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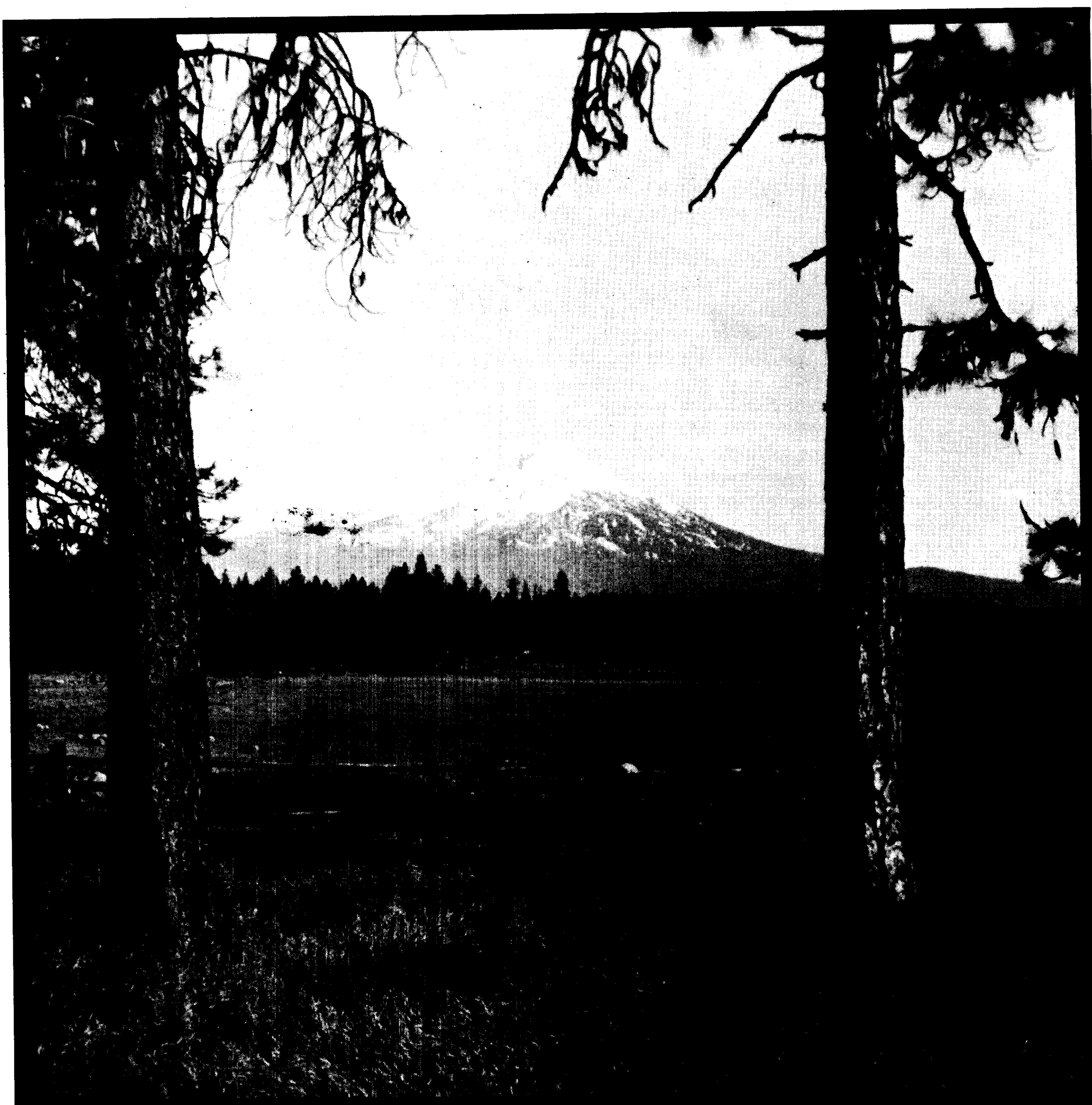
JOURNAL OF RANGE MANAGEMENT

SOCIETY FOR RANGE MANAGEMENT



November 1, 1974

Letter to the Membership of SRM:

The Society for Range Management is a growing society as is evidenced by the continued increase in membership. As the membership grows and the aggregate of expertises in the Society are recognized, there will be a greater demand from the Society and particularly from members within the Society to furnish information which will be used in the decision-making process locally, regionally, nationally, and internationally. The Society must be in a position to supply information and names of individuals who can represent the Society to meet these demands.

Having served the Society as a member of the Board of Directors and in other capacities, I know that the officers, directors, and staff of SRM are diligently trying to meet requests to the Society. In fact, many efforts are made to meet anticipated requests. The question I have often had is, "How well does the membership of SRM understand what is being done and the rationale behind that which is being done?" Some time ago several of us were discussing this point. The outcome of this discussion was to suggest to the Board of Directors that we attempt to clarify some of the most frequently asked questions at the next business meeting of SRM membership. The officers and board members felt that the business meeting in Mexico City would provide an excellent opportunity to initiate this effort.

The membership of SRM are invited to submit questions to me which will then be compiled into groupings and listed by frequency. After they have been compiled, the questions most frequently asked will be assigned to various officers and board members, who will then develop in-depth answers to these questions to be presented at the business meeting. Other parts of the business meeting will be reduced accordingly.

Your questions should be stated clearly and concisely so they will not be misunderstood. This is your Society and you have an obligation to question that which you do not understand because others may not understand it either. Let us have your questions mailed to the following address:

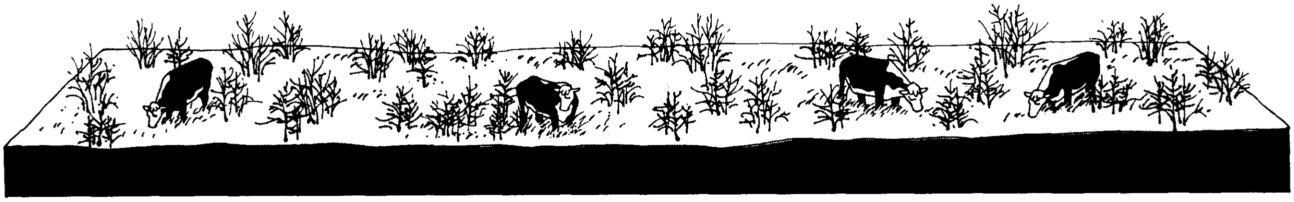
C. L. Leinweber
F. E. Box 119
Texas A&M University
College Station, Texas 77843

Please return questions by January 3, 1975.

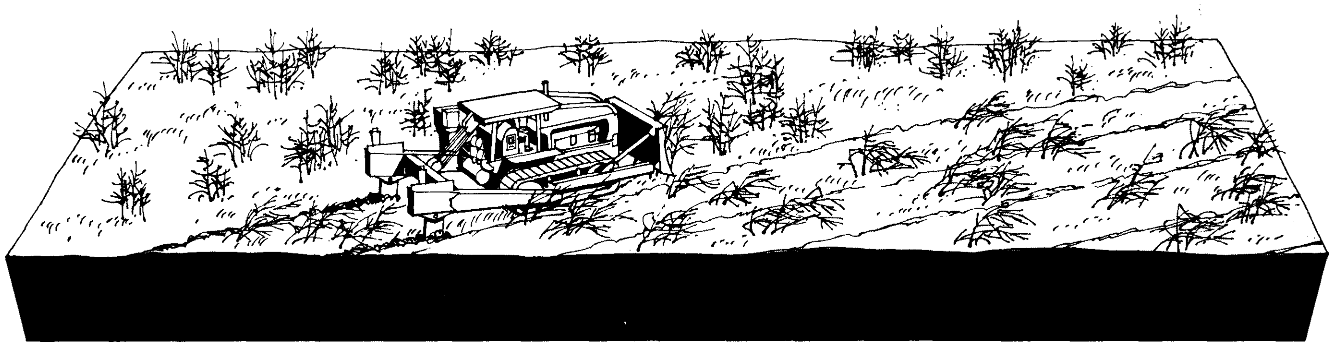
Your 1975 Program Chairman

C. L. Leinweber

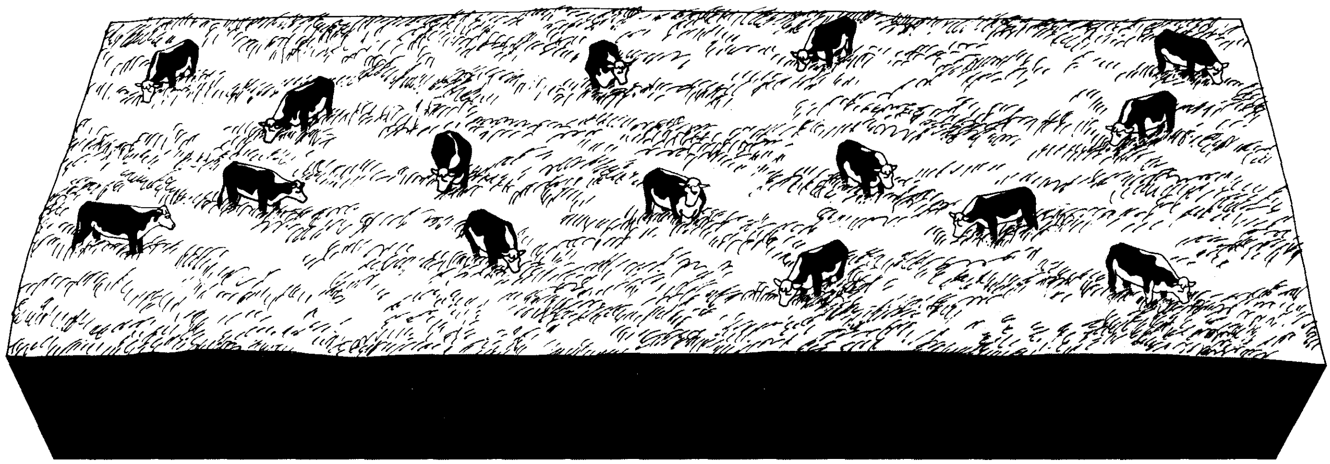
How to make your rangeland greener...



