurred in the shrub controlled grassland area. At the arid site high moisture levels occurred only down to the 12-inch depth.

Removal of undesirable woody species from native grassland, during the past decade, has become an accomplished fact with the development of selective herbicides. In the western United States large areas dominated by shrubs, principally big sagebrush (*Artemisia tridentata*) have been returned to climax composition by application of the hormonal herbicide 2,4-D (Kearl, 1965). Requisite criteria of time, amount, and method of application are well standardized.

The factors responsible for the vegetational change following sagebrush control, however, are not well understood. The present study was conducted to evaluate soil moisture, soil temperature, and herbage production changes following chemical control and non-grazing treatments of big sagebrush on two study sites, one a mesic grassland and the other an arid shrub type.

Study Areas and Methods

Fenced exclosures were constructed on the two sites in 1962. Big sagebrush was controlled in a portion of each exclosure as well as an adjacent grazing area. Crown cover of big sagebrush on the two areas was similar (approximately 15%) but individual bushes were much more robust on the mesic Granite Mountain site than on the arid Smilo site. Soil moisture was measured with a neutron moisture meter in access tubes set to a depth of 60 inches which were located in treatment sites of shrub control, no shrub control, grazing, and no grazing. Soil temperature was measured with thermister probes placed 1, 8, 15 and 22 inches below the soil surface. These were located only within the non-grazed exclosures but under both shrub control and no shrub control. Precipitation gauges were installed at each location. Basal cover and herbage production of understory vegetation were determined from transects of 20 plots which were read on the same date each year. Both sheep and cattle grazed the areas in spring and fall.

The Granite Mountain exclosure, in the mesic uplands of the Wind River Basin of central Wyoming, was situated at an elevation of 7,000 ft. Average annual precipitation is approximately 12 inches, with much occurring as snow in winter. Summer showers are common on these uplands east of the Wind River Mountain Range. The 8.9 inches average annual precipitation recorded for the 5 years of study is much below the long term average and probably reflects to some extent also, the fact that snowfall is not accurately measured in this type of precipitation gauge.

The Smilo exclosure was located in the Big Horn Basin of North Central Wyoming, a northern cold desert shrub area at an elevation of 4,500 ft, some 2,500 ft lower than the Granite Mountain exclosure. This area receives only about 7.5 inches of precipitation annually. Little snow occurs and summer rains are infrequent, but usually of high intensity. Almost 50% of annual precipitation occurs as rain during the spring from April 15 to June 30. Summer temperatures are much higher at the arid Smilo exclosure than at the Granite Mountain. The effective growing season is severely limited by high temperatures and aridity at the former.

Soils at the Granite Mountain site are classified as Encampment Loam, a deep, strongly developed soil with good drainage which is usually found on old terraces and fans. The Smilo exclosure is characterized by the Dry Creek Fine Sandy Loam soil. This is a deep soil also, but with low permeability and poor development, reflecting the arid climate of the Big Horn Basin.

Results

Herbage production response was phenomenal during the 5 years from 1962, when the shrub control and grazing treatments were initiated, through 1966. On the mesic Granite Mountain Exclosure *Agropyron smithii, Poa fendleriana,* and *P. secunda* were the dominant understory species. *A. smithii* exhibited a great increase in production under sagebrush control (Fig. 1). A minor increase was associated with cessation of grazing and no shrub control. Production in the grazed-native sites tended to decrease.

The major grasses on the Smilo Exclosure were *A. smithii* and *P. secunda.* Response of *A. smithii* to treatments was proportionally similar at both locations but was much less spectacular under the arid conditions at the Smilo site. The extremely

[1] Excerpts from a paper presented at Annual Meeting, American Society of Range Management, Seattle, Washington, February 16, 1967. Published with approval of Director, Wyoming Agricultural Experiment Station, as Journal Article No. 344.

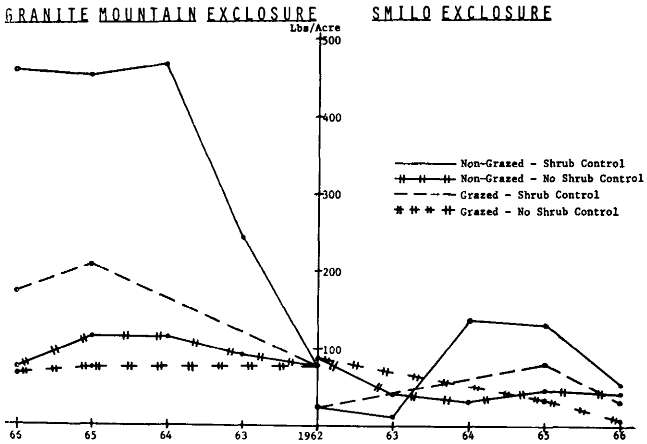

FIG. 1. Herbage production of western wheatgrass as influenced by the sagebrush and grazing control treatments.

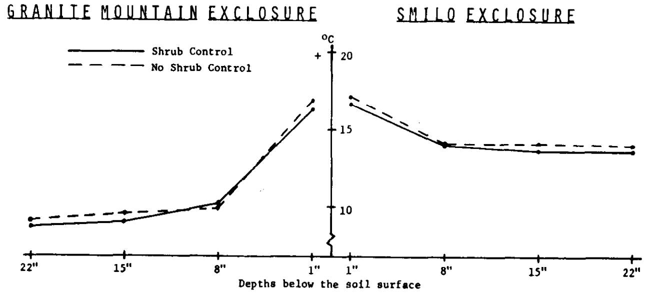

FIG. 3. Soil temperature by depths and treatment from initial data (July, 1963) through December, 1966.

arid 1966 moisture conditions were reflected by a sharp production decrease. Greatest production occurred under the shrub control and non-use treatments.

Soil temperature data, combining all depths and seasons of measurement, show a distinct difference due to location, with an annual average temperature of approximately 11 C at the mesic Granite Mountain site and 15 C at the arid Smilo site (Fig. 2). Soil temperatures during the spring increased most rapidly at Smilo and remained high through the summer and well into late fall. Temperature changes at the mesic site were characterized by a relatively slow increase during spring, followed by a rapid decrease in late summer and early fall.

Soil temperature differences due to sagebrush control appear insignificant at all depths, but have followed a consistent pattern at each of the two study sites during the past 5 years (Fig. 3). Under sagebrush (no shrub control), temperatures were almost 1 C warmer than in the shrub control areas. This relationship was reversed at the Granite Mountain site during the *winter* and *summer* periods but at the Smilo site, however, the only apparent reversal occurred during the *early summer* period (Fig. 2).

A greater variation between surface temperatures and subsoil temperatures was exhibited at Granite Mountain than at Smilo (Fig. 3). In the spring, subsurface temperatures at Smilo rose more rapidly than at Granite Mountain. During fall and winter, subsurface temperatures at Smilo fell more slowly and did not become as cold as those at Granite Mountain.

Greatest differences in subsurface temperatures resulting from sagebrush control were noted at the 15-inch depth where soils at both sites tended to be much warmer in the native shrub dominated areas than in those subjected to sagebrush control. At the 8-inch depth, temperatures were greater under the shrub control treatment at Granite Mountain and almost equal at Smilo. These variations from the normal pattern of higher temperatures under sagebrush must necessarily be associated with grassland moisture-utilization capabilities, associated with changes in soil moisture as influenced by site pecularities.

The influence of the grazing and shrub control treatments upon soil moisture levels presents important variations at the two study sites. The soil moisture recharge data are based on amounts of water in the soil and reflect water accumulation during the spring recharge period, as well as the water lost from the soil by evapo-transpiration

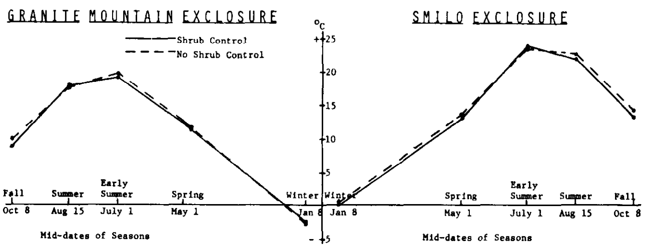

FIG. 2. Soil temperature changes averaged over all depths, by season and treatment from initial data (July, 1963) through December, 1966.

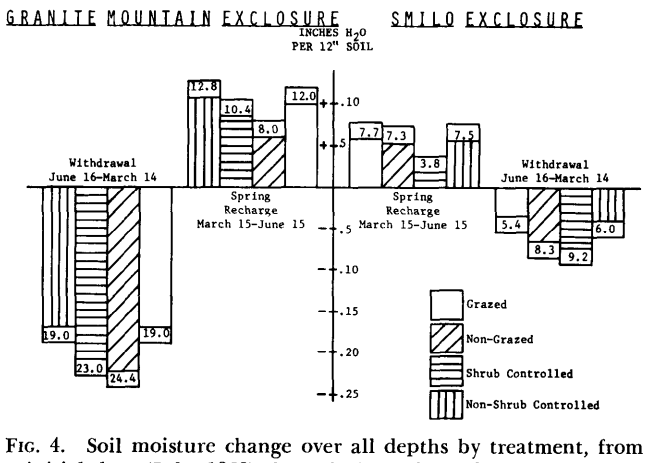

FIG. 4. Soil moisture change over all depths by treatment, from initial data (July, 1963) through December, 1966.

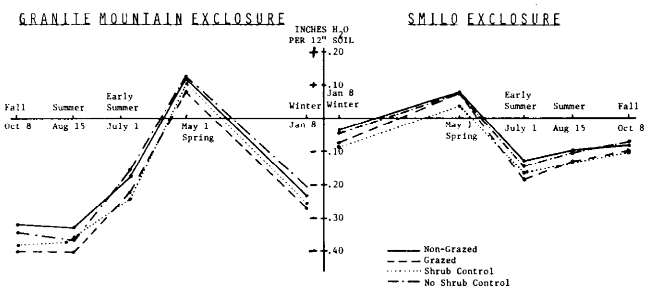

FIG. 5. Soil moisture change averaged over all depths by seasons and treatments from initial data (July, 1963) through December, 1966.

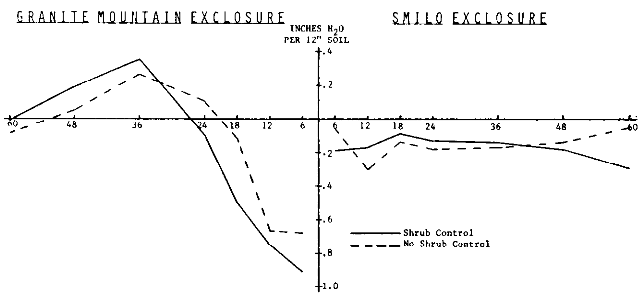

FIG. 7. Early summer moisture change by depths from initial data (July, 1963) through December, 1966.

during the recharge period (Fig. 4). At Granite Mountain, recharge under non-grazing was much less than in the grazed area. At Smilo a very insignificant variation occurred as a result of the grazing treatment.

Under the shrub control treatment at Smilo much *less* moisture was stored in the soil than in the *non*-sprayed sagebrush area. A similar pattern occurred at Granite Mountain but the variation was minor. These soil moisture recharge data certainly show the varying influence of differences in soil permeability and moisture loss due to plant use under the two study treatments.

Withdrawal of soil moisture was similar at the two study sites. Less moisture was taken from the soil under the grazed and non-sprayed treatments than in the areas which were non-grazed and shrub controlled.

Seasonal moisture levels, (Fig. 5) combining all depths and years, portray greater rates and amounts of soil moisture withdrawal and recharge variation at the mesic Granite Mountain site as compared to the arid Smilo site. Differences between treatments again appear insignificant.

During the spring period from mid-March to mid-June, soil moisture levels by depth, given in inches in depth below the soil surface, show the influence of high soil permeability at Granite Mountain (Fig. 6). Under *shrub control* high moisture content occurred below 24 inches in the zone from which sagebrush normally utilized great amounts of water. Low moisture levels occurred

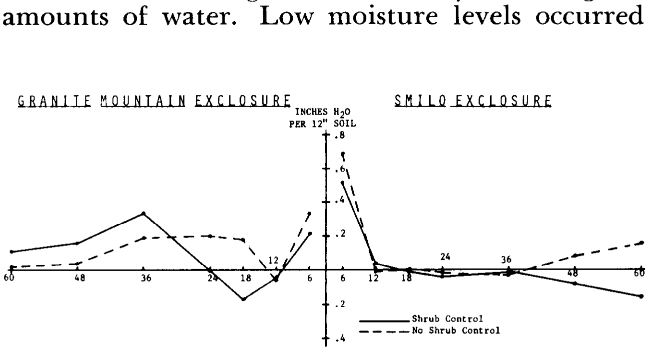

FIG. 6. Spring moisture change by depths from initial data (July, 1963) through December, 1966

above 24 inches in the grass root zone. At Smilo the very low moisture under shrub control below the 12-inch depth apparently resulted from utilization of most of the available moisture at the upper level by grasses. The very high moisture content of the surface to 6-inch depth reflects again the relative impermeability of soils at this site.

By early summer (Fig. 7) the pattern of soil moisture changes to a configuration which is similar through the summer, fall, and winter seasons. These data exemplify the influence of differing climates and soils on moisture relationships and the strong interaction at both locations, with time and treatments.

At Granite Mountain, grasses utilized almost all available moisture in the upper two ft of soil, but that which was not utilized moved downward to accumulate in the 36 to 60-inch zone from which sagebrush depends for its major water supply.

At Smilo, water losses due to runoff, even on level areas, combine with low infiltration to explain some of the contradictory findings of other workers. At the 6-inch level under shrub control, we see the same pattern as that exhibited through the 24-inch depth at Granite Mountain, and a similar pattern from 12 through 36 inches at Smilo, as compared to the 24 through 60 inches depth at Granite Mountain.

Discussion

Non-grazing and sagebrush control treatments result in similar vegetative responses. Greatest response to cessation of livestock utilization occurs on rangeland in poor condition relative to climax composition. Response to sagebrush control is analagous except on sites where condition has deteriorated to such an extent that insufficient native vegetation remains for reestablishment of formerly abundant species. In actuality this condition may occur, as well, in situations of continued intensive grazing pressure.

In association with the herbage production data (Fig. 1), basal area of understory species following the shrub control treatment increased more than two-fold during the 5 years of study. During the first 2 years, greatest increase was exhibited by *Poa secunda*, a short-leaved, early-maturing species. Basal area of *Agropyron smithii* increased more slowly as did other decreaser species which provide much more ground cover and production per unit of basal area than *P. secunda*. Thus the decreased soil temperature associated with sagebrush control must be related to light and heat interception by herbaceous vegetation. This concept has been examined by Geigey (1957) but few would extrapolate his work to the rather sparse and diminutive vegetation of the northern cold deserts.

Robertson's 1947 work in Nevada indicated that soil moisture increased under sagebrush control but Hutchinson (1956) found the opposite. Both men were probably correct in conceptual application to the sites on which their work was conducted. The present study shows two kinds of conditions. On the mesic study site at the Granite Mountain exclosure, soil moisture levels were much lower under sagebrush control and non-use than in the sagebrush and grazed areas, but little variation was noted on the arid study site at the Smilo exclosure.

At the Smilo exclosure, the more arid climate, associated with impermeable soils, resulted in greater restriction to vegetative potential, although species composition was similar to that at Granite Mountain. Increased herbage production and basal area innately require greater amounts of water, and sagebrush removal liberates soil moisture; but the key to the problem can be found in the Oklahoma work of Prill (1965) in which he found grasses able to utilize more of the soil moisture than sagebrush. It is generally recognized that sagebrush is a wasteful and rapid user of available moisture but grasses are apparently able to withdraw more from the soil, over a longer period of time, than the shrubs.

Soil moisture differences between the two study areas are thus a result of climatic variation, soil differences, and variation in rate of vegetative rehabilitation. At the mesic grassland site understory vegetation was able to increase sufficiently following sagebrush removal to utilize more of the soil moisture than pre-existing vegetation. At the arid cold desert shrub site, rigid climatic characteristics did not allow sufficient revegetation for effective utilization of the released soil moisture following sagebrush control.

Conclusions

Herbage production increased on both the arid and mesic sites following sagebrush and grazing control. The greatest increase occurred on the mesic site.

Average annual soil temperature combined for all depths was 11 C at the mesic site and 15 C at the arid site. Soil temperatures increased rapidly in the spring at the arid site and remained high through the summer. At the mesic site they increased more slowly in the spring and decreased earlier and more rapidly in the fall than at the arid site.

Average annual soil temperatures at both sites, combined for all depths, were almost 1 C warmer in the shrub-dominated areas than in the non-shrub grassland areas. On a seasonal basis this relationship was reversed on the mesic site during the winter and summer periods, but on the arid site the only reversal occurred during the early summer period.

The greatest differences in subsurface temperatures occurred at the 15-inch depth where temperatures were much warmer in the native shrub dominated areas than those subjected to sagebrush control. At the 8-inch depth however, temperatures were greater under the shrub control treatment at the mesic site and almost equal at the arid site.

Soil moisture recharge during the spring period at the mesic site was much greater under the non-use treatment than in the grazed area. At the arid site an insignificant variation occurred as a result of the grazing treatment. At the mesic site little variation in soil moisture recharge resulted from the shrub control treatment. At the arid site, however, soil moisture recharge was much less in the shrub controlled grassland area than in the non-controlled shrub area.

Soil moisture withdrawal was similar at both the arid and mesic sites. Less moisture was taken from the soil under the grazed treatment and the non-controlled shrub treatment than in the areas which were non-grazed and shrub controlled.

Variation of seasonal moisture levels combined for all depths and years showed a much greater variation at the mesic site than at the arid site. During the spring period from mid-March to mid-June soil moisture levels by depth were greatest from 24 to 60 inches below the soil surface at the mesic site. Greatest values occurred in the shrub-controlled grassland area. Low moisture levels occurred above 24 inches in the grass root zone. At the arid site, high moisture levels during the spring occurred only down to the 12-inch depth. At greater depths, moisture was low, apparently resulting from utilization of most of the available moisture at the upper levels by grasses.

At the mesic site, grasses utilized almost all available moisture in the upper two feet of soil but that which was not utilized moved downward to accumulate in the 36 to 60-inch zone from which sagebrush depends for its major water supply. At the arid site the same pattern was exhibited through the 6-inch level as that exhibited through the 24-inch depth at the mesic site and a similar pattern at the arid site from the 12 through 36-inch depth as that at the 24 through 60-inch depth at the mesic site.

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Effects of Nitrogen Fertilization on Native Rangeland[1]

FRANK RAUZI, ROBERT L. LANG, AND L. I. PAINTER

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Highlight

Nitrogen fertilizer was applied to native rangeland at the Archer and Gillette Substations in Wyoming to determine the effect on yield, crude protein and composition. Yields of the warm season grasses were not significantly increased by fertilization. The increase of cool season grasses was a function of time rather than fertilization with one exception. Nitrogen fertilization increased the percentage crude protein of the grasses studied. The decline of blue grama at both locations was attributed to the subnormal precipitation during the study period. Nitrogen fertilization was not an economical practice during the years of the study at the two locations because moisture was the greatest limiting factor.

Efecto de Fertilizacion Nitrogenado en Pastizales Resumen

Se hizo un estudio en las Subestaciones Archer y Gillette, Wyoming, para determinar el efecto de ciertas dosis y fechas de la aplicación de fertilizantes nitrogenados en la producción, por centaje de proteína cruda y cambios en composición. La precipitatción estuvo por abajo del promedio de muchos años por espacio de 3 de los 4 años de estudio en la subestación de Archer y durante los 4 años en la subestación de Gillette. Los resultados reflejan las condiciones de sequía que prevalecieron.

Los resultados de estos estudios indican que la fertilización de pastizales nativos representados por estas localidades y para los años de estudio no fue una práctica económica debido a la humedad que fue el factor limitante mas grande. Los zacates de épocas frías aumentaron en ambas localidades, pero el aumento no fue resultado directo de la fertilización. Un aumento significativo de los zacates de época fría en la loca lidad de Gillette, se obtuvo con 66 kg/ha (66 lb/acre) en 1959. Debido a la sequía el pasto *Bouteloua gracilis* redujo su cobertura relativa en las parcelas de la subestación de Gillette. La cobertura de *Poa secunda* aumentó por la utilización de la humedad de principios de primavera.

En ambas subestaciones el porcentaje de proteína cruda fue aumentando en las especies colectadas en los lotes fertilizados. El promedio de tres y cuatro años para las los localidades mostró algo de variación en el porcentaje de proteína cruda por tratamientos y época de siembra.

Response of native rangeland to fertilizer appears to vary with location in the Great Plains. Rogler and Lorenz (1957) reported increased yields and a change in botanical composition on overgrazed rangeland in North Dakota from application of nitrogen fertilizer. Retzer (1954) found that native plants responded to nitrogen application on soils derived from granitic rocks in Colorado. In the Central Cross Timbers Section of Oklahoma, Huffine and Elder (1960) found that weed production was 2 to 5 times greater on nitrogen-fertilized native pastures than on nonfertilized native pastures, indicating that the weeds responded much better than the native grasses. Other workers (Klipple and Retzer, 1959; Huffine and Elder, 1960; Cosper and Thomas, 1960) also reported that fertilization of native rangeland resulted in increased production of forbs.

The effect of fertilization on native rangeland depends upon climate, soils, and management. Some of the more important factors influencing the success of range fertilization include soil type, soil fertility level, soil and air temperatures, and amount and distribution of precipitation during the growing season. Hoagland et al. (1962) reported that low fertility limited forage production more than rainfall, or at least total rainfall did not vary enough among years to offset the beneficial effect of fertilizer on annual range in California. Kilcher (1958) reported that favorable precipitation in May was an important requirement for the successful and economical use of fertilizer on pure stands of cultivated grass in Canada.

Studies were conducted at the Gillette and Archer Substations in Wyoming to obtain additional data on the effect of commercial fertilizers on native rangeland. The studies were designed to

[1] Contribution from Northern Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, and the Wyoming Agricultural Experiment Station; Journal Article No. 345.

determine the effect of dates and rates of nitrogen application on yield, protein level, and botanical composition of shortgrass rangeland.

Study Areas and Methods

The Gillette Substation is located in northeast Wyoming at an altitude of approximately 4,500 ft. The dominant native vegetation is blue grama (*Boutelous gracilis*), Sandberg bluegrass (*Poa secunda*), and needleandthread (*Stipa comata*). The study area, a portion of a native pasture grazed by cattle, was fenced in the spring of 1958, and livestock excluded thereafter. The soil is classified as Maysdorf fine sandy loam.

The Archer Substation is located approximately 10 miles east of Cheyenne, Wyoming at an altitude of about 6,000 ft. The dominant native vegetation is blue grama, buffalograss (*Buchloe dactyloides*), and western wheatgrass (*Agropyron smithii*). The area used for the study was fall grazed by sheep until fenced in the spring of 1958. The soil on the study area is classified as Altvan fine sandy loam.

In the spring of 1958, plots 7 × 50 ft were established on native rangeland at the Gillette and Archer Substations. Ammonium nitrate was applied to three replications at rates of 0, 33, and 66 lb/acre of nitrogen on April 15, May 15, and June 15, 1958, and the same design was repeated in 1959. The ammonium nitrate was hand broadcast at the Gillette Substation and was applied to the soil surface with a grain drill at the Archer Substation.

The vegetation was inventoried with a modified point quadrat in the spring of 1958, and again in the fall of 1961. Only basal hits were recorded.

All old plant growth was clipped and removed from a 2-ft square plot early in April before plant growth started. The current year's vegetation on the same plot was harvested in mid-September. Different subplots were clipped each year from 1958 through 1961. Clipped herbage was separated as midgrass, shortgrass, annual grass, and forbs. Annual forbs and Sandberg bluegrass generally had matured and much of their production was lost prior to harvest. Blue grama at both locations and buffalograss and western wheatgrass at the Archer Substation were harvested separately in the first week of July and in mid-September to determine crude protein percentage.

Climatic conditions for the two Substations are similar; the long-time averages of annual precipitation are nearly the same, but growing season (April 1 to September 30) precipitation is higher at the Archer Substation (Table 1).

Table 1. Annual and growing season precipitation (inches) for the 1958–1961 period and the 31- and 43-year averages at the Gillette and Archer Substations in Wyoming.

Year	Annual		April–September	
	Gillette	Archer	Gillette	Archer
1958	11.00	14.31	8.08	10.79
1959	11.97	12.31	8.06	7.78
1960	12.52	10.60	9.28	6.96
1961	11.99	18.70	6.96	14.48
4-year average	11.87	13.98	8.09	10.00
31-year average	13.88		9.60	
43-year average		14.86		11.67

Results and Discussion

Yields

Fertilization did not significantly affect the yields of the warm season grasses at the two locations (Table 2). Yield of cool season grasses on the plots fertilized in the spring of 1959 varied among treatments. At Archer, the May application of 33 lb N/acre produced more cool season grasses than the check or June applications of 33 or 66 lb N/acre. There were no significant differences among yields from the other dates and rates of nitrogen application.

Plots fertilized in 1959 with 66 lb N/acre produced an average of 142 lb/acre more cool season grasses than the check plots at the Gillette location (Table 2). There were no significant differences in the yield of cool season grasses between the plots fertilized with 33 lb N/acre in 1959 and the check plots during the 3-year period, although average yields on the fertilized plots were almost twice as high as the check plot yields.

Yields of the cool and warm season grasses varied

Table 2. Average yields[1] (lb/acre air-dry) of warm and cool season grasses from plots fertilized in 1958 and plots fertilized in 1959 at the Archer and Gillette Substations, Wyoming.

Treatments	Archer				Gillette			
	Warm Season		Cool Season		Warm Season		Cool Season	
	1958[2]	1959[2]	1958[2]	1959[2]	1958[3]	1959[2]	1958[3]	1959[2]
Check—no nitrogen	185[a]	185[a]	131[a]	131[b]	220[a]	199[a]	77[a]	89[b]
33 lb nitrogen—April	215[a]	197[a]	175[a]	148[ab]	265[a]	204[a]	142[a]	155[ab]
33 lb nitrogen—May	235[a]	176[a]	119[a]	262[a]	259[a]	283[a]	103[a]	154[ab]
33 lb nitrogen—June	190[a]	229[a]	138[a]	100[b]	295[a]	270[a]	102[a]	160[ab]
66 lb nitrogen—April	223[a]	199[a]	73[a]	148[ab]	244[a]	228[a]	152[a]	249[a]
66 lb nitrogen—May	250[a]	234[a]	91[a]	193[ab]	254[a]	263[a]	173[a]	227[a]
66 lb nitrogen—June	216[a]	187[a]	114[a]	136[b]	276[a]	221[a]	136[a]	217[a]

[1] Means in each column with the same letter or letters superscript are not statistically different from each other at the 0.05 level of significance.
[2] 3-year average (1959, 1960, 1961).
[3] 4-year average (1958, 1959, 1960, 1961).

Table 3. Average yields[1] (lb/acre air-dry) of cool season and warm season perennial grass and annual grass and forbs at the Archer and Gillette Substations, Wyoming. 1958, 1959, 1960, and 1961 (data were averaged over all fertilizer treatments).

	Archer				Gillette			
Item	1958	1959	1960	1961	1958	1959	1960	1961
Fertilized 1958								
Cool season grasses	*	43^{b}	104^{a}	214^{b}	66^{c}	96^{bc}	207^{a}	137^{b}
Warm season grasses	*	163^{b}	186^{b}	300^{a}	457^{a}	333^{b}	152^{c}	93^{d}
Annual grass	*	1^{b}	13^{b}	111^{a}	24^{a}	1^{b}	13^{b}	8^{b}
Forbs	*	30^{b}	110^{a}	290^{a}	26^{b}	9^{b}	165^{a}	14^{b}
Total		237	413	915	573	439	537	252
Fertilized 1959								
Cool season grasses		55^{b}	144^{a}	281^{a}		96^{a}	251^{a}	190^{a}
Warm season grasses		136^{b}	184^{a}	284^{a}		400^{a}	214^{a}	101^{b}
Annual grass		2^{b}	15^{b}	131^{a}		1^{b}	8^{a}	6^{a}
Forbs		44^{b}	172^{a}	281^{a}		1^{b}	55^{a}	9^{b}
Total		237	515	977		498	528	306

[1] Means in each column with the same letter or letters superscript are not statistically different from each other at the 0.05 level of significance.
* No yields shown because of harvesting error.

among years at both locations (Table 3). Yields of cool season grasses increased during the study period at both locations except for 1961 at the Gillette Substation. The increase was a function of time rather than of fertilization. The increase of the cool season grasses may be partially explained in that no grazing was permitted on the experimental areas and plant vigor was increased. Also, the cool season grasses utilized the early spring moisture and available nitrogen.

Warm season grasses, blue grama and buffalograss, increased in yield at the Archer location. As with cool season grasses, the increase was not a direct result of fertilization but rather due to the experimental area not being grazed. At the Gillette Substation, yield of blue grama grass declined each year of the study. This decline was a result of drought and use of early spring moisture by the cool season grasses, especially Sandberg bluegrass.

As a result of over 2 inches of rain in early August 1960, forbs, mostly Russian thistle (*Salsola pestifer*), were present on all plots. The plots fertilized with 33 lb N in April 1959 had an abnormal amount of Russian thistle.

Total herbage production at the Archer Substation increased 386% between 1959 and 1961 on the plots fertilized in the spring of 1958, and 413% on plots fertilized in 1959 (Table 3). The increase was partially a result of more forbs and annual grasses and the above-average precipitation in 1961. Forbs and annual grasses accounted for 44 and 42% of the total herbage produced in 1961 from the fertilizer treatments applied in the spring of 1958 and 1959, respectively.

Crude Protein

Percentage crude protein of the three grass species harvested at Archer in September was significantly increased by the nitrogen fertilizer (Table 4). All fertilizer treatments except the May 1958,

Table 4. Percentage crude protein[1] in blue grama, buffalograss, and western wheatgrass harvested in September. Nitrogen was applied to separate plots in 1958 and 1959; Archer Substation, Wyoming.

	Blue grama Nitrogen applied		Buffalograss Nitrogen applied		Western wheatgrass Nitrogen applied	
Treatment	1958[2]	1959[3]	1958[2]	1959[3]	1958[2]	1959[3]
Check	6.92^{d}	7.67^{c}	6.45^{d}	7.11^{c}	7.28^{bc}	7.18^{c}
33 lb N/A April	7.46^{bc}	9.07^{b}	6.80^{cd}	8.30^{ab}	7.12^{c}	7.09^{c}
May	7.22^{cd}	9.65^{ab}	7.55^{ab}	8.13^{b}	7.58^{abc}	7.44^{bc}
June	8.19^{ab}	9.65^{ab}	7.74^{ab}	8.32^{ab}	7.75^{ab}	8.18^{ab}
66 lb N/A April	7.64^{bc}	9.78^{ab}	7.36^{bc}	8.97^{ab}	7.80^{ab}	7.86^{abc}
May	8.60^{a}	10.31^{a}	8.12^{a}	9.21^{ab}	8.04^{a}	8.33^{a}
June	8.59^{a}	9.90^{ab}	7.46^{b}	9.33^{a}	7.54^{abc}	8.33^{a}

[1] Means in each column with the same letter or letters superscript are not statistically different from each other at the 0.05 level of significance.
[2] 4-year average.
[3] 3-year average.

Table 5. Average percentage crude protein[1] of blue grama harvested in July and September. Nitrogen was applied in 1958 and 1959; Gillette Substation.

Treatment	Harvested July Nitrogen applied		Harvested Sept. Nitrogen applied	
	1958[2]	1959[3]	1958[2]	1959[3]
Check	12.64[b]	12.64[c]	9.34[c]	10.35[c]
33 lb April	13.38[b]	14.72[b]	10.68[bc]	11.49[b]
May	13.53[b]	14.51[b]	10.95[b]	11.89[ab]
June	13.41[b]	15.28[ab]	10.87[bc]	12.20[ab]
66 lb April	15.24[a]	15.91[ab]	12.02[ab]	12.46[ab]
May	15.15[a]	15.04[ab]	12.75[a]	12.63[a]
June	15.05[a]	16.58[a]	11.69[ab]	12.29[ab]

[1] Means in each column with the same letter superscript are not statistically different from each other at the 0.05 level of significance.
[2] 4-year average.
[3] 3-year average.

33 lb N/acre produced blue grama yields that were significantly higher in percentage crude protein than the check. For western wheatgrass, only the May 1958, May 1959, and June 1959 fertilizer treatments of 66 lb N/acre significantly increased crude protein percentage. Generally, the 1959 fertilizer treatments tended to produce a higher percentage crude protein content than the 1958 treatments. Percentage crude protein of fertilized blue grama harvested in July was not significantly different from that of the check except for the 66 lb N/acre treatment applied in May.

Percentage crude protein of the blue grama grass at Gillette, harvested in July, was significantly higher on the fertilizer treatments of 66 lb N/acre than on the check or the 33 lb N/acre treatments (Table 5). Significant differences in percentage crude protein of the blue grama grass harvested in September were found between treatments. The plots fertilized in 1958 with 66 lb N/acre and the May fertilizer treatment of 33 lb N/acre produced blue grama grass having a significantly higher percentage crude protein content than the check. The 1959 fertilizer treatments produced blue grama having a higher percentage crude protein content than that produced on 1958 fertilizer treatments.

Composition

The botanical composition of vegetation on each plot was determined in the spring of 1958 and again in the fall of 1961. The percentage composition of the major species declined at both locations between 1958 and 1961 (Table 6).

At Archer, blue grama and buffalograss cover declined an average of 9 and 19%, respectively, during the study. Decline of these warm season species was attributed to subnormal precipitation received in three years of the four-year study period.

Western wheatgrass, a cool season species, made its growth in the spring when moisture was available. Thus, western wheatgrass utilized the early moisture and nitrogen. Competition for moisture and nutrients early in the growing season by other species was not as critical as it was for the warm season species later in the growing season.

At Gillette, the relative cover of blue grama declined on all but the check plots and the plots fertilized with 66 lb N/acre in May 1958. The overall average decline of blue grama cover was 13%. Sandberg bluegrass, a cool season species, increased on all treatments. Sandberg bluegrass cover varied from year to year in the native composition but increased during periods of drought. Sandberg bluegrass was more abundant on the fertilized plots than on the check plots, and it was assumed that it utilized the early spring moisture and nitrogen and became more vigorous. The overall average increase of Sandberg bluegrass cover was 20%. The increase of this species was a function of years rather than fertilizer.

Table 6. Percentage vegetational composition of the major species determined by a modified point quadrat on plots fertilized in 1958 at the Archer and Gillette Substations, 1958 and 1961.

Treatment[1]	Archer						Gillette			
	Blue grama		Buffalograss		Western Wheatgrass		Blue grama		Sandberg Bluegrass	
	1958	1961	1958	1961	1958	1961	1958	1961	1958	1961
Check	65	54	24	14	8	10	76	76	12	19
33 lb N/A April	52	56	43	17	3	5	77	60	11	37
May	53	58	43	9	3	12	77	51	10	45
June	58	51	32	16	4	5	80	70	4	30
66 lb N/A April	65	41	24	21	4	9	76	65	17	23
May	56	35	35	17	6	4	67	74	21	26
June	53	49	43	17	3	6	80	44	14	51
Average	57	49	35	16	4	7	76	63	13	33

[1] Average of three replications.