Tear out the brush and reseed. Any stuff growing on your land that won't put weight on a cow is costing you money. And a fast, efficient way of dealing with it is rootplowing. A track-type tractor equipped with a rootplow cuts off the tap roots of the brush below ground to give you an effective kill. It breaks up hoofpan for better water retention, less run-off and a better seed-bed. And it can simultaneously reseed your range as it plows.



Call the land improvement contractor who has Caterpillar equipment. Ask him to look over your range and give you an estimate on what it'll cost to turn your brush into edible grass. You'll find that, because of the efficiency of his Caterpillar equipment, he can keep the lid on costs.



Mechanical brush control can pay for itself. Because you'll be able to graze more cows on your rangeland and their weight gain rates are usually much higher. With your land improvement contractor's methods of mechanical brush control, it won't take long to turn your brushland into grassland.

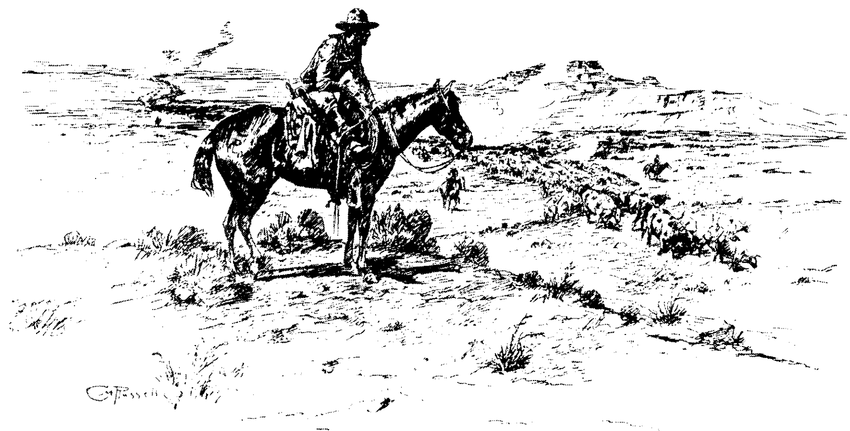
And boost your profits!

Land investment today builds tomorrow's profits.

CATERPILLAR

SOCIETY FOR RANGE MANAGEMENT

The term of office of all elected officers and directors begins in February of each year during the Society's annual meeting.



THE TRAIL BOSS

The **Society for Range Management**, founded in 1948 as the *American Society of Range Management*, is a nonprofit association incorporated under the laws of the State of Wyoming. It is recognized exempt from Federal income tax, as a scientific and educational organization, under the provisions of Section 501(c)(3) of the Internal Revenue Code, and also is classed as a public foundation as described in Section 509(a)(2) of the Code. The name of the Society was changed in 1971 by amendment of the Articles of Incorporation.

The objectives for which the corporation is established are:

–to develop an understanding of range ecosystems and of the principles applicable to the management of range resources.

–to assist all who work with range resources to keep abreast of new findings and techniques in the science and art of range management;

–to improve the effectiveness of range management to obtain from range resources the products and values necessary for man's welfare;

–to create a public appreciation of the economic and social benefits to be obtained from the range environment; and

–to promote professional development of its members.

Membership in the Society for Range Management is open to anyone engaged in or interested in any aspect of the study, management, or use of rangelands. Please contact the Executive Secretary for details.

The Journal of Range Management serves as a forum for the presentation and discussion of facts, ideas, and philosophies pertaining to the study, management, and use of rangelands and their several resources. Accordingly, all material published herein is signed and reflects the individual views of the authors and is not necessarily an official position of the Society. Manuscripts from any source–nonmembers as well as members–are welcome and will be given every consideration by the editors. Submissions need not be of a technical nature, but should be germane to the broad field of range management. Editorial comment by an individual is also welcome and, subject to acceptance by the editor, will be published as a "Viewpoint."

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INSTRUCTIONS FOR AUTHORS appear each year in the March issue; copies of these instructions are available from the editor.

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COVER: Rancheria Meadow, headquarters for the summer livestock operations of the Stanley Ranch (see article by Gordon Stanley, page 485). Soil Conservation Service photo.

Returns to Rangelands

W. GORDON KEARL

Highlight: *Gross value of production from western rangelands average$7.46 per AUM based upon aggregate data from Wyoming, Utah, Nevada, and Oregon for 1966-70 and reached about $10 per AUM in 1972. Privately owned lands leased on an acreage basis but with the lease expressed on an AUM basis generally leased at $1.50 to $2 per AUM during 1966-70 and a little over $2 per AUM in 1972. Returns to rangeland estimated from published research by a real estate appraisal approach in which returns are imputed from an income statement were comparable to the lease rates. The imputational procedures in arriving at returns to land and the definition of an AUM should both be standardized for better comparisons among diverse areas or ranching types where animal-size and herd composition vary.*

Gross value of production of rangelands and other associated types of land is significant from the standpoint of society or the economy of an area. It can best be measured by gross receipts adjusted for changes in inventory. It is basic income brought into the local economy as a result of ranching. It is spent and respent within the economy, producing activity which as been estimated conservatively at 2.25 to 3.0 times the actual cash received (Clark, et al., 1972; Osborn and McCray, 1972). It must be carefully distinguished from returns to land, which represents a fair lease from the standpoint of landlord or tenant and is relevant from the standpoint of individual land users and managers.

A third measure, net ranch income is the return to a ranch operator for his labor, management, and use of his capital. It is determined by deducting production expenses, including depreciation from gross value of production. This measure is relevant to individual ranch operators but must be carefully distinguished from either value of production or return to land.

Net ranch incomes and return to capital published in eleven different studies dated from 1926 through 1968 giving the results for 27 different particular situations have been summarized (Agee, 1972). A number of other studies since 1968 showing net returns may also be of interest (Goodsell, 1971, 1972; Goodsell and Belfield, 1972, 1973a, 1973b; Gray et al., 1969, 1970, 1971; Kearl, 1972; Stevens, 1971).

Some of these studies will be used in an elaboration of gross value of production and returns to land, which is the major purpose of this paper.

Gross Value of Production

Determination of gross value of production attributable to range or ranchlands, or returns to those factors, is complicated because the yearly production cycle often uses public and private rangelands of differing qualities and also uses croplands and harvested feeds. Published statistics combine value of beef produced from both dairy and beef animals and from rangelands and feedlots or farm lands. Wyoming, Utah, Nevada, and Oregon, are lowest in production from feedlots and the value of beef production from the dairy herds of the public land states in the West.

For purposes of further comparisons, an animal-month (A.M.) will be defined as the monthly forage requirement for five sheep or for cattle over six months of age, without regard to size. Gross value of production per A.M. was $6.31 for the 1966-70 price levels and $9.77 at 1972 price levels, which may represent a reasonable outlook for the longer-term future (Table 1). Variations among the four states are within the range of approximately plus or minus 10% of the four-state average.

Value of production and A.M.'s for cattle on feed or dairy breeds being grown out for beef have been included. Value of production is exaggerated slightly in relation to A.M.'s due to sale of cull dairy stock without corresponding allowance for animal months.

Table 1. Gross value of production from cattle and calves 1966-70 averages, and 1972.

Item	Gross value of production		
	Total	Per A.M.	Per AUM
1966-70 averages			
State aggregate data[1]			
Wyoming	$119,184,000	$ 6.83	$ 7.68
Utah	59,407,000	5.89	7.52
Nevada	43,692,000	5.85	6.43
Oregon	126,564,000	6.24	7.64
4-States	348,847,000	6.31	7.46
Costs and returns[2]			
Northern Plains	$ 41,763	$ 7.48	$ 8.24
Northwest mountains	42,941	8.71	9.05
Southwest[3]	34,913	7.42	7.58
University of Wyoming[4]	45,739	6.86	7.61
1972			
State aggregate data[1]			
Wyoming	$206,240,000	$10.98	$12.02
Utah	84,302,000	9.03	9.84
Nevada	73,556,000	9.15	9.55
Oregon	163,585,000	9.18	10.07
4-States	527,683,000	9.77	10.62
Costs and returns[2]			
Northern plains	$ 69,460	$11.76	$13.10
Northern Rockies	71,105	13.62	14.35
University of Wyoming[4]	67,936	10.19	11.30

Derived from the following sources:
[1] Annual Supplements to "Livestock and Meat Statistics, 1962." Stat. Bull. No. 333, A.M.S., S.R.S., and E.R.S., U.S. Dep. Agr.
[2] (Goodsell, 1971, 1972) (Goodsell and Belfield, 1973b) (Gray, Goodsell, and Belfield, 1969, 1970, 1971).
[3] 1965-70 averages.
[4] (Kearl, 1972).

Author is professor of agricultural economics, Department of Agricultural Economics, University of Wyoming, Laramie.

Manuscript received February 23, 1974.

Costs and returns studies of the U.S. Department of Agriculture can also give some useful indications of gross value of production from ranch and rangelands. Those studies indicate values ranging from $7.42 to $8.71 per A.M. at 1966-70 average prices, and considerably higher at 1972 prices, depending upon the area. It should be noted that these studies represent typical commercial ranch operations, rather than averages.

A study from the University of Wyoming indicates a gross value of production of $6.86 for the 1966-70 averages and $10.19 per A.M. at 1972 prices. These returns are reasonably consistent with state aggregate data but do not correspond closely with the costs and returns studies of the U.S. Department of Agriculture.

Coefficients for an animal-unit-month (AUM) related to basal metabolic requirements can be derived from the formula

$$AU = \frac{W^{.75}}{1{,}000^{.75}}$$

W is the average monthly weights of the animal in question; the denominator represents the weight of a mature cow in pounds and puts the AUM coefficients in relation to the maintenance requirements of a 1,000-lb cow. Average weight, AUM coefficients, months in inventory, and AUM's for annual use for various classes and weights of livestock are shown in Table 2. These coefficients were used to estimate AUM's more accurately than perhaps was done with the administrative basis for calculating A.M.'s used previously. AUM coefficients derived by this method have been found to be proportional to requirements for both maintenance and gain derived using net energy methods (Kearl, 1970). Calculated AUM's are slightly less than A.M.'s, and consequently returns per AUM are slightly higher.

Returns to Range and Ranchlands

Returns to rangeland may be indicated by lease rates on rented lands or returns imputed from an income statement or appraisal approach. These two methods are easily and universally applied to the type of data commonly available and are recommended on that basis. The imputation procedure has been subject to criticism by economists on theoretical and other bases. Shadow prices from mathematical programming or marginal value productivities from a production function approach are more acceptable from a theoretical point of view. However, there are other drawbacks to these approaches, primarily related to data requirements and costs.

Based on the imputation process, return to rangeland would be determined by deducting from net ranch income allowances for the non-land inputs including operators' labor, management, and capital invested in livestock and machinery. Obviously, return to rangeland would be much lower than net ranch income, which in turn must be much lower than gross value of production.

Frequently mentioned lease rates of $3.50 to $5.00 or more per animal month, per AUM, or per cow-calf pair for a month probably cannot be justified for the entire livestock complement on a year-long basis on typical ranches under price and cost conditions prevailing in the past few years. Pasture costs at those levels may be found: (1) under drought conditions; (2) where a ranch operator has a few more cattle than he can carry due to slight drought or over-large inventory and leases pasture for part of his cattle; or, (3) for yearling steers, but even then such lease rates are questionable from the standpoint of economics and from the leasee's point of view.

It should be noted that under pasture leases on head-month basis, the leasor usually takes care of all maintenance of improvements, does herding and moving, and looks after water and salting. Thus, considerably more than just the products of the land (forage) are provided by the leasor.

Public Land Studies

A study of effects of changes in fee levels or permitted use of National Forest or BLM lands was made in 1961-62. At that time, based upon data from about 100 ranch schedules, 90 to 95% of all privately owned grazing leased in Wyoming was leased on a per-acre basis. Rentals on a per-acre basis converted to costs per AUM were far below the commonly quoted head-month rentals. In fact, many of those leases were in the range of $1.25 to $1.75 per AUM (Kearl, 1962).

The U.S. Forest Service and Bureau of Land Management sponsored a second study of costs of using privately owned and public lands in 1966. About 14,000 personal interviews were made throughout the western states and information was obtained on 4,271 private leases. The average cost of private leases to Forest Service permittees throughout the study at that time was estimated at $1.86 per A.M. for cattle permittees and $1.64 for sheep permittees (Table 3). Private lease rates paid by BLM permittees in several states are summarized in Table 3. The relatively low lease rates for sheep permittees in Wyoming probably includes much "checkerboard" land of the Union Pacific Railroad in southern Wyoming sheep winter range area. Other analyses to be developed later indicate lower returns on winter than on other seasonal ranges (Table 4). It is likely that lack of alternatives to sheep use also depresses the rentals.

Although this study is two years earlier than the mid-point of 1966-70 average gross value of production data presented previously, comparisons are interesting.

Table 2. Animal-unit-month coefficients and annual requirements per head for various average weights of livestock.

Class of stock[1]	Average weight[2] (lb)	AUM coeff.	Months required	AUM's required
Cows 2+	1,000	1.00	12	12
Heifers 1–2	780	.83	12	10
Weaned calves	505	.60	10	6
Calves-birth to weaning	230	.33	6	2
Steers 1–2	780	.83	12	10
Bulls	1,345	1.25	12	15
Cattle on feed		1.50	6	9

[1] Numbers indicate age attained January 1.

[2] Beginning and ending weights which could produce these average weights include: nursing calves, 75-385 lb; weaned calves, 385-625 lb.

AUM Rental Rates Derived from Published Research

Studies reflecting 1966-70 cost and price levels also have been used to gain some insight into earning capacity per AUM for range and ranchlands (Table 3). Weighted average returns per AUM for 5,800 AUM's of carrying capacity on the Northern Plains cattle ranch amount to $1.60. This is consistent with those indicated previously from the 1961-62 and the 1966 U.S. Forest Service-BLM fee studies.

Studies on sheep ranching in Wyoming, based on the 1968 year and representing the 1966-70 cost and price averages also show returns to land consistent with other determinations indicated previously (Stevens, 1971).

Table 3. Summary of returns per animal-month (A.M.) or animal-unit-month (AUM) to rangelands and ranchlands.

Study	Returns per A.M.[1]	AUM
Public land studies (1966)[2]		
U.S. Forest Service		
All states, cattle, and sheep	$1.82	
Cattle	1.86	
Sheep	1.64	
Bureau of Land Management		
Montana, cattle and sheep	$1.89	
Colorado, cattle and sheep	1.77	
Idaho, cattle and sheep	1.76	
Utah, cattle and sheep	1.40	
Wyoming, sheep only	1.18	
Published research		
Northeast Wyoming cattle ranches (1966-70)[3]	$1.44	$1.60
Wyoming sheep ranches (1968)[4]		
North-central	$1.95	$1.67
Northeast	2.04	1.79
Southwest	1.76	1.56
State	1.88	1.64
Costs and returns studies (1966-70)[5]		
Northern plains cattle	$1.36	$1.50
Northern Rocky Mountain cattle	2.01	2.10
Intermountain sheep	1.52	

[1] Per animal-month for cattle over 6 months of age or per five sheep months.
Derived from the following sources:
[2] Lester Hoffman, Unpublished data, U.S. Dept. of Agriculture, Cheyenne, Wyoming.
[3] (Kearl, 1972).
[4] (Stevens, 1971).
[5] (Goodsell, 1971, 1972) (Goodsell and Belfield, 1972).

Returns to land based on cost and returns studies and summarized in Table 3 are also consistent with other information.

The ranches reported in these studies, whether U.S. Department of Agriculture or University of Wyoming cattle or sheep ranches, are all large enough to take advantage of most economies of size.

A study was initiated in 1972 to determine net rental returns on privately owned land in Wyoming (Table 4). A mail survey was used to collect basic data. There were 135 usable responses from ranch operations which made use of a considerable amount of leased rangeland, and 12 responses from complete leased ranch operations. AUM's were calculated using coefficients based on estimated weights of animals for various seasons of use.

Gross rent is the average of total cash rent reported paid by respondents. Landlord's cash expenses, except property taxes, and an allowance of 10% of current value of buildings to account for depreciation, repairs, and insurance were entered as costs to the landlord and deducted from gross rent to determine return to taxes and land, including buildings. A percentage of return on current value of buildings equal to percentage return on land was determined and deducted to arrive at return to land and taxes only. The return to land and taxes in this case differs from returns to land derived from the published research, but is probably comparable to the rental costs obtained from the 1966 public land study.

Return to land and taxes for all seasons of use was $2.28 and $2.38 per AUM for cattle ranges in western and eastern Wyoming, and $1.71 for the reasonaly well-balanced year-long uses on the complete leased ranch operations.

A regression analysis was used to estimate the net rental return to the landlord as a function of season of use of rented lands. The function was $\mathbf{NR = b_1 SS + b_2 F + b_3 W + b_4 H}$. The variables were: **NR**, total net returns to land and taxes, as defined above; **SS**, total AUM's of spring and summer use; **F**, total AUM's of fall use; **W**, total AUM's of winter use; **H**, AUM equivalents produced by hay. Each separate lease constituted one observation for this analysis. The $\mathbf{b_i}$ coefficients represent the return to land and taxes for each AUM of a particular seasonal use and are also summarized in Table 4.

The number of observations and acreages involved are sufficient to represent a good sample for western or eastern Wyoming. Most land was leased as marginal additions to an operating ranch unit. The returns are generally lower for fall and winter range than for spring-summer range. The returns are higher but still consistent with those shown previously. Since prices were higher in 1971 and 1972 than for 1966 or the 1966-70 averages, higher leases would be expected.

Table 4. Summary of returns to land and taxes for Wyoming cattle range and ranchlands.

Item	Cattle ranches Western	Eastern	Range and hayland
Number of observations	46	89	12
Average acres leased			
Rangeland	1,951	3,203	4,263
Hayland	–	17	202
Average production			
AUM's	863	1,264	1,182
Hay (tons)	–	11	181
Returns per AUM			
Weighted average	$2.28	$2.38	$1.71
Seasonal coefficient[1]			
Spring-summer	2.26**	2.99**	2.01*
Fall	2.56**	1.58**	–
Winter	1.71**	1.53**	–
Fall and winter	–	–	1.35*
Hayland	–	.45	1.74*

* Statistically significant, $P < .05$.
**Statistically significant, $P < .005$.
[1] Return to land and taxes derived from regression analysis.

Variations in returns to rangeland based upon costs and returns studies from 1960 through 1972 are summarized in Table 5. Returns were low in 1960, 1961, 1964 and 1965 due to low prices and drouth problems in some areas. The up-trend in prices for cattle for 1965 through 1972 is reflected in the rather strong increases in returns to land through those years. Prices for sheep and lambs and returns to range and ranchlands for the Intermountain Sheep Area kept pace with those for the cattle ranches up to about 1970. Prices for wool and lambs and sheep failed to keep pace in 1970 and 1971 with the advancing prices for cattle.

Returns to rangelands reached extremely high levels for the cattle ranches in 1972 as prices achieved high levels and costs were still lagging and increasing only gradually.

Summary and Conslusions

Gross value of production from rangelands and ranchlands is of particular concern to individual ranch operators, communities, and society, particularly in areas highly dependent on agriculture and upon the use of range and ranchlands. Gross value of production has been less than generally believed through the time periods perior to 1971, averaging $7.46 per

Table 5. Variations in returns ($/AUM) to rangelands and ranchlands based on costs and returns studies.