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Seasonal Forage Preferences of Grazing Cattle and Sheep in Western Oregon[1]

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Highlight

On perennial ryegrass–subclover and tall fescue–subclover forage mixtures, grazing cattle preferred grass to clover during the spring–summer period. Sheep selected a consistently high amount of subclover in both pasture mixtures during spring. In summer, sheep preferred tall fescue to subclover but on ryegrass–subclover pastures retained or increased dietary preferences for dry subclover over ryegrass. Light and heavy stocking induced no large differences in forage selection patterns for either cattle or sheep.

The most important forage species for dryland pasture improvement in western Oregon is subclover (*Trifolium subterraneum*). It possesses characteristics of rapid growth, high yielding ability, and superior nutritive value. Although an annual plant, it grows well with perennial grasses such as perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*), both of which are standard grass species used in pasture improvement in the western Oregon–Washington area.

Knowledge of management of improved forages for grazing by domestic animals logically follows research to determine establishment techniques. Data on animal preferences as related to type of pasture, season, stocking rate, and class of livestock should be collected so that subsequent management decisions are based on sound knowledge of the forage resource.

Both cattle and sheep may express different selectivity patterns while grazing the same forage mixture in common. For example, Meyer et al. (1957) reported that sheep were apparently more selective than cattle on orchardgrass (*Dactylis glomerata*)–trefoil (*Lotus* sp.) and on pure alfalfa (*Medicago sativa*) as attested by the higher total digestible nutrient (TDN) content of sheep diets. Sheep diets contained 3 and 10% more TDN than cattle diets on orchardgrass–trefoil and alfalfa, respectively. The degree of selection between sheep and cattle apparently dcreased as forage density increased but sheep selectivity tended to be greater.

Studies of sheep diets in Australia on subclover-type forage indicate no clear-cut preference patterns. Davis (1964) found that subclover was preferred over annual ryegrass (*Lolium multiflorum*) during summer but not during spring. Wilson (1963) reported that sheep preferred grass over subclover with diets apparently more nutritious than total available forage.

Arnold et al. (1966) have conducted dietary evaluation studies on hardinggrass (*Phalaris tuberosa*)-subclover forages in Australia. Sheep tended to select more subclover than available to them in early spring, but on the whole, dietary and forage botanical composition were similar over a two-year period. For annual ryegrass–subclover grazed by sheep, Hodge and Doyle (1967) also found no preference for or against subclover. However, sheep would select up to 50% of the diet as white clover (*Trifolium repens*) when grazing a perennial ryegrass–white clover sward containing only 15% clover.

Grimes et al. (1967) studying sheep preferences when grazing perennial ryegrass, tall fescue, and orchardgrass, with and without white clover, found a slight preference for clover during late spring. On the average, however, diets and forage were similar botanically. During spring, sheep preferred in increasing order these species grown alone: orchardgrass, perennial ryegrass, tall fescue.

Forage species selection patterns for sheep may vary depending upon the grass species growing with subclover. Arnold (1964) stated that sheep

[1] Technical Paper No. 2378, Oregon Agricultural Experiment Station.

prefer green material to dry. Grimes et al. (1967) found this to be more true for tall fescue than for perennial ryegrass and orchardgrass. Grazing intensity and the level of soil fertility may have marked effects on the species selected by grazing sheep (Davis, 1964).

In the work reported herein, seasonal (spring–summer) forage preferences were determined for sheep and cattle separately grazing perennial ryegrass–subclover and tall fescue–subclover pasture mixtures in 1964, 1965, and 1966. Dietary crude protein levels and estimates of dietary digestibility as a part of this study are reported elsewhere (Bedell, 1967a; 1967b).

Materials and Methods

The experimental site near Corvallis, Oregon faces northwest on a gentle slope of less than 5%. Two soil series occur on the pasture area, Abiqua-like silt loam upslope from McAlpin-like silt loam. The Abiqua series is relatively shallow (< 24 inches) and well drained, whereas the McAlpin series is deeper and moderately to imperfectly drained. Soil pH is 6.0. Available phosphorous is low; annually 200 lb/acre of single superphosphate (24 lb sulfur and 17 lb phosphorous) have been broadcast applied in fall.

Adjacent 5-acre blocks of Nangeela subclover–Oregon perennial ryegrass (C-R) and subclover–Alta tall fescue (C-F) were each divided into two 2.5-acre pastures in spring 1964. The resulting four 2.5-acre blocks were grazed from April through August with either cattle or sheep. In 1965, each block was split laterally to introduce a change in intensity of grazing. Fresh water and trace-mineralized salt were continuously available.

Pastures were sampled eight times in 1964 and 1966 and seven times in 1965. Sampling occurred at approximately bi-weekly intervals until late June and at monthly intervals during the summer dry period.

Botanical composition of available forage was determined using several techniques. Forage was obtained by clipping randomly-located 2.4 ft^2 sampling rings in each pasture. On the 1st, 5th, 6th, 7th, and 8th sampling dates in 1964, forage was hand-separated, while being clipped, into (1) ryegrass or tall fescue, (2) subclover, and (3) other forage. Botanical composition was determined on each clipped sample in percent by dry weight. On the 2nd, 3rd, and 4th sampling dates when species were growing in intimate mixture, the constituent differential method of determining percent of legume in the mixture using percent dry matter was used (Cooper et al., 1957). Data for the 1965 season were derived from weight estimates, one of four methods used by Pessot (1966) who evaluated four techniques of estimating forage production and botanical composition on the pastures. Weight estimates of production by species were obtained from 25 randomly-located 2.4 ft^2 plots. In 1966, on 10 randomly-located plots per pasture, botanical composition was estimated using the constituent differential method for the first six sampling dates until forage became dry and using the dry weight rank method (Mannetze and Haydock, 1963), one of the methods tested by Pessot (1966), for the July and August dates on 50 randomly-located plots per pasture. All forage botanical composition data are on a percent by dry weight basis. An attempt was made to utilize a laboratory method using microscopic analysis (Heady and Van Dyne, 1965) on clipped forage samples but was unsuccessful due to the large size of the species.

Amount of available forage was determined by weighing clipped samples used in determining botanical composition.

Dietary samples were obtained from esophageal-fistulated yearling beef cattle (Hereford and Hereford X Angus) and mature Willamette and Suffolk ewes. Surgical and sample collection procedures utilizing screen-bottomed canvas bags as outlined by Van Dyne and Torell (1964) were followed. Dietary samples were frozen until analyzed.

Van Dyne and Heady (1965) indicated that cattle and sheep tended to be more selective in the afternoon than in the morning on mature California annual-type range forage composed of many species. Kothmann (1966) suggested the same pattern for certain nutritive characteristics of sheep grazing sagebrush-grass range in Utah. Preliminary work on these pastures suggested little, if any, difference occurring between morning and evening sampling times. Late afternoon-evening sampling patterns were followed.

Length of sampling period was at least three days in all years as suggested by Arnold et al. (1964). Two to four animals were sampled per pasture.

Upon thawing, dietary samples were washed lightly, squeezed between two layers of cheesecloth, and subjected to botanical analysis with a microscopic method adapted from that reported by Heady and Torell (1959) and more recently discussed by Harker et al. (1964); Heady and Van Dyne (1965); and Van Dyne and Heady (1965). Each dietary sample was mixed thoroughly, spread and pressed down in a sheet metal tray and passed beneath a binocular microscope with a cross-hair in one eyepiece. Ingested material was identified by plant species and parts of species after head development. Two hundred observations (points) per sample were recorded and percent species composition, on a point basis, computed. Because of the simple botanical makeup of the available forage, all ingested material was identified.

Differences between forage and dietary percent subclover in 1964 and 1966 and forage and dietary percent perennial ryegrass and/or tall fescue in 1965 were assessed using the paired "T" test (Steel and Torrie, 1960). Analysis of variance of percent subclover or percent grass data in a factorial design determined among-forage and among-dietary differences. Sources of variation were intensity of grazing (not in 1964), class of livestock, pasture mixture, and sampling periods.

Results and Discussion

Although subclover is an annual plant, favorable moisture and temperature most years assures good growing conditions. Subclover germinates following approximately one inch of precipitation in the fall, grows slowly during winter and makes most of its growth in April and May. It flowers in late April after petiole elongation has occurred. Tall fescue remains green year around and growth occurs through the fall months until low temperatures prevail. In contrast, perennial ryegrass is dormant from early July until both moisture and temperature conditions become favorable in September and October. Growth rate of perennial

Table 1. Amount of available forage (lb/acre, ovendry) by grazing treatment, mid-June 1964, 1965, 1966.

Item	1964	1965	1966
C-F, Sheep, Light	6200 (65)[1]	4580 (74)	5800 (121)
C-F, Sheep, Heavy		1550 (190)	4410 (222)
C-F, Cattle, Light	5300 (67)	4830 (36)	3650 (141)
C-F, Cattle, Heavy		1000 (190)	1080 (223)
C-R, Sheep, Light	5560 (62)	1610 (40)	3420 (150)
C-R, Sheep, Heavy		800 (165)	2070 (223)
C-R, Cattle, Light	4270 (64)	2940 (42)	1800 (141)
C-R, Cattle, Heavy		1470 (147)	1190 (200)

[1] Total stocking rate in animal unit days per acre, April–August.

ryegrass effectively terminates after flowering, whereas tall fescue continues at a reduced rate. Tall fescue grows more rapidly than perennial ryegrass and initiates rapid growth earlier in spring. Also, perennial ryegrass in the mature state loses almost one-half of its weight as shattered leaves and seed whereas the comparable loss with tall fescue is approximately one-third.

Precipitation at the study site averages 40 inches annually, the bulk of which occurs as rainfall during October through March. Soils remain near field capacity during April and May; July and August are dry with no appreciable occurrence of moisture.

Growing season conditions differed in each of the three years, however, 1964 and 1966 were more alike than different. Weather during spring 1964 was relatively moist and cool resulting in a normal forage crop. Subclover germination was late in fall 1964 and accompanying low temperatures either killed or frost-heaved germinating clover seeds. An extremely dry spring in 1965 seriously limited growth of surviving clover plants which resulted in a forage crop composed almost entirely of annual grasses and the two seeded perennial grasses. Sufficient hard-seeded subclover remained ungerminated after 1964 to insure adequate clover populations when moisture occurred. Spring precipitation in 1966 was less than normal, which resulted in satisfactory, but not optimum conditions for the two pasture mixtures.

The amount of forage available to grazing animals in the various treatments and the stocking rates were different among years and among treatments (Table 1). The forage crop in 1965 contained virtually no clover and with inadequate spring moisture, production was much less than either 1964 or 1966. Also, the forage growth within ryegrass pastures was more severely limited by subclover absence and spring drought than within tall fescue pastures in 1965.

1964 Season

The seasonal pattern of subclover present in forage is shown in Fig. 1. Analysis of variance of

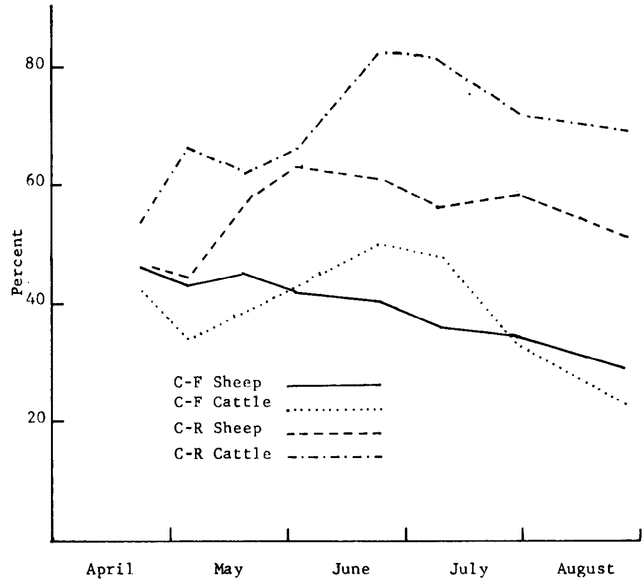

FIG. 1. Percent subclover occurring in forage available to grazing animals, 1964.

percent subclover data revealed significant differences for cattle vs. sheep (.01), pasture mixtures (.01), sampling periods (.05), class of stock X pasture mixture (.01), and pasture mixture X sampling period (.05).

Cattle-grazed pastures contained significantly more (.01) subclover than sheep-grazed pastures. Ryegrass pasture forage contained 22% more (.01) subclover than fescue forage. The average subclover content in all pastures increased from 47% in April to 61% in mid-June and then declined to 43% in August. All pastures had significantly different (.01) percentages of subclover, explaining the class of stock X pasture mixture interaction; the pasture mixture X sampling period (.05) interaction is shown in Fig. 1 by the relative seasonal increase in subclover in ryegrass pastures as opposed to the corresponding decrease in fescue pastures.

Seasonal patterns of dietary subclover are shown in Fig. 2. Sheep on tall fescue pasture selected significantly more (.01) subclover during May and early June than sheep on ryegrass pastures. By early July sheep preferences on tall fescue forage had strongly shifted to the still-green fescue as opposed to an increase in dietary subclover percentage for ryegrass–clover sheep. Seed heads of tall fescue were selected by sheep in late May and by early July had increased to 50% of the diet. However, by early August fescue seed percentage dropped to 6; the high dietary fescue component was largely green leaves. Sheep on dry mature ryegrass–subclover in summer exhibited preferences for dry clover burrs and seed. They did not strongly reject ryegrass until it had matured at

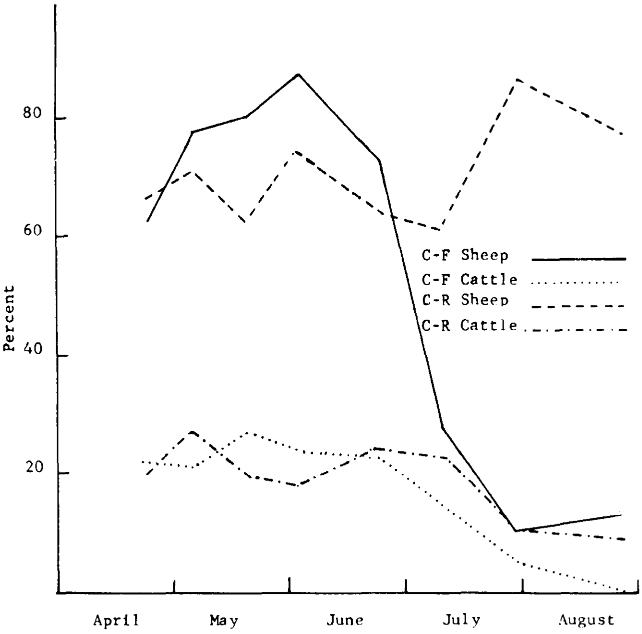

FIG. 2. Percent subclover in diets of cattle and sheep grazing tall fescue–subclover (C-F) and perennial ryegrass–subclover (C-R) pastures, 1964.

which time their preference for dry subclover intensified. Tall fescue did compose about 30% of sheep diets in early April before subclover had started rapid growth. During March and early April tall fescue grows more rapidly than either perennial ryegrass or subclover.

Cattle showed no preference for subclover at any time during the season (Fig. 2 and Table 2). Either tall fescue or perennial ryegrass made up in excess of 75% of the diet during spring and 85 to 95% in summer. Although the stocking rate was low, it is possible that the effect of cattle rejection of subclover contributed to significantly more (.01) subclover in cattle-grazed than in sheep-grazed forage (Fig. 1). Contrarily, sheep on both mixtures preferred more subclover than available to them in the April–June period. This was also true in summer for sheep on ryegrass but not for those on fescue. Arnold (1964) indicated that sheep almost always prefer a green to a dry forage. Apparently, relative succulence of available species plays a large role in sheep preferences.

Table 2. Percent subclover in diets as compared to forage, 1964.

Item	April–June	July–August
C-F Sheep	More**	Less**
C-R Sheep	More*	More**
C-F Cattle	Less**	Less**
C-R Cattle	Less**	Less**

** $P < .01$.
* $P < .05$.

1965 Season

Unfavorable climatic conditions limited subclover to less than 4% of available forage except in the lightly-grazed cattle ryegrass pasture (10%). Data for 1965 show dietary preferences in the relative absence of subclover, as this situation does occur periodically and has practical significance. Annual fescue (*Festuca myuros*) and ripgut brome (*Bromus rigidus*) composed up to 22% of available forage in fescue pastures but increased in ryegrass pastures to as much as 82%. Perennial ryegrass appeared to be in a less favorable competitive position with annual grasses than tall fescue.

Sheep diets on heavily-grazed tall fescue contained significantly more (.05) fescue than those under light grazing during May and early June. Sheep preferred the small amount of subclover and annual grasses to tall fescue but due to stocking rate were forced to consume tall fescue to a significantly greater (.05) extent under heavy grazing. However, during July and August, sheep under both stocking rates selected 90% of their diets as tall fescue.

For cattle grazing tall fescue pastures, few differences occurred in dietary composition between grazing intensities. Tall fescue composed 79 to 98% of the diet under heavy grazing, except that mid-May diets contained 34% annual grasses and 61% fescue. At this same time cattle under light grazing consumed 33% of their diets as fescue; invader perennial ryegrass accounted for 50% of the diet. During summer, no difference existed due to grazing intensity. Tall fescue composed 90 to 98% of diets. The two pastures were greatly different in appearance; under heavy grazing few seed heads appeared and growth was mostly vegetative.

Sheep grazing ryegrass forage exhibited no consistent preference pattern between ryegrass and annual grasses until mid-June. Annual grasses constituted 30 to 50% of diets through mid-June. As annual grasses dried in late June, perennial ryegrass preferences increased to more than 80% of the diets in July. Resident velvet grass (*Holcus lanatus*) made up 19 to 28% of diets in heavily and lightly-grazed pastures, respectively, in early August. This plant retains some greenness in lower leaves during the summer.

Dietary preferences of cattle grazing ryegrass were similar for both grazing intensities. Percentage ratios of ryegrass to annual grass under heavy grazing were 87 : 12 in late April, 68 : 36 in mid-May; 46 : 52 in mid-June, and 85 : 3 in early August. Comparable percentage ratios for light grazing were 94 : 5, 83 : 13, 70 : 22, and 88 : 7. Cattle grazed proportionately more perennial ryegrass than that available to them which contributed to

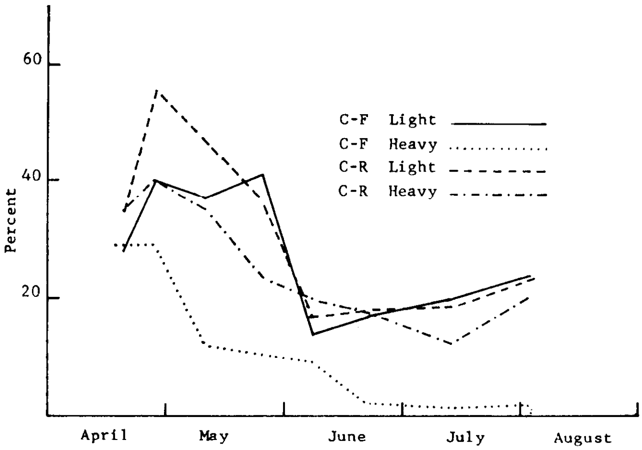

FIG. 3. Percent subclover occurring in forage available to sheep, 1966. $LSD_{.05}$ = 11.5% subclover on any one sampling date between any two treatments.

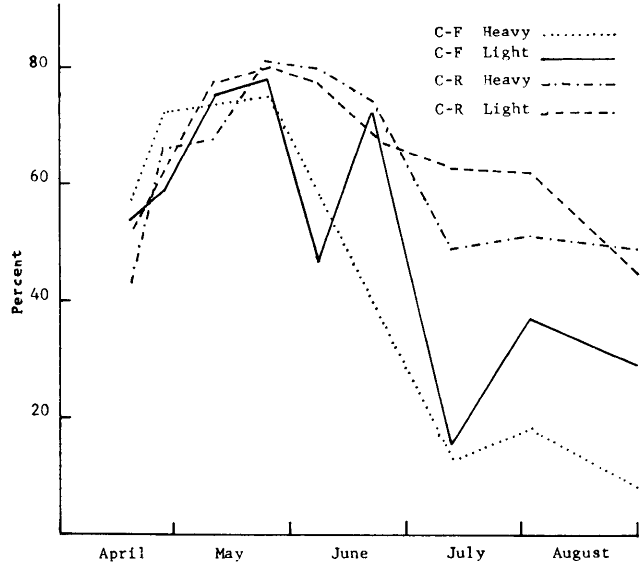

FIG. 4. Percent subclover in diets of sheep, 1966.

relatively high percentages of annual grasses in the total forage, especially during summer.

To compare dietary botanical composition among grazing treatments, percentage dietary perennial grass was tested in analysis of variance. Both sheep and cattle selected a significantly greater (.05) percentage of the major species under heavy as compared to light grazing. Cattle preferences for major perennial grass species exceeded those of sheep on both pasture mixtures (.01). Significantly more (.05) tall fescue than ryegrass occurred in diets. Much of this effect was due to heavy grazing in tall fescue pastures during summer when less opportunity for selection existed (intensity of grazing X pasture mixture; .05).

1966 Season

Favorable conditions occurred for subclover germination and early growth in fall 1965. Most seedlings occurred from hard seed lain over from 1964; the initial clover population for the 1966 season may be considered less than optimum for this reason. Also, low spring 1966 moisture partially accounted for all forage species not achieving maximum production.

Sheep-Grazed Pastures.—Initial forage subclover percentage at the start of the grazing season averaged 31% (Fig. 3). Clover populations in all pastures except fescue heavily-grazed were relatively high until early June. Strong preferences for clover by sheep grazing fescue heavily during April, May and early June accounted for the decline in clover available (Fig. 4). Clover shatters severely when dry to partially account for the percentage decline in early June in the lightly-grazed pastures. However, sheep on ryegrass maintained a relatively high dietary percentage of dry subclover during this time. The relatively high preference for tall fescue by sheep grazing fescue lightly in early June is unexplainable as the same sheep selected 72% of their diet as subclover two weeks later before changing to the summer selection pattern for fescue which was observed in 1964 and 1965. Lessened availability of subclover in the heavily-grazed fescue pasture due to early utilization of this species accounted for the earlier shift to tall fescue. Even so, during summer when in excess of 20% of available forage was dry subclover in the lightly-grazed fescue pasture, sheep expressed a strong preference for fescue leaves.

Sheep on ryegrass pastures preferred significantly more (.01) subclover than available to them throughout the season. This pattern was also observed in 1964 (Table 2). Sheep on both fescue treatments selected significantly more (.01) subclover than contained in forage. This interpretation should be viewed in a practical sense, however, in that limited availability of clover in the heavily-grazed pasture would account for much of this. Statistical interpretation shows that lightly-grazed fescue sheep diets contained similar amounts of clover to that found in the forage during early July and significantly more (.05) during early August. The practical significance, however, is that ryegrass sheep prefer dry subclover to dry ryegrass during summer regardless of grazing intensity, and that sheep on tall fescue will select fescue leaves in preference to dry subclover. Approximately one-half of the summer diet of sheep on heavily grazed ryegrass was perennial ryegrass. The trampling and fouling effect on clover by intensive stocking may have lowered its acceptability.

Cattle-Grazed Pastures.—Forage in cattle-grazed pastures contained similar amounts of subclover as sheep pastures; over the season no significant

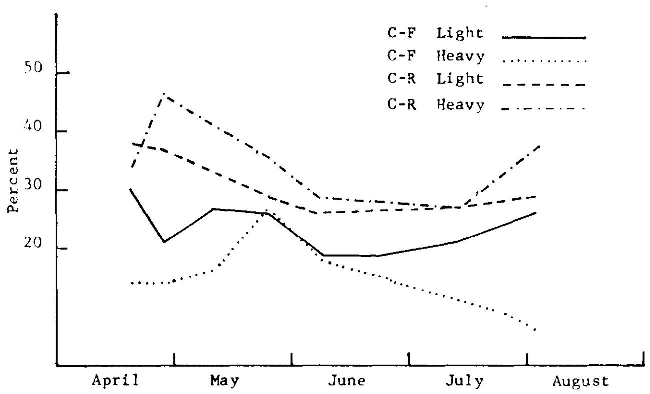

FIG. 5. Percent subclover in forage available to grazing cattle, 1966. $LSD_{.05}$ = 11.5% subclover at any one sampling date between any two treatments.

difference occurred in percent forage subclover due to class of stock grazing the forage (Fig. 5). Forage percent subclover in heavily grazed fescue was significantly less (.05) than in other cattle pastures during summer primarily due to cattle grazing pressure although cattle grazing fescue heavily selected less than 20% of their diets as clover from May onward (Fig. 6). Cattle diets were grass-dominant throughout the grazing season. This tended to maintain the subclover portion of the forage near 30%, especially on ryegrass pastures.

Tall fescue plants appear as more discrete entities than do perennial ryegrass plants when both are in mixture with subclover. Thus, when cattle are selecting against subclover in favor of grass it may be expected that diets on ryegrass could contain more clover than those on fescue with a similar degree of selection pressure (Fig. 6). Averaged over the season, percent dietary subclover was 17, 23, 27, and 32 for fescue heavily-grazed and lightly-grazed and ryegrass heavily-grazed and lightly-grazed, respectively. The data seem to suggest relatively easier selection for grass by cattle in fescue–clover as opposed to ryegrass–clover mixtures.

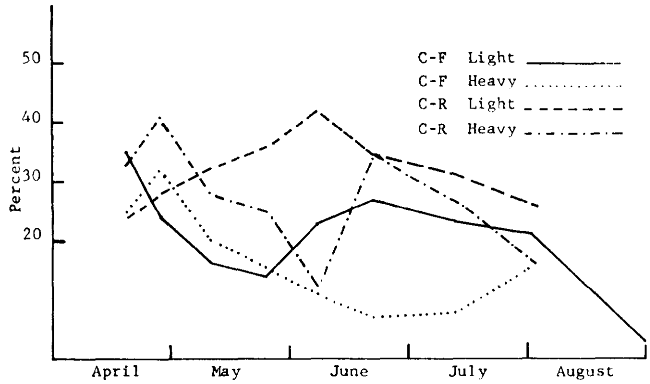

FIG. 6. Percent subclover in diets of cattle, 1966.

Conclusions

When subclover was present with perennial ryegrass or with tall fescue in amounts such that selection for or against it might be exhibited, as in 1964 and in 1966, sheep preferred clover to grass. The single exception existed with tall fescue–subclover during summer when sheep behaved similarly to cattle and selected fescue leaves in preference to dry subclover in 1964 and 1966. When subclover was not available, as in 1965, sheep expressed preferences for annual grasses until plant maturity and then selected for either dry perennial ryegrass or green tall fescue during summer. Cattle preferences remained constant for the major perennial grasses.

More clover was found in dietary samples from ryegrass pastures than from fescue pastures, on the average. However, seasonal differences occurred such that clover preferences by sheep on both pasture mixtures were similar in the spring but different in the summer as explained above. Clover percentage contained in cattle dietary samples was never high but those from ryegrass pastures exceeded those from fescue pastures.

Stocking rate affected dietary preferences relativly more for sheep than for cattle. More clover existed in dietary samples under light stocking than under heavy stocking. For sheep, this appeared to be largely as a result of more rapid early-season depletion of the clover supply in both pasture mixtures. Higher dietary clover preferences existed from late April to late June for sheep; early spring sheep diets contained up to 50% tall fescue or perennial ryegrass. An exception to this occurred under light sheep grazing on ryegrass in 1964 when summer preferences for clover exceeded spring preferences.

Utilization of perennial ryegrass–subclover and tall fescue–subclover forage differs when grazed by sheep or by cattle. Whether grazing animals should be manipulated to best suit the forage conditions or whether the forage should be manipulated to suit animal grazing behavior has not been studied here. Management considerations, however, should be different for sheep and cattle on these two forage mixtures.

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Seasonal and Livestock Influences in Estimating Foliage Density of Vegetation[1]

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Highlight

A knowledge of the influence of advance in season and activity of grazing animals on foliage-density estimates is necessary to properly assess trends or evaluate range treatments. Foliage-density estimates were made at 14-day intervals from June 20 through August 17 of the years 1964 and 1965 at the Scotts Bluff Experimental Range. Significant differences were found in foliage densities of various species among dates of sampling. These differences varied between years of the study. Grazing and trampling of livestock had little effect on foliage-density estimates. Optimum time for estimating foliage density of mixed-prairie vegetation was established as being the period one week prior to and one week following July 20. Grazing influences did not alter these dates.

In order to study trend in botanical composition within a range area over a period of years, some knowledge of the influence of advance in season and/or livestock disturbance by trampling or grazing on foliage density estimates is desirable.

Tosun (1961) recorded foliage cover early and late in the growing season on a true prairie range. Trends in his data indicated that further study throughout the growing season was needed. Spedding and Large (1957), studying cocksfoot and ryegrass swards, recorded large differences in foliage density within a height increment above the ground on five successive dates. Winkworth (1955) and Wilson (1959) showed that a geometrical change in leaf angle as the plant developed changed the foliage area measured.

Surveys taken during the growing season or even at the end of the growing season to make comparisons between areas, treatments, or years are subject to much criticism. Owing to the complex interactions of the edaphoclimatic cycles, the relative proportion of plant species at any time during the growing season may vary widely.

Crocker and Tiver (1948) suggest that since all species do not occur at the same stage of maturity within the edaphoclimatic cycle on a given date, one must record stages of maturity of the various species at the time the survey is taken. However, data from numerous sources (Henson and Hein, 1941; Spedding and Large, 1957; Sant, 1964) sug-

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gest that stage of maturity may not always be positively correlated with foliage density.

Influences of grazing pressure and trampling by livestock on foliage-density estimates have been recorded indirectly by several investigators (Spedding and Large, 1957; Norman, 1957; Henson and Hein, 1941; Sant, 1964).

This study was initiated to measure the effect of advance in season and livestock disturbance on foliage density in order to ascertain the best time within the growing season to make vegetation surveys.

Study Area and Procedures

The study was conducted at the Scotts Bluff Experimental Range, 10 miles north of Scottsbluff, Nebraska. The area supports a mixed-prairie vegetation. The dominant grasses are needleandthread grass (*Stipa comata*), prairie sandreed (*Calamovilfa longifolia*), and blue grama (*Bouteloua gracilis*). Various perennial forbs and two shrubs (*Artemisia filifolia* and *frigida*) are present. Annual forb populations fluctuate widely, depending on weather conditions.

Average annual precipitation at the Scotts Bluff Experiment Station, six miles south of the study area, is 12.88 inches. Precipitation during the growing season (April 15 to September 1) measured at the study area was 5.19 inches in 1964 and 12.66 inches in 1965. The long-term average precipitation for this period is 10.27 inches.[2]

Surface textures of soils in the study area range from loamy very fine to fine sands. These soils are characteristically low in organic matter and water-holding capacity.

Two adjacent locations, representing differences in range condition, were selected. Two grazing treatments, i.e. grazed vs. nongrazed, were established within each location on similar sites. Each treatment plot was subdivided systematically to give 100 sampling stations. The stocking rate for locations under grazing influences was 0.73 AUM/acre.

Twenty randomly-selected points were recorded at 20 randomly-selected stations using the focal point technique described by Burzlaff (1966). Only first hits were recorded. A hit was recorded as the species encountered, litter, or bare soil.[3] Species hits were defined as a point intercept with any material originating from the current year's forage production. Terminology for cover characteristics follows that suggested by the National Academy of Sciences–National Research Council (1962).

Repeated readings were made on each plot at 14-day intervals, beginning the third week in June and continuing through the third week in August.[4]

Because of the large number of species of low abundance which contributed only a minor portion to the total foliage density, some species were grouped into categories according to their life history. Various perennial grasses of very low abundance will not be discussed.

Treatments were evaluated by an analysis of variance of the mean foliage density of plots. The main effect of advance in season (dates) was analyzed by using data from the nongrazed plots. Since the main objective of this study was to study the effect of sampling dates, emphasis was placed on the interpretation of dates and its interaction with the grazing main effect. Therefore, grazing treatments were evaluated by their failure to respond the same between grazed and nongrazed sites with advance in season. The interaction of dates and grazing treatments was determined using all the data.

Reduction sums of squares for linear, quadratic, cubic, and quartic response surfaces indicated that there was not enough consistency in response of a given species to advance in season or livestock disturbance between years to establish regression equations. Therefore, Duncan's multiple range test was used to determine on which consecutive dates foliage density remained the same within the .05 level of probability with advance in season and livestock disturbance.

Results and Discussion

Advance in Season

Significant differences ($P < .05$) in foliage density were found among date means during both years for needleandthread grass. Significant differences were also found among date means in 1964 for the category of perennial forbs and shrubs and in 1965 for prairie sandreed, sand dropseed (*Sporobolus crytandrus*) and the category annual forbs and grasses. No significant differences were found among date means for blue grama in either year.

Greater fluctuations in foliage density of needleandthread grass were found between years than within a growing season because of a severe drought in 1964 which resulted in high death loss and the inability of the surviving plants to produce flowering culms in 1965. The significant difference in date means between June 20 and July 5 in 1964 (Table 1) can be attributed to the increased exposed vegetation due to the emergence of the flowering culm. The linear increase in foliage density after July 20, 1965, resulting in a significant difference in date means between July 20 and August 3, may be attributed to a gradual recovery from the 1964 drought.

The drought of 1964 had little effect on the foliage density of prairie sandreed in 1965, however, growth characteristics were altered. In 1964 no differences among date means were found because vegetative growth was limited, but in 1965 normal growth resumed resulting in a significant difference in date means between July 20 and August 3 (Table 1). This period corresponds to the maximum rate of jointing stage of growth.

Because of the low abundance of blue grama, sand dropseed, and perennial forbs and shrubs, sampling was inadequate to fully evaluate their

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[2] Measured at the Scotts Bluff Experiment Station.

[3] Litter cover and bare soil percentages will not be discussed in this article.

[4] The authors recognize that in using this procedure the errors are no longer independently associated, but since stations within a plot were rerandomized on each date, it is assumed that for the purpose of this study, this violation of the assumptions of the analysis of variance does not introduce bias.

Table 1. Date within the sampling period at which significant differences in foliage density of various species or categories was found in 1964 and 1965 under nongrazed conditions.[a]

Species or category	S. E. of a date mean	Foliage-density percentage 6/20	7/5	7/20	8/3	8/17	Mean
1964							
Needleandthread	.802	18.3	21.2	19.7	22.2	20.5	20.4
Prairie sandreed	.427	3.8	4.0	3.8	4.5	3.8	4.0
Blue grama	.465	2.9	1.3	1.6	1.5	1.4	1.8
Sand dropseed	.320	2.6	2.3	1.7	1.7	1.7	2.0
Perennial forbs & shrubs	.199	.5	.5	.7	.4	.2	.5
Annual forbs & grasses	.220	1.8	1.4	1.5	1.2	.8	1.3
1965							
Needleandthread	.757	6.5	5.8	6.3	8.2	9.1	7.2
Prairie sandreed	.639	3.4	3.5	3.3	5.9	4.8	4.2
Blue grama	.524	1.6	1.5	1.7	2.0	2.3	1.8
Sand dropseed	.296	.9	1.0	.5	1.9	1.5	1.2
Perennial forbs & shrubs	.364	.7	1.9	1.7	1.5	1.2	1.4
Annual forbs & grasses	1.173	14.0	13.8	14.7	18.5	16.5	15.5

[a] Lines, either solid or broken, connect means for consecutive sampling dates at which foliage density was significantly different (P > .05) from those not underlined or connected with solid or broken lines.

response to advance in season. No explanation can be offered for the significant differences among date means for the category perennial forbs and shrubs in 1965 (Table 1). Many of the established plants of sand dropseed succumbed to the 1964 drought. The significant difference in date means between July 20 and August 3, 1965, can be attributed to seedlings initiating growth the latter part of July.