Year	Cattle ranches: Northern Plains	Cattle ranches: Northern Rocky Mountains	Intermountain sheep
1960	.34	.23	–.12
1961	.05	.75	–.28
1962	1.24	1.61	.84
1963	.84	1.33	.35
1964	–.01	.10	.57
1965	.19	.73	1.01
1966	.83	1.44	.93
1967	.95	1.43	1.57
1968	1.18	1.85	1.64
1969	1.72	2.81	2.09
1970	2.11	2.51	1.49
1971	2.61	3.08	1.19
1972	4.52	5.47	.89

Derived from the following sources:
(Goodsell, 1971, 1972) Goodsell and Belfield, 1972, 1973a, 1973b).

AUM based upon aggregate data from Wyoming, Utah, Nevada, and Oregon for 1966-70. Gross value of production reached $10 per AUM levels in 1972 when prices were higher.

Lease rates of $3.50 to $5.00 per AUM or more are commonly quoted as prevailing returns to rangelands. However, privately owned lands leased on an acreage basis but with the lease converted and expressed on an AUM basis generally leased at $1.50 to $2.00 per AUM during 1966-70, and a little over $2.00 per AUM in 1972.

Most of the actual production of value occurs in the spring-summer-fall period when green forage is available. Nevertheless, animals must be maintained through the winter time period, using hay or winter range in some fixed proportion to the summer use. The animal unit must generate enough production and value during the period of a year when both forage and animals make most of their growth and operating costs are lowest, and then part of that value must sustain the animals when forages are in their dormancy, supplemental feeding may be required, and operating costs are high.

Return to land may be determined by marginal value productivities from mathematical programming or production function techniques. Those approaches would be preferred for accurately determining returns to specific types of ranching or range types. Land rental rates (a market approach) or imputation procedures similar to those used by an appraiser using an income approach could also be used. These approaches, particularly the appraisal imputation procedures, can be used to give "ball-park" estimates of aggregate or average values for larger areas or more generalized types of ranching and range conditions. Although the data sources used in this paper have some limitations, they are thought adequate to provide such "ball-park" estimates to indicate levels and trends in returns to rangelands.

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Effect of Fire on Southern Mixed Prairie Grasses

HENRY A. WRIGHT

Highlight: *The long-term effect of fire was studied on the major grass species of west Texas when the winter-spring precipitation was 0 to 40% above normal. This and other studies indicate that sideoats grama and Texas wintergrass are harmed by fire. Buffalograss, blue grama, and sand dropseed were neither harmed nor benefited by fire. Vine-mesquite, Arizona cottontop, little bluestem, plains bristlegrass, and Texas cupgrass increased after burning for 1 or 2 years.*

Most data that we have on mixed prairie grasses following fire is either short-term or was taken following wildfires during drought years. We lack data on the long-term effects of fire during normal to wet years, when prescribed burning would be recommended. Moreover, for several species, we don't have any information as to how they respond to fire. This study was designed to collect data for several years on major grass species in west Texas, where prescribed burning might be recommended during years with normal to above normal winter and spring precipitation.

In the shortgrass prairie of Kansas, Launchbaugh (1964) found that the recovery time for a buffalograss (*Buchloe dactyloides*)-blue grama (*Bouteloua gracilis*) mixture, following a spring wildfire when the soil was extremely dry, took three growing seasons. The mixture recovered 36, 62, and 97% following the first, second, and third growing seasons respectively. Hopkins et al. (1948) and Dix (1960) reported similar results following spring burning in west-central Kansas and western North Dakota, respectively. Following another wildfire in New Mexico, Dwyer and Pieper (1967) found that production of blue grama was reduced 30% the first year. With above average precipitation the second year after burning, recovery was 97% of normal. Other studies on blue grama by Trlica and Schuster (1969) and on buffalograss by Heirman and Wright (1973) indicated that neither species was harmed by fire during years with average to above average precipitation.

Yield of sideoats grama (*Bouteloua curtipendula*) was reduced 51% by burning during a drought year, but only 12% during a wet year (Wink and Wright, 1973). Hopkins et al. (1948) found that a spring wildfire reduced the basal area of sideoats grama by 9 to 50%. In another study on bluestem ranges the basal cover of sideoats grama remained remarkably stable over a 10-year burning period (Anderson et al., 1970).

Little bluestem (*Schizachyrium scoparium*) decreased as much as 42%, if burned during dry years, and increased as much as 81%, if burned during wet years (Wink and Wright, 1973). Hopkins et al. (1948) found that little bluestem can decrease as much as 58% during dry years. Generally, however, it increases following prescribed burning (Aldous, 1934; Penfound and Kelting, 1950; Kucera and Ehrenreich, 1962; Anderson et al., 1970), unless it is burned too early or too late in the growing season or when soil moisture is low at the time of burning (McMurphy and Anderson, 1965; Owensby and Anderson, 1967; Box and White, 1969).

The long-term effect of fire on tobosa grass (*Hilaria mutica*) was reported by Wright (1972). During normal to wet years, tobosa produces two to three times more herbage after burning than the controls. By contrast, during dry years, it produces slightly less than the control. It is well adapted to fire and produces more than unburned tobosa for 3 to 4 years after a burn.

As long as moisture is adequate, vine-mesquite (*Panicum obtusum*) and meadow dropseed (*Sporobolus asper* var. *hookeri*) thrive after fire (Box et al., 1967; Wink and Wright, 1973). Tall grama (*Bouteloua pectinata*) also does well after burning during wet years, but declines as much as 60% during dry years (Wink and Wright, 1973). As indicated by changes in basal diameter, sand dropseed (*Sporobolus cryptandrus*) and red threeawn (*Aristida longiseta*) are generally harmed by fire (Trlica and Schuster, 1969). Dwyer and Pieper (1967) also found sand dropseed to be harmed by fire. Other species that they found to be harmed by fire included slimstem muhly (*Muhlenbergia filiculmis*), ring muhly (*M. torreyi*), wolftail (*Lycurus phleoides*), and galleta (*Hilaria jamesii*). However, this latter data is based on a wildfire during a year when precipitation was below average. Spring burns severely harm Texas wintergrass (Dahl and Goen, 1973), which is not surprising since it is a cool season perennial.

On the High Plains, tumble windmill grass (*Schedonnardus paniculatus*) was not harmed by fire (Trlica and Schuster, 1969). Arizona cottontop (*Digitaria californica*) was harmed by fire during dry years, but not during years when the fire was

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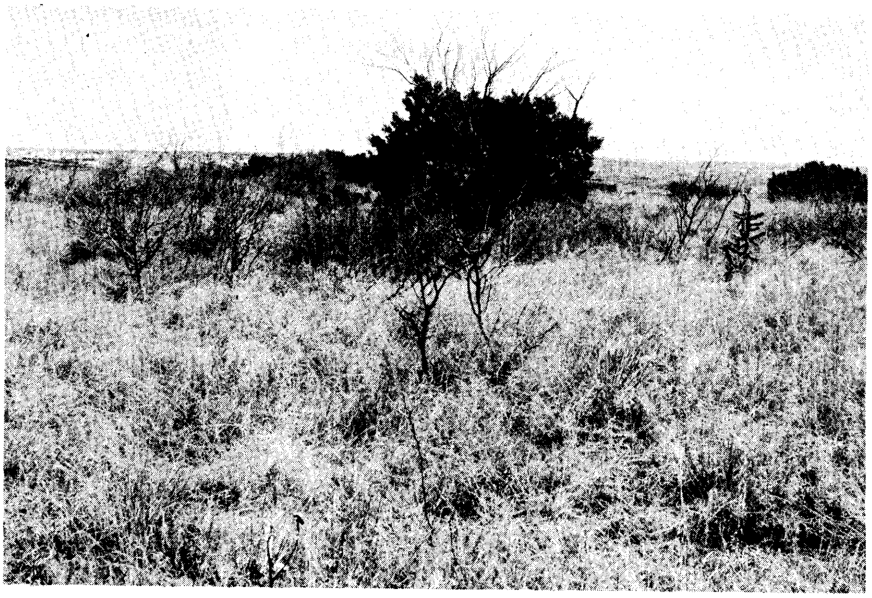

Fig. 1. *A variety of grass species existed in each study area. Only pure stands of grass species were sampled.*

followed by favorable moisture (Cable, 1967).

Methods

During years with average to above-average precipitation, yields of pure stands of the major grasses in west Texas were measured on burned and unburned paired plots for 2 to 4 years after a burn. Data were taken at various locations on the High and Rolling Plains of Texas, including Lubbock, Post, Guthrie, Colorado City, and Baird. Annual precipitation is 19 to 20 inches at all study sites except the one near Baird, which is 26 to 28 inches. Half of this precipitation falls during the winter-spring period. Elevation varies from 1,620 to 3,200 ft.

Plots were burned in late winter or early spring from March 15 to April 7, 1968, 1970, or 1972, when winter precipitation had been normal or above normal. Size of plots varied from 1 to 90 acres and were protected from grazing until the end of the study. A variety of grass species existed in each area with a few forbs which were considered insignificant on the sampling sites (Fig. 1).

Ten quadrats (2.4 ft^2) were clipped to sample current growth, and dead plant material (litter) on burned or unburned plots at each location. Vegetation at all sample locations was clipped in late July. Samples were oven dried and weighed.

Results and Discussion

During the years of the burns (1968, 1970, and 1972), winter-spring precipitation was 0 to 40% above normal on all sites. It was 40% above normal in 1968 and 1969, 5% above normal in 1970, 5 to 45% below normal in 1971, and normal in 1972 and 1973.

Buffalograss was burned at three locations in 1968 and at one location in 1972. The yields fluctuated somewhat from year to year, depending on precipitation, but they were similar on burned and unburned areas at all four locations. The data is summarized in Table 1.

Blue grama responded similarly to buffalograss (Table 1) for the one location at Lubbock in which it was studied. Data from both species is in direct contrast to that of Launchbaugh's (1964) and illustrates the difference in response of these species to a dry year vs a wet year. These species are not benefited by any kind of fire, nor are they harmed if burned following a winter-spring period with above-normal precipitation.

Sideoats grama (Table 1), the rhizomatous form (predominant form in west Texas), is always harmed by fire. During exceptionally wet years, it tolerates fire reasonably well (Wink and Wright, 1973), but it never benefits from fire. The data for this study were collected near Guthrie,

Table 1. Yields (lb/acre) of several grass species in west Texas on burned (burned in the spring of the first year listed) and unburned sites following fires when winter and spring precipitation was 0 to 40% above normal.