Annuals, being opportunist plants, showed wide fluctuating foliage density between years. In 1964 most annual species had either reached maturity or had ceased growth by the time vegetation inventories were initiated on June 20. No significant differences in foliage density were found among date means. In 1965 most species of forbs were in the initial flowering stage on June 20. No significant differences were observed between the first three and the last two sampling dates (Table 1). Maximum cover of annual forbs and grasses, occuring on August 3, was a result of the rapid growth of two prostrate growing *Euphorbia* spp. (*E. geyeri* and *E. petaloidea*) between July 20 and August 3. In 1965 lambsquarter (*Chenopodium pratericola*) made up more than 50% of the annual forbs and grasses category. A significant decline in foliage density of lambsquarter was observed throughout the season.

Livestock Disturbance

It appears that livestock disturbance by grazing and/or trampling had little influence on foliage density estimates. No significant interaction (P > .05) of grazing treatments and dates was found in either year for any species or category.

Changes in foliage density of needleandthread grass were of about equal magnitude between any two dates regardless of grazing treatment. Data collected by Streeter (1966) in an adjacent pasture showed that animals utilized little or no needleandthread between June 20 and August 17; however, trampling damage was severe on the low-condition sites.

In 1964 maximum utilization of prairie sandreed occurred between July 1 and July 20 (Streeter, 1966). Foliage density declined significantly between July 5 and July 20 (Table 2). Since moisture was inadequate for continued growth, less foliage density was measured from July 20 through August 17 than from June 20 through July 5, resulting in a significant difference in these two periods of time. In 1965 the effect of grazing on foliage density of prairie sandreed was masked by growth to the point that there was no significant interaction between grazing treatments and dates. Maximum utilization occurred after August 1. This accounts for the significant decline in foliage density by August 17 (Table 2).

Foliage densities of the remaining species or categories, i.e. blue grama, sand dropseed and the categories perennial forbs and shrubs and annual forbs and grasses (except for the latter in 1965) were too low to fully evaluate their response to livestock disturbance.

Selecting a Sampling Time

Because of morphological and phenological variations among and within species, it is difficult to determine an adequate date for sampling foliage density. If a common date over all species or categories, years, and use could be established when no progressive or regressive changes in fo-

Table 2. Date within the sampling period at which significant differences in foliage density of various species or categories was found in 1964 and 1965 under grazed conditions.[a]

Species or category	S. E. of a date mean	Foliage-density percentage					
		6/20	7/5	7/20	8/3	8/17	Mean
1964							
Needleandthread	.802	15.1	20.0	15.5	17.9	17.4	17.2
Prairie sandreed	.427	4.7	5.5	3.8	3.8	4.5	4.4
Blue grama	.465	2.1	1.2	1.3	1.8	1.8	1.6
Sand dropseed	.320	2.3	2.3	1.8	1.9	1.3	1.9
Perennial forbs & shrubs	.199	.8	.7	1.2	.9	.7	.9
Annual forbs & grasses	.220	2.1	1.3	1.8	1.6	.8	1.5
1965							
Needleandthread	.757	5.3	7.0	7.7	8.4	8.2	7.3
Prairie sandreed	.639	4.2	4.3	5.1	5.5	3.5	4.5
Blue grama	.524	1.3	2.4	2.0	2.5	2.0	2.1
Sand dropseed	.296	1.4	1.3	.7	2.7	1.7	1.6
Perennial forbs & shrubs	.364	1.2	2.6	1.8	2.3	.8	1.7
Annual forbs & grasses	1.173	12.2	13.2	11.8	12.3	11.5	12.2

[a] Lines, either solid or broken, connect means for consecutive sampling dates at which foliage density was significantly different (P > .05) from those not underlined or connected with solid or broken lines.

liage density occur between any two sampling dates, this date would be the ideal date for inventorying mixed-prairie vegetation. It is further logical to assume that if a change in foliage density between two dates is of sufficient magnitude to be significant (.05 level), at some point in time between these two dates the foliage densities would not be significantly different from that determined for either the preceding or following date.

Based on this assumption, the most reliable sampling time for measuring year to year changes in foliage density under grazed (Table 2) or nongrazed (Table 1) conditions on a mixed-prairie vegetation would be a week prior to and immediately following July 20.

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Preliminary Economic Evaluation of Cattle Distribution Practices on Mountain Rangelands

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Highlight

The grazing capacity of mountain rangelands can be increased by management practices which improve cattle distribution. In this study, the increased economic returns resulting from pond construction, spring development, and trail construction appear to justify investment in these projects by either private operators or the federal government. Guzzler construction may be a sound investment for the stockman, but does not appear profitable for the federal government. Under the conditions of this study, fencing mountain rangelands was not profitable for either stockmen or the federal government. Both strategic salting and cattle herding (drifting) appear to be profitable practices for the rancher.

The carrying capacity of mountain ranges can often be increased by improved livestock distribution which results in more uniform forage utilization. It has long been known that practices such as fencing, trail building, herding, and manipulating water and salting locations improve cattle distribution on mountain ranges (Cook, 1967; Cook, 1964; Cook and Jefferies, 1963; Skovlin, 1965; and Skovlin, 1957). However, very little has appeared in the literature regarding the economic soundness of such practices. The purpose of this paper is to present an economic evaluation of the increased grazing capacity resulting from practices designed to improve cattle distribution on mountain rangelands.

Methods

During the summer grazing seasons (June 10 to September 10) of the years 1960 to 1966, a study was conducted on the Cache National Forest of northern Utah to determine the effects of water development, trail construction, fencing, salting, and herding on cattle distribution and the resulting forage utilization. The study area consisted of 25,000 acres located in aspen, sagebrush-grass, and mountain brush summer range types typical of much of the Intermountain area. A total of 300 random study sites were used to determine the degree of forage utilization throughout the study area. Basic data provided by this study were taken from Cook (1967).

Water development, trail construction, and fencing represent capital investment and the results of these practices were therefore subjected to economic analysis on the basis of the present value of a future annual income stream for a definite number of years. Calculations of the "internal rate of return" (Nielsen, 1967) could be made but, for the sake of simplicity in this preliminary study, a simple present-worth analysis was used. Present values of future income streams follow those set forth by the American Institute of Real Estate Appraisers (1964). Annual costs of maintaining facilities have been ignored in this preliminary investigation. The annual costs are small in magnitude and have little effect on investment decisions.

Since capital investment might be undertaken by either public or private interests, the costs and returns of these practices were analyzed from the points of view of both the stockman and the federal government. An interest rate of 8% was used as the rate necessary to justify investment by ranchers in range improvements on federal lands. Eight percent is higher than the 6¾ to 7½% which ranchers must pay for production credit. However, the uncertainty associated with federal grazing permits appears to justify a rate of at least 8%. An interest rate of 7% was used as the rate necessary to justify investment by ranchers on private land. Seven percent is approximately the average rate which ranchers pay for production credit and, of course, improvements on private rangeland are not associated with the uncertainty of federal grazing permits.

Because the Federal government acts as an agent of the people, attempts to measure the economic efficiency of investments in public lands must include all benefits to society, not merely returns to the U. S. Treasury. Although all benefits, primary and secondary, both tangible and intangible, should be measured, in this preliminary study only grazing receipts were included in benefits to show that range improvements are profitable even when the only benefits measured are returns to the U. S. Treasury.

A 4% interest rate was deemed sufficient to justify capital investment by the federal government since government credit is obtained at a rate of about 3¾%. The 4% rate is consistent with guidelines established by Senate Document 87–97 (U. S. Senate 1962). This document states the rate of interest to be used in benefit-cost analyses is that rate payable by the Treasury on interest bearing marketable securities with 15 years or more of maturity upon issue.

The rates used ignore opportunity costs of capital and are for illustrative purposes only. The reader may wish to use different rates in similar calculations.

Because of ever increasing competing land uses, federal grazing permittees cannot necessarily expect additional AUMs to become available even if an increase in carrying capacity does result. Increases in AUMs can be thought of, however, as AUMs which might otherwise be cut from the allotment. The forestalling of a cut of one AUM for a given time period is, in effect, the same as gaining one additional AUM annually for the same time period.

Since drifting and strategic salting represent increased operating costs rather than capital investment, the costs and returns of these practices were analyzed on an annual basis and only from the viewpoint of the stockman. Most ranchers willingly accept the responsibility for these two practices on public as well as private land. Otherwise, only those areas in which livestock graze of their own accord can be classified as usable range.

Results and Discussion

Water Development

From 85 to 150 additional AUMs (animal unit months) were obtained annually from each added water development. The present cost of these water developments ranged from $90 each for small ponds to $2,000 each for guzzlers (surfaced areas to provide water runoff and storage). Springs or seeps were developed at a cost of about $200 each.

Ponds.—A value of $0.60/AUM (representative fee charged by U. S. Forest Service) was assigned to the increased grazing capacity resulting from investment by the federal government. For the $90 spent on pond construction, a return of at least 85 AUMs × $0.60 = $51 (disregarding a nominal annual maintenance cost and benefits other than Treasury receipts from grazing) can be expected annually for the life of the pond. Assuming a life of 10 years, the present value of such an income stream is $413.61.[1] It is conceivable that the present value of the return might be in the neighborhood of 150 AUMs × $0.60 × 8.11 = $729.90. An annual increase of 18.5 AUMs is required to break even with a $90 expenditure by the federal government under current grazing fee rates.[2] For a private operator, experiencing a value per additional AUM of $2.40, the increase in grazing capacity necessary to break even on a $90 investment on public lands is 5.6 AUMs.[3] On private lands, each additional AUM has a value of $3.00 and an increase of only 4.3 AUMs is required to justify investment by the rancher. With a higher marginal return, the stockman can, of course, afford to intensify to a greater degree than can the federal government.

Springs.—The development of a spring at a cost of $200 will result in a gain of at least 85 AUMs annually for 15 years. The present value of such a gain is 85 × $0.60 × 11.12[4] = $567.12. If the spring development results in a gain of 150 AUMs, the present value of the increased grazing capacity is 150 × $0.60 × 11.12 = $1,000.80. An AUM increase of 30 is required to break even with a $200 investment by the federal government.[5] Again, the higher marginal return which the stockman receives allows greater intensification with private capital than is possible with federal government capital. The increased grazing capacity necessary for a private operator to break even on a $200 investment is 9.7 AUMs on public lands and 7.3 AUMs on private lands.

Guzzlers.—At present (ignoring benefits other than grazing receipts), federal government investment in guzzlers does not appear economically feasible, even if each of the structures results in 150 additional AUMs annually for 20 years. The present value of 150 additional AUMs of grazing capacity annually for 20 years is 150 × $0.60 × 13.59 = $1,223.10, which is nearly $800 less than the construction cost of a guzzler.[6] An increased grazing capacity of 245 AUMs annually is necessary to offset a $2,000 investment by the federal government.[7] However, since guzzlers are sometimes the only available method of water development on high plateaus, the resulting improvement in wildlife habitat may justify public investment in these structures.

Guzzler construction may be a sound investment for the private operator on public lands since only 85 additional AUMs of annual carrying capacity are necessary in order to break even. On private lands, only 63 additional AUMs are required to justify guzzler construction by ranchers.

Trail Construction

Trails built through rocks, down timber, and heavy brush which had formerly prevented livestock movement increased available grazing by 75 to 100 AUMs per $100 cost. Trails built through brush and timber will become grown over with time, but those built through rocks will last indefinitely. An average life expectancy of 10 years was assigned to all trails constructed. The present value of an annual increase of 75 AUMs is $364.95.[8] If a trail results in an annual increase of 100 AUMs, the present value of the increase is $486.60. An AUM increase of 20.5 is the necessary break even point for a $100 investment by the federal government.[9] The increased grazing capacity necessary for a private operator to break even on a $100 investment in trail construction on public lands is 6.2 AUMs. On private lands, only 4.7 additional AUMs are required to offset trail construction by ranchers.

Fencing

Fencing mountainous pastures across drainages to form pastures of 700 to 1,000 acres increased utilization by 4.4% on areas with 35 to 55% slopes. Fencing had very little effect on forage utilization of slopes other than those in the 35 to 55% category. The average air-dry forage production was 517 lb/acre and areas sloping between 35 and 55% made up 22% of the total area fenced. If one cow

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[1] The present value of one dollar per annum for 10 years at 4% compound interest is $8.11. $51 × 8.11 = $413.61.

[2] The present value of 18.5 additional AUMs annually for 10 years at 4% compound interest is 18.5 × $0.60 × 8.11 = $90.

[3] The difference between (say) $3/AUM paid on the open market and (say) $0.60/AUM charged by the Forest Service is the true value of each forest AUM saved by ranchers (excluding variable non-fee user costs). Fixed costs such as interest on investment do not enter into the calculations. Thus 5.6 × $2.40 × 6.71 = $90.

[4] The present value of one dollar per annum for 15 years at 4% compound interest is $11.12.

[5] The present value of 30 additional AUMs annually for 15 years at 4% compound interest is 30 × $0.60 × 11.12 = $200.

[6] The present value of one dollar per annum for 20 years at 4% compound interest is $13.59.

[7] The present value of 245 additional AUMs annually for 20 years at 4% compound interest is 245 × $0.60 × 13.59 = $2,000.

[8] 75 × $0.60 × 8.11 = $364.95.

[9] 20.5 × $0.60 × 8.11 = $100.

and calf consume 35 lb of air-dry forage daily, 4.9 AUMs can be added on a 1,000-acre pasture by fencing.[10] If the expected life of the fence is 20 years, the value of this increase to the federal government is $39.95 under current Forest Service grazing rate.[11] The value to the stockman of an annual increase in grazing capacity of 4.9 AUMs on public lands is 4.9 × $2.40 × 9.82 = $115.48. On private land, the value of the increase is $155.67.

The cost of constructing fences on areas similar to the one studied is about $1,000 per mile. If an isolated 1,000-acre pasture is completely fenced, about 5 miles of fencing will be required. However, since natural barriers such as cliffs, talus slopes, high ridges, and thick brush can be incorporated into the pasture design, and since some of the fences will be common to at least two pastures, the amount of fencing required will be considerably less than 5 miles. On typical mountain rangelands, about one-fourth of the necessary boundaries must be provided by fences and the remaining three-fourths are furnished by natural barriers, bringing the cost of fencing a 1,000-acre pasture to about $1,250 (1¼ miles of fencing at $1,000/mile). Thus, it does not appear economically feasible for the federal government to invest in fencing since the added grazing capacity necessary to break even is 153 AUMs for a $1,250 investment.[12] Fencing also appears unprofitable for the private operator on range similar to the study area since the added grazing capacity necessary to break even on a $1,250 investment is 53 AUMs[13] on public land and 39 AUMs on private land. The above analysis does not include other benefits of fencing accruing to the federal government and private owners such as improved management, reduced costs of administration, and reduced trespass problems.

Salting

Since livestock distribution on federal lands is largely a responsibility of the stockman, increased utilization gained through increased annual operating costs should be evaluated from the point of view of the private operator rather than from that of the federal government. Therefore, the additional carrying capacity gained on public lands by proper salting was assigned a value of $2.40 per AUM. Strategic salt placement (salt placed in forage producing areas where cattle do not go by preference) increased forage utilization by 18.6%. Thus, on a federal area currently yielding 1,000 AUMs of grazing, improved distribution through proper salt placement can be expected to result in 186 additional AUMs annually valued at $446.40. On private lands, the value of such an increase is $558.

Since most cattlemen currently feed a salt supplement anyway, the cost of the salt itself should not be charged to obtaining improved cattle distribution. The cost of strategic salting includes the man and horse hours necessary to pack the salt to the proper locations and to drift cattle into the new salt areas. Since about 2 lb of salt are required for each AUM, slightly less than 2,400 lb of salt would be placed at proper sites on the area in question. Under typical mountain range conditions, such a project would require one rider, one saddle horse, and two pack horses for three days. If the rider received $10/day for his labor and $2/horse per day for the use of his three horses, the total annual cost of salt distribution would be $48. The net return, then, to the salting practice would be $398.40 on public lands and $510 on private lands. The increased grazing capacity necessary to break even on a $48 investment in salting on public lands is 20 AUMs. On private lands, an increase of 16 AUMs is necessary to cover all costs.

Herding

Drifting cattle out of the stream bottoms and onto adjacent slopes increased forage utilization 20% on the areas sloping less than 35%. Forty percent of the study area (10,000 acres) was composed of range which was adjacent to stream bottoms and which had less than a 35% slope. The average air-dry forage production of the range falling into this category was 630 lb/acre. Thus, on the 25,000 acres studied, 1,200 AUMs were added by drifting.[14] Drifting, like salting, is the responsibility of the rancher rather than the Forest Service and represents an increase in annual operating costs rather than a capital investment. For this reason, the increased carrying capacity resulting from drifting on public lands was assigned a value of $2.40 per AUM and the value of the 1,200 AUM annual increase on public lands is $2,880. The value of such an increase at a rate of $3 per AUM on similar private land is $3,600.

[10] 4.4% increase × 517 lb = 23 lb/acre additional forage.

$$\frac{\text{23 additional lb}}{\text{35 pounds daily}} = \text{0.66 added animal unit days/acre.}$$

22% × 1,000 acres = 220 acres sloping 35 to 55%.

220 acres × .66 = 147 animal unit days.

$$\frac{\text{147 AUDs}}{30} = \text{4.9 AUMs.}$$

[11] 4.9 × $0.60 × 13.59 = $39.95.

[12] 153 × $0.60 × 13.59 = $1,250.

[13] 53 × $2.40 × 9.82 = $1,250.

[14] 20% increase × 630 lb = 126 additional lb/acre.

$$\frac{\text{126 lb}}{\text{35 lb daily}} = \text{3.6 additional AUDs/acre.}$$

40% × 25,000 acres = 10,000 acres. 10,000 acres × 3.6 AUDs = 36,000 AUDs.

$$\frac{\text{36,000 AUDs}}{30} = \text{1,200 AUMs.}$$

The cost of the drifting practice included a wage of $250/rider per month for two riders, $40 food allowance/month for each rider, and $2/horse per day for the animals in actual use. Thus, the total cost of cattle drifting was $2,100 for the three-month summer grazing period and the net return was $780 on public range. The increased grazing capacity necessary to break even on an investment of $2,100 is 875 AUMs on public lands and 700 AUMs on privately owned lands.

Summary and Conclusions

On the particular area studied, some methods of improving cattle distribution appear economically feasible for private investment only, some appear profitable for both private and federal investment, and some appear unprofitable for investment by either interest group. Each new water development increased annual grazing capacity by 85 AUMs. Under conditions similar to those of the study area, the increased annual grazing capacity resulting from each pond construction required for federal investment is 18.5 AUMs and that required for private investment is 5.6 AUMs on public lands and 4.3 AUMs on private lands. Federal expenditure for spring development requires an increase of 30 AUMs annually per development while private spring development on public lands is justified by an annual increase of 9.7 AUMs. On private lands, only 7.3 additional AUMs are required. Guzzler construction is an unprofitable investment for the federal government since an annual increase in grazing capacity of 245 AUMs is necessary to offset construction costs. Guzzler construction may be a sound investment for the private operator since only 85 additional AUMs are required annually to justify guzzler construction on public lands and only 63 additional AUMs are required on private lands.

Trail construction appears profitable for both the federal government and private operators since at least 75 additional AUMs annually can be expected to result from each $100 invested. An annual AUM increase of 20.5 is the necessary break even point for a $100 investment in trail construction by the federal government. An increase in annual grazing capacity of 6.2 AUMs is necessary to justify a $100 expenditure by a private operator on public lands. Only 4.7 additional AUMs are required on private lands.

Based on increased utilization in the study area, fencing on mountain rangelands appears unprofitable for both public and private investment. A $1,250 investment in fencing yielded an increase of only 4.9 AUMs annually while increases of 153 AUMs and 53 AUMs are necessary to cover the costs incurred on public lands by the federal government and private operators, respectively. On private lands, 39 additional AUMs are necessary to justify investment in fencing by ranchers.

Annual investment in strategic salting appears to be a highly profitable venture for the rancher. An additional 186 AUMs of grazing capacity resulted from a $48 investment in improved salt placement. An increase of only 20 AUMs was required to cover all costs on public lands and an increase of 16 AUMs was sufficient to offset all costs on private lands. Increased annual operating costs which the stockman incurs from herding practices are easily justified by the annual increase in carrying capacity. An increase of 1,200 AUMs resulted from the $2,100 spent on herding while an increase of 875 AUMs was necessary to cover all costs on public lands and an increase of 700 AUMs would cover all costs on private lands.

Specific recommendations are not to be inferred from these data. Recommendations must be based on detailed analysis of individual areas and must take into account the intensity of management and the many combinations of the above distribution practices possible. However, methods and calculations reported here serve as an indication of the economic feasibility of cattle distribution practices on mountain ranges of the Intermountain area.

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Drought and Phosphorus Affect Growth of Annual Forage Legumes[1]

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Highlight

Three annual forage legumes, apparently differing in their drought resistance in the field, were grown in controlled environments to better understand mechanisms of their drought resistance and to determine relationships between phosphorus nutrition and drought. Phosphorus fertilization stimulated growth of the annual legumes and decreased water use (ml/g dry weight of top growth). Relative top growth and phosphorus uptake of Spanish clover tended to confirm observations of its drought resistance in the field. Water use was higher in Spanish clover than in subterranean clover and therefore does not appear to contribute to its drought resistance. This study provides information that will be helpful in future research on the morphological and physiological traits that contribute to drought resistance in these and other range plants.

Annual legumes apparently differ in their adaptation to arid conditions. Mt. Barker subterranean clover (*Trifolium subterraneum* L.) is well adapted to the moist coastal range of California. Rose clover (*Trifolium hirtum* All.) is better adapted and often more productive than subterranean clover in the semi-arid central valley of California. Subterranean and rose clover usually complete their life cycle before summer drought and high temperatures, but Spanish clover (*Lotus purshianus* [Benth.] Clements & Clements) often continues vegetative and reproductive growth during the dry summer months.

A study was established under controlled conditions to better understand drought resistance in these annual legumes and to determine the role that phosphorus might play in their response to soil moisture stress.

Drought resistance in plants includes 2 components—avoidance and tolerance (Levitt, 1964). Drought avoiding plants escape drought by means of deep root systems, water storage, or low transpiration. Drought tolerant plants lose water from their tissues in dry environments and yet are able to (1) survive, or (2) continue growth, development, and metabolism.

Since in this study moisture stress in plant tissues was not measured, the more general term *drought resistance* is used. Nevertheless, it is realized that annual legumes, growing in pots in small volumes of soil, have little opportunity for drought avoidance.

This study concerns the ability of annual legumes to continue growth in dry environments rather than their ability to survive in dry environments.

Materials and Methods

A dilute solution of H_3PO_4, in amounts equivalent to 0, 44, or 175 lb P/acre, was thoroughly mixed with 550 g of Auburn silty clay loam, a phosphorus deficient soil (McKell et al., 1962). Six germinated seeds were planted in the soil and were allowed to grow through small holes in the container lid. Cotton was placed in the hole around each plant to minimize evaporation from the soil. During a 25-day period for seedling establishment, plants were grown in a greenhouse at a soil moisture stress below 1 atmosphere. Plants were then transferred to a controlled environment with a light intensity of 1000 ft-c, day length of 16 hr, temperature of 21 C, and relative humidity of 60 to 80% during the day and 80 to 95% during the night. At the same time, soil moisture regimes of 1, 3, and 15 atmospheres were established. A calibration curve relating soil moisture percentage to soil moisture stress was prepared by the pressure membrane method (Richards, 1947). The containers in which plants were growing were weighed twice daily and the soil moisture percentage was calculated by using the total weight and the known weights of the soil and container. When soil moisture decreased to the percentage corresponding to 1, 3, or 15 atm, water was added to increase soil moisture to the percentage corresponding to 0.3 atm (approximately field capacity). The amount of water added at each irrigation was recorded. After 6 weeks of growth under the 3 moisture regimes, top growth was harvested and roots were washed from the soil.

The experiment was conducted with 4 replications. Statistical comparisons were made by using the Duncan multiple range test. Plant material from the 4 replications was pooled for the determination of total phosphorus in tops and roots.

Results and Discussion

Soil Moisture Regimes.—The maximum moisture stress reached before irrigation and the duration of moisture stress levels which restrict growth

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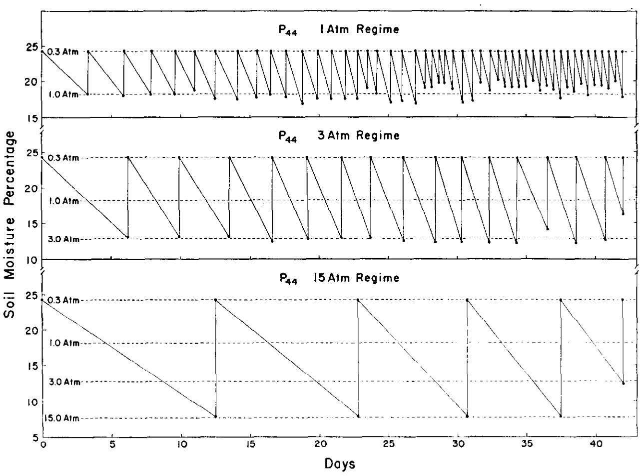

FIG. 1. Drying cycles of plants fertilized with 44 lb P/acre and held in the 1, 3, and 15 atmosphere soil moisture regimes, including all 3 annual legumes. Points on lower side of curves represent average dates of irrigation and average soil moisture percentages prior to irrigation. Assumption of a linear loss of soil moisture with time was made in plotting the data. Horizontal broken lines indicate soil moisture percentages corresponding to a soil moisture stress of 0.3, 1, 3, and 15 atmospheres.

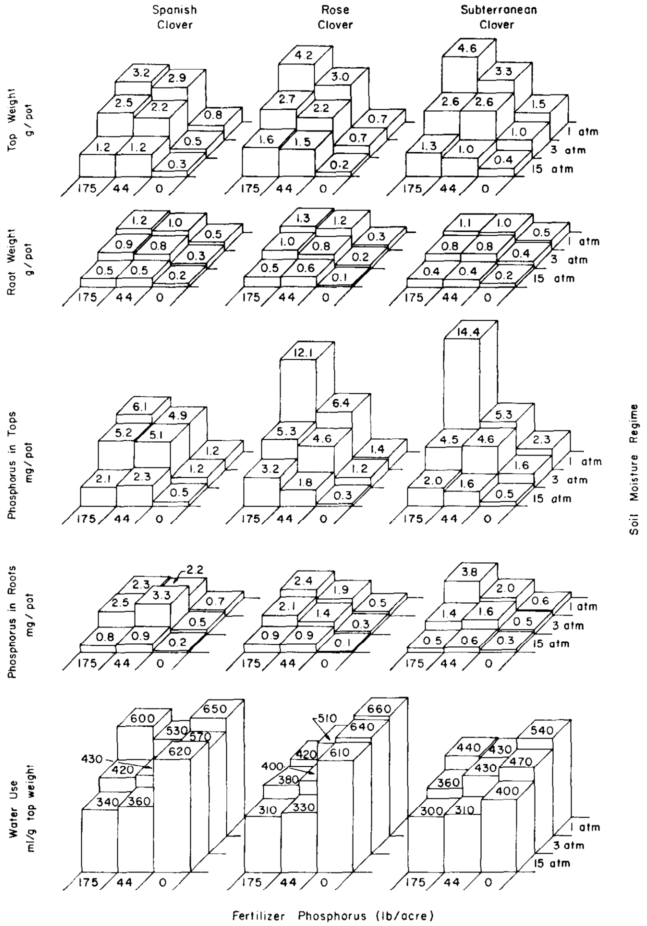

FIG. 2. Top and root growth, phosphorus uptake, and water use of annual legumes in response to soil moisture regimes and phosphorus fertilization.

need to be considered in the interpretation of plant growth in response to a series of drying cycles. Fig. 1 gives the drying cycles of plants fertilized with 44 lb P/acre and held in the 1, 3, or 15 atm regimes. The maximum soil moisture stress to which plants were subjected was approximately constant within each moisture regime. However, because of increased top growth and transpiration, the duration of a single drying cycle decreased as the experiment progressed. When compared with plants in the 44 lb P/acre treatment, small plants in the 0 lb P/acre treatment required less frequent irrigation and large plants in the 175 lb P/acre treatment required more frequent irrigation (Table 1).

The performance of species growing in moisture regimes can be validly compared if the regimes and frequencies of irrigation are similar. In this study the similarity of moisture regimes of the 3 annual legumes, particularly in treatments receiving 44 and 175 lb P/acre (Table 1), permits meaningful comparisons of their responses to drought.

The detailed illustration of top and root growth, phosphorus uptake, and water use is given in Fig. 2. Statistical evaluations of relationships between species, moisture regimes, and phosphorus fertilization are presented in the tables.

Plant Growth.—Spanish clover was lowest and subterranean clover was highest in top growth production in the 1 atm regime (Table 2). In the 3 and 15 atm regimes, top growth of the 3 annual legumes did not differ significantly.

Comparisons of relative top growth of plants in the 1 and 3 atm regimes suggest that the growth of Spanish clover was inhibited less by moderate

Table 1. Number of times annual legumes were irrigated during a 6-week exposure to 3 moisture regimes.

Moisture regime	Spanish clover			Rose clover			Subterranean clover		
	P175	P44	P0	P175	P44	P0	P175	P44	P0
1 atm	54	48	18	54	49	16	56	48	24
3 atm	18	16	5	17	15	6	15	16	8
15 atm	5	4	2	6	6	2	5	4	2

Table 2. Top growth (g/pot dry weight) of 3 annual legumes in response to 3 moisture regimes.[1]

Moisture regime	Spanish clover	Rose clover	Subterranean clover
1 atm	2.32[c]	2.65[b]	3.11[a]
3 atm	1.75[d]	1.83[d]	2.04[cd]
15 atm	0.89[e]	0.89[e]	1.11[e]

[1] These data include all 3 phosphorus fertilization treatments. Numbers having the same letter in the superscript do not differ significantly at the 5% level.

Table 3. Relative top growth (percent[1]) for 3 annual legumes as influenced by moisture regime.

Moisture regime	Spanish clover P175	P44	P0	Rose clover P175	P44	P0	Subterranean clover P175	P44	P0
1 atm	100	91	25	100	71	17	100	72	33
3 atm	78	69	16	64	52	17	57	57	22
15 atm	38	38	9	38	36	5	28	22	9

[1] Values given are in relation to yields of plants fertilized with 175 lb P/acre and held in the 1 atm regime.

stress than the growth of rose and subterranean clover (Table 3).

In the 1 atm regime, the average top growth of the 3 annual legumes increased with each increase in phosphorus (Table 4). In the 3 and 15 atm regimes, the application of 175 lb P/acre did not produce greater top growth than 44 lb P/acre.

The pattern of root growth response to moisture stress for the 3 annual legumes was essentially similar. The application of 44 lb P/acre increased root growth in all 3 moisture regimes (Table 4). But the application of additional phosphorus did not result in a further increase in root growth.

Phosphorus Uptake.—Subterranean and rose clover apparently have a greater ability than Spanish clover to absorb phosphorus in the 1 atm regime, but do not maintain this superiority in the 3 atm regime (Table 5). Comparisons of relative phosphorus uptake by plants fertilized with 175 lb P/acre and held in the 1 or 3 atm regimes showed that moisture stress reduced phosphorus in Spanish, rose, and subterranean clover by 8, 49, and 68%, respectively.

Water Use.—Efficient water use by fertilized annual legumes (Table 6) suggests that phosphorus increased photosynthesis per unit leaf area more than transpiration per unit leaf area. In experiments where moisture was not a limiting factor, Watson (1947) showed that phosphorus deficiency reduced net assimilation rate in barley and mangolds during the period when leaf area was increasing.

Table 4. Effects of phosphorus fertilization and moisture regime on top and root growth (g/pot dry weight) of annual legumes.

Moisture regime	Top growth[1] P175	P44	P0	Root growth[1] P175	P44	P0
1 atm	3.97[a]	3.09[b]	1.01[e]	1.19[a]	1.10[a]	0.43[cd]
3 atm	2.61[c]	2.35[c]	0.71[e]	0.89[b]	0.82[b]	0.32[d]
15 atm	1.37[d]	1.20[de]	0.32[f]	0.49[c]	0.49[c]	0.17[e]

[1] Data include all 3 annual legumes. Values having the same letter in the superscript do not differ significantly at the 5% level. Separate statistical comparisons are made for top and root growth.

Table 5. Phosphorus uptake on an absolute basis and on a relative basis by species.

Moisture regime	Spanish clover P175	P44	P0	Rose clover P175	P44	P0	Subterranean clover P175	P44	P0
Total P uptake, mg/pot[1]									
1 atm	8.4	7.1	1.9	14.5	8.3	1.9	18.2	7.3	2.9
3 atm	7.7	8.4	1.7	7.4	6.0	1.5	5.9	6.2	2.1
Relative P uptake (%)									
1 atm	100	85	23	100	57	13	100	40	16
3 atm	92	100	20	51	41	10	32	34	12

[1] Total P in roots and tops.

More efficient water use in the 3 and 15 atm regimes than in the 1 atm regime suggests that during moderate stress, transpiration is reduced more than photosynthesis. This more efficient use in dry regimes might not occur in field conditions because evaporation from the soil contributes to total evapotranspiration.

The ability of Spanish clover to continue growth during dry summer months is not explained by more efficient water use (Table 6). Spanish clover apparently possesses some other means of avoiding drought.

Drought Resistance.—The stimulation of growth by phosphorus fertilization in the drier regimes does not necessarily mean that phosphorus enhances the drought resistance of annual legumes. Supplying phosphorus certainly results in more rapid root and top growth during the portion of the drying cycle when moisture is favorable. Also, rapid recovery of plants from the effects of moisture stress may be assisted by phosphorus fertilization. But it is uncertain whether plants having adequate phosphorus would continue growth under drier conditions than phosphorus deficient plants.

Moisture stress has been shown to seriously disturb the metabolism of phosphorus-containing nucleic acids in tomato (Gates and Bonner, 1959), corn (West, 1962), and sugar beet (Shah and Loomis, 1965). Concentrations of phosphate esters

Table 6. Effects of main treatments on water use (ml/g dry weight of top growth).[1]

Phosphorus treatment[2] P175	P44	P0	Moisture regime[3] 1 atm	3 atm	15 atm	Species[4] Spanish clover	Rose clover	Sub. clover
396[a]	416[a]	573[b]	531[a]	455[b]	398[c]	501[a]	473[a]	411[b]

[1] Statistical comparisons are made within each main treatment. Values having the same letter in the superscript do not differ significantly at the 5% level.
[2] Includes all species and moisture regimes.
[3] Includes all species and phosphorus treatments.
[4] Includes all moisture regimes and phosphorus treatments.

drop to low levels in wilted subterranean clover plants (Wilson and Huffaker, 1964). Research is needed to learn whether phosphorus deficiency intensifies these injurious effects of drought.

In studies of drought resistance, comparisons of performance on a relative basis may be more meaningful than on an absolute basis. In this way the performance of a species under drought is compared with its own performance under favorable moisture. Top growth (Table 3) and phosphorus uptake (Table 5), on a relative basis, suggest that Spanish clover possesses greater drought resistance than rose and subterranean clover. However, this evidence of drought resistance in Spanish clover must be considered as being preliminary. Additional work is needed to clearly establish its resistance and to discover the morphological and physiological traits that contribute to its resistance.