Species and year after burn	Burned: Current growth	Burned: Litter	Unburned: Current growth	Unburned: Litter
Buffalograss				
1968	1686	–[3]	1494	728
1969	2063	306	1928	458
1970	1398	1572	1330	906
Blue grama				
1970	1680	–[3]	1429	2474
1971[1]	1369	699	1247	2584
1972	2142	1750	1754	1932
Sideoats				
1968	1854*	–[3]	2978	–[3]
1969	1841*	1052	3350	3271
1970	1120	2651	897	5571
1971[2]	748	1088	789	1933
Sand dropseed				
1968	2243	–[3]	2149	–[3]
1969	2543	2984	2557	4273
1970	2748	3020	2328	4128
Arizona cottontop				
1968	5152*	–[3]	2024	–[3]
1969	2649	2523	2694	4128
1970	456	4770	466	2326
Little bluestem				
1972	2518*	–[3]	1289	3560
1973	1240	1760	1216	2808

[1] Precipitation was 6% below normal.
[2] Precipitation was 45% below normal.
[3] Litter data was not taken.
[4] Different from the control (unburned) at the .05 level of significance.

Table 2. Yields (lb/acre) of vine-mesquite at two locations on burned and unburned sites following fires when winter and spring precipitation was 5 to 49% above normal.

Location and year after burn	Burned		Unburned	
	Current growth	Litter	Current growth	Litter
Colorado City				
1968	4272*	–[1]	708	–[1]
1969	659*	3936	78	3587
1970	790	3874	623	1638
Post				
1968	2527*	–[1]	1524	–[1]
1969	2742*	2385	1324	2794
1970	3368	4452	3496	5952

[1] Litter data was not taken.
*Different from the control (unburned) at the .05 level of significance.

Texas, and the first 2 years were relatively wet years with precipitation about 40% above normal. Even with good moisture, vegetative yields were reduced 40 to 45% for the first 2 years after burning. Thus, fire should not be recommended as a range improvement tool where the rhizomatous form of sideoats grama is a dominant species of the vegetation.

Sand dropseed showed no harmful effects from fire during a series of wet years. This is in contrast to data by Dwyer and Pieper (1967) and Trlica and Schuster (1969), who indicated that fire was harmful to sand dropseed. Since it is a bunchgrass, some harm might be expected if the plants are large. However, during this series of wet years at one location near Post, Texas, the small and medium-sized plants were not harmed by fire, nor were they benefited.

Arizona cottontop was studied at Colorado City, Texas, and observed at several other locations. In all cases it responded positively to fire for at least 1 year. On most sites we didn't know the species was so prevalent until the areas were burned. Seed production was very prolific on this species after being burned.

With average winter and spring precipitation in a 26- to 28-inch precipitation zone near Baird, Texas, little bluestem doubled in production the first year after burning and then reached equilibrium during the second growing season. Unless precipitation is below normal, little bluestem always seems to do well after a fire.

Vine-mesquite thrives after burning and produced more herbage than the controls for 2 years after a fire (Table 2). In addition, it produces many long stolens that spread and occupy new areas after a burn. It appears to be a true fire species, provided it is not subjected to heavy grazing immediately after burning.

Based on observations, plains bristlegrass (*Setaria leucopila*) and Texas cupgrass (*Eriochloa sericea*) do well after fire during wet years. Observations of the bunchgrass form of sideoats grama indicate that it also thrives after fire.

Conclusions and Management Implications

Winter-spring precipitation is the key to a successful prescribed burn. If precipitation is above normal, this and other studies indicate that sideoats grama and Texas wintergrass are the primary perennial grasses that will be harmed by fire in west Texas, and it will take at least 2 years for these species to fully recover. Buffalograss, blue grama, and sand dropseed are neither favored nor harmed by fire. Species that seem to thrive for one to three growing seasons after a fire include Arizona cottontop, little bluestem, vine-mesquite, tobosa, plains bristlegrass, and Texas cupgrass. Generally, these are the species that accumulate the most litter.

Except for tobosa grass, all of these species should be allowed adequate time for recovery before they are grazed. With normal to above normal precipitation, this means a 3- to 4-month rest period after burning. During drouth years the rest period will have to be longer, although we have never had to rest a pasture for longer than 7 months. Since tobosa grass is so coarse, it should be grazed within a few weeks after new growth begins on a burn. Otherwise, cattle will not eat it.

Burning should always be done on a manageable unit basis. If only a portion of a pasture is burned, animals will concentrate on the burn, no matter how long it has been rested. This is generally because burned plants are slightly more nutritious and there is no litter in the plants.

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Effect of Burning and Mowing on Composition of Pineland Threeawn

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Highlight: *The object of the experiment was to determine the effect of burning and mowing treatments on the composition of Pineland threeawn (*Aristida stricta *Michx) over a 5-year period. Treatments were control; burning annually; burning in alternate years; and mowing annually and in alternate years both with clippings removed or left on. Annual treatment dates varied from February 20 to March 6. Threeawn samples were analyzed for protein, ether extract, fiber, ash, calcium, magnesium, and phosphorus (P). The grass from all treatments improved in nutritional quality from March to June and decreased from July to the following March. There was a highly significant difference among collection dates in level of all seven nutritional factors, indicating strong seasonal trends. Effect on new growth was greater for protein than for the other factors. Samples collected from all plots 35 days after treatment averaged 5.9% protein, while grass collected 289 days after treatment had 3.8% protein, a reduction of 36%. Forage from threeawn plots either mowed or burned was higher in protein and lower in fiber and P than the control with no differences between the burned or mowed plots. Grass growth after burning approached the recommended minimum protein level for a nursing cow in only a few instances. Ash was lower in grass from the control than from the treated plots. Burning increased P compared to mowing. Threeawn from all treatments lacked sufficient P for good cattle production.*

Pineland threeawn (*Aristida stricta* Michx) (threeawn) commonly known as wiregrass, was the most common grass species on the unimproved flatwoods of central and south Florida in the 1940 decade and provided much of the forage for free-roaming range herds. The usual pasture management practice was the uncontrolled burning of different sections of a native range during the November to March period. The new growth for several weeks after burning was sparse but provided nutritious and palatable forage and all cattle responded with improved production if the range was not too heavily stocked.

Since 1940 there has been a yearly increase in the establishment of improved grass pastures, thus native forage plays a reduced role in providing grazing for the rapidly expanding beef herds. The Institute of Food and Agricultural Sciences (1965), however, estimated there were over 2 million hectares (ha) of unimproved pasture, much of it in central and south Florda. Cattlemen use the combination of native range and highly developed pastures to provide year-round grazing. Native range frequently is reserved for grade cows after their calves are weaned until they freshen again 4 to 5 months later. By this method some improved pastures can be rested and others can be renovated or used to grow a crop of hay for supplemental winter feed. Pineland threeawn is still an important source of forage for the beef herd in the 1970's.

Yarlett (1965) describes several threeawn grass varieties adapted to the flatwoods of Florida. Pineland threeawn is the most prevalent grass on much of the cut-over pineland of central Florida. It appears to be adapted to low fertility fine sand soils of the Ona Agricultural Research Center (ARC). Moore (1974) reported that threeawn was a desirable forage for 3 to 4 months after burning but as it matured it became less palatable.

Response of a herd of native cows on a threeawn range, sections of which were burned each fall and winter, averaged 541 lb in March, 623 lb in June, 645 lb in September, and 621 lb in December (Kirk et al., 1945). The higher quality native forage from March to September increased carrying capacity, growth rate of calves, and weight of cows and improved the quality of market cattle.

Methods

The site selected to study the yearly composition change of threeawn under different treatments was cut-over pine land of Immokalee fine sand soil, typical of large areas of flatwoods in central Florida. Saw-palmetto [*Serenoa repens* (Bartr.) Small] occurred in abundance with a few second-growth pine trees (*Pinus palustris* Mill.). Palmettos on one half the experimental area were removed by grubbing and the remainder left untouched. Topography of the site was level and drainage was poor, similar to large areas of low fertility flatwoods land.

The treatment plan is shown in Table 1. Treatment date varied each year according to temperature and moisture conditions which affected grass growth. The first forage samples each year were collected from 30 to 43 days after treatment, averaging 35 days for the 5 years. Threeawn blades, approximately 225 grams green weight per sample, were plucked on the same day for all treatments.

Forage samples were obtained at 8 dates in 1945-46 and at 10, 8, 7, and 6 dates in following years. More grass samples were collected from April to June than in the other 3-month periods of the year to facilitate the

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Table 1. Treatment plan.

Treatment dates	Treatment[1]						
	Control	Burned		Mowed, clippings removed		Mowed, clippings left on	
		Every year	Alternate years	Alternate years	Every year	Alternate years	Every year
3- 2-45	none	burned	burned	mowed	mowed	mowed	mowed
2-20-46	none	burned	none	none	mowed	none	mowed
3- 5-47	none	burned	burned	mowed	mowed	mowed	mowed
2-29-48	none	burned	none	none	mowed	none	mowed
2-17-49	none	burned	burned	mowed	mowed	mowed	mowed
Number of samples	39	39	31	31	39	31	39

[1] Four treatment areas in 1945 and seven in the following four years.

immediate effects of the treatments on forage composition. A total of 249 samples were analyzed on an air-dry basis for crude protein, ether extract (EE), fiber, ash, calcium, magnesium, and phosphorus at the nutrition laboratory, University of Florida, Gainesville, by the methods outlined by A.O.A.C. (1940).

Analytical results were calculated on a moisture-free basis using the formula Response/1.00-moisture with moisture expressed as a decimal fraction. Results on this basis were studied statistically using the analysis of variance technique. Differences in results of ($P < .05$) or greater reliability were accepted as significant.

Six contrasts among the treatments were studied to maximize the information from the statistical analysis.

1. Treatment vs control.
2. Annual vs alternate year burning.
3. Burning vs mowing.
4. Mowing, clippings removed vs clippings left on.
5. Annual vs alternate year mowing.
6. Interaction between 4 and 5.

Results and Discussion

Rainfall previous to and after burning or mowing affected forage composition. For example, the protein of threeawn obtained from all treatments on April 7, 1947, averaged 8.19% protein after 12.07 inches of rain the previous months, while samples collected April 10, 1950, averaged 3.61% protein when rainfall totaled 1.79 inches January to March (McCaleb and Hodges, 1960). Rainfall had more effect on protein level of threeawn than on the six other nutritional factors studied.

The first collection of grass after treatment was always included in the April to June period. Threeawn forage samples from April to June had higher levels of protein, EE, Ca, Mg, and P and lower levels of ash than for the other periods of the year (Table 2). Fiber and ash percentages were highest in July to September and protein and Mg the lowest in January to March. Analysis of variance showed that there were highly significant seasonal differences for each of the seven nutritional factors in every year except for Ca and P in the first year. The main effect means for all samples of threeawn are given in Table 3.

Crude Protein

The average protein level during the 5-year period ranged from 3.71% (control) to 4.65% (burned every spring). The highest average protein level, 4.65%, furnished only 51% of the protein required for the adequate nutrition of a producing cow according to the National Research Council (1963) (NRC). Protein content of threeawn from all treated areas was significantly greater than grass from the control but differences observed among the burned and mowed areas were not significant.

Sampling date means show that protein level in threeawn was highest in late March and April with the most rapid decrease from June to September. There was a slight increase in protein from January to March 1947 when soil moisture and weather conditions were favorable for grass growth. The greatest increase in level of protein occurred when nursing cows require this element for milk production. The effect of the different treatments on composition of threeawn was more apparent for protein than with the other six factors studied.

Seasonal trends in percentage protein in threeawn from the control and average of six treated areas for 1947-48 are illustrated in Figure 1. The eight samples from the control averaged 3.59% and the 48 from the six treated areas 4.25% protein, an 18% higher yearly level in favor of the treatment areas. The significant facts to be observed from Figure 1 are: protein in the grass from the control generally decreased throughout the year; treated areas showed a rapid increase in protein after treatment, going from 4.1% 13 days before treatment to 8.8% 30 days after treatment, an increase of 115%; after reaching its maximum, protein of treated areas rapidly returned to their pretreated levels, being 4.2% 80 days after treatment; and after 110 days, there was no essential difference between control and treated areas.

The protein level of the 249 threeawn samples collected over a 5-year period ranged from 1.20% (1-20-48, mature grass mowed every year, clippings left on) to 11.46% (4-4-47, burned alternate years and obtained 30 days after treatment). Thus during six short periods after burning treat-

Table 2. Average composition (%, dry matter) of threeawn by 3-month periods, all treatments.

Period	No. of samples	Composition						
		Protein	EE	Fiber	Ash	Ca	Mg	P
Apr. to June	13	5.39	1.96	35.72	3.30	0.53	0.22	0.085
July to Sept.	10	3.77	1.91	36.49	3.52	0.45	0.15	0.076
Oct. to Dec.	8	3.59	1.58	34.66	3.38	0.37	0.14	0.076
Jan. to Mar.	8	3.31	1.80	35.46	3.51	0.37	0.10	0.076

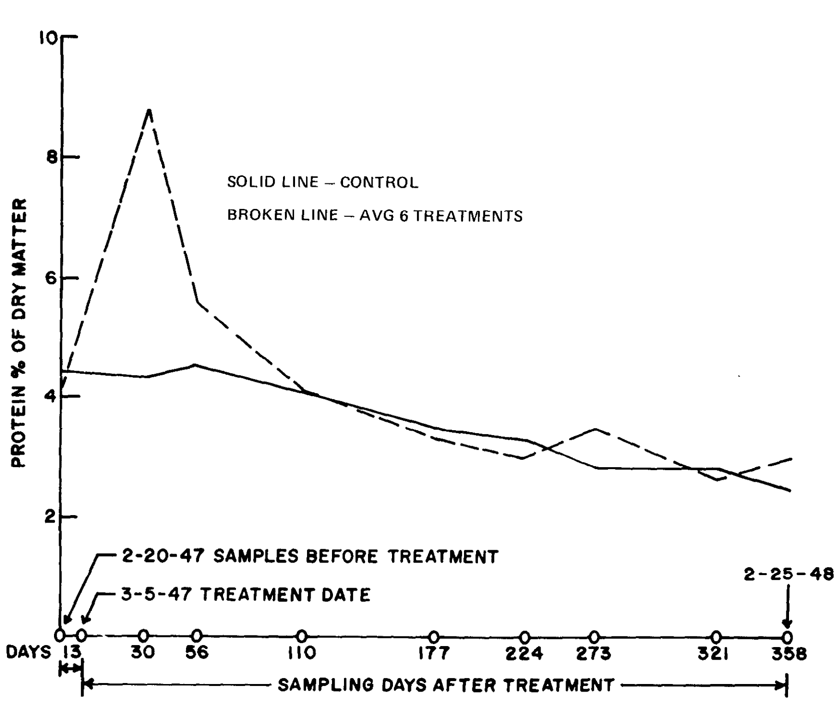

Fig. 1. *Percentage protein in pineland threeawn grass from control and average of six treated areas for nine collection dates in a year.*

ment did protein content of threeawn meet optimum requirements of 9.2% for good animal production (NRC, 1970), while for most periods of the year the grass is inadequate in protein.

Ether Extract

Average ether extract of threeawn from all treatments ranged from 1.67% (mowed alternate years, clippings left on) to 1.86% (burned every year) with a mean of 1.71% for the 249 samples. The extreme levels in single samples were from 0.83% (8-3-49, burned alternate years) to 5.54% (8-1-45, mowed alternate years, clippings left on). There was a significant difference in level of ether extract in threeawn between sampling dates in each of the 5 years. An analysis of variance showed a highly significant difference between dates with years but no detectable difference among the six contrasts.

Fiber

Average fiber content of threeawn from all treatments varied from 35.19% (mowed alternate years, clippings left on) to 36.05% (control) with a mean of 35.58% for all samples. Level of fiber in single samples ranged from 24.73% (8-29-47, mowed alternate years, clippings removed to 42.20% (9-12-45, mowed alternate years, clippings left on). Davis and Kirk (1952) obtained similar values, 23.24% for very young to 36% to 40% fiber for mature forage. There was a significant difference in fiber content between collection dates in each of the 5 years and between years, with the lowest in year 3 (33.25%) and the highest in year 2 (37.90%). A suggested reason for the variation in fiber level is in the difference in total rainfall, 69.91 inches in year 3 and 52.67 inches in year 2 (McCaleb and Hodges, 1960).

Frequency of mowing had some influence on the fiber level, but this was not consistent over the 5 years of the experiment. The observed differences favoring alternate year mowing were not significant except for year 3, when fiber was higher in plots mowed annually.

Ash

Average ash content of threeawn ranged from 3.17% (control) to 3.63% (burned alternate years). Single samples of forage varied from 2.25% (6-2-48, burned alternate years) to 7.3% (4-4-47, burned alternate years) with an average of 3.43% for all samples. Ca, Mg and P made up 12.8%, 5.5% and 2.2%, respectively, or 20.5% of the total ash. Forage analysis revealed a greater percentage of ash from all treated areas than from the control.

There was a highly significant difference in ash of grass between sampling dates in each of the 5 years. Except for year 1 there was a significant difference between the control and treated areas, with treated areas having a higher level of ash. The plot which was burned alternate years had a higher ash content than the plot burned annually. Leaving clippings on after alternate-year mowing reduced forage ash below that of the clipping removal treatment. Clipping removal and non-removal had no effect on forage ash under annual mowing.

Ash level was found to significantly interact with years X treatments between treatment vs control, annual

Table 3. Average composition (%, dry matter) of threeawn from the six treatments and the control plots.

No.	Treatment	No. of samples	Composition						
			Protein	EE	Fiber	Ash	Ca	Mg	P
1	Control	39	3.71	1.80	36.05	3.17	0.43	0.19	0.083
	Burned:								
2	Every year	39	4.65*	1.86	35.44	3.57	0.44	0.18	0.091
3	Alternate years	31	4.09*	1.79	35.34	3.63	0.42	0.19	0.086
	Mowed, clippings removed:								
4	Alternate years	31	4.07*	1.68	35.19	3.46	0.40	0.17	0.069
5	Every year	39	4.47*	1.79	35.52	3.36	0.46	0.20	0.076
	Mowed, clippings left on:								
6	Alternate years	31	3.93*	1.67	35.43	3.31	0.44	0.19	0.068
7	Every year	39	4.22*	1.78	35.92	3.51	0.45	0.19	0.067

*Significantly higher than control.

vs alternate year burning, burning vs mowing, and removal of clippings vs clippings left on. Interaction showed that removal of clippings reduced the ash if alternate year mowing was employed but increased the response if grass was mowed annually. Similarly, alternate year mowing increased ash when clippings were removed and decreased the response if left on the area.

Calcium

The five-year average of calcium in threeawn from the seven treatments ranged from 0.40% (mowed alternate years, clippings removed) to 0.46% (mowed every year, clippings removed). Single samples of grass had 0.11% (4-30-47, control) to 1.28% (4-1-49, burned alternate years) Ca with an average of 0.44% for all samples. Thus the medium value provided more than sufficient Ca to meet the needs of all classes of beef cattle (0.30% of ration, Cunha et al., 1964) although 33% of the samples were deficient in this essential nutrient element. There was a difference between collection dates each year in level of Ca. In the third year, 1947-48, level of Ca was higher when clippings were left on compared to when they were removed. Analysis of the 5-year data detected a highly significant difference between dates with years but no difference between treatments and years × treatments.