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Cheatgrass Range in Southern Idaho: Seasonal Cattle Gains and Grazing Capacities

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Highlight

Yearling cattle gained weight satisfactorily on cheatgrass range under rotational (moderate) and continuous (moderate and heavy) grazing systems during a 3-year study. This study was designed to determine effects of these systems on the rangeland—not on individual plant species. Assignment of these systems to different pastures each year precluded evaluation of long-term vegetal response to the treatments. Weight gain was greatest in late spring. Grazing capacity of the range and cattle gain per acre increased through the summer, then declined. Yearly variation in production of forage and beef was apparently due to weather. Grazing capacity and beef production increased under continuous heavy grazing, but possible vegetation changes not evaluated in this study make heavy grazing undesirable.

The maintenance or improvement of cheatgrass range, and efficient use of the vegetation, is an important goal of range management in the Intermountain and Columbia basins. In 1960 the Bureau of Land Management, U. S. Department of the Interior, and the Intermountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, began a cooperative research project to explore ways to improve management of cheatgrass ranges. One of many objectives of this research is to measure livestock gains and grazing capacities on cheatgrass range. This information is essential for management planning. In this paper we report the results of studies relating cattle gain and grazing capacity to season of use under rotation and continuous grazing. At the outset, it should be emphasized that the rangeland dominated by cheatgrass (*Bromus tectorum* L.)[2], and not the plant itself, was the subject of this study.

Cheatgrass range occurs widely in the Intermountain and Columbia basins and supports large numbers of livestock. In this region, cheatgrass range provides the bulk of spring grazing for all classes of stock and is especially important as spring lambing range. Hull and Pechanec (1947) considered cheatgrass the most important forage plant in southern Idaho, mainly because it dominates such a large area, but many associated species are seasonally or periodically valuable forage, depending on weather cycles and other factors.

Despite the acknowledged importance of cheatgrass range, little is known of its forage value. In Nevada, Fleming et al. (1942) found that cattle

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[2] Plant names follow those published by R. J. Davis, *Flora of Idaho,* 828 p. Dubuque, Ia.: Wm. C. Brown Co. 1952.

gained on cheatgrass until August 1, maintained their weight until August 20, and then began to lose. Stewart and Hull (1949), however, found that cattle sometimes graze yearlong with satisfactory results. Generally, the grazing value of cheatgrass range after it reaches maturity in late spring or early summer has been heavily discounted (Fleming et al., 1942; Pechanec and Stewart, 1949; Reid, 1942).

Average grazing capacity of cheatgrass range in southern Idaho has been recently judged by the Bureau of Land Management to be 5 to 8 acres/animal unit month (AUM) (Klemmedson and Smith, 1964). On good cheatgrass range, the capacity is reported to be between 1.5 and 3 acres/AUM (Hurtt, 1939; Hull and Pechanec, 1947; Stewart and Hull, 1949), while on poorer, eroded rangeland, 4 acres/AUM are required (Stark et al., 1946). Since the annual yield of cheatgrass fluctuates widely (Klemmedson and Smith, 1964), the variation in these reported grazing capacity figures is understandable.

Experimental Area and Design

Studies described here were conducted at Saylor Creek Experimental Range, a joint facility of the Bureau of Land Management and the Intermountain Forest and Range Experiment Station. The range is on the Snake River Plains approximately 9 miles southwest of Glenns Ferry, Idaho. The topography is level to gently undulating; soils are derived from Black Mesa gravel and aeolian deposits (Malde and Powers, 1962).

The vegetation at Saylor Creek consists of a fairly uniform stand of cheatgrass, interspersed with varying amounts of Sandberg's bluegrass (*Poa secunda*), squirreltail (*Sitanion hystrix*), and streambank wheatgrass (*Agropyron riparium*), with minor amounts of needleandthread grass (*Stipa comata*). During certain seasons and years, Russian-thistle (*Salsola kali* v. *tenuifolia*) and pinnate tansy mustard (*Descurainia pinnata*) are prevalent. Repeated burning and grazing by both sheep and cattle over many years have transformed the original sagebrush–grass vegetation, probably *Artemisia tridentata–Stipa thurberiana*,[3] into the present seral communities. In much of the present cheatgrass type, bluebunch wheatgrass (*Agropyron spicatum*) was the original dominant grass species, rather than Thurber's needlegrass (*Stipa thurberiana*) or needleandthread.

Annual precipitation averages 8.59 inches at Glenns Ferry, the majority occurring in the period October through April. Total precipitation by crop years (September–August) for 1960–1961, 1961–1962, 1962–1963, was 6.06, 9.96, and 11.34 inches, respectively. The average annual temperature is 51.9 F. Monthly precipitation and mean monthly temperature regimes at the Experimental Range for the period of study, 1961 to 1963, are given in Fig. 1.

The experiment measured animal gains and grazing capacity of cheatgrass range at four consecutive seasons of use under both rotation and continuous grazing for 3 years (1961–1963). The seasons and their durations were early spring, 6 weeks (April 1–May 12); late spring, 6 weeks (May 13–June 23); summer, 10 weeks (June 24–September 1); and fall, 8 weeks (September 2–October 27). These seasonal treatments were selected to coincide with developmental stages of the dominant vegetation: an early slow growth period, a rapid growth and maturing period, a long summer dry period, and a fall period when regrowth of perennials and germination of cheatgrass may occur. The early spring period began on or about April 1 each year, the date on which the Bureau of Land Management normally opens surrounding ranges to grazing. The rotation treatment was applied at a moderate rate of grazing that allowed about 40% of the available herbage to be consumed. The continuous treatment was applied at two intensities of grazing, moderate and heavy. About 60% of the available forage was consumed under heavy use. All treatments were replicated.

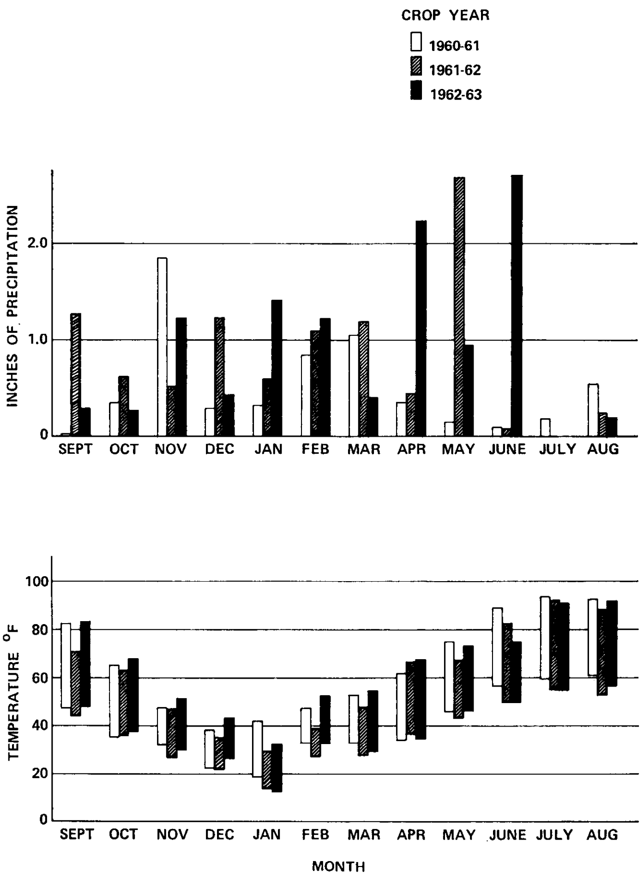

FIG. 1. Monthly precipitation and mean monthly maximum-minimum temperatures at Saylor Creek Experimental Range, September 1960 to August 1963.

Local stockmen provided yearling cattle (averaging 330 lb on April 1) of beef breed (Angus, Hereford, and Angus–Hereford cross) for the experiments. The cattle arrived at the Experimental Range on April 1 each year, were ear-tagged, weighed, and assigned to treatment groups on a random basis. Once assigned, an animal remained in the same treatment group through all four seasons, unless removed for purposes of adjusting the stocking. Animals in the rotation treatment group were moved to fresh pasture at the start of each seasonal period while those in the continuous treatment groups remained on the same pasture

[3] Personal communications with M. Hironaka, University of Idaho, Moscow.

for all four seasonal periods. Since this study was not designed to measure the carryover effect of the applied treatments year after year, pastures were randomly selected for the treatments each year with the restriction that no pasture would receive the same use in consecutive years.

Cattle were weighed at the beginning and end of each treatment period and midway through the summer period. Since the "put-and-take" system was used to adjust stocking to prescribed utilization, it was necessary to weigh some animals periodically between regular weighing days. All animals were allowed to shrink overnight without feed or water before weighing.

Because the number of animals varied from treatment to treatment and year to year according to intensity of use and available forage, there were disproportionate numbers of animals. We chose to use the average response of animals in the statistical analysis rather than resort to an extensive analysis based on disproportionate subclass numbers, or an analysis based on proportionate but unequal subclass numbers (whereby much of the data would not be used). Animal days per acre and gain per acre were computed from the daily-gain data following the technique of Lucas and Mott (n.d.). This method gives reliable estimates for tester animals (animals which remain on the treated pasture for the entire season or year as opposed to put-and-take animals).

Results and Discussion

Seasonal Effects on Daily Cattle Gain.—To compare seasonal gains, data for all treatments and intensities were pooled. On this basis, over the 3-year study period, cattle gained an average of 1.70, 2.06, 1.38, and 0.82 lb daily for the early spring, late spring, summer, and fall periods, respectively. Statistical analysis showed that differences in daily gains between seasons were highly significant. Differential gains primarily reflect rapidly changing quality of forage on cheatgrass range through the normal growing season. As noted below, quantity of available feed may have affected early spring gains.

These results may be compared with the daily gain of yearling cattle on crested wheatgrass at Benmore Experimental Range in Utah. Gains reported (U. S. Forest Service, 1964) were 2.72, 1.87, 1.00, and 0.22 lb for early and late spring, summer, and fall grazing periods ranging from April 20 to about December 1. The elevation of Benmore is 5,700 ft; hence, seasonal development of forage would be comparable with that at Saylor Creek on the opening date of early spring grazing.

In contrast to the Benmore cattle, cattle on cheatgrass range made their best gain in late spring when vegetation was both abundant and presumably most nutritious. Successively lower gains occurred during early spring, summer, and fall when forage was either less abundant—allowing less selectivity on the part of animals—or less nutritious. Gains of cattle on cheatgrass range during the fall were exceptionally good compared with those on crested wheatgrass, even considering that the later fall grazing season at Benmore undoubtedly depressed livestock gains somewhat. The pattern of lower gain of cattle in early spring than in late spring on cheatgrass range is not unlike that found with many other forages. Although its nutrient content is high as measured on a dry-matter basis, vegetation on cheatgrass range is high in water content during early spring (Cook and Harris, 1952). Animals evidently have difficulty ingesting sufficient dry matter to satisfy nutritional requirements for optimum growth and maximum gains. Moreover, most species (except Sandberg's bluegrass) do not reach the rapid stage of growth until early May, and the forage supply is often limited, particularly at the beginning of the early spring period and in years of lower than normal spring temperatures. As a result, animals must forage further in search of preferred species, expending relatively more energy, so that less energy is available for weight gains.

Table 1. Grazing capacity (animal days per acre) of cheatgrass range by seasons under three systems of grazing.

Seasons	System: Rotation	Continuous: Moderate	Continuous: Heavy
Early spring	5.7[a]	1.4[a]	2.2[a]
Late spring	7.3[a]	1.7[a]	2.6[a]
Summer	10.7[b]	3.8[b]	5.9[b]
Fall	10.0[b]	3.2[b]	5.1[b]

NOTE: Differences between within-system values not having the same superscript letters are significant at the 5% level.

The decline in cattle gain presumably parallels the steady decline in nutrient content of cheatgrass during the summer and fall seasons (Cook and Harris, 1952). After cheatgrass matures in June, green feed is furnished only by Russian-thistle and sparse needleandthread and squirreltail. Thistle is an undependable source of green feed; the volume depends mostly on summer moisture supply.

Seasonal Effects on Grazing Capacity.—For this study, comparison of differences in grazing capacity can only be made within a grazing system—or on the yearly basis. Differences in the manner in which pastures under rotation and continuous systems are grazed preclude realistic seasonal comparisons between systems.

Grazing capacity increased steadily with seasonal development of the forage crop, reaching a maximum in the summer period for all systems each year (Table 1). For each system and intensity, grazing capacity in the two spring periods was rather similar and lower than in summer and fall periods. Because growth of the vegetation is not complete until the late spring or early summer, the maximum capacity is achieved during summer and fall rather than in late spring when growth is

Table 2. Cattle gain (lb) per acre by seasons under three systems of grazing.

Seasons	Rotation	Continuous Moderate	Continuous Heavy
Early spring	10.2[a]	2.3[a]	4.1[a]
Late spring	14.5[b]	3.5[ab]	5.5[a]
Summer	13.2[b]	5.2[b]	8.2[b]
Fall	8.6[a]	3.0[a]	3.4[a]

NOTE: Differences between within-system values not having the same superscript letters are significant at the 5% level.

most rapid. Only in the occasional "thistle year" does significant summer growth take place. Although differences between summer and fall grazing capacities are not statistically significant for individual systems, the pooled effect would appear to indicate a slight drop in capacity during the fall. This apparent loss of forage results from seed and leaf shattering, mostly associated with livestock movements and trampling during the dry forage period. Losses from insects, rodents, and other causes were probably not as important for this range type as for others (Heady, 1960).

Seasonal Effects on Gain Per Acre.—Gain per acre on cheatgrass range was highest in the late spring and summer seasons (Table 2). For the rotation and continuous-moderate grazing systems, production per acre was about equivalent in both seasons. However, cattle gain per acre was significantly greater in the summer season under continuous heavy grazing. During early spring and fall, equivalent gains per acre were obtained within each of the three systems.

Effects of Grazing System on Gain Per Acre.—Yearling cattle gained equally well (Table 3) under rotation, continuous moderate, and continuous heavy systems. The difference between rotation and continuous systems was not statistically significant. These results indicate that the change to fresh, ungrazed feed periodically through the grazing season had no effect on the gaining ability of the cattle. Neither did the heavier rate of grazing under the continuous system have an effect; evidently cattle under the heavy grazing system still had access to forage comparable in quality to that available to animals under moderate grazing conditions.

Table 3. Cattle gain, grazing capacity, and gain per acre for three systems of grazing.

Item	Rotation	Continuous Moderate	Continuous Heavy
Daily gain, lb	1.39	1.45	1.45
Animal days/acre	8.4	10.2	15.8
Gain/acre, lb	11.6	14.0	21.2

Effects of Grazing System on Grazing Capacity.—Grazing capacity was lowest under rotation grazing at a moderate intensity (Table 3). Continuous moderate and continuous heavy grazing enabled 21 and 88% more stocking, respectively, than rotation over the 3-year period. Stocking under the continuous heavy system was 55% greater than for continuous moderate. Lower capacity obtained with the rotation system is due to timing of the seasonal treatments in relation to the growth cycle. Maximum forage for once-over grazing is not available until midsummer. Thus, in pastures grazed rotationally in early spring, a large percentage of the annual forage crop was produced after animals were removed from the pastures in mid-May. By late summer and fall these pastures appeared ungrazed. Even in pastures grazed only during late spring, a significant amount of forage is probably produced in good years after animals depart. Presumably, this "unused" forage could be regrazed in the fall or left for soil replenishment in a comprehensive grazing system. Undoubtedly, rotation systems that employed regrazing of spring-grazed pastures, even at moderate rates, would compare favorably in grazing capacity with continuous systems.

In the continuous systems, grazing pressure was necessarily light in the spring periods so as to leave sufficient forage for the remainder of the 7-month season. Moreover, since annual herbage yield of cheatgrass is so variable and is apparently highly dependent on spring precipitation,[4] the annual herbage crop can seldom be predicted before mid-May to late May. This explains the fact that grazing capacities for early and late spring seasons were more similar than those for late spring and summer.

Effects of Grazing System on Gain Per Acre.—Beef production per acre in the three combinations of grazing system and intensity (Table 3) paralleled that of the grazing capacity. In the continuous moderate and continuous heavy systems, 21 and 83% more animal gain per acre was obtained, respectively, than in the rotation system. Since daily gains were similar in the three systems, gain per acre is largely a function of carrying capacity. Because the gains per acre were nearly twice as great for the continuous heavy system as for the rotation system, it may appear logical to graze at the heavy rate. However, this cannot be recommended as yet, for to date we have no information regarding effects of various intensities of grazing on vegetation and soils. Presumably, such informa-

[4] Unpublished data, filed at Intermountain Forest and Range Experiment Station, Boise, Idaho.

Table 4. Cattle gain, grazing capacity, and pasture yield of cheatgrass range by year (data pooled for systems and intensities).

Item	1961	1962	1963
Cattle gain in lb/day:			
Early spring	1.47	2.10	1.52
Late spring	2.18	2.25	1.76
Summer	1.62	1.35	1.17
Fall	0.95	0.89	0.63
Yearlong (spring through fall)	1.52	1.55	1.21
Grazing capacity and pasture yield:			
Animal days/acre	5.4	16.3	12.7
Gain in lb/acre	8.2	23.4	15.3

tion will be forthcoming from studies currently underway.

Yearly Effects on Daily Cattle Gain.—When data for all treatments are pooled, cattle gain over the 3-year period of the experiment averages 1.43 lb/head daily for the 7-month grazing period. Unfortunately, we have no comparable data for bunchgrass or seeded range in southern Idaho. However, data obtained at Benmore Experimental Range (U. S. Forest Service, 1964) in Utah suggest that cattle can gain as well on cheatgrass range as on crested wheatgrass range. At Benmore, yearling cattle gained about 1.25 lb daily during a similar but slightly different spring-through-fall grazing season. The cattle gains on cheatgrass range seem particularly satisfactory when it is recalled that the green feed period is only 2 to 3 months long. Only in an occasional year does Russian-thistle contribute more than 5 to 10% of the total forage and thus provide significant green feed after July 1.

Daily gain of yearling cattle varied significantly between years (Table 4). The gains were similar in 1961 and 1962, but about one-third lb less in 1963. The low gain in 1963 cannot be attributed to a particularly low rate of gain during any one seasonal period. On the contrary, daily gains were low throughout the year. Pastures were grazed at the same intensity each year, and despite some problems in estimating utilization on cheatgrass range, we are confident that between-year variations were not large enough to result in the observed differences, particularly at the rates of utilization applied. Neither is the difference in forage production between years a likely cause, for the stocking rate was adjusted each year to the forage available. Moreover, the fact that individual cows gained at similar rates in 1961 and 1962, despite a threefold difference in herbage production, suggests to us that difference in amount of forage produced in 1962 and 1963 probably had little effect on daily gain in those years.

Although data are not at hand to support our suppositions, we believe that weather may influence animal weight gains as much from its effect on forage quality as on forage quantity, and that weather was the likely factor in low gains in 1963. The effect was twofold. In the absence of normal winter snows, much residue from the 1962 forage crop was left standing and available for grazing in the spring, 1963. With new forage in short supply in April (not an unusual circumstance), cattle grazed considerable amounts of this residue along with Sandberg's bluegrass, streambank wheatgrass, and whatever cheatgrass was available at that time. The resulting diet was probably of lower nutritional quality and less conducive to growth and weight gain than the diet of other years. Secondly, in June 1963, 2.71 inches of rainfall were recorded, about 97% more than in the corresponding month in either 1961 or 1962. This amount of moisture, coming when cheatgrass was maturing, probably leached plant nutrients, thus lowering forage quality for the remainder of the grazing year.

The high daily gains obtained in 1962 seem primarily attributable to the exceptionally good early spring gain of 2.10 lb/head daily. This was 0.6 lb higher than the corresponding gain of cattle in 1961 and 0.5 lb higher than the early spring gain of 1963. Presumably higher nutrient content of the forage during this period is primarily responsible, but nutrient analyses of the forage were not obtained to support these suppositions.

Yearly Effects on Gain Per Acre.—Productivity also fluctuated greatly between years; both grazing capacity and gain per acre increased threefold from the dry, poor forage year of 1961 to the good forage year of 1962, then decreased in 1963 to about double the 1961 levels. It is difficult to reconcile these results for 1962 and 1963 on the basis of forage yield. As measured in ungrazed exclosures, forage production was 79 and 132% greater in 1962 and 1963, respectively, than in 1961. From these yield data, higher grazing capacity would have been expected in 1963. The gain per acre in 1963, which was nearly 10 lb/acre or 38% lower than in 1962, primarily reflects the lower daily gain of cattle in 1963 and the 24% lower grazing capacity from the 1962 high.

Interaction Effects.—There were inconsistencies in the trends of data for seasons and systems. The explanation for this is shown in Fig. 2. For some unknown reason, in both 1961 and 1962, cattle in the heavy treatment seemed to fare better in the spring grazing period than cattle grazed at a moderate rate, thereby bringing the average for the 3 years to the level shown in the figure. However, this pattern did not maintain itself throughout the 7-month season; by fall the situation was reversed and in each year cattle grazed at the heavy rate gained less than those grazed at a mod-

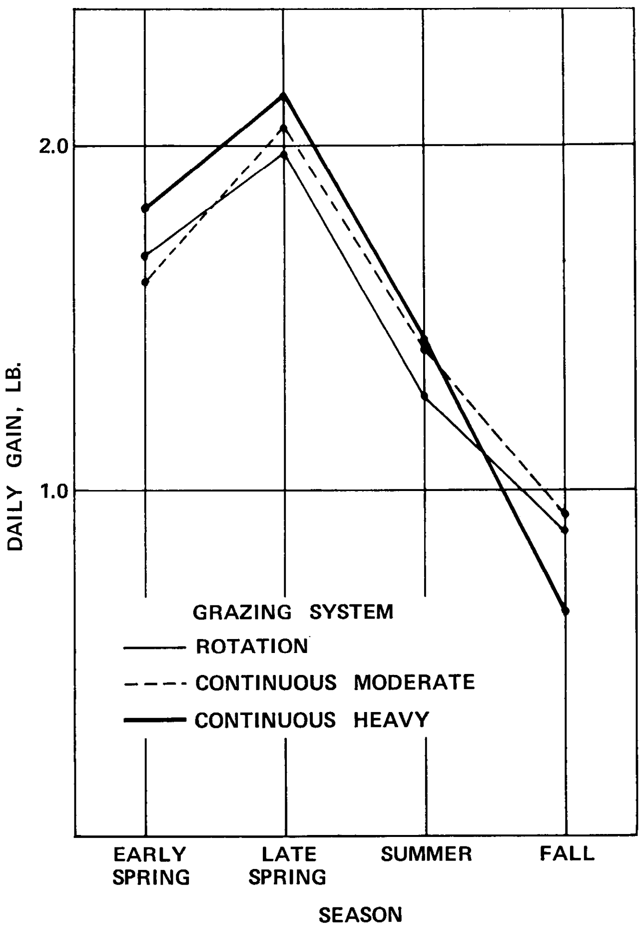

FIG. 2. Daily gains of cattle under three grazing systems, averaged over 3 years, by seasons. A change in pattern of daily gains for cattle in the heavy grazing treatment (relative to other treatments) seems responsible for the significant interaction between season and grazing system.

erate rate. Undoubtedly, by fall, forage in the continuous heavy pasture was relatively more scarce than in moderately grazed pastures, thereby forcing animals to forage longer and farther for desired herbage. Even so, over the entire season, cattle grazed at the heavy rate gained as well as those grazed at moderate rates.

The trend in daily gain by season in 1962 and 1963 showed a peak in the late spring and a steady decline through fall. In 1961, however, during the first 5 weeks of summer, cattle gained 1.43 lb daily, but in the late summer (last 5 weeks) they gained at an exceptional rate of 1.80 lb/head per day. Thus in 1961 cattle gain during the summer was actually higher than in early spring (Table 4). The most plausible explanation for the high late summer gain in 1961 is that during this season cattle foraged heavily on Russian-thistle plants that made up about 50% of the available herbage. In 1962 and 1963 the quantity of thistle was greatly reduced (less than 10% of total herbage); cattle gains were likewise reduced from the 1961 level.

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Germination of Winterfat Seeds Under Different Moisture Stresses and Temperatures

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Highlight

Germination of winterfat decreased and was delayed as moisture stress increased. Decreases were proportionately less at lower temperatures, which indicates soil drying may not be as detrimental to germination during cool weather. One of the two sources of seed tested germinated better under all moisture stresses. Further research may reveal certain sources are superior for revegetation.

The specific temperature and moisture requirements for germination of winterfat (*Eurotia lanata* (Pursh.) Moq.) are not known. According to the Woody Plant Seed Manual (U. S. Forest Service, 1948), winterfat seeds will germinate at about 50 F (night) and 77 F (day). Hilton (1941) found germination was highest at temperatures from 42 to 76 F. Riedl et al. (1964) reported six lots of seed germinated 47 to 78% at 70 F. Statler (1967) obtained 91% germination at room temperature. No studies have been reported concerning the effects of moisture stress on the germination of winterfat seeds. Several investigators have used mannitol solutions, however, to regulate the water available to germinating seeds of grasses and legumes (Dotzenko and Dean, 1959; Helmerick and Pfeifer, 1954; Knipe and Herbel, 1960; McGinnies, 1960; Powell and Pfeifer, 1956). In a recent study with the shrub *Atriplex canescens,* I found moisture stress had less effect on germination when temperatures were near optimum (Springfield, 1966).

This report summarizes the results of a study of six levels of moisture stress at five temperatures on the germination of two sources of winterfat seeds. Objectives were to determine: (1) if winterfat seeds would germinate under the higher moisture stresses, (2) if temperatures influence the germination responses, and (3) if the responses to moisture stresses and temperatures vary with source of seed.

Materials and Methods

Winterfat seeds from two sources were selected for the study. One source was located near Corona in eastern New Mexico at an elevation of 6,300 ft; the other was near Horse Springs in western New Mexico at an elevation of 6,900 ft. The Corona site is characterized by an open stand of juniper, sandy clay loam soil, and 15 inches annual precipitation, 30% of which falls during winter (October to April). The Horse Springs site is characterized by plains grassland, sandy loam soil, and 11 inches annual precipitation, 34% of which falls during winter.

The seeds were collected in October 1964 and stored in paper bags at room temperatures until July 1966 when the experiment was conducted. Fruit and seed characteristics were as follows:

		Length mm	Width mm	No./lb 1000's
Corona	Fruit	7.6	5.9	78
	Seed	2.9	1.8	211
Horse Springs	Fruit	7.1	4.2	120
	Seed	2.7	1.4	255

The seeds were germinated in plastic dishes on three thicknesses of standard germination blotter paper. Fifty seeds were placed in each dish, and the dishes were randomly arranged in a factorial design with three replications per treatment. At the start of the study, 15 ml of the appropriate water-mannitol solution was added to each dish. Evaporation of the solution was negligible; trays containing the dishes were enclosed in polyethylene bags.

Moisture stresses against the seeds were maintained by using solutions of mannitol, with the concentrations adjusted to give osmotic pressures of 0.0, 0.3, 3.0, 7.0, 11.0, and 15.0 atmospheres. The grams of mannitol required per liter of distilled water to give solutions with these moisture stresses were calculated from the following formula by Helmerick and Pfeifer (1954): $P = gRT/mV$, where P = osmotic pressure in atmospheres, g = grams of solute, R = 0.08205 liter atm/degree per mole, T = absolute temperature, m = molecular weight of solute, and V = volume in liters.

The five temperature regimes for the experiment were: alternating 86 (8 hours, light)–68 (16 hours, dark), alternating 78 (12 hours, light)–58 (12 hours, dark), and constant 53, 43, and 37 F (in darkness).

Germinated seeds were counted daily from the second through the seventh day, and at 3- to 4-day intervals thereafter. Counts were continued for 42 days. Seeds were considered germinated when the radicles and plumules measured one inch or more and were free from the seed coat.

Germination percentages were transformed to arcsin for analysis of variance. Sources of variance list out as a $5 \times 6 \times 2$ factorial, with temperatures as the main effect and moisture levels and source as minor effects. Temperatures were not replicated so there was no explicit error term for testing this factor. Data means were compared at the .05 probability level by means of Duncan's new multiple range test.

Results and Discussion

Germination of winterfat seeds was influenced by moisture stress, temperature, and seed source (Table 1).

As moisture stress increased, germination generally was reduced, regardless of temperature. The

[1] Forest Service, U. S. Department of Agriculture, with central headquarters maintained at Fort Collins in cooperation with Colorado State University; research reported here was conducted at Albuquerque in cooperation with the University of New Mexico.

Table 1. Percent germination of two sources of *Eurotia lanata* seeds under six levels of moisture stress at five temperatures.

Seed source	Germ. temp. (F)	Germination (by moisture stress in atmos.) 0	.3	3	7	11	15	Avg.
Horse Springs	86–68	89	90	82	51	17	11	57a*
	78–58	92	94	91	89	79	29	79b
	53	90	94	83	83	67	43	77b
	43	92	83	79	73	69	55	75b
	37	80	81	71	67	47	32	63b
Average		89a	88a	81ab	73b	56c	34d	70
Corona	86–68	84	67	57	37	5	5	42a
	78–58	91	85	83	58	20	18	59b
	53	81	79	79	67	41	29	63b
	43	83	80	77	72	67	51	72b
	37	80	80	76	61	49	29	62b
Average		84a	78a	74a	59b	36c	26d	60

* Values followed by the same letter do not differ significantly at the .05 level using Duncan's multiple range test.

difference between germination under 0.0, 0.3, and 3.0 atm was not significant, but germination under these levels was significantly greater than under 7, 11, or 15 atm.

Germination of both seed sources was less at alternating temperatures of 86–68 F than at the other temperatures.

The Horse Springs source of seed germinated better than the Corona source.

All interactions between seed source, moisture stress, and temperature were significant.

The effects of moisture stress on germination were strongly influenced by temperature. At alternating temperatures of 86–68, germination dropped sharply as moisture stress increased beyond 3.0 atm. This suggests soil moisture approaching field capacity is necessary for appreciable germination of winterfat during the summer when temperatures are in the 80 to 100 F range in New Mexico. The interacting effects of moisture stress and temperatures were less pronounced at the four lower temperatures. Nevertheless, as moisture stress increased to 15 atm, seed germination decreased proportionately more at 78–58 than at 53, 43, or 37 F. These trends indicate the effects of increased moisture stress would be less detrimental at relatively low temperatures, or that drying of the soil might not be as damaging to germinating winterfat seed during cool weather as during warm weather.

Germination was delayed by increasing moisture stress (Fig. 1). The influence of temperature was reflected in these delays. Germination began sooner and progressed more rapidly under stresses of 0.0, 0.3, and 3.0 atm and at temperatures of 86–68 and 78–58 F. Delay in germination was most noticeable under 15 atm stress, and at 37 F. The

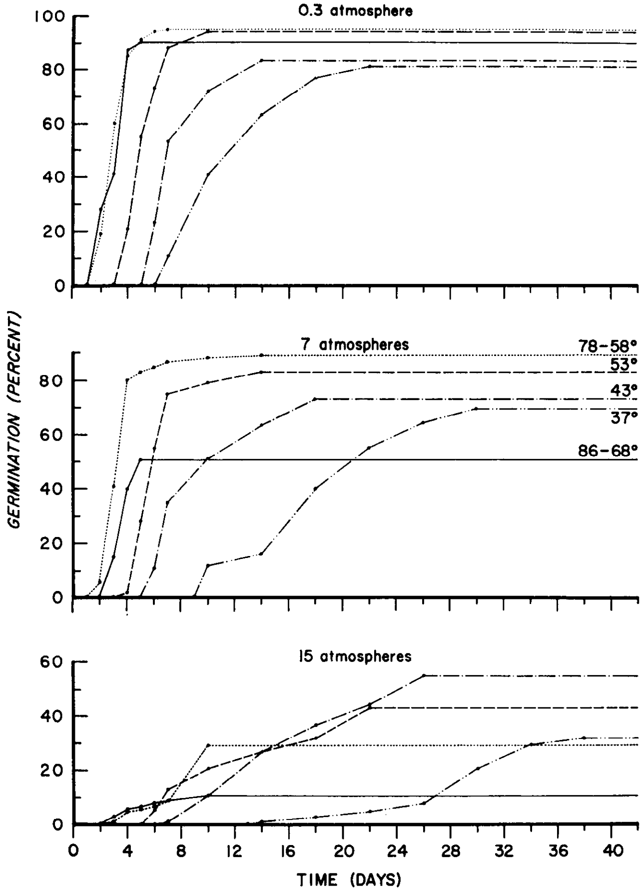

FIG. 1. Trends in the germination of Horse Springs winterfat seed under three levels of moisture stress at five temperatures.

two seed sources responded about the same under stresses of 0.0, 0.3, 3.0, and 15 atm, but somewhat differently under 7 and 11 atm. For example, under 11 atm stress the germination of the Horse Springs seed was most rapid and highest at 78–58 F, whereas for the Corona seed, germination at 43 F, though delayed a few days, was nearly as rapid and markedly higher than at 78–58 F. This suggests that responses of winterfat seeds to different combinations of moisture stress and temperature probably vary somewhat with source of seed. Further research may reveal that certain sources are superior for range revegetation.

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Sand Dune Rehabilitation in Thal, Pakistan[1]

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Highlight

Rangeland improvement in Thal, Pakistan through reseeding was started in 1962. These operations were impressively successful on heavy soil valley flats but loose sand dunes defied all efforts of sowings. These dunes have been successfully rehabilitated through planting tufts of *Cenchrus ciliaris* (dhaman) and *Elyonurus hirsutus* (karera). On better sites, grasses seeded in flats are spreading naturally to the dunes. Under "Thal Technique of Planting Trees" more than 100,000 fodder trees have been transplanted successfully since July 1964 in earthen tubes (baked) without watering. Experiments to determine effects of exposure and different competition levels on height growth of *Zizyphus jujuba* (ber) are presented. Southeastern (leeward) exposures have been found to be significantly (highly) better than tops and northwesterly (windward) exposures. The minimum plant competition level gave significantly (highly) more height growth than the other three levels.

Rehabilitacion de las Dunas de Arena en Thal, Pakistan

Resumen

El mejoramiento de los pastizales en Thal, Pakistán por medio de la siembra, fue iniciado en 1962. Se obtuvo un éxito impresionante en las siembras hechas en valles planos con suelos pesados, pero en las dunas de arena suelta todos los esfuerzos por sembrar resultaron fallidos. Sin embargo, dichas dunas han sido rehabilitadas exitosamente por medio del transplante de macollos de *Cenchrus ciliaris* y *Elyonurus hirsutus.* Los zacates sembrados en los valles están invadiendo en forma natural las dunas.

Los pastizales de verano en Thal tienen zacates verdes disponibles por seis meses únicamente; a excepción de *Elysine flagellitera* en general durante su dormancia dichos zacates no mantienen un alto valor nutritivo. Tradicionalmente durante el invierno la principal fuente de alimento es el ramoneo. Los árboles de ramoneo se presentan como fuente esencial de abastecimiento de forraje durante todo el año, su aumento estable por medio de técnicas de plantación es entonces un problema mayor en el área.

Una técnica conocida como "técnica Thal para plantar árboles" ha probado tener mucho éxito en ciertas especies de árboles bajo situaciones específicas. La técnica incluye la construcción de tubos de arcilla cocidos, con una longitud de 30 cm (1 pie) y con un diámetro de 11.25 cm (4.5 pulgadas). Las especies deseadas son plantadas en los tubos en invernaderos para que posteriormente cuando tengan sus raíces y follaje adecuadamente desarrollados sean transplantados en el campo. El propósito del tubo es proporcionar a la planta un medio en el cual pueda sobrevivir hasta que pueda tomar ventaja de la humedad existente en la arena de las dunas, siendo entonces el tiempo de plantación el factor mas determinante. Se encontró que el transplante no se deberá intentar hasta que haya humedad adecuada en 30 cm (1 pie) en el estrato superficial del suelo.

Las plantaciones de *Prosopis spicigera* han sido las de mas éxito, otras especies fueron susceptibles a la destrucción por insectos.

Las plantaciones de exposición sureste fueron significativamente mejores que los realizados en exposición noroeste y en la cima de las dunas. Una mínima competencia con las plantas dio un crecimiento en altura significativamente mayor.

The tract Thal, covering 5 million acres, lies between latitudes 30°–32° N. and longitudes 71°–72° E. It is an alluvial formation with sandy loam to clayey soil in valley flats which are interspersed with loose sand dunes. The region is characterized by an extreme continental desert climate i.e., high temperatures (120 F) meager monsoon rainfall (9 inches) and severe wind storms in summer, low temperatures in winter (less than 32 F). This, a great potential range area, has been depleted due to uncontrolled interference by man and his livestock since very old times. Efforts to reestablish better grass cover through reseeding were started in 1962. The reseeding works on valley flats have already been published (Khan, 1965, 1966). The present paper presents the efforts to establish grasses and trees of fodder value on loose sand dunes where failures followed the usual reseeding operations.

Forty to sixty percent of this tract consists of

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FIG. 1. Tufts of *Elyonurus hirsutus* and tube plants of *Zizyphus jujuba* (fodder tree) planted on active loose sand dunes at D. kotli, Thal. Planted July, 1964; photo August, 1964.

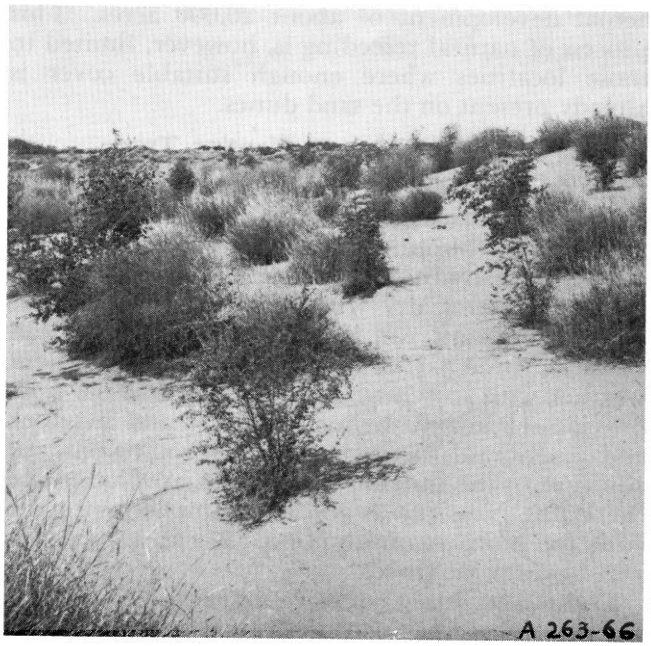

FIG. 2. Same area as in Fig. 1, after 85 weeks of planting. Photo, March, 1966.

loose sand dunes with inadequate vegetal cover of species of low forage value. Not only the grasses of good forage value have disappeared but the trees of fodder value have also been continuously browsed by camel and lopped heavily to feed sheep and goats in winter. The social economic conditions of the population resulted in ruthless cutting of trees for firewood. The traditional rain-fed cultivation has been responsible for much of the blowing sands and shifting sand dunes. Khan (1966) reporting on the effect of site on success of reseeding in Thal, observed that slopes and dunes could not be reseeded properly with the available practices. He concluded that reseeding operations in Thal should be confined to flats.

In order to rehabilitate these loose sand dunes a two-pronged attack was made. Where better grasses were established through "tuft planting," a new technique called "Thal Technique of Planting" was evolved to establish trees of range value on the sand dunes.

Tuft Planting and Reseeding

Grasses dug with at least a 9-inch root system and 6 inches above the collar were termed "tufted." This operation was specially needed to cover sand dunes where sowings had not been successful. In order to tackle the problem of severe winds and loose textured sands, the tufts of *Cenchrus ciliaris* (dhaman) and *Elyonurus hirsutus* (karera) were planted. Plantings (since 1963) have been made successfully during spring as well as monsoon showers. Spacings of 5 × 5, 10 × 5, and 10 × 10 ft have been tried. Where the success percentage has varied from 10% to 80% "time elapsed between uprooting and planting of these tufts" and "the time of planting with respect to rainfall" have been the determining factors for its success (Khan, 1966). Tufts planted in rainfall or within 24 hours after rainfall gave 80% success. Areas where the tufts received the second shower soon after the planting gave a very high percentage of success. The very fact that the success of this operation depends upon the most opportune time and rainfall, which is often very short, renders this operation of limited application. Tuft planting has been extended on larger and extensive areas. If labor and the tuft sources would be managed and rainfall could be duly predicted, the operation can be adopted with success. By 1966, this operation had been attempted on about 2,000 acres (Figs. 1 and 2).

The tufts which had been overgrazed did not give a high survival percentage as compared to the tufts with greater aerial parts dug out from our pastures.

Topography lends a peculiar aspect to Thal ranges. Shrubby vegetal cover on sand dunes renders natural reseeding possible. Actual seeding is done on flats covering 40 to 60% of the total area. Seed disseminated by wind from such reseeded areas lodges in bushy and shrubby growth on sand dunes. They provide not only the much needed protection but underneath a good seed bed where humus mixes with loose soil. Thus dhaman and karera are coming up naturally on such dunes. So seeding of 10,000 acres of Thal ranges means the actual development of about 20,000 acres. This process of natural reseeding is, however, limited to those localities where enough suitable cover is already present on the sand dunes.

Thal Technique of Planting Trees

In summer ranges of Thal, green grasses are available for six months only. Except for *Eleusine flagellifera* (chhimber) grasses do not cure well. People have traditionally been depending on fodder trees during dry winters. Trees, being more drought resistant, can better face the years of lean rainfall. In Thal, a tract marked by inclement weather with scorching and stormy summers, trees provide shade and shelter to grazier and livestock and ameliorate the general living conditions. In addition to the nutritious fodder, *Zizyphus jujuba* (ber) and *Zizyphus nummularis* (mallah) provide fruit for human consumption. Ber is also a suitable host for lac insect.

Loose sand dunes conserve moisture. Even after six months of the monsoon rainfall (in July and August), moisture in sand dunes is available at 10 to 12-inch depth. The technique, therefore, aimed at the effective utilization of this moisture. After planting, no watering was done. The technique was first tried in July 1964 and by 1967 more than 100,000 transplants have successfully been made.

Earthen Tubes.—One foot long, 4.5 inches in diameter, open on both ends, earthen (baked) tubes are used to raise plants in the nursery. The tube tapers slightly towards the bottom, and ensures holding the soil. Four holes 0.25-inch in diameter are made in the tube shell to provide drainage and aeration. The tube shell is 0.5 inch thick. The length of the tube ensures one-foot long root system of the plant before transplanting.

Tree Species.—Ber, mallah and *Prosopis spicigera* (jand) have been successfully tried. Jand, being a relatively slow growing species, large scale planting has been done with the former species only. Similarly transplanted rooted cuttings of *Tamarix articulata* could not survive. They are invariably attacked by white ants.

Planting Season.—As absolutely no watering is done after planting, rainfall is obviously the limiting factor. Monsoon season (July and August) has been found to be the best. Planting was also tried in spring (March–April) showers of 1965. Even unusually good spring rains did not give a survival of more than 5%. Subsequent drought and high soil temperatures of summer (May and June) killed the survivals.

Planting Time.—Time of planting is one of the most important factors. Every effort must be made to complete planting within 48 hours and preferably within 24 hours of a real good rainfall. However, if nursery beds be irrigated prior to the transfer of tube plants, the period of planting can safely be extended up to 72 hours. Unless the top one-foot sand layer is wet, planting must not be undertaken. This is to ensure proper soil moisture and humidity conditions for the plants newly transferred from nursery conditions. Also, the root system of the tube-plant can utilize moisture only if it be available at a one foot depth.

FIG. 3. Close up of ber transplant after planting. Note "shelter" provided against blowing sands. Planted and photo, July, 1964.

Planting Site.—Flats with heavy soil are unsuitable; only loose sandy sites should be selected for planting. The more sandy the site the better it is.

Planting Technique.—Survival of plants in the earthen tubes was compared with the success of those whose tubes were broken immediately before planting. The observations were continued for 20 months i.e., July, 1964 to April, 1965. The higher survival under the former technique was highly significant. Careful planting under the former technique may give a survival 95%. The former technique has therefore been generally adopted with great success. Vertical narrow holes are dug out at a point preferably clear from bush growth and grass clumps. The tube plant is then carefully placed in it. The soil (sand) is then refilled and pressed. Top of the tube should be at least four inches below the dune surface. The transplants should preferably be 1.5 to 2 ft high before transferring from the nursery.

Shelters.—The desiccating impact and abrasive action of sand-laden summer storms seriously damage the tender leaves of the young plants. The plants already being under moisture stress, may often succumb to the onslaught of wind storms.

FIG. 4. Windward exposure of sand dune (same as Fig. 5). Winds have blown away sand layers; also note stunted fodder plants (*Zizyphus jujuba*). Planted July, 1964; photo March, 1966.

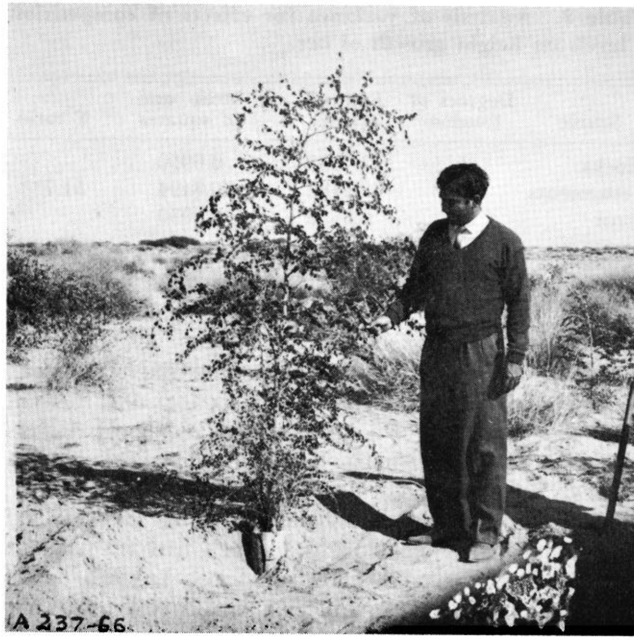

FIG. 5. Leeward exposure of the same dune as in Fig. 4. Tree height 9.5 ft. Planted July, 1964; photo January, 1966.

Plants without guard shelters showed high mortality. The shelter is also known to at least reduce the frost effect usually experienced in Thal. They also cut the moisture losses. The shelters are therefore provided during the first year (Fig. 3). The shelters are made of local vegetal material, conical in shape with a vertical opening facing east. This not only ensures sufficient sunlight but also protects the young plant from severe northwestern wind storms.

Growth of Transplants

Moisture is the limiting factor in these desert ranges. There is a characteristic rainfall gradient within Thal. There is a linear increase from the southern most apex (at M. Garh) towards the northern base (foot of salt range) of the great triangle of Thal. Other site conditions remaining the same, environmental factors are more favorable in the northern half than those of the southern half. Where ber plants grew to the maximum height of 4.5 ft in Shergarh, maximum heights attained in 20 months at Chubara and Dagarkotli were 9.5 and 10 ft, respectively.

Effects of Exposure on Height Growth of Ber.—Corresponding to the prevalent direction of wind storms in Thal the sand dunes form a regular pattern from NNE to SSW. The study was conducted to determine the effects of three typical exposures i.e., northwestern, top, and southeastern, on height growth of ber transplants. The experiment was laid out as a completely randomized design with three treatments and ten replications. The experimental sites (in Dagarkotli project) were cleared of all the vegetal cover with a D-4 dozer. The natural form of dunes was not disturbed. Slopes on northern and eastern exposures averaged 10 and 18%, respectively. The area was fenced. To ensure uniform planting stock, the ber plants were grouped into one-inch height classes of 18, 19, 20, and 21 inches. They were so grouped that each plot had a comparable group of 12 plants. Allocations of such groups of tube plants to each plot was made at random. The planting was done at 15 × 15 ft spacings. Each plot had an area of 90 × 30 ft. The planting was made on July 15, 1964. Final height measurements were made on March 1, 1966 i.e., 85 weeks after planting. Height was measured from the collar of the tube to the top of the leading shoot and measurements recorded were to the nearest half inch. The mean heights on northwestern, top and southeastern exposures were 3.08, 3.89, and 6.33 ft, respectively (Figs. 4 and 5).

The analysis of variance (Table 1) showed that

Table 1. Analysis of variance for effects of exposure on height of growth of ber.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F ratio
Treatments	2	25.813475	12.906737	8.896**
Error	27	39.169138	1.6507	
Total	29	64.982613		

** P = 0.01.

Table 2. Analysis of variance for effects of competition levels on height growth of ber.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F ratio
Blocks	5	3.4753	0.6950	
Treatments	3	62.5482	20.8494	51.7**
Error	15	6.0558	0.4030	
Total	23	72.0793		

** P = 0.01.

increased height growth on eastern exposure was highly significant as compared to top and northwestern exposure. There was no significant difference in height growth between top and northwestern exposure.

Effects of Competition on Height Growth of Ber.—This study was conducted at Chubara project of Thal from July 22, 1964 to March 1, 1966. The randomized block design was employed to block the sites at different exposures of the sand dunes. Twenty tube plants grouped as mentioned before, were planted in each experimental plot of 200 × 40 ft. Planting spacings were 20 × 20 ft. The entire area was fenced. The four competition levels applied as four treatments were:

U. Dune untouched. Old grass clumps of fitsain (*Pennisetum* spp.) were present within 5-ft radius of the tube plant.

U5. Dune untouched. Old clumps of fitsain were stubbed out from within 5-ft radius of the tube plant.

D. Dune cleared of all grass clumps with bulldozer (D-4). Tufts of *Elyonurus hirsutus* (karera) were planted at 10 × 10 ft spacings with tufts within 5-ft radius of the tube plants.

D5. After preparation as in D., tufts were planted so as to leave a clear space of 5-ft radius around the tube plant.

The mean height of ber plants under treatments U, U5, D, and D5 were 2.4, 2.61, 5.05, and 6.20 ft, respectively. The analysis of variance (Table 2) shows that D5 was the most effective and highly significant. D was highly significant as compared to U5 and U. There was no significant difference in height growth between U5 and U.

Discussion

Due to severe microclimatic factors and blowing sands on these active sand dunes of Thal ranges of Pakistan, sowings and seedings of grasses did not succeed. Such areas when planted with tufts of dhaman and karera were successfully covered by better grasses of great forage value. Proper time and season of planting, proper amount of rainfall and technique of planting is the key to the success of this operation.

FIG. 6. Earthen tube (baked) broken by growth pressure of *Zizyphus jujuba.* Planted July 15, 1964; photo March, 1966.

The establishment of seeded grasses from windblown seed depends on the site factors of the sand dunes. If dunes are relatively stable and there is enough of shrubby cover over them the natural propagation may be satisfactory. On other places, however, seed may not get protection from blowing sands. On such active spots, tuft planting is the answer.

Tube planting seems to have some advantages over planting without tubes. In the former case the root system remains undisturbed and intact. As the tube plant, with one-foot root system already developed, has moisture available only on the downward open end of the tube, it is not unlikely that roots in search of moisture should have a stimulus to elongate only downward. This might help in development of a deeper root system and ensuring better survival conditions. The top 10 to 12 inches of dry soil in sand dunes during drought may not have any appreciable effect on tube plant. By the time the plant grows higher and the critical period has been successfully overcome, the growth pressure has been observed to break the earthen tubes automatically (Fig. 6). The plants with collar girth of five to six inches usually break the tube more or less vertically.

After 12 months, a tube plant with 10 inches of bare tube standing above the dune surface is not uncommon (Fig. 4). This is specially true on northwestern (windward) exposures. Thus an earthen tube by providing mechanical support enables the plant to face the moving sand blows.

The impact of sand-laden winds seems to be the main factor in reducing growth rates on northwestern exposures as well as on the tops. The direct impact of desiccating winds not only blows off top soil but also results in quicker loss of moisture conserved in sand dunes. Under desert conditions of Thal even a little loss of moisture may make a great difference. That is why eastern exposures are relatively safer and better sites for height growth of ber.

The study of four different competition levels suggests moisture to be a critical factor. The massive root system of old clumps of fitsain seem to use most of the moisture. New tufts even planted within 5-ft radius of tube plant did not offer as much competition for moisture as the old well-established clumps. However, the lowest competition level represented by complete removal of old clumps and no new tufts within 5-ft radius gave the maximum height growth of ber.

Conclusions

Where sand dunes are active, sowings of grasses may not be successful. Alternative practices of surface stabilization may be too costly to apply over extensive desert ranges of Pakistan.

If done properly, tuft planting is a reasonably sure method of establishing vegetal cover on active sand dunes. The operation is relatively economical. Under Thal conditions, its cost is Rs. 12.00/acre.[3]

Ten to 25 fodder trees/acre of dunes will not only ameliorate the general environment but also be a dependable fodder source in winter. As no watering is done after planting, the operation is extremely economical. Under Thal conditions the total cost of planting fodder trees does not exceed Rs. 75.00/hundred plants.

For better height growth, ber should be transplanted on southeastern (leeward) exposures. Even tops may be slightly better than northwestern exposures. If possible, the 5-ft radius around the ber plant should be cleared of all vegetation. To avoid wind erosion on sensitive spots, tufts of karera or dhaman may be planted without much harmful effects on height growth of ber plants. Ber, being a fast growing species, should be able to check wind erosion within two years.

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[3] \$1.00 U. S. = Rs. 4.76. Labor cost under Thal conditions is Rs. 0.50/man hour.

Critical Nitrate-N Concentrations for Growth of Two Strains of Idaho Fescue[1]

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Highlight

Nitrate-N in shoots of different strains of Idaho fescue, *Festuca idahoensis,* can be used for an adequate diagnosis of their respective N statuses at the late vegetative growth stage. The suggested critical nitrate-N concentration for growth of Elmer Idaho fescue, the improved strain used in this study, is 500 ppm of nitrate-N in the shoots, dry basis. The suggested critical nitrate-N concentration for growth of the nonimproved strain is 140 ppm of nitrate-N, dry basis. These critical concentrations are guides that can be used to determine the N status of Idaho fescue on rangelands. Nitrate-N in shoots of Idaho fescue should be above 500 ppm, dry basis, during active vegetative growth, if maximum forage production is desirable.

[1] Research financed in part by Forest Service, PSW Forest and Range Experiment Station, Berkeley, California. Cooperative investigations of Crops Research Division, Agricultural Research Service, U. S. D. A., Berkeley; and the Department of Soils and Plant Nutrition, University of California, Berkeley.

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Strains of Idaho fescue are important components of many perennial grasslands in western United States north of latitude 40. Nitrogen fertilization is frequently a part of the management of these grasslands. But, the fertilization is often done without knowledge of the concentration of nitrate-N required in the plant for maximum plant growth. Nitrogen fertilization of grasslands may become more efficient when the critical nitrate-N concentrations of the component grasses are known (Hylton et al., 1964).

We want to make efficient use of N fertilizer in the management of rangelands, rather than simply apply more fertilizer. To help achieve this goal the critical nitrate-N concentration might be used as a guide (Ulrich, 1952) to determine if, and when the grasses are deficient in N. Application of this guide should result in more efficient use of N.

Different strains of Idaho fescue vary in their ability to produce forage from a given amount of nitrogen. But, it is not known if the critical nitrate-N concentration is different for different strains. This study was conducted to determine the critical nitrate-N concentrations for growth of two strains of Idaho fescue; an improved strain (Elmer Idaho fescue) and a nonimproved strain.

Materials and Methods

Experiment 1.—Twenty-one-day-old seedlings of an improved strain of Idaho fescue were transplanted on May 24, 1966 from tap water to aerated nutrient solutions in a greenhouse. The nutrient solutions were in 20-liter tanks. Fifteen seedlings were transplanted to each tank. The solutions contained the following basal nutrients when the seedlings were transplanted: (in meq/l) 2.0 K^+, 0.5 Na^+, 1.0 Mg^{++}, 5.0 Ca^{++}, 0.5 $H_2PO_4^-$, 0.25 Cl^-, 0.25 $SiO_3^=$, and 3.5 $SO_4^=$ (plus $SO_4^=$ added with certain micronutrients); (in ppm) 0.125 B, 0.125 Mn, 0.0125 Zn, 0.005 Cu, 0.0025 Mo, and 2.5 Fe (as a Fe-EDTA complex). Manganese, Zn, Cu, and Fe were added as sulfate salts. Boron was added as H_3BO_3 and Mo as $MoO_3 \cdot 2H_2O$ (85% assay). The foregoing nutrients were added again in these same amounts 21 days after the seedlings were transplanted, and again in double these amounts 35 days after they were transplanted. Distilled water was added to keep about 20 l of solution in each tank. The pH of the solution was maintained between 5.5 and 6.0 with H_2SO_4.

Seven different N treatments (Table 1) were provided from $Ca(NO_3)_2 \cdot 4H_2O$. The 5 lowest treatments were provided when the seedlings were transplanted. An additional 4 meq of NO_3^- were added to the two highest N treatments 21 days after the seedlings were transplanted, and a final 8 meq of NO_3^- were added 14 days later to the highest N treatment. The seven N treatments were replicated four times in a randomized complete block design.

The plants were harvested on July 19 at the late vegetative stage of growth. Tops were separated from roots and fresh weights were obtained. Two shoots were selected from each plant, i.e. 30 shoots/tank, for blade and stem separation. The youngest blade that was completely out of the sheath and fully open was removed from these shoots and designated as recently matured. The immediately younger blade and the immediately older blade were also removed and designated as immature and matured, respectively. Stem samples included leaf sheaths and buds after all blades were stripped from the shoots. One shoot from each plant, 15 shoots/tank, was also selected and left intact. The top material that remained was residue. The roots were washed with distilled water and centrifuged at 40 *g* for 5 minutes.

The plant material was dried in a forced-draft oven at 70 C. Dry weights were recorded. Top weight was the sum of the plant parts plus the residue, but exclusive of roots. The plant material was ground to pass a 60-mesh sieve. Nitrate-N was determined by a modified phenoldisulfonic-acid method described by Johnson and Ulrich (1959). Letters in tables are in accordance with Duncan's Multiple Range Test (Duncan, 1955).

Experiment 2.—Adequate seed could not be collected for the nonimproved strain, therefore, clonal material was used. Idaho fescue plants of a nonimproved strain were collected in Lassen County, California. The plants were divided into clones and the roots were washed with tap water. The tops and the roots were each cut to 8 cm in length. Clones were then selected at random and transplanted to nutrient solutions in a greenhouse on May 26, 1966. Ten clones were supported on each tank.

Plant culture methods were like those described for Experiment 1, except for nutrient additions. The initial basal nutrients were the same as for Experiment 1. But, the second addition of basal nutrients was made 35 days after the clones were transplanted, and the third addition was made 119 days after the clones were transplanted.

Six different N treatments were provided from $Ca(NO_3)_2 \cdot 4H_2O$ (Table 3). The 4 lowest treatments were provided when the clones were transplanted. An additional 4 meq of NO_3^- were added to the two highest N treatments with the second addition of basal nutrients. A final 8 meq of NO_3^- were added to the highest N treatment with the third addition of basal nutrients. The six N treatments were replicated four times in a randomized complete block design.

The plants were harvested on October 26. The harvest methods and the treatment of plant material were like those described for Experiment 1, except shoots were the only plant part selected for nitrate-N analysis. Two shoots from each plant, 20 shoots/tank, were selected for nitrate-N analysis.

Results and Discussion

Experiment 1

Tops of N deficient plants were light green, but only the tips of the leaves of severely deficient plants were markedly chlorotic. Top growth was retarded before abnormal coloration was evident. Nitrogen deficient plants were upright while plants with ample N had a tendency to lodge. Roots of N deficient plants were darker brown than normal roots.

Plant growth from treatments of less than 8 meq of NO_3^-/l was limited by the lack of N (Table 1). Fresh weight of tops, dry weight of tops, and total

Table 1. Growth of an improved strain of Idaho fescue from nutrient solutions with variable N supply.[1]

Treatment, meq of NO_3^- per liter	Weight, g per plant: Fresh tops	Oven-dry: tops	Oven-dry: roots	Oven-dry: total	Top-root ratio[2]
0.25	0.80 e[3]	0.23 e	0.17 c	0.40 e	1.39 d
0.5	1.40 e	0.41 e	0.26 c	0.67 e	1.60 d
1	4.07 d	1.11 d	0.64 b	1.75 d	1.75 cd
2	7.35 c	1.83 c	0.80 a	2.63 c	2.31 c
4	12.25 b	2.54 b	0.69 ab	3.23 b	3.68 b
8	16.01 a	3.04 a	0.63 b	3.67 ab	4.88 a
16	18.12 a	3.12 a	0.67 ab	3.79 a	4.67 a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Values within a column followed by like letters not significantly different at the 5% level.

Table 2. Nitrate-N concentration in various parts of an improved strain of Idaho fescue as affected by N supply.[1]

Treatment, meq of NO_3^- per liter	Nitrate-N, ppm dry basis[2]				
	Blades				
	Immature	Recently matured	Matured	Stem	Shoots
2	95 b[3]	340 b	220 b	45 c	140 c
4	80 b	240 b	240 b	470 b	310 b
8	2500 a	4680 a	6470 a	5800 a	5140 a
16	4240 a	6100 a	8160 a	7290 a	6460 a

[1] Data are means of four replications.
[2] Nitrate-N was not detected in plant material from treatments of less than 2 meq of NO_3^- per liter.
[3] Values within a column followed by like letters are not significantly different at the 5% level, as determined on the log transformations of these data.

dry weight (tops plus roots) increased as the N in solution increased from 0.25 to 8 meq of NO_3^-/liter. Root weight, however, reached a peak with 2 meq of NO_3^-/liter and then declined, although not significantly at the 5% level, with more N in solution. The top-root ratio (Table 1) shows that top growth and root growth were not affected equally by changes in N treatment. Dry top weight increased about 13-fold while dry root weight increased only 3.7-fold with a 32-fold increase in N supply, from 0.25 to 8 meq of NO_3^-/liter. Similar results have been observed for the effect of N on top growth of other grasses in nutrient solution (Hylton et al., 1965) and in field tests (Lorenz and Rogler, 1967).

Nitrate-N could not be detected in dried plant parts from N treatments of less than 2 meq of NO_3^-/liter (Table 2). Matured blade tissue contained more nitrate-N than the other plant parts at the two highest N treatments. But, nitrate-N

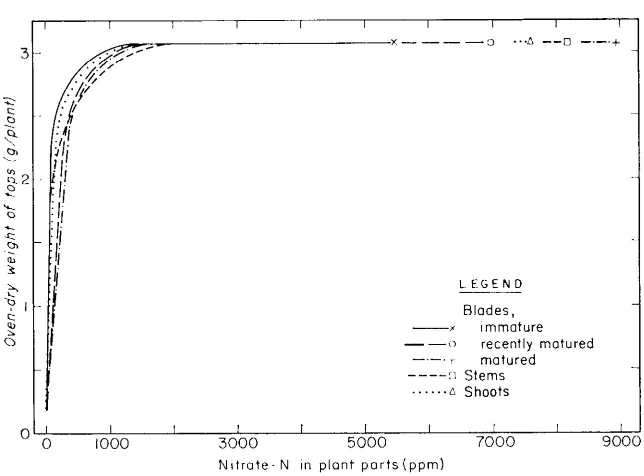

FIG. 1. Relation of dry weight of tops to nitrate-N in immature, recently matured, and matured blades, stems, and shoots, of an improved strain of Idaho fescue, dry basis, shown schematically.

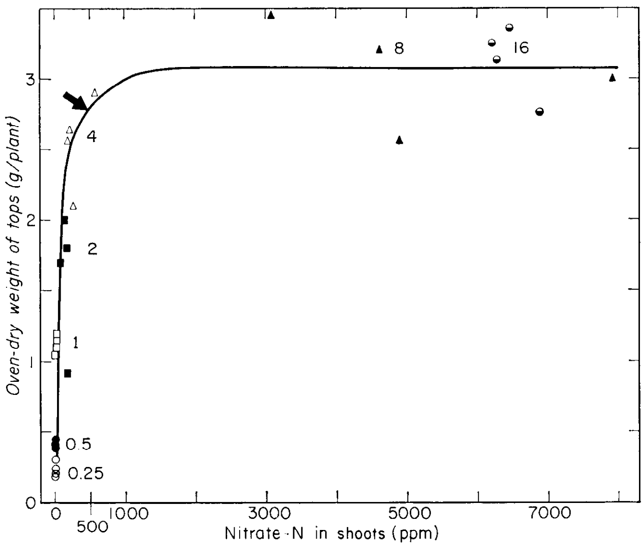

FIG. 2. Relation of dry weight of tops to nitrate-N in shoots of an improved strain of Idaho fescue. Critical nitrate-N concentration for top growth at 10% below maximum growth as indicated by arrow is 500 ppm of nitrate-N, dry basis. Numbers with like symbols show the meq of NO_3^- added/l of nutrient solution.

accumulation varied among plant parts for treatments of 2 and 4 meq of NO_3^-/liter.

Dry weights of tops was plotted against the concentration of nitrate-N in respective plant parts that were sampled from each N treatment. These nitrate-yield relations are illustrated schematically in Fig. 1. The curves are similar for each plant part except for two noticeable differences; 1) there are differences among plant parts in the accumulation of nitrate-N at the two highest N treatments, and 2) the transition area, i.e. the change from deficient to adequate nitrate-N, is not as sharp for the stem tissue as for the other plant parts.

A nitrate-yield calibration curve for the shoots is shown in Fig. 2. This curve shows how the nitrate-N content in the shoots changed relative to N treatment and plant growth. The vertical part of the curve shows the area of N deficiency and represents plants that increased in growth but did not accumulate nitrate-N, with a gradual increase in N treatment. The horizontal part of the curve shows the area where the N treatment was adequate to very high. Points along the horizontal part of the curve represent plants that accumulated nitrate-N, but top growth did not increase. The part of the curve where the vertical and horizontal portions converge is a transitional area. This transition ranges from 250 to 1,200 ppm of nitrate-N in the shoots. The nitrate-N concentration in the transitional area of the curve at 10% reduction from maximum top growth, and shown by the arrow, is 500 ppm (Fig. 2). Hence, 500 ppm (dry basis) is the suggested critical nitrate-N con-

Table 3. Growth and nitrate-N concentration of a nonimproved strain of Idaho fescue from nutrient solutions with variable N supply.[1]

Treatment, meq/l NO_3^-	Weight, g per plant				Top-root ratio[2]	Nitrate in shoots, ppm[3]
	Fresh tops	Oven-dry tops	Oven-dry roots	Oven-dry total		
0.5	3.15 e[4]	0.87 e	0.76 d	1.63 e	1.18 c	——
1	6.92 d	1.85 d	1.48 abc	3.33 d	1.26 c	——
2	12.67 c	3.33 bc	1.82 a	5.15 b	1.92 b	——
4	21.65 a	4.88 a	1.60 ab	6.48 a	3.18 a	300 b
8	18.50 b	3.93 b	1.29 bc	5.22 b	3.05 a	2200 a
16	14.70 c	3.12 c	1.04 cd	4.16 c	3.02 a	2540 a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Dry basis. Nitrate-N was not detected in shoots from treatments of less than 4 meq of NO_3^- per liter.
[4] Values within a column followed by like letters are not significantly different at the 5% level.

centration in the shoots for growth of this improved strain of Idaho fescue.

Experiment 2

The nonimproved strain of Idaho fescue grew slowly. Twenty-two weeks were required to obtain large differences in growth attributable to N treatment. Growth was retarded at the two highest N treatments (Table 3 and Fig. 3) because too much nitrate-N was added to the solutions before the plants were capable of rapid nitrate-N reduction and subsequent assimilation of reduced compounds. Plant growth increased as the N treatment increased from 0.5 to 4 meq of NO_3^-/liter (Table 3). The top-root ratio indicates that high N in solution retarded top and root growth equally, while low N retarded top growth more than root growth.

Nitrate-N was not detected in plants from N treatments of less than 4 meq of NO_3^-/liter (Table 3). A nitrate-yield calibration curve for the shoots is shown in Fig. 3. The two highest N treatments were not used to draw the horizontal portion of the curve because the growth depression described earlier was not desirable. Otherwise, the construction of the curve in Fig. 3 is similar to that in Fig. 2, described under Experiment 1. The transitional area for the curve in Fig. 3 ranges from 50 to 500 ppm of nitrate-N. The nitrate-N concentration in this transitional area of the curve at 10% below maximum top growth and shown by the arrow, is 140 ppm (Fig. 3). Thus, 140 ppm (dry basis) is suggested as the critical nitrate-N concentration in shoots of this nonimproved strain of Idaho fescue.

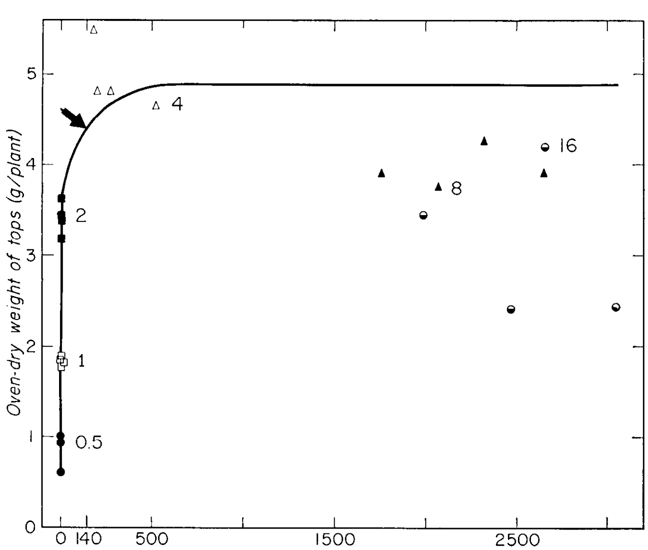

FIG. 3. Relation of dry weight of tops to nitrate-N in shoots of a nonimproved strain of Idaho fescue. Critical nitrate-N concentration for top growth at 10% below maximum growth as indicated by arrow is 140 ppm of nitrate-N, dry basis. Numbers with like symbols show the meq of NO_3^- added/l of nutrient solution.

Summary and Conclusions

Two strains of Idaho fescue, one improved and one nonimproved, were grown separately in nutrient solutions in a greenhouse. The improved strain was grown from seed. The nonimproved strain was grown from clonal material because seed was unavailable. Nitrogen in the solutions was varied to give six and seven N treatments, respectively, for the nonimproved and the improved strains.

Plant growth for the improved strain was rapid relative to that for the nonimproved strain. Top growth of both strains suffered more than root growth when N deficiency caused a reduction in plant growth.