Magnesium

Average magnesium content of threeawn ranged from 0.17% (mowed alternate years, clippings removed) to 0.20% (mowed every year, clippings removed) for the seven treatments, with a mean of 0.19% for all samples. Variation in level of Mg in individual samples was from 0.01% (1-15-46, burned every year) to 0.64% (8-29-47, mowed every year, clippings left on), with 88% being above the 0.06% level requirements of Florida beef cattle (Cunha et al., 1964). As with all factors studied there was a significant difference in level of Mg between collection dates for each year.

There was a difference between burning vs mowing in year 3, with level of Mg being higher in forage from plots which had been mowed. Magnesium was increased in year 1 when clippings were removed. Frequency of mowing interacting with years affected the level of Mg, and this interaction was found to be significant because the magnitude of the difference was not consistent from year to year.

Phosphorus

Phosphorus level in threeawn from seven treatments varied from 0.067% (mowed every year, clippings left on) to 0.091% (burned every year), with a mean of 0.077% for all samples. Variation in single samples of grass was from 0.044% (6-2-48, control to 0.16% (burned alternate years).

Becker et al. (1953) recommended 0.13% P in dry ration, but only 11% of the 249 grass samples equalled or excelled this level. Cunha et al. (1965) stated that the Florida cow ration should have 0.25% P and NRC (1970) that the ration of a nursing cow contain 0.22% P.

Significant differences in level of P were detected among sampling dates except in year 1. Annual vs alternate-year burning increased P in the threeawn in year 4. Except in year 1, threeawn from burned areas had more P than grass from areas that were moved. Only in year 4 did removal of clippings increase P.

Analysis of data showed that variation among sampling dates within years was highly significant. Threeawn from treated plots had lower P level than grass from the control. Burning threeawn increased the amount of P compared to mowing.

Summary

The data has historical and current value as there is little information in the literature showing the effect of season and management treatment on the composition of threeawn. Burning grass every second or third year is fully as applicable in 1974 as 30 to 40 years earlier on the over 2 million ha of Florida range. Camp (1932) found that burning mature threeawn grass stimulated new forage growth, removed unpalatable mature grass of low nutritional value, and reduced ground cover of saw-palmetto and brush. Other advantages of systematic controlled burning include the reduction of insects which annoy cattle and the lessening of danager of wild fire which could destroy ranch buildings and forage on adjacent improved pastures. Controlled burning an area of the native range in the late fall and a similar area in the winter months will provide the herd with palatable feed over a longer period of the year. Mowing of native range is not considered practical in 1974. Chopping with a medium weight machine controls brush growth and reduces the ground area shaded by saw-palmetto with little injury to a stand of threeawn if the operation is performed when soil moisture is adequate.

Frequent observation showed no observable change in density of stand of threeawn over the 5-year treatment period, although there were more threeawn plants where saw-palmetto had been removed. There was no intrusion of carpet grass (*Axonopus affines* Chase) and creeping bluestem (*Andropogon stonifer* Nash), which would indicate a slight improvement in soil fertility.

Cows grazing threeawn with an average of 4.18% protein and 0.077% P would not produce up to their potential and might develop deficiency diseases. Kirk et al. (1974) found that factors which permitted the maintenance of a herd on the adjoining 324 ha native range to the plots of this experiment during the same period in a moderately productive state were: separate areas of each pasture were burned each fall and winter; herd had access to a large area; soil types varied from flatwoods to lower sites which were more fertile and produced more nutritious forage; herd had free access to a mineral mixture containing Ca, P, common salt, iron, copper, and cobalt; four of the five lots in this trial were given limited feed from November to March, which supplied a minimum of protein and energy nutrients.

All seven treatments of threeawn coupled with new spring growth improved in nutritional quality from March to June. Forage growth was sparse after treatment, but it was not mixed with mature grass except on the control plot. There was a decrease in feeding value as the threeawn matured from July to the following March. Extremes of moisture and frost in late winter and early spring affected quality of new threeawn growth.

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Management Practices to Minimize Death Losses of Sheep Grazing Halogeton–Infested Range

LYNN F. JAMES AND EUGENE H. CRONIN

Highlight: *Data concerning the ecology of* Halogeton glomeratus *are reviewed. Information collected in a number of experiments in which halogeton was fed to sheep is summarized to formulate a management program for the prevention of halogeton poisoning in sheep.*

Halogeton [*Halogeton glomeratus* (M. Bieb) C. A. Mey.], a poisonous plant introduced into the Intermountain Region nearly 40 years ago, has established a permanent niche for itself in the cold desert vegetation of the region. Physiologically well adapted to the harsh, saline, arid environment of the cold desert, this pioneer annual has secured its place in the intermountain flora through prolific seed production, development of two physiologically different kinds of seeds, and early establishment of seedlings each spring (Cronin, 1965). However, halogeton cannot compete successfully with established perennials nor can it establish enduring dominance in vegetation on the more mesic and less saline sites (Tisdale and Zappetini, 1953).

Halogeton produces more than 70 seeds per inch of stem. Approximately one-third are brown seeds, produced during the early part of the flowering period. A low rate of germination helps brown seeds survive 10 or more years in the soil. After about the middle of August, the plant produces black seeds. These seeds germinate early in the spring, and they germinate rapidly after the onset of favorable environmental conditions. Survival of black seeds for more than a year in the field remains highly questionable. Rapid germination of black seed early in the spring provides halogeton seedlings with a competitive advantage over seedlings of most other species. The long-lived but slowly germinating brown seeds provide the species with a mechanism for surviving adverse periods of low seed production, low seedling survival, or both (Cronin, 1965).

Most of the dense stands of halogeton grow on physiologically dry saline soils. On these soils, halogeton challenges our present control methods and defies our efforts to eradicate it. Treatments with herbicides may temporarily suppress halogeton, but it is the pioneer reinvading the site when the toxicity of the herbicide disappears. Treatment with certain herbicides such as 2,4-D injures the perennial shrubs and increases the space likely to be invaded by halogeton (Cronin, 1960).

The prospects of improving the density or production of forage on these saline soils through grazing management are not fully understood. However, as much as 20 years' total protection from grazing has failed to produce any significant changes in the vegetation in some areas, but some improvement seems to be being made in other areas.

Reseeding with perennial grasses has been used successfully to control halogeton. However, the effectiveness of reseeding has been limited to the more mesic and less saline sites. Little research and no positive results have been reported for revegetating the more xeric sites.

Much harsher sites than are now being reseeded could be artificially revegetated by applying all available management tools. The site should be fallowed the summer before it is reseeded. The land can be fallowed either mechanically or by herbicide treatments. Seed should be planted in the fall. Herbicide treatments can be applied the next spring to remove seedlings of weedy species because they use the soil moisture and nutrients essential for survival of the grass seedlings. The reseeding should be

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protected from all grazing by both domestic and native animals until the seeded species reach maturity (Cook, 1965). Grazing should be maintained at a level to assure vigorous and reproductive plants to prevent reinvasion by halogeton.

Halogeton is grazed readily by sheep and cattle and constitutes a fairly large part of the diets of both sheep and cattle under certain conditions. Animals are poisoned during late fall, winter, and early spring on cattle and sheep range where halogeton grows (Cook and Stoddard, 1953).

Signs of poisoning include depression, weakness, recumbency, coma, and death (Cook and Stoddard, 1953). On autopsy, hemorrhage can be seen on the surface of the rumen. Crystalline deposits may be seen on the cut surface of the kidney if it is viewed closely. Histologoically, crystalline deposits and hemorrhage can be seen in the rumen wall and in the renal tubules (Van Kampen and James, 1969). Analysis of the blood reveals a hypocalcemia (James, 1968).

The toxic principle in halogeton consists of soluble salts of oxalic acid, primarily as sodium and potassium salts (Cook and Stoddard, 1953). These salts of oxalic acid react readily in solutions containing calcium or magnesium ions to form insoluble calcium or magnesium oxalate. Halogeton is unique because it produces a high proportion of soluble to insoluble salts (Williams, 1960).

Other species that inhabit the cold desert and are closely related to halogeton contain salts of oxalic acid. They include Russian thistle (*Salsola kali*), greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), salt sage (*Atriplex nuttallii*), and others. However, only greasewood and Russian thistle contain concentrations of soluble oxalates normally dangerous, but soluble oxalates in Russian thistle only rarely reach the potentially dangerous concentration.

When sheep or cattle graze halogeton, three things may occur (James, 1972): (1) the soluble oxalates can be detoxified by metabolic activities of the rumen microflora (James et al., 1967): (2) the soluble oxalates may react with calcium ions in the rumen to form the insoluble calcium oxalate that is excreted in the feces, or (3) the soluble oxalates may be absorbed into the bloodstream where they react with the blood calcium and other constituents (James, 1968).

Oxalate intoxication is a complex phenomenon. A number of adverse reactions take place. A severe hypocalcemia results from the exhaustion of calcium in the bloodstream by the formation of the insoluble calcium oxalate. Calcium oxalate crystals form in the rumen wall and in the kidneys and damage these organs. Shock may follow (Van Kampen and James, 1969). The oxalates may also interfere with the action of the lactic dehydrogenase and succinic dehydrogenase enzymes (James, 1968). These enzymes are vital links in energy metabolism.

Chronic poisoning apparently does not exist in oxalate poisoning (James and Butcher, 1972). Poisoned animals either die quickly or they recover without lasting signs of injury. Animals are poisoned only when they eat excessive amounts of halogeton in a short period of time (James and Butcher, 1972).

Certain microorganisms are capable of detoxifying the oxalate ion. Ingestion of sublethal levels of soluble oxalates can increase the rate of degradation of oxalate by the rumen (James et al., 1967). This change in the rumen microflora permits the animal to ingest as much as 75% more soluble oxalate without intoxication (Van Kampen and James, 1969).

If soluble oxalates are ingested rapidly, the microflora cannot detoxify them fast enough to prevent their absorption into the bloodstream, and the animal becomes intoxicated. (James et al., 1967).

Allowing ruminants to graze plants with low levels of oxalate or to graze small amounts of plants such as halogeton permits the adaptation of the rumen microflora to the oxalate and consequently increases protection against oxalate poisoning. This adaptation lasts for only short periods of time (2-3 days).