Nitrate-N in shoots of these two strains of Idaho fescue can be used for an adequate diagnosis of their respective N statuses at the late vegetative growth stage. Shoots would probably be satisfactory at younger growth stages also. The critical nitrate-N concentration for the improved strain is 500 ppm of nitrate-N in the shoots, dry basis, while that for the nonimproved strain is 140 ppm of nitrate-N, dry basis. This difference in the critical concentrations may not be of practical significance in evaluating the N status of these or other strains of Idaho fescue for the management of rangelands.

This study indicates that nitrate-N in the shoots of most strains of Idaho fescue should not be allowed to fall below 500 ppm, dry basis, during the active vegetative growth period, if N deficiency is undesirable for the growing season.

Acknowledgment

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Chemical Control of Low Sagebrush and Associated Green Rabbitbrush[1]

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Highlight

Low sagebrush species were effectively controlled with low volatile esters of 2,4-D at 2 lb/acre applied from May 1 to May 15 on sites with early phenology and May 15 to June 1 on sites with late phenology. Sandberg bluegrass phenology ranged from late boot to fully headed but preanthesis. Green rabbitbrush in mixed stands with low sagebrush was effectively controlled with 2,4-D at 3 lb/acre applied near the end of the treatment period for low sagebrush. A combination of picloram plus 2,4-D was also evaluated for green rabbitbrush control.

Low sagebrush (*Artemisia arbuscula* Nutt.) and alkali sagebrush *(A. longiloba* (Osterhout) Beetle) characteristically grow on soils with a fine-textured B horizon. Some of the physical and chemical properties of these soils have been discussed by Eckert (1957), Passey and Hugie (1962), Tueller (1962), and Robertson et al. (1966). In this paper, the term "low sagebrush" refers to both brush species.

In the Intermountain States, a poor to excellent stand of grass may dominate the understory in a low sagebrush type. Perennial species include: bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer), Sandberg bluegrass (*Poa secunda* Presl.), squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith), and Thurber needlegrass (*Stipa thurberiana* Piper). Annual species include: downy brome (*Bromus tectorum* L.) and 6-weeks fescue (*Festuca octoflora* Walt.). Site potential and range condition determine the dominant species and species composition. Many sites with an understory of desirable perennial grasses have a potential for increased forage production if brush were killed and grass released from competition.

This study has two phases: (1) chemical control of low sagebrush and associated green rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.); and (2) response of understory species. Chemical control is discussed here. Previous research on control of low sagebrush was by Cornelius and Graham (1951, 1958) on forest ranges in northeastern California.

Methods and Materials

Studies were conducted at 9 locations during the period 1963 through 1965. Low sagebrush cover ranged from 6 to 25%; density ranged from 28 to 88 shrubs/400 ft.[2] Green rabbitbrush was present on 3 sites with a range in cover of from 0.2 to 5%, and a density range of from 8 to 22 shrubs/400 ft.[2] During the study, precipitation on the most xeric site ranged from 8 to 10 inches, and on the most mesic site from 13 to 21 inches.

In the spring of 1962 and 1963 on 2 sites, we evaluated propylene glycol butyl ether esters of 2,4-dichlorophenoxyacetic acid (2,4-D); of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); and of 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) for control of low sagebrush. All were applied at rates of 1, 2, and 3 lb/acre on four dates: 5/1, 5/15, 6/1, and 6/15. Based upon results from these treatments, 2,4-D at 1 and 2 lb/acre, applied on three dates, were uniform treatments for seven sites in 1963 and 1964. Additional treatments were added in 1964 and 1965 to evaluate a mixture of triisopropanolamine salt of 4-amino-3,5,6-trichloropicolinic acid (picloram[2]) and triisopropanolamine salt of 2,4-D, and 3 and 4 lb/acre of 2,4-D ester for simultaneous

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[2] Picloram is not registered for use on grazing lands.

control of low sagebrush and green rabbitbrush. Two rates of picloram + 2,4-D were used: 0.27 lb/acre picloram plus 1 lb/acre of 2,4-D (low rate) and 0.54 lb/acre picloram plus 2 lb/acre 2,4-D (high rate). Treatment dates for 2,4-D treatments in 1963 and 1964 were 5/1, 5/15, and 6/1 on sites with early phenology, and 5/15, 6/1, and 6/15 on sites with later phenology. Picloram + 2,4-D was applied on 6/1/64 and 5/15, 6/1, and 6/15 in 1965.

Herbicides were applied in water at 10 gpa with a backpack sprayer. All herbicide-water mixtures contained the surfactant X-77 at 0.1% v/v. Treatment plots were 20 × 20 ft with 3 or 4 replications. Phenology and environmental conditions were recorded for each date of application. We evaluated brush control by the density of living shrubs the year after treatment.

Gypsum soil moisture blocks were installed at five locations in the spring of 1964. Block depth varied with location except that all locations had one block at 6 inches. All locations had one block in the B_2 horizon (approximately 12 inches) and one block in the B_3 horizon immediately above the C horizon (17 to 34 inches). Blocks were placed in the check plot and in a treated plot of each replication. Readings were made during the spring and summer of 1964 and 1965.

Results and Discussion

Control of Low Sagebrush

Neither application dates, nor rates of 2,4-D, 2,4,5-T, or silvex, gave significant variation in brush control in the initial trials. Control averaged 94% and ranged from 71% to 100%. However, both date of application and rate of 2,4-D resulted in significant variation in control of low sagebrush in 1963, 1964, and 1965 at other locations (Table 1). Date of application was the more important variable. In 1963, treatments on the middle and late dates of application at three of five locations were 98% effective as compared to 88% on the early date. In 1964, treatments on the early and middle dates at three of seven locations were 96% effective as compared to 85% on the late date. In 1965, treatments on the early and middle dates at one of four locations killed more low sagebrush (91%) than on the late date (80%). Over the 3-year period, average control was 96% on the better date(s) and 84% on the poorer date(s) of application.

We measured significant differences in brush control between 1 and 2 lb/acre of 2,4-D at two of five locations in 1963, at four of six locations in 1964, and at two of three locations in 1965. In all instances control was better with the 2 lb/acre rate. Over the 3-year period, average control with 2 lb/acre was 98% as compared to 90% with 1 lb/acre.

The date × rate interaction was significant in all years on at least one site. In 1963 at one location 1 lb/acre of 2,4-D applied on 5/15 gave 84% control while the other 2,4-D × date combinations gave 99% control. In 1964 at two locations, the 1 lb/acre rate applied on 6/15 resulted in 75% control, compared to 98% with other 2,4-D × date combinations. In 1965 at one location, control with 1 lb/acre applied on 5/15 and 6/1 (last two dates on sites with early phenology) was 86%, and when applied on 5/1 control was 97%. Each instance of poor control with the 1 lb/acre rate was related to extremely early phenology at time of spraying, to rain or hail after spraying, or to vegetation wet from precipitation several hours prior to spraying. The 1 lb/acre rate of 2,4-D is evidently near the minimum herbicide concentration necessary for adequate low sagebrush control when environmental conditions are not optimum. The 2 lb/acre rate resulted in excellent control even under relatively adverse conditions.

Table 1. An evaluation of 1 (D_1) and 2 (D_2) lb/acre of 2,4-D treatments (Tr.) applied on 3 dates, and average percent control (Con.) obtained by the best treatment(s).

Location	1963 Tr.	1963 Con.	1964 Tr.	1964 Con.	1965 Tr.	1965 Con.
Date comparisons						
Lower Silver Cr.	NS	100	NS	98	NS	94
Upper Silver Cr.	NS	100	NS	100	5/1 5/15*	91
Dobe Summit	6/1 6/15**	99	5/15 6/1**	98	—	—
Bishop Flat	6/1 6/15**	98	5/15 6/1**	98	—	—
Carroll Summit	6/1 6/15*	96	NS	97	—	—
Lower Duck Cr.	—	—	5/15 6/1*	93	NS	100
Upper Duck Cr.	—	—	NS	95	NS	100
Rate comparisons						
Lower Silver Cr.	NS	100	D2*	100	D2**	97
Upper Silver Cr.	NS	100	NS	100	D2**	96
Dobe Summit	D2**	100	D2**	98	—	—
Bishop Flat	NS	93	D2**	98	—	—
Carroll Summit	D2*	96	D2*	99	—	—
Lower Duck Cr.	—	—	—	—	—	—
Upper Duck Cr.	—	—	NS	95	NS	100

NS No significant differences between or among treatments.
* Date(s) or rate comparisons listed significantly better (.05) than the unlisted date or rate.
** Date(s) or rate comparisons listed significantly better (.01) than the unlisted date or rate.
— Comparisons not made.

Higher rates of 2,4-D ester, and picloram + 2,4-D were used on sites with green rabbitbrush, therefore, we were able to measure the effect of these treatments on both species.

Low sagebrush control with 3 and 4 lb/acre rates of 2,4-D averaged 99% on the dates used, and did not differ significantly from the 2 lb/acre rate.

A comparison of 2,4-D and picloram + 2,4-D for control of low sagebrush indicated: (1) All rates of 2,4-D ester controlled low sagebrush significantly better (99%) on the 5/15 and 6/15 dates than did the low rate of picloram + 2,4-D (71%), however, on the 6/1 date the two materials gave similar results; (2) The 2, 3, and 4 lb/acre rates of 2,4-D ester all controlled better (99%) on the 6/15 date than did the high rate of picloram + 2,4-D (67%); (3) In 1965 average control of 99% with 2 lb/acre of 2,4-D was significantly greater than with either the high or low rate of picloram + 2,4-D (86% and 74%); (4) In 1964 the high rate of picloram + 2,4-D controlled better (94%) than did the low rate of this material (83%), however, in 1965 control was similar with both rates; (5) Control with both rates of picloram + 2,4-D was significantly less (55%) on the 6/15 date than on the other two dates in 1965 (93%).

For control of low sagebrush picloram + 2,4-D was less effective than 2,4-D, perhaps because 2,4-D was a salt in the former mixture and an ester in the latter. Tueller and Evans (1965) also indicate that picloram was not as effective as 2,4-D ester for control of big sagebrush (*Artemisia tridentata* Nutt.).

Control of Green Rabbitbrush

Control of green rabbitbrush with 1 and 2 lb/acre of 2,4-D ester averaged 53% and ranged from 8% to 92%. The heavier rate of 2,4-D and later dates of application resulted in significantly better control, however, the percent and consistency of control were inadequate.

Treatment with picloram + 2,4-D salt increased rabbitbrush control as compared to 2,4-D ester at 1 and 2 lb/acre. At two locations control with the high rate of picloram + 2,4-D was significantly better (98%) than with 2 lb/acre of 2,4-D ester (68%). At one location, control with the high and low rates of picloram + 2,4-D applied on 6/1 was similar and averaged 94%. Results from another location also suggest that although both rates of picloram + 2,4-D gave similar results when applied on 6/1, the heavier rate was superior on the 5/15 or 6/15 dates. At this location the two rates applied on 6/1 controlled 100%. Control with the lower rate applied on 5/15 and 6/15 averaged 56%, while control with the higher rate applied on the same dates was significantly higher at 98%. Also on the 6/1 date, control with 3 lb/acre of 2,4-D ester was 100%. Rabbitbrush control from the heavier rate of picloram + 2,4-D and the 3 and 4 lb/acre of 2,4-D ester applied on 6/15, averaged 96% compared to 51% with 2 lb/acre of 2,4-D ester applied on the same date.

In 3 year's work at nine locations, control of low sagebrush was best with 2 lb/acre of low volatile ester of 2,4-D plus X-77 at 0.1% v/v applied from May 1 to May 15 on sites with early phenology and May 15 to June 1 on sites with late phenology. During this period low sagebrush had from 1 to 2 inches of new twig growth and Sandberg bluegrass phenology was from late boot to fully headed but pre-anthesis.

In 1964 and 1965, soil moisture tensions during the spray period ranged from 0.3 to 30 bars at the 6-inch depth, from 0.3 to 5.5 bars at the 12-inch depth, and 0.2 to 20 bars at depths of 17 to 34 inches. The high reading of 20 bars was obtained on 6/15/64 at one location. This high tension was related to significantly reduced brush control on this date. Excluding this location, tensions at 17 to 34 inches ranged from 0.2 to 2.0 bars at all other locations.

A low density of rabbitbrush is characteristic of the shrub overstory on the more mesic and higher elevation low sagebrush sites in good condition. Control of sparse rabbitbrush is not an important consideration in a low sagebrush control project. Application of 2 lb/acre of 2,4-D near the end of the effective spraying season for low sagebrush will kill some of the rabbitbrush, and the released understory species will compete vigorously with the surviving rabbitbrush.

On sites in poor condition, control of rabbitbrush is important to prevent domination of the stand by this species within a few years after control of low sagebrush. Under these conditions, 3 lb/acre of 2,4-D applied near the end of the spraying season for low sagebrush, has controlled both species adequately. Hyder et al. (1958) also reported similar methods and results for simultaneous control of green rabbitbrush and big sagebrush in mixed stands.

Areas within the low sagebrush type are used by sage grouse (*Centrocercus urophasianus* (Bonaparte) for strutting grounds, nesting, roosting, resting, and escape cover. In addition, sage grouse are dependent upon sagebrush species and associated forbs for a major portion of their diet. Chemical control of low sagebrush will destroy their habitat. Therefore a large-scale low sagebrush control project should be a joint venture between the action agency and wildlife interests, to select sites in need of treatment but not sage grouse habitat.

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TECHNICAL NOTES

Stabilizing Small Seed Dilution Mixtures[1,2]

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Highlight

Twelve diluent treatments were compared for their effectiveness in preventing separation of small seed from dilution mixtures. Rice hulls in combination with methyl cellulose sticker was the best of the diluents tested. Simple, practical procedures for field use of this modified rice hull dilution method were developed.

Small seed such as lovegrass (*Eragrostis* spp.) can not be accurately dispensed with conventional farm drills. To overcome this difficulty the seed is usually diluted with some other material. Sand, sawdust, wheat shorts, and other materials have been used as diluents. Lemmon and Hafenrichter (1947) tested several kinds of cracked cereals. Cracked and screened barley proved most satisfactory. Southworth (1949) described how Hogland developed the use of rice hulls and proved them superior to the other commonly used seed diluents.

Nord and Knowles (1958) used rice hulls as a seed diluent for planting bitterbrush with a standard grain drill. There was some separation of the bitterbrush seed from the rice hulls during drilling operations. Ratio of seed to hulls, however, remained sufficiently constant to give satisfactory seeding rates, providing agitators were not used in the seedbox.

Personal experience with lovegrass and dropseed (*Sporobolus* spp.) indicated that these seeds separated from rice hull mixtures even with minimum handling or shaking. This separation resulted in erratic ratios of seeds to hulls and unsatisfactory seed distribution.

Various diluents and diluent-sticker combinations were compared for their effectiveness in preventing separation of small seed from dilution mixtures. Based on these results the rice hull dilution method as described by Southworth (1949) was improved and simple, practical procedures for field use were developed.

Materials and Methods

Laboratory Procedures.—Preliminary laboratory tests were made with rice hulls and with ground barley. Rice-hull seed mixtures were tested both with and without stickers but stickers were not used with the barley seed mixtures.

Barley was ground to four textures in an electric coffee grinder at the four marked settings (very coarse, coarse, medium, and fine). Then, each texture was mixed separately with Boer lovegrass (*Eragrostis chloromelas* Steud.) seed. Amounts used were 7.3 g of seed with 234 g of barley. This is the same proportion as 3 lb seed to 92 lb barley. Lemmon and Hafenrichter (1947) recommended a volume of material with a weight of 95 lb as the optimum amount per acre when planted with a fluted-feed type grain drill.

Seven stickers were tested with rice-hull seed mixtures. Sticker treatments consisted of condensed milk; condensed milk diluted to half strength with water; commercial liquid laundry starch diluted to half strength with water; 7 g gelatin dissolved in 227 ml water; 14, 28, and 42 g methyl cellulose (MC) dissolved in 3,785 ml water; and the control without sticker.

Components used for the rice hull dilution treatments were 9.4 g of Boer lovegrass seed, 50 g of rice hulls, and 25 ml of sticker solution. These amounts are proportionate to 3 lb of seed mixed with 16 lb of hulls and 3.5 quarts of sticker solution. Miller (1959) recommended use of 16 lb rice hulls as the standard amount per acre together with the required amount of seed.

Seed and rice hulls were thoroughly mixed. Then, separate lots of this mixture were treated with each of the different stickers. Sticker was applied by sprinkling the sticker solution over the surface of the dry rice-hull seed mixture, a small amount at a time, and mixing it in after each application. After all the sticker solution had been applied mixing was continued until the rice hulls did not cling together. Finally the mixture was spread in a thin layer on paper and dried in a mechanical convection oven at 95 F.

Tests for seed separation from the diluent mixtures were made by agitating each mixture in a plastic bag. The plastic bag partially filled with the test mixture was agitated by dropping to the surface of a table from a height of 3 inches, at the rate of once a second for five minutes. Several samples were taken from various depths of each

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

[2] Acknowledgments are made to Louis P. Hamilton, formerly Manager, S. C. S. Plant Materials Center at Tucson, Arizona and to Robert W. Owen, Chief Chemist, WestAg Division, Arizona Agrochemical Corp., Phoenix, Arizona for their advice and assistance; also to the Cortez Chemicals Division, Arizona Agrochemical Corp., for supplying the methyl cellulose and the commercial sticker solution.

mixture before and after agitation. Diluents and diluent sticker combinations were rated visually and with a dissecting microscope as to their effectiveness for preventing seed separation. Ratings were based on the amounts of free seed in the bottom of the plastic bag after agitation and comparative amounts of seed in the different samples.

A second dilution mixture was prepared with the 42 g concentration of MC sticker solution. The same amounts of rice hulls, Boer lovegrass seed, and sticker solution as previously described were used. After this mixture dried it was examined with a dissecting microscope. Then it was screened with a 840-μ soil sieve and the free seed weighed. The remaining mixture was agitated as before and screened again. Then the additional free seeds were weighed.

Field Procedures.—The dilution mixture for the field test consisted of 2 lb of sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray), 1 bu of rice hulls weighing 8 lb, and 3.5 quarts of a commercial MC sticker solution.[3]

Mixing was done with a scoop shovel on a smooth concrete slab. The rice hulls were spread out in a layer about 3 inches thick. The seed then was scattered over the surfce of the hulls in small increments and mixed thoroughly after each addition. The sticker solution was applied with a hand pressure sprayer after all the seed had been combined with the dry rice hulls. Mixing was continued throughout sticker application and until all the ingredients appeared uniformly combined and the rice hulls did not cling together.

The mixture was spread out in a thin layer under direct sunlight and dried. During the required 2 hours drying time it was stirred and turned over 4 times. The dry dilution mixture was sacked and the free seed weighed.

Table 1. Effectiveness of diluent and sticker treatments for preventing separation of Boer lovegrass from seed dilution mixtures.

Diluent	Sticker solution	Ocular rating
Ground barley		
Very coarse	None	Fair–Poor
Coarse	None	Fair
Medium	None	Good
Fine	None	Good–Fair
Rice hulls	None	Failure
do.	Condensed milk, full strength	Excellent
do.	Condensed milk, half strength	Fair
do.	Laundry starch, half strength	Fair
do.	Gelatine, 7 g in 227 ml water	Fair
do.	MC, 14 g in 3,785 ml water	Fair–Poor
do.	MC, 28 g in 3,785 ml water	Fair
do.	MC, 42 g in 3,785 ml water	Excellent

Results and Discussion

Barley ground to a medium texture was the best small seed diluent for use without a sticker (Table 1). Fine ground barley was less satisfactory because seed tended to concentrate in the upper part of the mixture. The recommended rate of 95 lb cracked barley-seed mixture per acre (Lemmon and Hafenrichter, 1947) makes the use of barley diluent more expensive than rice hulls, and also more difficult to handle because of the greater weight. Also, grinding barley to the proper texture involves use of facilities that might not be available.

The rice-hull seed mixture without sticker was a failure because the seed completely separated from the hulls by the end of the 5-minute agitation period.

The two most effective stickers were judged to be MC at the 42 g concentration and full strength condensed milk. MC dissolved in cold water makes a good, relatively inexpensive adhesive. The solution can be kept over a long time if stored in a cool place to prevent mold. MC does not delay or reduce germination (O'Bannon and Reynolds, 1960). It has had previous application in agriculture as a suspensory and adhesive agent for applying fungicides, nematocides, and insecticides to seed (Owen, personal communication).[4]

Condensed milk, although an excellent sticker, is more expensive than MC. Also, seed mixtures containing condensed milk tend to turn rancid and mold rapidly if not planted soon after treatment. Starch and gelatine had no particular advantage over MC and were not as effective for sticking the seed to the hulls.

The second rice hull dilution mixture prepared with the 42 g concentration of MC sticker solution had the seed well distributed on the rice hulls and rated excellent. This mixture screened before agitation yielded 8% free seed. An additional 26% free seed was obtained from screening after agitation. Under normal field conditions fewer seed would separate from the mixture because the rice hulls would not individually rub against a rough metal surface comparable to the screen. Agitation probably would be less severe. In addition, some seed would be kept from separating out of the mixture by the depth of hulls in the drill box.

In the field trial, the drying, mixing, and sacking operations resulted in only 2% seed separation. Thus, mixing on a smooth surface with a scoop shovel, applying sticker solution with a hand pressure sprayer, and drying by natural sunlight and mixing all appeared to be satisfactory procedures for field use.

Conclusions

MC at a concentration of 42 g (1.5 oz) to 3,785 ml (1 gal) water was the best of the stickers tested for stabilizing mixtures of small seed with rice hulls. Future investigations may reveal other materials superior to MC or with certain special advantages.

The modified rice-hull dilution method using MC sticker retains all the advantages of the original method (Southworth, 1949; Miller, 1959). In addition, it stabilizes the mixture so that more uniform seed distribution can be obtained. MC sticker also makes possible addition of fertilizers, insecticides, fungicides, and other ingredients to the mixture should this be desirable. Mixtures can be prepared in advance for planting at a

[3] The commercial sticker solution had a concentration of 42 g MC to 3,785 ml water but also contained a plasticizer and a wetting agent.

[4] Robert W. Owen, Chief Chemist, WestAg Division, Arizona Agrochemical Corp., Phoenix, Arizona.

later date since neither the rice hulls nor the MC deteriorate.

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Seeding Annuals and Perennials in Natural Desert Range[1]

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Highlight

Seeding of pasture plants in a desert in a 78-mm rainfall year resulted in complete failure of all perennials to establish themselves. Annuals, on the other hand, in spite of stunted growth, completed their life cycle and produced seed. Water-spreading is a prerequisite for successful establishment of perennial pasture plants under desert conditions.

In many desert environments the pasture vegetation has been destroyed by overgrazing so that range seeding is necessary to reclaim the pasture resources. To that end, a range research program was initiated at the Avdat Desert Research Center in the central Negev of Israel (30° 47′ N lat., 35° 46′ E long., alt. 550 m). This program deals mainly with range development under water-spreading conditions, and has been reported elsewhere (Evenari et al., 1963, 1964, 1965; Tadmor et al., 1966). A preliminary investigation, carried out in 1960–61 to study range seeding under the *natural* desert conditions, i.e., without supplemental water, is reported here. Annual rainfall averages 86 mm, from November to April, with wide inter-seasonal fluctuations (Shanan et al., 1967). The period from May to October is usually completely dry. Mean daily, mean maximum and mean minimum temperatures for the hottest month (August) are 25.0 C, 32.4 C, and 18.2 C, and those for the coldest month (January) are 10.5, 15.0, and 5.3 C, respectively.

Table 1. Development of pasture plants under natural desert conditions. AVDAT 1960/61. Seeded January 26, 1961. Total rainfall 78 mm.

Species	Origin	Final development, May 10, 1961: Height of leaves (cm)	Stalks per plant (No.)	Height of stalks (cm)	Depth of roots (cm)	Dry weight (g/m²)
Annuals						
Avena sterilis L. (red wild oats)	local	6.5	3	24	15	36.4
Lolium rigidum Gaud. (Wimmera ryegrass)	local	10	3	12	18	7.6
Medicago polymorpha L. (burr clover)	local	4	–	–	12	3.0
M. polymorpha L.	local	3	–	–	13	6.5
Vicia dasycarpa Ten. (woolly pod-vetch C.v. Lana)	California	13	–	–	16	14.0
Perennials						
Agropyrum elongatum (Host.) P.B. (Tall wheatgrass)	local	1	2	4	0.5	4.7
Dactylis glomerata L. (Orchard grass)	local	*	*	*	*	0.3
Festuca arundinacea Schreb. (Tall fescue)	local	*	*	*	*	2.7
F. arundinacea Schreb.	Morocco	7	1	–	5	2.4
Oryzopsis holciformis (M.B.) Richt. (mountain ricegrass)	local	2	2	4	2	11.0
O. miliacea (L.) Benth. et Hook (smilo)	local	7	1	7	7	1.5
Phalaris tuberosa L. (Harding grass)	California	14	5	4	6	5.5
P. tuberosa L.	Cyprus	7	1	2	12	6.8
P. tuberosa L.	local (Moledet)	7	1	3	4	8.2
P. tuberosa L.	local (Yoqne'am)	7	1	5	6	2.6
Sanguisorba minor Scop. (Burnet)	Newe Ya'ar	*	*	*	*	0.7

* Very patchy development, isolated plants only.

[1] This study is part of a broader desert agriculture research program supported by grants from the Rockefeller Foundation of New York and the Edmond and James de Rothschild Memorial Group. Contribution from the National and University Institute of Agricultural Research, Rehovot, Israel 1967 Series, No. 1235-E.

Methods

The soil is a non-saline, deep light sandy loam (loess). The seedbed was prepared by plowing 25 cm, and then raking. Sixty kg/ha of nitrogen was applied as ammonium sulphate and 120 kg/ha P_2O_5 as superphosphate. Seeding was carried out with a planet hand-seeder on January 26, 1961, when the soil was wet to a depth of 15 cm. Two to four replicates of 16 m² each, of each species, were then drilled in 1-m spaced rows to 2 to 4 cm depth at a seed rate of ca. 10 kg/ha.

Results and Conclusions

Total annual rainfall in the winter of 1960–61 was 78 mm, which is close to the long-term seasonal average. Prior to seeding, 36 mm rain had fallen, including 8.4 mm during the preceding week; 13 mm fell immediately following seeding, and 26 mm more within one month. Most species germinated and emerged satisfactorily, but all plants were severely stunted (Table 1). The annuals flowered within 6 to 10 weeks of emergence, and produced seed, though yields were very low. Most perennials, on the other hand, never advanced beyond the seedling stage. While flowering stalks were formed in a few species, neither seed nor bulbs were produced. None of the perennial plants survived the summer. Development of *Agropyrum elongatum, Oryzopsis holciformis,* and *Phalaris tuberosa* was relatively better and full seedling rows were observed. *Dactylis glomerata, Festuca arundinacea, Oryzopsis miliacea,* and *Sanguisorba minor* emerged very patchy and made hardly any growth at all.

In subsequent work reported elsewhere (Evenari et al., 1963, 1964, 1965, 1968; Tadmor et al., 1966) both perennial and annual range plants were very successfully grown in the same desert under water-spreading conditions. The above results, obtained in a year with average rainfall distributed in a way conducive to seedling development, stress the fact that seeding perennial range plants is doomed to failure unless additional water is applied. Water spreading is thus a prerequisite for establishing perennial plants in range seeding in the Negev Desert. Annual plants, however, were able to mature and produce seed. This shows the greater flexibility of annuals under the extreme conditions described, and also why ephemeral annuals constitute a major component of the native vegetation in many semi-deserts and deserts.

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Production and Persistence of Wild Annual Peanuts in Bahia and Bermudagrass Sods[1]

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Highlight

A wild annual forage peanut was seeded in Pensacola bahiagrass and Coastal bermudagrass sods and found to persist for at least 3 years and showed indications of persisting for a much longer time. The peanut can be established by either preparation of a seed bed and planting or by seeding directly into the undisturbed sod. Preparation of a seed bed before planting improved peanut establishment but reduced total forage yields for at least one season. The total forage yield of the grass and peanut was not higher than that of the grass alone. Adding P and K fertilizers did not increase forage yields of either the peanut or grass over a 3-year period. A 50 lb/acre application of N increased total forage production but reduced the amount of peanut forage produced.

In range areas of the Southeast and probably throughout much of Latin America where little N is applied, the forage peanut is one of the first tropical legumes to show promise in grass-legume mixtures.

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Legume use as either food or feed probably antedates written records. McKee (1948) concluded the early use of legume crops suggests that the superiority of legumes was recognized early in recorded history. The importance of legumes in temperate pastures is well established and cultural practices necessary to keep legumes in such swards are rather well known.

It can be reasoned that legumes should be equally as important in tropical pastures as in temperate climate swards. However, in spite of the vast acreages of tropical grasslands, relatively little is known about tropical legumes; even less is known about the relationships between tropical grasses and legumes.

The purpose of this investigation was to determine the ability of a wild annual peanut, *Arachis monticola* (Pi 263393), probably of Brazilian origin, (Hermann, 1954) to establish and persist in sods of Pensacola bahiagrass *Paspalum notatum* (Flugge) and Coastal bermudagrass *Cynodon dactylon* (L) Pers.). A second objective was to establish the forage contribution of the peanuts when grown with the grasses.

Procedure

The experiment was initiated on established sods of Pensacola bahiagrass and Coastal bermudagrass at the Americus Plant Materials Center near Americus, Georgia. The sods were approximately 0.25 mile apart and are not directly comparable. Both sods were well fertilized and productive. Soil type was Eustis loamy sand. Treat-

Table 1. Established peanut plants per square foot by treatment four years after initial seeding (May 17, 1966).

Fertilizer rate (lb/acre NPK)	Sod type: Bahiagrass Plowed	Bahiagrass Planted	Bahiagrass Grass	Coastal bermudagrass Plowed	Coastal bermudagrass Planted	Coastal bermudagrass Grass
1. None	1.92	1.28	0.22	1.43	0.58	0.03
2. 0–31–58	1.47	0.95	0.18	0.88	0.62	0.00
3. 50–31–58	0.67	0.38	0.10	0.26	0.37	0.03
4. 0–31–58[1]	1.60	0.88	0.19	1.21	0.43	0.03

[1] One ton of agricultural lime and 250 lb of gypsum in addition.

ments were replicated three times in a split-plot randomized complete block design. Whole plot treatments were established at the beginning of the experiment on April 9, 1963, and in 1964 and 1965 the peanuts were allowed to re-establish without preparation or seedling.

Whole plot treatments consisted of (A) complete seedbed preparation and peanuts seeded in rows 2.5 ft apart, (B) narrow furrows opened 2.5 ft apart in the established sod and peanuts seeded, and (C) no seedbed preparation and no peanuts planted. Split plot treatments were fertilizer rates of: (a) none, (b) 0–31–58 lb/acre of NPK, (c) 50–31–58 lb/acre of NPK and, (d) 0–31–58 lb/acre of NPK and one ton of agricultural lime with 250 lb/acre of gypsum ($CaSO_4 \ 2H_2O$).

At planting, hulled peanuts were seeded 5 inches apart in the drill. The initial fertilizer application was made on April 17, 1963, and in late March or early April in later years. Plots were clipped three times per season using a sickle bar mower. The first harvest was made between June 9 and 18. The second harvest was made between August 1 and 12 and the third harvest between September 25 and October 10.

The clipped forage was separated into grass and peanuts while green and dried in a forced-air dryer. Split plots were six feet square and plots were separated by 6-inch plowed furrows. At harvest the entire plot was clipped. On May 17, 1966, a final stand count of established peanuts growing inside the plowed furrows was made.

Results and Discussion

Persistence of the peanuts in the sod is shown by the data in Table 1. At the initial planting, peanut emergence averaged 2 plants/ft^2. The spread of peanuts into adjoining plots was limited. The bahiagrass plots where peanuts had not been seeded adjacent to plots where peanuts had been seeded has less than 0.22 plants/ft^2. The Coastal plots similarly treated had only .03 plants/ft^2.

Plots where no fertilizer had been applied were consistently higher in number of peanut plants per square foot than those where fertilizer was applied. The application of 50 lb N reduced the number of peanut plants by an average of more than 50% as compared to plots where N was not applied. Therefore, peanut persistence was actually reduced by fertilizer application.

The failure of the peanuts to respond to fertilization applied could be attributed to their origin in Brazil on soils low in most nutrients, with grasses offering only limited competition under natural conditions. The fertility level of the soil on which this investigation was conducted was probably much higher than that of the soil on which the peanuts evolved and the peanuts were incapable of responding to the added nutrients. Thus, it would appear that this peanut is likely to persist on lower fertility soils but will probably not persist where increased competition is caused by the addition of N to either of the grasses and the peanuts are not likely to respond to applications to P, K, and Ca. Close utilization could be expected to favor persistance of the peanut (Jamison, 1963).

Forage yields of the peanuts are given in Table 2. Yield data shown represent only that harvested and are conservative relative to that grown. Peanut leaves are produced on long runners located near the soil surface. During dry weather the peanuts tended to drop many of the older leaves while the stems remained vegetable. In seasons of favorable rainfall more leaves will be retained and a higher yield will result. In dry season, leaf growth occurs after rains and unless forage harvests are made before the onset of dry weather, yields of peanut forage are likely to be underestimated relative to production.

Peanut forage production for the first season showed an average of approximately 620 lb/acre when grown with bahiagrass and approximately 1,650 lb/acre when grown with Coastal. In the second season, peanut forage yield on bahia sod tended to be 100 to 200 lb/acre lower as compared to the first year but on Coastal sod the

Table 2. Yield of dry peanut forage per acre by treatments 1963–1965.

Fertilizer (lb/acre NPK)	Yield lb/acre dry forage: Bahiagrass 1963	Bahiagrass 1964	Bahiagrass 1965	Coastal bermudagrass 1963	Coastal bermudagrass 1964	Coastal bermudagrass 1965
Plowed seedbed						
a 0–0–0	602	962	116	1708	565	287
b 0–31–58	893	634	203	1783	460	189
c 50–31–58	854	447	95	1325	243	108
d+ 0–31–58	890	685	183	1779	558	272
Seeded direct						
a 0–0–0	479	470	171	1823	287	225
b 0–31–58	500	596	172	1798	225	211
c 50–31–58	404	231	103	1133	60	145
d+ 0–31–58	606	490	174	1882	165	220
Grass						
a 0–0–0		31	44		48	43
b 0–31–58		48	48		38	40
c 50–31–58		33	74		39	27
d+ 0–31–58		37	47		34	67

+ Lime and gypsum in addition.

Table 3. Yield of Pensacola bahiagrass and Coastal bermudagrass and peanut forage by treatments 1963–1965.

Fertilizer (lb/acre NPK)	Yield (lb/acre dry forage)							
	Bahiagrass				Bermudagrass			
	1963	1964	1965	Avg.	1963	1964	1965	Avg.
Plowed seedbed								
a 0–0–0	1850	3543	2102	2498	5127	2529	2513	3390
b 0–31–58	2977	4297	2700	3325	5380	3208	2514	3701
c 50–31–58	3594	4388	4912	4298	7647	4606	4490	5581
d+ 0–31–58	2616	3907	2510	3011	5935	2966	2580	3827
Average	2759	4034	3056	3283	6022	3327	3024	4125
Direct planted								
a 0–0–0	2828	3387	2804	3006	6813	3845	2725	4461
b 0–31–58	3323	3942	2485	3250	6577	4183	3066	4609
c 50–31–58	5706	5425	4466	5199	9215	4245	4919	6126
d+ 0–31–58	3486	4016	2704	3402	6000	3872	2776	4216
Average	3836	4193	3115	3715	7151	4036	3372	4853
Grass alone								
a 0–0–0	2763	3676	2249	2896	4458	3576	2941	3658
b 0–31–58	3438	4012	3110	3520	5110	4853	3001	4321
c 50–31–58	5914	6438	4849	5734	8009	5157	5426	6197
d+ 0–31–58	3100	3417	2292	2936	4616	4153	3054	3941
Average	3804	4386	3125	3772	5548	4435	3606	4530

+ Lime and gypsum in addition.

peanut forage yield was reduced 1,200 to 1,400 lb (Table 2). The third season's peanut forage production was approximately 200 lb/acre on both grasses. The year to year variation is thought to be due primarily to dry weather causing the leaves to drop. After the low forage production of 1965, peanut plant establishment in 1966 (Table 1) showed enough plants to maintain the population at approximately its original level.

The addition of 50 lb N reduced peanut forage production relative to that of the no N treatment. It is probable that when N is applied to a peanut-bahiagrass or peanut-Coastal bermudagrass sward, the value of the peanuts in the mixture will be reduced with the possibility of the peanuts being eliminated entirely. It appears the peanuts have their maximum potential in range or extensive operations, where high forage production per acre is not needed.

The higher peanut forage production on bahiagrass sod in 1964 as compared to the production on the bermudagrass was probably due to the higher water holding capacity of the bahiagrass soil.

Total forage yields by treatments and years are given in Table 3. While forage production of the two areas are not comparable an explanation for the difference in production is available. Coastal bermudagrass averaged approximately 1,000 lb more dry forage per year than Pensacola bahiagrass. The higher yield of the Coastal was due to the higher yield during the first year of the experiment and probably represents residual fertility. During the same year, peanut forage production on the Coastal plots exceeded that on the bahia plots (Table 2), probably due to reduced competition early in the season. During the second and third years of the experiment, total forage production between the grass species did not vary appreciably.

Forage production on the plowed seed bed averaged approximately 515 lb less forage per year than did the direct seeded plots or the grass without peanuts. The reduced yield on the plowed plots was due to grass stand reductions by plowing that required time to re-establish. At the low level of N fertility used in this experiment more time was required for grass to re-establish than had a more adequate N supply been available. Preparing a seed bed for peanut seedlings in grass sods will reduce the grass production for one to 3 years but will increase peanut forage production.

Applying P and K increased grass forage production up to 300 lb/acre of dry forage, but did not increase peanut production. Applying 50 lb/acre of N increased total forage production by approximately one ton/acre but reduced the percentage forage contributed by the peanuts.

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Grazed Plant Utilization Method[1]

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Highlight

The purpose of this study was to determine if one regression line for crested wheatgrass and one for needle-andthread grass could be used to determine utilization on different sites in different years. Regression lines were developed for each of 4 sites and 2 years and then compared by co-variance analysis. It was determined that a common linear regression line was satisfactory for field application.

El Método de Planta Pastoreada para Determinar Utilización
Resumen

Se usó el método de planta pastoreada para determinar el porcentaje de utilización por peso para *Agropyron desertorum* y *Stipa comata*; el método fue exacto, rápido y de fáciluso aunque tuvo ciertas limitaciones. No se pudieron determinar mayores grados de utilización arriba de 57% para *Stipa comata* y 75% para *Agropyron desertorum* debido a que en estos puntos el 100% de las plantas fueron pastoreadas (Fig. 1 y 2). Tampoco se pudo determinar la utilización para ambas especies en áreas con menos de 5% de las plantas pastoreadas.

Los datos indican que una sola ecuación de regresión puede usarse para la determinación de utilización de esas especies en diferentes sitios y en diferentes años. Una regresión lineal sirvió satisfactoriamente en diferentes sitios y años en el área donde se llevó a cabo el estudio (cerca de Craig, Colorado). Le ecuación de regresión que se determinó para *Agropyron desertorum* es similar a la determinada por Springfield (1959, 1961) en Nuevo México, lo cual indica que una ecuación de regresión puede tener una aplicación amplia para esta especie.

Early studies have shown the grazed-plant method to be of value in determining range utilization because it is rapid, easy to use, and reasonably accurate. The method has been tested by Roach (1950) in Arizona, Hurd and Kissinger (1953) in Idaho, Mattox (1955) in Montana, Springfield (1959, 1961) in New Mexico, and Springfield and Peterson (1964) in New Mexico. The method involves making field determination of the percent of plants grazed. Then from a regression line, which correlates degree of use with percent of plants grazed, degree of utilization can be determined. The purpose of this study was to determine if a single regression line could be used to determine utilization of crested wheatgrass and needleandthread grass on different sites in different years.

Methods

Field data used in this study were collected at the Great Divide Experimental Range located 30 miles northwest of Craig, Colorado. A "Rolling Upland" site, the vegetation is characterized by big sagebrush (*Artemisia tridentata*) and the soils by a sandy loam texture. The average annual precipitation for 11 years of record is 10.68 inches.

Mature plants of crested wheatgrass (*Agropyron desertorum*) and needle-andthread grass (*Stipa comata*) used in developing height–weight tables were collected in 1964 and 1965 on four sites in the pastures of the experimental range. These sites included the north slope, south slope, ridge top, and swale bottoms. Thirty plants of each species were collected on each site in 1964 and 15 plants were collected on the same sites in 1965 as a check on the annual variation in growth form. Height–weight graphs were constructed for each site in each year following the procedure described by Mattox (1955).

Utilization data was also collected in 1964 and 1965. Different degrees of utilization were sampled on each site to provide a range of values upon which to base the regression relationship of number of plants grazed to weight of forage removed. One hundred plant-paced transects were used to collect utilization data and plants were recorded as being grazed or ungrazed. For grazed plants the average stubble height was recorded. For ungrazed plants the compressed maximum height was recorded.

Percentage utilization for each grazed plant, based on stubble height, was determined from the height–weight charts. These individual percentages were totaled for each transect and the average utilization based on the total number of plants per transect was computed. Percentage of plants grazed was also computed for each transect. These data were then used to determine the regression equations. Separate regression analyses were computed by sites and years for each species. These regression lines were then compared by analysis of covariance.

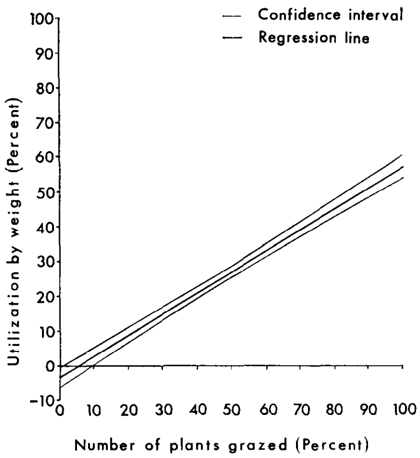

FIG. 1. Relationship between percentage of number of plants grazed and percentage utilization by weight of *Stipa comata* with a 99% confidence interval.

Results and Discussion

A close correlation was found between the percentage of plants grazed and percentage utilization in both needleandthread grass and crested wheatgrass. In this study, regression relationships were computed for eight groups of data for each species. These groups constituted different sites in different years. The purpose in testing these regressions was to determine if one regression line could be used to predict percentage utilization on different sites as well as in different years.

The tests of the individual regression lines showed that a curved line fitted the points only slightly better than a straight line and that all points fit the line very closely. The correlation coefficient of the straight line for crested wheatgrass was 0.99 and for needleandthread grass 0.98. These were higher than those computed by Roach (1950) and equivalent to those computed by Mattox (1955) and Springfield and Peterson (1964).

Considering the tests in light of the data used, it was determined that a common linear regression line could

[1] Excerpt from a thesis presented to the Department of Range Science, Colorado State University in partial fulfillment of requirements for the Master of Science Degree. Credit is due the U. S. Bureau of Land Management for helping to finance the study under a research grant.

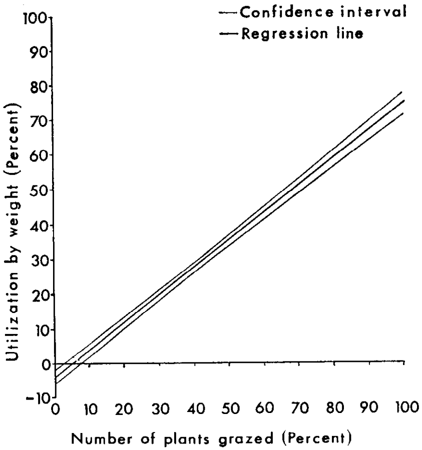

FIG. 2. Relationship between percentage of number of plants grazed and percentage utilization by weight of *Agropyron desertorum* with a 99% confidence interval.

be used to predict percentage utilization from percentage of plants grazed, using a separate regression line for each species. The regression equation for needleandthread was $Y = -3.0623 + 0.6036x$ and the equation for crested wheatgrass was $Y = -4.0165 + 0.7874x$, where x = percent of plants grazed and Y = percent utilization. The R^2 for needleandthread grass was 0.95 and for crested wheatgrass it was 0.98. Fig. 1 shows the regression line for needleandthread grass and Fig. 2 shows the regression line for crested wheatgrass, each with a 99% confidence interval.

Previous studies have found that one is unable to predict utilization at very low and very high degrees of use with this method (Springfield, 1959, 1961; U. S. For. Serv., 1960; Springfield and Peterson, 1964). The regression equation in this study limited the determination of utilization to less than 57% for needleandthread grass and to less than 75% for crested wheatgrass because at these points 100% of the plants were grazed. This latter figure is only 3% greater than the upper limit of 72% found by Springfield (1959, 1961) on crested wheatgrass.

Because of the slope of the line, utilization could not be determined on areas with less than 5% of the plants grazed, which also corresponded to the lower limit of Springfield (1959, 1961). The similarity of the regression equation determined for crested wheatgrass in this study and that used by Springfield (1959, 1961) in New Mexico, indicates that the regression relationship for this species may have quite wide applicability.

Conclusion

The general conclusion was that the grazed-plant method of determining utilization on crested wheatgrass and needleandthread grass is an accurate, rapid, and easy to use method. Based on the data collected, a common linear regression relationship is satisfactory on different sites and years in the area where the study was conducted. The regression relationship on crested wheatgrass in particular may extend over a greater area than that in this study.

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Cold Storage Not Required for Fourwing Saltbush Seeds

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Highlight

Seeds refrigerated 4 years germinated no better than seeds stored under ordinary conditions. Viability was retained for 6 years under storage at 55 to 95 F.

Little information is available concerning proper storage of fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.) seeds. The U. S. Forest Service (1948) recommended storing the seeds in a dry place, and reported the seeds apparently do not deteriorate appreciably, as one lot of seed germinated 19% after 9 years of dry open storage. Wilson (1928) concluded germination decreases little if any until at least 6 or 7 years after maturity.

We conducted studies to determine the effects of refrigeration on viability of fourwing saltbush seeds. Four sources of seed were included; three were collected in 1961 and one in 1962. Samples of these seeds were put in cloth bags in June 1963 and stored in a refrigerator (38 to 42 F). Other samples were kept in paper bags and stored in a heated garage (55 to 95 F).

The principal experiment was conducted at Santa Fe, New Mexico, in July 1967, after 4 years of storage at the two temperatures. Fifty seeds from each sample were placed on moist vermiculite in petri dishes. Each dish contained 100 ml of vermiculite and 50 ml of distilled water. Dishes were randomly arranged on one tray in a germinator. There were six replications. Germination temperatures during the 30-day test ranged from 63 to 65, and averaged 64.4 F.

Germinated seeds were counted at 2- to 4-day intervals. Seeds were considered germinated when radicles and

[1] Central headquarters maintained at Fort Collins in cooperation with Colorado State University; research reported here was conducted at Albuquerque in cooperation with the University of New Mexico.

shoots measured 0.5 inch or more. Germination percentages were transformed to arc sin for analysis of variance.

Seeds stored under refrigeration for 4 years germinated no better than seeds stored at ordinary temperatures:

Seed source and year collected	Percent germination when stored at—	
	55–95 F	38–42 F
Isleta (1961)	79	74
Mountainair (1961)	53	61
Corona (1961)	47	43
Bernalillo (1962)	29	33

There were large differences, however, between sources of seed.

Additional evidence shows that viability of fourwing saltbush seeds is retained satisfactorily under ordinary storage temperatures. Two of the lots of seed used in the comparisons discussed above were tested for germination prior to 1967. Samples used in these earlier tests were taken from paper bags stored at 55 to 95 F. Germination test procedures were essentially the same as described above. The results show no decline in viability:

Year of test	Average germ. temp.	Percent germination	
		Isleta	Corona
	F		
1963	68	72	30
1965	68	67	36
1966	68	75	41
1967	64	79	47

In fact, the above germination percentages indicate a trend toward increased viability with age.

We may conclude that special storage conditions are not necessary for fourwing saltbush seeds. Certainly refrigeration does not seem to improve retention of viability. The evidence shows viability is retained at a high level for at least 6 years when seeds are stored under dry conditions at temperatures of 55 to 95 F.

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BOOK REVIEWS

The Land System of the United States. By Marion Clawson. University of Nebraska Press (Lincoln). 145 p. 1968. 22 illus. $3.75.

This small volume treats the United States land system from the early colonization period to the present—how it came about, how it has worked, how it works now, and what are its prospects for the future. The history and characteristics of the land system used in the United States are described for comparison with other land systems in the world. The purpose is to show by example how crucially important the choice of land institutions really is.

This publication is based on Dr. Clawson's "Man and Land in the United States" which was redrafted as an introduction to the United States land system for foreign readers. It was initiated and sponsored by the North Central Land Economics Research Committee, a group of state universities, and the Economics Research Service of the U. S. Department of Agriculture.

A particularly valuable part of this work, in my opinion, concerns the origin of the public domain, land surveys, and records and disposal of federal land in chapters 5, 6, and 7. Similarly, chapters 8 and 9 on farm land use, ownership, and tenure are especially informative. These sections will render the book very useful to students, upwards of high school level, and will serve as a worthwhile reference for many professionals and specialists.

As to the future, Clawson says that the United States land system appears likely to serve as well, with certain minor changes, as it has in the past and is so doing at present. He adds that the most pressing land problems in the future will concern space for living, communication, and leisure. The volume is recommended to members of the American Society of Range Management.—*E. J. Woolfolk,* Susanville, California.

The Day of the Cattleman. By Earnest Staples Osgood. University of Chicago Press (Chicago). 283 p. 1929 (Reprint 1957). $1.50 paperback.

Earnest Staples Osgood, a knowledgeable historian of the Old West, tells here the story of the open range cattle empires of the Central and Northern Plains. Their day had come and gone by 1900. The herds, which began in the 1840's with abandoned draft oxen from the wagon trains, were rapidly expanded by trail herds from Texas after the Civil War. The golden heyday of the late 1870's and 1880's was ended by overstocking, severe winter losses, and disillusionment of investors. Rapid settlement by the farmer and small rancher with his hay stacks soon crowded and replaced the range with farms and smaller, more intensive livestock operations.

The legends of this romantic era still live on in song, fiction, movies, and television, though often distorted. The true story of the cattlemen did include battle with Indians, rustlers, and the elements, and did include cattle–sheep wars and attempts to prevent settlement. However, the story also includes the establishment of a great and lucrative enterprise in an all but abandoned environment. It attracted eastern and foreign capital, stimulated railroad building, and laid the economic foundations of several western states.

Much of the material is from the files of the Wyoming Stock Growers' Association, which was an active cattlemen's organization during the period. —*Walter R. Houston,* Miles City, Montana.

NEW PUBLICATIONS

Copies of the PROCEEDINGS of the 11th Annual Arizona Watershed Symposium held at Tempe in September 1967 can now be obtained from the Watershed and Forestry Division, Land Department, State of Arizona. Society members will be most interested in the topic "Water Management on Semiarid Watersheds" by R. B. Hickok.

A new book titled THE ANALYSIS OF RESPONSE IN CROP AND LIVESTOCK PRODUCTION by John L. Dillon will be of interest to many range scientists. In the future, emphasis on response surfaces will largely replace the more restrictive F-test analysis, and this is a good primer on the subject. The text gives an introductory outline of the analytical principles involved in appraising the efficiency of crop-fertilizer and livestock-feed responses for both economic and physical evaluations. (Pergamon Press, Inc., New York, 1968, 135 p, $4.50.)

A FLORA OF KERN COUNTY, CALIFORNIA by Earnest C. Twisselman and illustrated by Eben and Gladys McMillan includes chapters on geography, soils, weather, plant associations, etc., and concludes with a non-illustrated, non-keyed catalogue of plants. The considerable emphasis on plant associations and abiotic conditions will be valuable to land owners, administrators, and conservationists. (The University of San Francisco, 1967, 395 p. Available through the author at Cholame, California in paperback at $6.00.)

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Range Management Theses 1967

Compiled and Edited by
Paul T. Tueller
University of Nevada, Reno.

The Range Management Education Council in cooperation with the Journal of Range Management annually publishes the titles of theses and dissertations completed during the current year (Kinsinger and Eckert, 1961, 1962; Box, 1966, Schmutz, 1967). It is hoped that this listing will serve to speed up the dissemination of the results of range management research. Many theses or dissertations may be borrowed through Inter-library Loan, some are available on microfilm. M.S. and Ph.D studies completed in 1967 are listed by school. Asterisks identify Ph.D. dissertations.

University of Arizona

Bartlett, Thomas Ellsworth. The effects of several herbicides on creosotebush in relation to carbohydrate and moisture levels. 87 p.

*Blydenstein, John. The savanna vegetation of the Llanos Orientales, Colombia. 179 p.

Burkholder, Dennis Alan. Interspecific differences among five southern desert grasses as affected by varying moisture and fertilizer levels. 49 p.

Chaudhry, Anwar Tariq. Drought hardiness in tomatoes. 57 p.

*Claveran, Ramon Alonso. Desert grassland mesquite and fire. 164 p.

Koltz, Bruce George. Root responses of crested wheatgrass to nitrogen and phosphorus fertilization. 79 p.

*Marquiss, Robert W. Influence of seedbed microclimates on soil moisture retention in sagebrush rangelands. 169 p.

O'Rourke, James T. Edaphic conditions influencing vegetative response following pinyon-juniper control in north-central Arizona. 83 p.

*Saunier, Richard Eugene. Geographic variability in creosotebush (*Larrea tridentata* (D. C.) Cov.) in response to moisture and temperature stress. 99 p.

Colorado State University

Astatke, Haile. Oak defoliation and understory plants. 62 p.

*McGinnies, William J. Effects of seeding and row spacing on crested wheatgrass seedings. 55 p.

Sparks, Donnie R. Diet of black-tailed jackrabbits on sandhill rangeland in Colorado. 34 p.

Welch, Tommy G. Carbohydrate reserves of sandreedgrass under different grazing intensities. 49 p.

Humboldt State College

Bonn, Richard. Deer-soil-vegetation relationships in the forest and grasslands. 86 p.

University of Idaho

Andrews, Duane S. Factors affecting revegetation of salt-desert shrub rangelands in Idaho. 81 p.

Burkhardt, Jerald W. Ecology of western juniper in Idaho. 93 p.

Evans, Gary R. Ecology of *Aristida longiseta* in northcentral Idaho. 69 p.

Fort Hays Kansas State College

Dodd, Jerald L. Environmental gradient analysis of remnant grasslands in the shale-limestone region of western Kansas.

Goodman, Clyde L. A survey of phreatophytes at Cedar Bluffs reservoir.

Hladek, K. L. The vegetation of remnant shale-limestone prairies in western Kansas.

Schmidt, N. D. Seasonal and morphological variation in caloric content of *Andropogon gerardi, Andropogon scoparius,* and *Bouteloua curtipendula* in the Hays, Kansas area.

Sloan, C. D. The vegetation of remnant grasslands in the loessial region of northwestern Kansas and southwestern Nebraska.

University of Montana

Lewis, Burton P. Forage production and utilization in western Montana clearcuts. 101 p.

University of Nebraska

French, Carrol G. The accumulation and distribution of nitrogen in the above-ground and below-ground plant material of *Sorghum vulgare* var. *subanensis.*

University of Nevada

Blackburn, Wilbert H. Plant succession on selected habitat types in Nevada. 162 p.

Bruner, Allen D. Replacing shadscale range with perennial grasses and trends of crested wheatgrass seedings in northern Nevada. 80 p.

New Mexico State University

Bailey, Oran F. Water availability and grass root distribution in selected soils. 67 p.

Lowance, Samuel A. Burning and fertilization of a blue grama range site. 48 p.

Zimmerman, U. Douglas. Response of grassland to disturbance in northeastern New Mexico. 30 p.

North Dakota State University

*Prasad, Naresh. Influence of microclimate on diurnal water relations in western wheatgrass leaves. 149 p.

Oklahoma State University

*McCord, Emmett Watson. Comparative analysis of leaf surfaces and related functions of four nativegrass species and bermudagrass. 93 p.

Oregon State University

*Hall, F. C. Vegetation-soil relationships as a basis for resource management on the Ochoco National Forest of central Oregon.

South Dakota State University

Emevoldsen, M. E. The effect of range site and range condition on the growth and development of western wheatgrass.

Texas A & M University

Allen, Jerry V. A physical and economic comparison of grazing management systems on livestock production and profitability—Western Edwards Plateau of Texas. 93 p.

Bowmer, Wm. J. Establishment of bermudagrass seeded with annual ryegrass. 42 p.

Ketchum, Richard V., III. The structure and growth of tobosa grass (*Hilaria mutica*) as related to grazing. 38 p.

Radde, Kenneth A. Salivary influences upon levels of certain chemical constituents in forage residues collected from ecophogeally cannulated sheep. 45 p.

Wied, Jesse L. The effects of mesquite control upon forage production and soil moisture. 64 p.

Texas Technological College

Bryant, David A. Day vs. night spraying of plains pricklypears. 39 p.

Drawe, Dale Lynn. Welder Wildlife Foundation. 97 p.

Utah State University

Baker, Robert C. The effect of season and intensity of herbage removal on the physical and chemical responses of summer range plants. 49 p.

Fears, Robert Dubois. The effect of intensity and season of use on the recovery of desert range plants. 74 p.

Isaacson, Harold Edwin. Ecological provinces within the pinyon-juniper type of the Great Basin and Colorado Plateau. 41 p.

*Sharif, Chaudry Mohammed. Seasonal, diurnal and species variation in forage moisture content in relation to site on mountain summer range in northern Utah. 183 p.

*Sims, Phillip Leon. The effect of thick and thin stands of four introduced wheatgrass species on production stature, chemical composition, animal preference and digestibility. 93 p.

*Singh, Teja. Quantitative analyses of perennial *Atriplex*-dominated vegetation of southeastern Utah. 178 p.

Workman, John P. Germination and seedling response of *Eurotia lanata* (Pursh) Moq. in relation to salinity and temperature. 89 p.

University of Wyoming

*Gartner, Robert. Microclimate, vegetation and soils along a critical gradient on Elk Mountain, Wyoming. 162 p.

Hiser, Leonard. Seedling emergence in relation to exposure and seeding date on highway right-of-way in Logan County, Colorado. 32 p.

King, Thomas W. A study of vegetation, soils and small mammals of limber pine stands in north-central Wyoming. 63 p.

Kirkham, Dale R. Harvester ant (*Pogonomyrmex owyheei* Cole) abundance in relation to grazing, vegetation and soil in northcentral Wyoming. 55 p.

Russey, G. Reagan. The effect of grazing intensities on the roots of Nuttall's saltbush (*Atriplex nuttallii* S. Wats.). 62 p.

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Box, Thadis W. 1966. Range management theses 1961–1965. J. Range Manage. 19:310–313.

Kinsinger, F. E., and R. E. Eckert. 1961. Range management theses since 1955. J. Range Manage. 14: 51–54.

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Schmutz, Ervin M. 1967. Range management theses 1966. J. Range Manage. 20:329–330.

Letters to the Editor

Letters may be accepted for publication which contribute to the objectives of the American Society of Range Management. The Society, however, assumes no responsibility for statements and opinions by contributors.

Worth Repeating

The following by Roy Komarek appeared in *The Wildlife Society News*, No. 107, December 1966. What Mr. Komarek says so aptly about wildlife and vegetation management, and his closing quotation that he leaves with us to ponder, applies not only to the forest and crop lands he talks about but equally to the Nation's billion acres of grasslands.

His broad and elegantly expressed insight so impressed me that I clipped his message to add to the very few items of this nature that I have felt worthwhile collecting in my lifetime. Today by accident I came across it again. I pass it along here for others of our Society to enjoy and perhaps ponder. Those who are also members of The Wildlife Society may have read Mr. Komarek's remarks earlier. But I am sure they will enjoy rereading them, as I did.

MERT J. REED

Berkeley, California

Mr. Komarek's comments are reprinted below with the permission of The Wildlife Society News.—FTC.

Wildlife and Vegetation Management

ROY KOMAREK[1]

All species of wildlife, in the final analysis, are dependent on vegetation in one way or another. Man, himself, in the final analysis, is dependent for his very existence, directly or indirectly on plant life. If vegetation is basic, then man prospers in direct proportion to his skill in managing that vegetation. Again, if vegetation is basic, then wildlife prospers in direct proportion to man's skill in managing the vegetation. If this is a valid summation, then research concerning the manipulation of vegetation to determine wildlife response should be of major import to the wildlife management profession and to the whole field of wildlife conservation. Why, then, are reports of such research so scarce in *The Journal of Wildlife Management?* Why are there no *Wildlife Monographs* detailing the methods and techniques in managing vegetation which have successfully achieved more abundance for various species of wildlife?

More than thirty years ago, Aldo Leopold defined game management as, "... the art of making land produce sustained annual crops of wild game for recreational use." Wildlife management is fundamentally a form of land management and it produces a crop—wildlife. Its relation is to forestry and agriculture, both of which are forms of land management, and each also produces a crop. All of them, wildlife management, forestry and agriculture are basically similar, for they are concerned with managing vegetation. Now you cannot have a forest without trees, or you cannot have a farm without fields or pastures, but you can have a forest lacking wildlife or a farm lacking wildlife. What is it then that produces abundant wildlife on the farm and in the forest? Essentially, it is the composition, quality, and arrangement of the vegetation. Wildlife management, therefore, is a form of landscape management. It is an active pursuit which demands skill in arranging and caring for vegetation and these skills can only be developed by the application of biological knowledge. How can we develop those skills without experimental research to determine cause and effect of vegetation manipulation on wildlife populations?

Across my desk recently, came a reprint forwarded by the Secretary of the Agricultural Board, National Research Council. It is a copy of an editorial ("Atlas" 1966, Vol. 2, No. 2, issued by Elsevier Publishing Co., Amsterdam) the last paragraph of which might well be pondered. It reads as follows:

> "Research may be essential for progress, but it can be an expensive and unproductive luxury. Applied research is not a luxury, it is at least essential, and at most vital to our continued existence. Pure research has a prestige or snob value which is out of place in the modern world. It should be valued for what it is, an investment for the future particularly suited to a relatively small number of dedicated scientists. The application of scientific knowledge is a scientific duty, not a second class variety of mental activity, and demands an equal degree of dedication. Science itself is a challenge, but world problems present another challenge which cannot be avoided, and no scientist with any conscience can idly ignore their urgent demands."

—*The Wildlife Society News*, No. 107, December 1966.

[1] Tall Timbers Research Station, Tallahassee, Florida.

Scholarship Policy

At the Albuquerque meeting I talked with two Mexican lads who were in the process of completing their degrees at Arizona and New Mexico in range.

Their problem was assistance in financing. Through being misinformed, they assured me that the national scholarship of our Society was limited to US citizens.

I find nothing in the policies on scholarships accepted by the directors at the Santa Barbara meeting that supports that view. If unfortunately the Society's scholarships are so limited, then I for one strongly feel our directors and members need to reexamine the Society's policies. If it is not true, then an urgent need is apparent for a clear statement on this point. I cannot believe that we as a Society can fulfill our obligations to our profession and Society cultivating a narrow nationalistic view in any aspect.

MERT J. REED

Berkeley, California

The scholarships which have been awarded by the parent Society originated from a proposal accepted by the Board of Directors on July 28, 1966. Although the proposal, as recorded in the minutes of the meeting, reads "... a $500 national scholarship ...," it is presumed the intent of the word "national" is to distinguish this scholarship from those awarded by Sections. At a meeting of the Board of Directors on July 19, 1967 (Santa Barbara), a scholarship policy adopted by the Board states: "The American Society of Range Management Trust will consider acceptance of donations for scholarships to worthy and capable university students ... (provided) that the donation is unrestricted as regards its geographic area of applicability."—FTC.

Dear Bob:

This is in reference to the article: "Food Habits of Juvenile Grouse," by Don A. Klebenow and Gene M. Gray, JRM 21(2):80–83, 1968.

This paper presents research information concerning the food habits of juvenile grouse that is very interesting. Certainly the more information accumulated concerning the food habits and other habitat requirements of any animal contributes to an understanding of the animal and eventually to better management. From this paper it would appear that sage grouse chicks in their earlier stages of growth utilize primarily tender forbs. As forbs dry and mature, grouse chicks utilize less of them. It would appear as these foods dry, grouse tend to take a greater amount of sagebrush. This may be due primarily to the relative abundance or availability of the various plant species. I am sure we cannot discount preference but assume that to some degree diet is a function of availability.

The authors state that desirable plant species for sage grouse chicks are absent on range where sagebrush had been controlled by applications of 2,4-D. I wonder if the authors have ever made a critical study of the amounts of the species indicated on areas that have been sprayed for sagebrush control. If they have not, I would suggest this as a follow-up to their study. In fact, it should have preceded formation of their conclusions. My observations have been that while spraying for sagebrush may knock down or even kill some of the plants indicated, it by no means eradicates them from the stand. In fact, many ranges which have been sprayed for sagebrush control, in addition to the tremendous increases in grass production, also have a greater amount of forbs in the stands than they had prior to brush control. In many instances, 2,4-D for sagebrush control is applied at a relatively early stage insofar as development of many forbs is concerned.

Again, this appears to be an excellent article from the standpoint of food habits of juvenile grouse. In my opinion, it fails in any way to link grouse habitat to range improvement programs. It does suggest the need for further study on the part of the authors to provide factual data on which to base their conclusions. No such data were presented. Researchers should base conclusions on data; if they chose to hypothecate or speculate on possible application or use of the information that is okay but it should be clearly labeled as such.

As far as I can see, this research furnishes no information to indicate that properly conducted sagebrush control programs are in any way detrimental to sage grouse.

Sincerely,
Dillard H. Gates
Corvallis, Oregon

Dear Bob:

The selection of food by juvenile sage grouse is based on availability as Dr. Gates suggests, but preference plays an important role. The presence of one or more species of preferred food plants attracted grouse to certain portions of the habitat. These plants were important in the diet while available, and grouse selectively searched for them. Other plants, more abundant in the habitat and available at the same time as the preferred species, were not utilized significantly until the tender forbs had dried. Sagebrush falls into this category. Another factor influencing selectivity in juvenile birds is that there is an increase in the total volume of food required as they get older. Probably some of the preferred plants were not present in sufficient amounts to fully satisfy the requirements for an adult or large juvenile.

We stated that the decision to control sagebrush must include consideration of the effect of herbicide on species other than sagebrush. The literature indicates that damage of forbs by 2,4-D is common and my observations on sprayed ranges agree with the literature. However, I have observed that there is variation in the length of time that sage grouse may find a sprayed area unsuitable. Some of the species preferred by grouse, i.e., the loco (*Astragalus convallarius*), sego lily (*Calochortus macrocarpus*), and common dandelion (*Taraxacum officinale*) were adversely affected by herbicides and my concern stems from that.

I heartily agree with Dr. Gates that more information is needed on the side effects of sagebrush control and that there should be a follow-up to our study. Our research projects in Idaho have ended, although not all the habitat data have been published. Hopefully, others will take up where Mr. Gray and I left off.

Sincerely,
Donald A. Klebenow
Lubbock, Texas

Conservation Organizations

ASRM was represented at a meeting of Cooperating National Conservation Organizations with representatives of the Departments of the Interior and Agriculture on August 5 in Washington, D. C. Glen D. Fulcher, Chairman of ASRM National Capital Section, reports that seven of the 17 conservation groups were represented: Wildlife Management Inst.; Resources for the Future; International Game, Fish and Conservation Commissioners; Colorado Wildlife Federation; Wilderness Society; National Wildlife Federation, and ASRM.

During the informative four-hour meeting, BLM and Forest Service presented background and current status of the grazing fee study. Costs included death losses, association fees, veterinary, moving livestock, herding, salt and feed, travel to and from allotment, water, horses, fence maintenance, depreciation of developments, and private lease rates. Average costs were presented. Selling price of grazing privileges was also determined. A major issue is whether the selling price of these grazing privileges should be included as a cost of using public land in determining grazing fees. The livestock industry contends that a 6% interest on price of grazing privileges should be allowed as a cost of grazing on public lands.

The conservation groups felt that the Government should receive a fair market return for its forage. A much better understanding of the complexities of the grazing fee issue was gained by CNSO representatives. Both Forest Service and BLM were criticized for not having discussed critical policy issues with conservation groups in the past. CNSO representatives stressed that their major interest is more in how the land is used and that it be properly managed for the benefit of all rather than what the exact grazing fee should be.

NEWS AND NOTES

More About the PLLRC

On April 5 and 6 the Public Land Law Review Commission held public hearings in Washington, D. C., at which time the views of eight Federal agencies were heard. The PLLRC's Information Memorandum No. 10 (June 5, 1968) presented resumes of the views expressed; excerpts from this memorandum are printed here.

Forage (Department of the Interior)—The debatable grazing fee provisions of the Taylor Grazing Act give rise to perennial uncertainties which are unsatisfactory to both the user and the administrator.

Allowing private improvements on public grazing lands may lead to a proprietary attitude toward the public land, increasing the difficulty of making later land use adjustments. If the range is needed later for another use, arranging for just compensation may be difficult.

An estimated 2,300 fences totalling 13,000 miles and more than 2,100 water developments have been constructed on public lands by livestock interests without permits as required by the regulations. Many of the fences interfere with or prevent the movement of big game animals, and some water developments were constructed without provision for wildlife use.

Adjudication (Department of Justice)—There is a great diversity between and within agencies as to what goes into the administrative record for judicial review; standardization would be extremely helpful.

Land Exchanges (Department of Agriculture)—Lack of flexibility in National Forest boundaries rules out many land exchanges which would be of mutual benefit to the Forest Service and non-Federal owners.

(Department of the Interior)—The various restrictions of the Taylor Grazing Act make it impossible to consummate many desirable exchanges, and often require lengthy negotiations before exchanges may be effected. A possible solution is the use of cash payments to equalize values.

Fish and Wildlife (Department of Agriculture)—The cooperative approach to wildlife management has worked well and meets most of the needs of this Department, which has recognized the States' authority to manage and regulate resident fish and game populations.

(Department of the Interior)—Procedural requirements in readjusting livestock use under provisions of the Taylor Grazing Act and the Administrative Procedure Act may lead to long delays, which could be detrimental to forage and wildlife habitat resources.

Intensive Agriculture (Department of the Interior)—Future allocations of public lands toward cropland use should ordinarily have to compete fully with other demands without special subsidies such as nominal land prices. Present agricultural land statutes raise false hopes, foster disrepute for the government, stimulate fraudulent conduct, cause unnecessary scarring of the land, and incur social costs far exceeding the land values.

User Fees and Charges (Department of Agriculture)—The basic guideline for setting fees for the private use of National Forest land . . . seems to be quite well set and has general public acceptance. The guideline is simply that the fees should represent the value of the use made of the land.

(Department of the Interior)—Grazing fees on lands administered by the Bureau of Sports Fisheries and Wildlife are based on local prevailing rates. It is difficult to explain to the public and users the reasons for this divergence from the rates on lands managed by the Bureau of Land Management and Forest Service.

It is difficult to establish benefit values on recreation use that can be converted to a corresponding fee.

These few sample statements give only a clue to the type and extent of the testimony, and certainly should not be construed as fully representing the position of the agencies quoted. Additional information may be obtained from PLLRC, 1730 K Street, NW, Washington, D. C. 20006.

The Commission has announced the publication of a "Digest of Public Land Laws" dating back to 1792. The volume is unique in scope and has been termed "a natural prerequisite to the consideration of recommendations for a future land policy." It is available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402; the price is $6.50.

A contract has been awarded by PLLRC to South Dakota State University for a study of the Use of Agricultural Resources on Public Lands. The study, to be completed by March 31, 1969, covers five major areas: (1) effects of the laws on settlement, land development, and the operation of farm units; (2) economics of farm operations in dry land and irrigated areas of the eleven western states; (3) estimate of area of public lands suited for agricultural development, and probable effect on the agricultural economy of developing this acreage; (4) effect on a local economy of developing new agricultural lands; (5) effects of the existing and alternative systems of laws and policies.

Dr. Eugene E. Hughes has been appointed to the professional staff of PLLRC. A native of New Mexico, Dr. Hughes received his B.S. degree in range management from Colorado State University, and earned his M.S. and Ph.D. degrees in range management from Texas A & M. He has previously served as project leader for the ARS, engaged in water conservation and flood prevention studies.

The National Wildlife Refuge System

The national wildlife refuge system is the subject of the recently completed third report of the Secretary of the Interior's Advisory Board on Wildlife Management. Board members are **Clarence M. Cottam,** Ian McT. Cowan, Ira N. Gabrielson, Thomas L. Kimball, and **A. Starker Leopold** (Chairman).

The report attempts to appraise the significance of the national refuges in migratory bird conservation, with emphasis on waterfowl. It contains several succinct comments relative to the management of game ranges and other types of refuges. For example—

"By comparison with the waterfowl refuges, the intensity of management on game ranges, island refuges, and preserves for rare species is very low indeed—perhaps too low in some situations. For these areas collectively, present management consists largely of protection from undue disturbance or change.

"On mainland game ranges, where ungulate populations are concerned, there is often required some control of numbers. Nothing can be more deleterious to the habitat and to the animals themselves than carrying too many on the range. Reduction normally is accomplished most effectively through public hunting, although removal of small numbers may be more easily done by refuge personnel.

"Whereas there is general recognition of the need to protect big game ranges from overgrazing, *there is much less attention paid to the possibility of raising range capacities for wildlife through plant manipulation or water development.* We are aware of some experimental burning on the Kenai Moose Range in Alaska and the National Bison Range in Montana. Some modest reseeding trials have been attempted on several other game ranges. *But the point of view toward range management has been predominantly one of protection rather than manipulation."* (Italics added.)

The National wildlife refuge system now comprises 317 major units and a combined area of nearly 29 million acres. The Advisory Board presents its observations on a philosophy for the refuge system, administration and planning, public recreational use, hunting and fishing, and research on refuges.

Higher Education Act Funds for Community Resource Problems

Title I of the Higher Education Act authorizes federal matching grants to help colleges and universities apply themselves to the solution of community problems, specifically including many environmental planning and conservation problems. Each state has appointed an agency to allocate its share of Title I funds among project proposals received from institutions.

As an example of the type of project under this Act, the University of Idaho's College of Forestry, Wildlife and Range Sciences will use Title I funding for a project to assist rural county and municipal officials having outdoor recreation responsibilities. An on-campus training program will be held several days each year. Classroom work will be followed by field tours and instruction at a demonstration site on the University Forest. Additionally, an Extension recreation specialist will visit communities in a consulting capacity.

1968 Student Enrollment in Range Management

Enrollment records for range management students recently tabulated by the Range Management Education Council show that 447 students were enrolled as Junior or Senior students in Range Management during the spring semester or quarter of 1968 (Table 1). A total of 168 students were enrolled as graduate students in Range Management, Range Science or an equivalent program of instruction. Freshmen and sophomore statistics are not included since many schools do not identify majors until the junior year.

Table 1. Student enrollment in Range Management Education Council schools, spring 1968.

Schools	Jr.	Sr.	M.S.	Ph.D.	Qualifying
Abilene Christian College[1]	–	–	–	–	10*
University of Arizona	14	8	12	5	6
Brigham Young University	11	10	3	1	3
Calif. Polytechnic College	–	–	–	–	–*
University of California	1	1	6	2	2
Colorado State University	20	16	10	5	0
Humboldt State College	15	1	0	–**	7
University of Idaho	5	9	6	4	2
Iowa State University	–	–	–**	–**	–*
Ft. Hays, Kansas State College	0	6	2	0	0
Kansas State University	5	4	1	2	0
Montana State University	9	10	1	–**	0
University of Montana	9	9	2	1	2
University of Nebraska	4	4	4	1	1
University of Nevada	0	0	6	–**	3
New Mexico State University	16	21	9	–**	2
Northern Arizona University	23	0	0	0	10
North Dakota State University	0	2	1	5	3
Oklahoma State University	2	7	2	–**	0
Oregon State University	6	6	4	3	0
South Dakota State University	3	4	2	–**	0
Southwest Texas State College[1]	–	–	–	–	7*
Sul Ross State College	12	8	2	–**	35
Texas A & M University	10	17	7	8	10
Texas Technological College	24	21	15	–**	0
Utah State University	28	31	16	21	10
University of Washington	–	–	–	–**	–*
Washington State University	3	4	1	–**	0
University of Wyoming	15	13	10	6	4
Totals	235	212	122	64	117
Percent change calculated	+10.8***	–0.09	+0.08	–8.4	–25.7
Totals reported from 22 schools in 1967	200	233	121	63	113

* No major in range management or equivalent.
** Degree not awarded in range management or equivalent.
*** Percent change calculated from 22 schools reported in both years.
[1] Included in RMEC statistics for first time in 1968.

There are 25 schools that award a B.S. degree in range management or equivalent; 23 schools award the M.S. degree and 14 award the Ph.D. degree. Seventeen of the 29 schools that reported have indicated that some students without a degree in range management qualify for the Civil Service Range Conservationist Register. The total number of qualifying students was 117 which was a 25.7 percent decrease from 1967 based on a comparison with the 22 schools reporting in 1967. This can be considered as a continued reflection of the general upgrading in Civil Service standards with regard to course-work in range management.

The 1967 to 1968 trends in graduate student enrollment show no appreciable change in the number of M.S. students although an 8.4 percent decrease in the number of Ph.D. students was reported. The actual numbers reported were 122 M.S. students and 64 Ph.D. students. In view of the new Selective Service regulations calling for the drafting of all first year graduate students it seems likely that graduate student numbers will decrease at least during the next two years.

It is hoped that the increased number of junior students might possibly reflect an upward trend in under-graduate students as a result of the upgrading of the range management course work requirements by the Civil Service Commission. Students who were not majors before the requirements were increased may now have changed their major to Range Management.

Two additional schools have reported this year for the first time, Abilene Christian College, Abilene, Texas and Southwest Texas State College at San Marcos. Both of these schools qualify students as range conservationists and range managers and have expressed an interest in the Range Management Education Council.

A few schools reported an increase in freshmen and sophomore majors. The profession can look forward to a greater number of range management graduates in the immediate years ahead.—*Paul T. Tueller,* Vice-chairman, RMEC, University of Nevada, Reno.

Conservation Awards

W. Caleb Glazener and **Erling B. Podoll** were among the 20 winners of the 1968 American Motors Conservation Awards.

Glazener, assistant director of the Welder Wildlife Foundation, was honored for his more than a quarter of a century of study and management of wildlife throughout Texas. Podoll, SCS biologist for North Dakota, was honored for his sound judgment and perseverance in spelling out the potential wildlife habitat losses that could result from watershed projects.

In announcing the selections American Motors Corporation Board Chairman Roy D. Chapin, Jr., said:

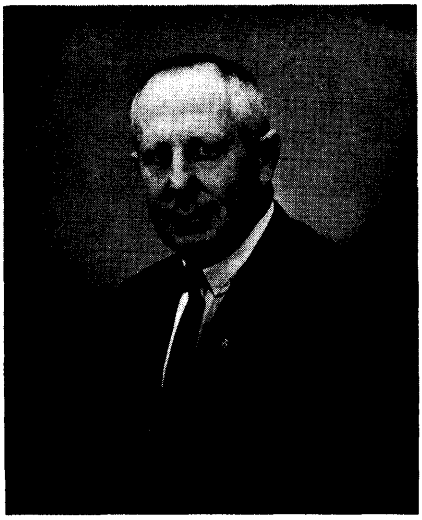
"A nation's prosperity can only be based on its natural wealth—on its food-producing top soil, on its ample supplies of unpolluted water, and on its soil-building, water-storing forests and rangelands.

"And since we, like all other business and industrial enterprises are beneficiaries of that prosperity, all of us are indebted to the professional and citizen conservationists who work to see that the foundations of prosperity remain sound."

Glazener and Podoll received sculptured bronze medallions and honorariums of $500.

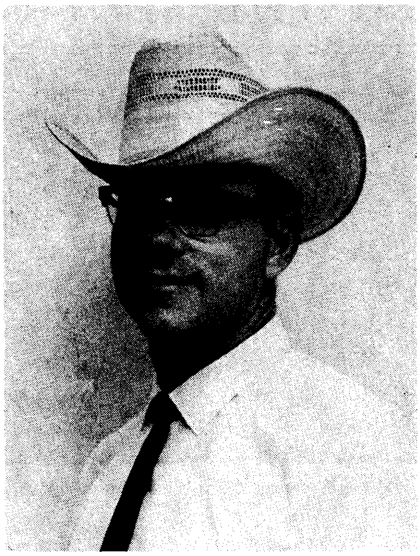
People

Former SCS State Range Conservationist in Arizona, *Charles C. Michaels* has been selected by FAO to serve as Range and Pasture Management Specialist in Saudi Arabia for a two-year period beginning last March. Michaels is a 1933 graduate of Utah State University and has been with the SCS since 1935.



Albert P. (Bert) Thatcher

Albert P. (Bert) Thatcher has succeeded Michaels as Arizona State Range Conservationist, transferring to Phoenix from Casper, Wyoming where he served in a similar position for several years.



Durwood E. Ball

Durwood E. Ball, formerly Range Conservationist, SCS, Cotulla, Texas, follows Thatcher as State Range Conservationist, SCS, for Wyoming. A native Texan, Ball received his range management degree from Texas A&M.

Dr. Glen D. Fulcher has transferred from his position as Chief, Range Management Staff, BLM, to the Office of Water Resources Research in the Office of the Secretary, U. S. Department of the Interior. Fulcher is currently president of the National Capital Section, ASRM, and states that although his new title is Water Resources Scientist, he is a rangeman at heart, and his interest in range management and the Society's activities continues.

Dr. Merton Love and *Dr. Harold Biswell* were featured speakers at the University of California's Whitaker's Forest Field Day held last June.

Recently named as Assistant Director of the Southern Forest Experiment Station, New Orleans, is *Dr. Vinson L. Duvall.* He will be in charge of research in watershed management, recreation, range management, and wildlife habitat. Duvall transferred from Alexandria, La., where he headed the USFS range research team working on systems by which cattle can be successfully grazed on forest lands managed for timber.

Gerhart H. Nelson has been named to the Division of Range and Wildlife Management staff of the Forest Service's Pacific Northwest Region. Before coming to Portland, Nelson served as a USFS management analyst in Washington, D. C.

Fred N. Ares, Superintendent of the Jornada Experimental Range near Las Cruces, New Mexico, is retiring this fall after 46 years with the U. S. Department of Agriculture (ARS). Fred was reared on a ranch in New Mexico and became a Ranger on the Apache National Forest in 1922. In 1931 he transferred to the Jornada where he has become widely known for his sharp comprehension of ranch management in this area of low precipitation, periodic drought, and brush encroachment.

International Biological Program

The International Biological Program is one of worldwide scientific cooperation reminiscent of the recent International Geophysical Year. IBP's objectives and functions were outlined by T. C. Byerly in the May Journal (*JRM* 21(3):178–179, 1968). An ASRM Committee on IBP will report on the World's Grasslands in the lead article of the November, 1968 Journal.

Range Management.—The heart of the U. S. effort lies in its integrated research programs with coordinated studies by many scientists in different disciplines. One of these integrated programs—Analysis of Ecosystems—will include a thorough systems analysis of six different biomes: grassland, tundra, desert, coniferous forest, deciduous forest, and tropical rain forest. This program has recently been launched by a $350,000 National Science Foundation grant to Colorado State University to start an intensive study of a Colorado grassland area.

Dr. George M. Van Dyne, associate professor at CSU's College of Forestry and Natural Resources, is director of the grassland biome study. He also is a member of the IBP's Subcommittee on Productivity of Terrestrial Communities. A large number of ASRM members are proposing studies of various kinds in the IBP biome projects; if funded they will add greatly to our knowledge of rangeland and ecosystems. The research is not to be constrained to "natural" areas, but will include manipulated (e.g., grazed, fertilized, seeded) sites. The emphasis is, however, to understand the fundamentals of both primary and secondary productivity.

In its March 11, 1968 report on the IBP, the House Science, Research and Development Subcommittee said this program is "aimed at the ultimate understanding of the environment and how man-made changes will affect it. In other words, it will determine the capacity of an ecosystem to change and the degree to which productivity levels are affected by a variety of natural and artificial disturbances."

Public Responsibility for Natural Resources

This is the title of the USFS Research Note PSW-165 published by the Pacific Southwest Forest and Range Experiment Station, Berkeley. It highlights the results of a study conducted by the Forest Service and Brigham Young University in an attempt to gain information to help combat the carelessness, thoughtlessness, apathy, and vandalism which annually costs the taxpayer millions of dollars in damage to and destruction of forests and other natural resources.

From the answers to a special questionnaire circulated in Utah County, Utah, it was learned that:

Only 26% of those persons in the 14 to 25 year age bracket showed any concern for public property, whereas 50% of those 60 years old or older showed concern.

Only 1% of those who were widowed, divorced, or separated showed concern for public resources, compared to more than 28% of the married people, and 35% of the single people.

A strong correlation was found between the length of time people had lived in a community and their concern for its resources. Those who had lived in a community for 10 years or more showed the greatest concern.

Ford Foundation Grants

The Ford Foundation has announced the awarding of grants totalling almost $4 million for research and education projects in ecology. Grant recipients, amounts, and projects include—Colorado State University, $62,000 to study the impact of weather changes on grasslands; University of Washington, $587,695 for a new graduate program in quantitative ecology and natural resource management; Yale University, $909,655 for a new graduate program in the management of terrestrial environment; and the University of British Columbia, $483,200 for a new interdisciplinary program of graduate education in resource science. The thrust of these programs is to seek ways in which man can prevent crises in his environment instead of being constantly overtaken by his own creations.

WITH THE SECTIONS

Arizona and Utah

The first joint summer meeting of the Utah and Arizona Sections was held at St. George on June 28 and 29. The temperature outside the air-conditioned Dixie High School auditorium, the scene of the opening sessions, was 109 F. Mayor Marion Bowler and the respective Utah and Arizona Section Presidents Nick Cozakos and John Ehrenreich welcomed nearly 60 members, students and guests.

Presentations given by: Barry Freeman, Arizona Extension Range Specialist, *Approach to Resolving Public Lands Grazing Problems*; Horace Andrews, Soil Conservation Service, *What Management Has Done for the Individual*; Flint Wright, Rancher, *Improvement in Private Lands*; Roger Hungerford, Professor, University of Arizona, *Kaibab Deer Herd as Influenced by Range Improvement*; Gordon Bentley and Marv Woodbury, Bureau of Land Management, *Grazing Systems as Used in Allotment Planning on the Arizona Strip*; and John Workman, Economist, Utah State University, *The Economics of Livestock Distribution*.

Gilbert Jordan discusses response of grass species planted in Arizona Strip country.

Nearly 70 people joined in the following day. Dr. Gilbert Jordon, University of Arizona, and Owen Wright, Bureau of Land Management, Arizona Strip District, conducted a tour to several range reseeding studies in big sagebrush types. Some 400 acres of experimental plots were installed to determine the response of several wheatgrasses, gramas, bluestems, and lovegrasses under various seedbed preparations, planting times and planting techniques.

Lunch was served at the Jacob Lake area on the Kaibab National Forest. The pit-barbecued beef was prepared by Rex Christensen, Marvin Woodbury, Gordon Bentley, William McNally, and Cloyd Swapp, all BLM personnel of the Arizona Strip District, in cooperation with the Fredonia, Littlefield and St. George Soil Conservation Districts.

The gorged group then waddled across the road to a presentation on deer and livestock management on the Jacob Lake and Big Springs District of the Kaibab National Forest, given by Foresters Fred Arbogast, Sam Wolfskill, and Doug Barton. The program ended with a series of stops on the Kaibab where the group observed and discussed water developments, interseedings, meadow maintenance, and wildlife habitat improvement activities.

The interesting and provocative program was arranged by Drs. Jim Grumbles and Phil Ogden, Program Chairmen for Utah and Arizona respectively, and BLM District Managers Garth Colton and Delmar Vail.

Idaho

Section officers and committees made elaborate preparations for a fine summer meeting of the parent ASRM Society and Board of Directors, July 29–31. Program and tours through Bear Valley, Dagger Falls, and Redfish Lake were outstanding. See full report in November issue.

Kansas–Oklahoma

Historical Medicine Lodge, Kansas, was the site for the Spring meeting. Tall, lush, green grass added to the scene as 68 members and guests assembled for the two-day meet, June 7–8.

Dinner Friday evening was capped by a film presentation of the reenactment of the Medicine Lodge peace treaty. John W. MacGregor, president of the Medicine Lodge Peace Treaty Association, gave a brief description of the event commenting that there were five Great Plains Indian Tribes present at the signing of the peace treaty. The Indian Sun Dance is one of the big highlights of the pageant.

The Saturday Tour included a stop at the Gress Hereford Ranch where Mr. Gress gave a brief history of his ranch. He owns 5,400 acres and leases other rangeland for summer grazing. The major range sites are shallow prairie and loamy upland. Gress usually runs 450 cows but operates with a flexible program whereby he can add or cut back as the need arises. He provides 1 lb/cow protein supplement on dry grass in the winter months and reduces this amount just before calving. He believes this decreases the chance of scours in the calves.

He weans 500-lb calves in October from calves dropped in January. The entire range is well managed and provides abundant forage.

The 7,500-acre Hereford ranch of Jim Lonker was visited. Jim, a Kansas State graduate, has been on the ranch about eight years, and is doing an outstanding job of managing the herd as well as conserving the range plants. The ranch accommodates 390 head of cows, with 94% calf crop. He pregnancy-tests the heifers. The steers weigh out at 480 lb at weaning time in October. The ranch has varying range sites with eroded red shale and red shale which are both low in production of forage.

After the tour members and guests were treated to a real Western steak fry at the Chapin ranch with Barber County (Kansas) 4-H Club and chef Ray Etheidge, County Agent.

The tour of the Chapin Ranch was of real interest. The 5,430-acre ranch has been in the Chapin family since 1886. In order to accommodate the herd of 400 Angus cows, additional rangeland is leased. The range sites are sandy, loamy lowland and sub-irrigated, all high producing sites. Protein supplement is provided throughout the winter on dry grass. The calves are dropped in January and weaned at 450 lb in the fall. Chapin watches his grass as range indicator rather than his cattle.

Some interesting geology of the permian Redbeds was explained by Darold Dodge, Soil Scientist for Barber County. Roy Brown discussed the vegetation and its production for the various range sites.

Members are anticipating the fall meeting in Scott City in October.

Pacific Northwest

The Wallowa Chapter of ASRM and the Wallowa County Stock-growers co-hosted the summer meeting and tour of the Pacific Northwest Section on June 24–25. Using practically all the school buses in Wallowa County, the two-day tour afforded members and guests a comprehensive view of the livestock industry and rangeland and forest resources of northeastern Oregon.

At an early stop rancher Mike Brennan discussed his management program, and explained in detail the practice of winter and spring burning of north slopes to improve forage quality. Clippings made of excellent condition hill sites on the Brennan ranch have shown forage yields of up to 1,300 lb/acre.

The first-day lunch stop was at "Indian Village" on Bob Freels' Fence Creek Ranch. Later the group witnessed a spectacular view of the Imnaha and Snake River canyons from Buckhorn Lookout. Jack McClaren, a lifelong canyon rancher, described the management system employed in this unique country. This area is perhaps the only place in the world where one can look up the stovepipe to spot the horses in the wrangle pasture!

Returning to Enterprise for the night, the hungry crowd was gratified with a bountiful barbecue dinner.

The second day of the tour included stops at the Harley Caudle ranch, the Bill Wolfe ranch, and the Hadley ranch—well-managed operations where the native rangeland is complemented by irrigated hay and pasture.

Lunch was served by the Wallowa Grange, after which the group visited the Gaylord Madison operations where they were informed of the livestock and range management practices applied on the land Madison leases from the Boise-Cascade Corporation. The latter is the largest private land owner in Wallowa County and, hence, has an important influence on the range resources of the area.

Texas

Texas Tech's Chapter, ASRM, held its annual Bar-B-Q May 11, 1968. Cooks for the occasion were Range Management Profs, Joe Schuster, Bill Dahl, Henry Wright, John Hunter, Don Klebenow, and Gerald W. Thomas.

Chapter officers installed for 1968–1969 were Mike McMurray, President; Joe Bob Watson, Vice-President; Tony Dean, Secretary-Treasurer; and John Tharp and John Adkins, Councilmen.

Alex Johnston of Agricultural Experiment Station, Lethbridge, discusses improved range condition in Porcupine Hills area of Alberta.

International Mountain

The Porcupine Hills of southwestern Alberta was the site of the Section's annual summer tour on July 25–27. Total attendance was 340 members, their families, and guests.

Sherm Ewing and Hal Sears secured a beautiful range campsite, and arranged for and helped cook the meals to feed the hungry crowd. Ed McKinnon initiated a fully-equipped camp trailer he had built for such Section activities.

Highlight of the three-day event was the plant identification contest conducted by L. Mackenzie Forbes. Winners of the contest, by groups, were:

Ladies and Junior Students

1st—Gordon Cartwright, High River, Albta.
2nd—Sandra Beck, Butte, Mont.
3rd—Mrs. Gordon Bruins, Voxhall, Albta.

Ranchers

1st—Charles Jarecki, Polson, Mont.
2nd—Jim Baker, High River, Albta.
3rd—Jim Cartwright, High River, Albta.

Professionals

1st—Steve Weiss, Missoula, Mont.
2nd—Joe Wagner, Missoula, Mont.
3rd—Jerry Wheeler, Calgary, Albta.

SOCIETY BUSINESS

1969 Annual Meeting Palliser Hotel, Calgary, Alberta February 10–13, 1969

Program Chairman Alex Johnston reports there will likely be about 100 excellent papers presented at the forthcoming annual meeting of the Society. The November issue of the Journal will carry the complete program, together with information on facilities, reservations and transportation.

Canadian hospitality is known far and wide, and here's your opportunity to take advantage of it. Don't miss it!

The annual range seeding equipment meeting is scheduled to be held in Great Falls, Mont. on February 9. Meetings of the Range Management Education Council and the newly-formed Association of Range Extension Specialists will be held concurrently with the ASRM meeting in Calgary. More details on these events will appear in the next issue.

1969 Photo Contest Rules

All members of the American Society of Range Management are invited to participate in the annual photo contest to be held at the 22nd Annual Meeting in Calgary, February 10–13, 1969.

Eligibility

1. Each contestant must be a member of the American Society of Range Management and be present or represented at the annual meeting. Those members who cannot obtain representation at the annual meeting may send their entries to a member of the photo contest committee prior to January 15, 1969.

2. Members may enter a maximum of sixteen (16) exhibits; one per category. An exhibit is one photo in all categories except picture story and range condition and trend.

3. All photos must have been taken by the contestant, with one exception. In Picture Story, at least one photo in the series must have been taken by the contestant.

4. All photos must be labeled on the back, with the category and the contestant's name and address. Photos mailed to committee members must contain self-addressed stamped envelopes for return mailing.

5. Winners *may* be required to furnish a copy upon request.

6. Previous grand champion and first place photos are not eligible for this contest.

Size of Photos

1. Black and white photos will be no larger than 11 × 14 inches with a glossy to matte finish. No hand-colored photos will be accepted. Prints will be mounted so they remain flat and ridged, preferably mounted on standard mounting board. Prints may not be framed.

2. Color slides must be in standard 2 × 2 inch mounts.

Deadline

All entries must be registered with Contest Committee, in the contest room, before 4 PM, Tuesday, February 11, 1969.

Scoring

Persons registering for the meeting will receive a ballot to vote on black and white and color slides. Voting should be completed and ballots placed in ballot box before 4 PM, Wednesday, February 12, 1969.

Awards

1. Ribbons will be awarded to first, second, and third place winners in each category and to the grand champion black and white and grand champion color slide.

2. Suitable awards will also be given the first and second place winners in

each category and the grand champion black and white and grand champion color slide.

3. Grand champion winners must place first in their respective category. Grand champions will be selected by vote shown on the ballots.

Journal Cover Photos

Winning entries will be eligible for selection as cover pictures for forthcoming issues of the Journal of Range Management.

Categories

Categories for black and white photos and color slides are:

1. Range Plant(s)
2. Range Animal(s)
3. Range Condition and Trend (may include single photos or a series of two to four photos showing changes in native vegetation, results of cultural treatment, or a range site in different conditions).
4. Range Improvement
5. Range and Ranch Scene
6. Range Recreation
7. Associated Range Use
8. Picture Story (Black and white photos only)
   a. Tell a story concerning range management.
   b. Use sufficient captions to explain the story.
   c. Minimum of three and a maximum of six photos.
   d. Each print no larger than 11 × 4 inches.

Contestants will specify the category in which photos are to be entered.

Responsibility

The Committee will exercise care to protect photos, but will not be responsible for damaged, lost or stolen photos.

Committee Members

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Journal Editor

Robert S. Campbell, Editor of the *Journal of Range Management,* has expressed to the Board of Directors his desire to relinquish this position after February, 1969. The Board, therefore, is actively soliciting applications for the Editor's post.

It is considered most desirable, although not absolutely essential, that a new Editor reside in the Denver area. The planning and production of the *Journal of Range Management* (as well as other Society publications) necessitate a close working arrangement between the Editor and the Executive Secretary. Office space and secretarial help are available at the Society's new headquarters location.

For the immediate future the editorship will not be a full-time job, and, therefore, may be satisfactorily handled by a person who is otherwise employed or who is retired.

If you know of anyone whom you believe would be interested and qualified for the position of Editor (or if you, yourself, are interested), please write to the Executive Secretary, ASRM, 2120 South Birch Street, Denver, Colorado 80222; or telephone (303) 756-3205. Detailed information regarding the requirements and qualifications for this position will be furnished by the Executive Secretary. Final selection of the new Editor will be made by the Board of Directors.

Regarding ASRM Committees

I see by the published list of committee chairmen in the May 1968 issue of the Journal that the committees are again filled almost exclusively by educators and researchers.

This is most disappointing to me because I have a feeling there are some good men among us unwashed peons.

The Advisory Council has either dropped the ball in supplying names to our President or the President has chosen to ignore the Advisory Council recommendations. In either case, this is a sad situation. Because, if we want a strong, worthwhile Society, each of us must feel he is doing his part for the organization. If it is to be run primarily by educators and researchers, I doubt that our range organization will move ahead as vigorously as it should.

D. W. "Coop" Cooper
Eureka, California

No one person can be aware of the talents of each of our members. For this reason one must depend on information furnished by others, and on the record of individuals' previous performance, in selecting committee chairmen. Experience indicates that even with this approach some chairmen fail to function. No doubt there are many reasons why this happens, but the result is that parts of the Society's program are delayed or, in some cases, even stopped. Hence, every effort must be made to fill the committee slots with people who *will* function.

From the time I became a director of the Society until the present, there has been a constant effort to balance—geographically as well as by agency or institution—both the elected and appointed workers in the Society.

In the final analysis, however, the principal criterion for selecting committeemen is the individual's willingness to function effectively as a committee member. Properly, after one is appointed to or accepts a job in the Society, he should, in the performance of such duties, shed his work-a-day role and function as a member of the Society for its benefit. I am of the opinion this has been the goal of the people I have been privileged to work with.

Donald A. Cox
President Elect, ASRM

Having been employed in action-on-the-ground until recently, I'm sympathetic to D. W. Cooper's questioning. It is true that most committee chairmanships are now held by researchers and educators. It is not correct that the committees are filled "almost exclusively" by men in these categories. The balance tilts strongly the other direction.

The establishment of 15 Sciential Committees, as described in the July issue (*JRM* 21(4):279, 1968), did result in appointment of a very high percentage of researchers and educators for, I think, good and obvious reasons. However, all Section presidents, as well as the Board of Directors were given opportunity to make changes.

On August 23, 1967, I wrote all Section presidents as follows:

> "You men are in the best possible position to help me in selecting knowledgeable and energetic committeemen for 1968. From experience you know men who *work* if

appointed; and, also, men who simply stymie committee action by not promptly answering letters.

"Some committees, like the Nominations Committee, should be established well before the Albuquerque meeting. Then they can actually meet together at Albuquerque to settle some matters that are difficult to handle by correspondence.

"Following is a list of committees and names of current members. Back of each name is a blank space. In these blank areas, please write either "retain" or the name of some member that you believe would be *as good* or better.

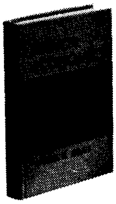
"You may wish to consult with other officers and present members of these committees in your section. Two extra committee lists are attached for this purpose. But, please don't take more than a *month* to send *one* consolidated mimeo list back to me with your suggestions.

"Many of you have worked in more than one section. You know members in all sections from previous society committee work and from national meetings. There is no objection to suggesting men outside your section. I'm hoping that the lists will show several sections suggesting the same man, particularly for certain chairmanships. This would assure me that you were thinking Society-wide, instead of Section-wide, for these Society-wide offices."

Responses to this letter were received from only 8 of 18 Sections. Very few suggestions for new chairmen were made. The suggestions received certainly were not ignored. Many men that were well recommended were appointed even though I did not know them or their work. The chairman of the very important Nominations Committee was unknown to me at the time, and his appointment was based entirely on recommendations. Even now, I am unable to provide an accurate percentage breakdown of chairmanships and other officers by type of employment because I do not know the work of all of the men.

I, too, had the feeling that the "Advisory Council . . . dropped the ball." Two revisions of the proposed committee lists were circulated after August 26—one on January 15 and the other on March 1. Response to these revised lists, from the Sections, was almost nil. I think the cause may have been the changing of Section officers at that time of year. Possibly many outgoing Section presidents do not promptly forward mail from the Society's president elect to the incoming Section officers. Names and addresses of new Section officers should henceforth promptly be sent to the president elect.

E. J. Dyksterhuis
President, ASRM



LAURENCE A. STODDART

July 17, 1909–July 17, 1968

The passing of Dr. Laurence A. Stoddart last July 17 in Logan, Utah was a cause for deep sadness throughout the range management community. A charter member of the American Society of Range Management, and its fifth president (1952), Laurie Stoddart epitomized the complete range scientist: he was, in all respects, Mr. Range Management. Throughout his professional career he was an influential leader in his field, and always enjoyed the well-deserved esteem—both personal and professional—of all who knew him.

Born in Trinidad, Colorado on July 17, 1909, Dr. Stoddart received his B.S. and M.S. degrees from Colorado State University. He subsequently studied under Dr. J. E. Weaver at the University of Nebraska, where he earned his Ph.D. degree in plant ecology in 1934. The following year Dr. Stoddart joined the staff of Utah State University as professor and head of the Department of Range Science.

Laurence A. Stoddart made a brilliant record as both scientist and teacher, being at the same time a true intellectual and a perfectionist. Students from all parts of the world came to learn from him. He was demanding in scholarship and performance, but also understanding and patient; his wise guidance and friendly counsel helped his many students to attain their goals. That there are today so many eminent range scientists and rangemen who received their early training from Stoddart is an outstanding tribute to his ability.

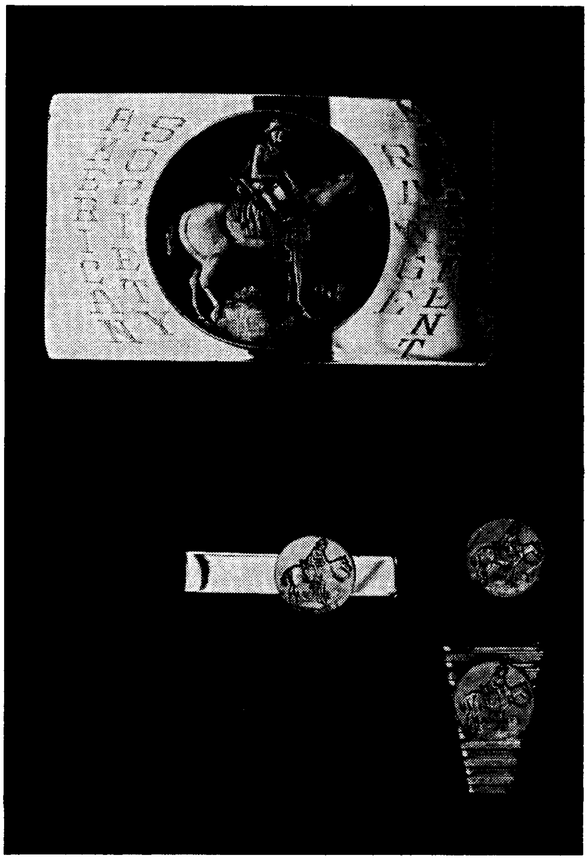
He also was recognized as an accomplished and prolific writer. He had hundreds of publications to his credit, while Stoddart and Smith's "Range Management" has been since 1943 the most authoritative and widely-used text in the field. He co-authored the manual "Technical Writing," which is not only an indispensable guide for scientific writers, but serves too as a reminder of his mastery and superb use of the English language.

Dr. Stoddart served as an officer of the Range Management Education Council. He was a member of the Range Research Committee of the National Academy of Science–National Research Council, and also held membership in the Ecological Society of America, the Society of American Foresters, American Society of Animal Science, American Society of Plant Physiologists, American Society of Agronomy, Xi Sigma Pi, Alpha Zeta, and Phi Kappa Phi.

But behind this distinguished career as scholar and scientist was the man himself—the Laurie Stoddart we all loved and admired. Tall and rangy, his physical presence was never unnoticed. But he was humble, possessed a realistic sense of values, and always gave more than he took. He stood firm for what he believed, yet approached the subject at hand with logic and without undue emotion. All were captives of his keen wit and his droll, subtle humor.

Laurie was an outdoorsman and a pragmatic—rather than a maudlin—lover of nature, stemming from a lifelong association with the out-of-doors, and a perceptive understanding of the forces of nature. An expert hunter and fisherman, he was always ready to assist the less experienced in these sports. Around the campfire, as elsewhere, Laurie was excellent company, talking easily and in depth on many subjects. He was a comfortable companion.

To Laurie Stoddart's family we express our deepest sympathy and condolences. To the memory of Dr. Stoddart we pay tribute and honor, and take both pride and joy in saying, "We knew him."



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