Some interacting factors related to halogeton poisoning are: (1) amount of halogeton ingested, (2) rate consumed, (3) concentration of soluble oxalates in the plants, (4) the amount of other forage in the rumen, and (5) recent exposure to oxalate-producing plants.

A sheep may eat large amounts of halogeton if ingested slowly over the grazing period, whereas the same amount may prove lethal if ingested rapidly. The soluble oxalates may constitute from 8 to over 30% of the plant's dry weight (Williams, 1960). The higher the oxalate content of the plant, the more toxic it is. The amount of other forage in the rumen determines how much halogeton an animal is likely to eat and how fast. Also, the rumen content may dilute the toxic oxalate that is ingested and thus influence the rate of absorption. Sheep adapted to oxalates can graze more halogeton than those not so adopted (James et al., 1970).

Water consumption is controlled by three factors: dry matter intake, salt intake, and ambient temperature (Winchester and Morris, 1956; James et al., 1968a and b). Soluble salts, including the soluble salts of oxalic acid, influence the amount of water consumed by an animal. Animals on a high salt diet consume more water than those on a normal diet. Five gallons of water is required to excrete each pound of salt absorbed from the rumen (Cardon et al., 1951). Sheep fed diets with high halogeton content respond in the same manner.

Water intake is also influenced by the amount of dietary dry matter; and, conversely, if water intake is reduced, feed consumption decreases. Therefore, an animal may be made hungry by withholding either feed or water (James et al., 1970). Sheep are usually poisoned on halogeton when they have been made hungry by a lack of water or feed. After their thirst has been quenched, they are then ready to graze. Under these conditions, they are less selective in their grazing. On sites where halogeton, or any other toxic plant, dominates, the animal may become intoxicated. Such grazing patterns may be lethal. Most large numbers of sheep are lost after they leave water points along established trails where the depleted native shrubs have been replaced by heavy stands of halogeton. Many sheep in the field have been poisoned on halogeton during periods of moderating temperatures, which cause an increase in water intake by the sheep.

Sheep poisoned on halogeton drink excessive amounts of water during intoxication (James et al., 1968a and b). Limited success has been achieved in the treatment of halogeton-poisoned sheep by the force feeding of water (James and Johnson, 1970).

Although the success of this treatment has been limited, it is the only effective method of treating this malady and illustrates the importance of water in this type of poisoning.

The reaction of calcium with the oxalate radical in a solution to form an insoluble and nontoxic substance has contributed to the popularity of the concept of using calcium as an alleviator of halogeton poisoning (Cook and Stoddard, 1953). Dicalcium phosphate was once recommended on the basis of experiments where sheep survived a lethal dose of halogeton. The halogeton was force-fed simultaneously with enough calcium (dicalcium phosphate) to combine with the oxalate in the halogeton. In subsequent experiments, researchers learned that lesser amounts of the dicalcium phosphate failed to prevent poisoning of a sheep fed a lethal amount of halogeton. The amount required to prevent intoxication was larger than can be practically used under range conditions. Further, when the mineral was administered 2 to 4 hours after a lethal level of halogeton was given, it was of no value in preventing death (James and Johnson, 1970). Currently, the concept of a practical alleviator for halogeton poisoning is not recommended by researchers (James and Johnson, 1970). However, they do advocate the use of mineral supplements for general nutrition. Most of these supplements contain calcium salts and many include dicalcium phosphate.

Although the livestock industry has, in part, learned to "live with halogeton," it remains as a constant threat to the individual stockman. Successful stockmen who have grazed their animals within the halogeton area have suddenly, through carelessness, neglect, or a unique set of circumstances, sutained catastrophic losses.

Implementation of the following management practices should minimize deaths in sheep from halogeton poisoning.

1.) Avoid overgrazing and all other activities that will remove or deplete the existing perennial vegetation. Destroying or weakening the perennials reduces forage production and increases the susceptibility of the area to invasion by halogeton.

2.) Develop a grazing program that will allow your range to improve. Healthy, vigorous perennial vegetation will prevent invasion by halogeton.

3.) Reduce grazing pressure during periods of drought. The added stress of grazing on the perennials during drought can destroy them.

4.) Avoid grazing or graze very lightly during the growing season of the perennials. The growing season for the perennial vegetation of the cold desert is during late winter and spring but sometimes extends into early summer when soil moisture is favorable.

5.) Supply adequate water and forage of a good variety. It is economical to haul water (Hutchings, 1954 and 1958).

6.) Watch your livestock, know what they are grazing, and know what will be available for grazing. (Have a grazing plan.)

7.) Allow sheep time to adapt by grazing safe amounts of oxalate. This allows time for the rumen microorganisms to adapt to the oxalate. These organisms metabolize oxalates into nontoxic components. Supplying small, safe amounts of oxalates will encourage adaptation of rumen microorganisms. Grazing plants low in oxalate content such as shadscale, Russian thistle, and salt sage will adapt a sheep in about 4 days.

8.) Introduce animals to halogeton-infested areas gradually. Even after a short absence (2-3 days) from halogeton areas, they should not graze in dense stands.

9.) Do not unload animals from truck into halogeton unless both supplemental feed and water are available.

10.) Never allow hungry animals to graze in large, dense patches of halogeton often found on old bedgrounds, along trails or roads, and around watering places in the desert of the Intermountain Region. This rule includes animals currently grazing halogeton. The animal is poisoned when too much halogeton is ingested rapidly.

11.) Do not trail thirsty sheep into watering places surrounded by halogeton without supplementing them with other food. Thirst inhibits grazing; sheep will not graze until they have been watered. Even small quantities of supplemental food will increase the selectivity of the grazing animal.

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Plant and Sheep Production on Semiarid Annual Grassland in Israel

NAPHTALI H. TADMOR, EZRA EYAL, AND ROGER W. BENJAMIN

Highlight: *A stocking rate experiment with sheep was carried out over a 12-year period, 1962-1973, in a semidesert area with 250 mm rainfall. Four pasture types were investigated. Site and experimental conditions are described in this paper as well as grazing results on the unimproved native grassland. This is a herbaceous sward composed entirely of annuals. It yielded between 2 and 4 ton/ha dry matter per year in accordance with rainfall fluctuations. These yields are high in comparison with records from other parts of the world. It was shown that this area could give unsupplemented year round support to Mutton Merino sheep at stocking rates of 0.6-1.0 hectare per sheep per year. Annual lamb production ranged between 20-30 kg per ewe and between 30-60 kg per hectare. This is the first report of lamb production in such a low rainfall area.*

The wide arid belts that border the North African and Middle Eastern deserts have had nomadic populations since ancient times. The 150-350 mm rainfall belt is the border between the desert and the sown. The climate there is extremely variable (Butzer, 1951). Interseasonal rainfall variations, in a ratio of 10:1, are the result of changes in major upper level synoptic conditions (Levi, 1963). Human settlement in this area has been traditionally unstable since Biblical times: "Then Isaac sowed in that land, and received in the same year a hundredfold." (Genesis 26:12). On the other hand: "And there was a famine in the land, and Abram went down into Egypt (i.e., the irrigated lands) to sojourn there; for the famine was grievous in the land" (Genesis 12:10). The total dependence of the farmer on the seasonal rains has been stated dramatically in the Bible: "The land which you are entering... is not like the land of Egypt... where, after sowing your seed, you irrigated it by foot like a vegetable garden. But the land into which you are crossing is ... watered by the rains of heaven" (Deutoronomy 11:10-11).

For the last 1300 years, nomads have subsisted on marginal grain cropping for human consumption with very low grain yields (200-700 kg/ha), necessitating traditional government handouts in drought years. As a marketable produce, as well as a sign of wealth, flocks–mostly goats and sheep–were raised. In "good" (high rainfall) years the flocks grazed the uncultivatible arid wastelands of the 100-350 mm rainfall belt. In drought years, or in the dry season, grazing traditionally necessitated wide nomadic movements. Modern agricultural systems and high standards of living–whether real or only expected–no longer make these movements possible. Besides, political reality and modern land tenure systems restrict the shepherd as well as the farmer to definite plots.

In spite of these constraints, sheep are potential producers of protein from the desert. Survival and production in hot dry conditions from low quality sparse pasture is due primarily to the sheep's ability to withstand dehydration (Purohit et al., 1972), heat (Lyne et al., 1970), and extreme fluctuations in feed availability, and to quickly recover from starvation and dehydration. To be economically productive, desert sheep must also have reasonable fertility, lactational potential, satisfactory growth rate, and carcass quality. In many countries, modern dry land farming integrates grain cropping and livestock production into one single farm system (Rossiter, 1966). Under this system, the farmer owns cropland, pasture–and sheep. In "good" years, a grain crop is harvested. In these years the pasture will be plentiful and sufficient for the sheep. In "drought" years the grain is unharvestable. The pasture also will be insufficient. In such years, the drought-failed grain is a welcome high-yielding complement to the pasture, allowing the farmer to keep his flock alive, on his own land, without buying costly outside feeds and without society-disrupting migration. Such an operation, essentially an adaptation of ley farming to arid conditions, turns separate losses from sheep and grain in a drought year into a profit. This makes the long-term grain-sheep operation in a variable climate profitable where grain farming or sheep alone would be a failure, and leads to sociological and political stability. The inclusion of livestock thus allows grain farming to be pushed more and more into "marginal" lands.

With the fast-rising standard of living that followed the establishment of the State of Israel in 1948, traditional grain-farming in this arid belt soon became untenable. It was first supported by a farmers' drought-insurance system at a high annual cost to the taxpayer. It soon became apparent that where irrigation water was insufficient to irrigate large parts of a farm, alternative systems of dryland-farming had to be found. This led, in 1962, to a series of experiments. The course and results of these experiments may be of relevance not only to Israel but to large parts of the Middle East and other countries of similar climate.

The present communication includes a general description of the experimental site, of the methods used, and the results obtained on the unimproved native pasture of the area.

Migda Experimental Site

This arid grazing land project has been carried out over 12 years, 1962 to 1973, at the Migda Experimental site (34°25'

At the time of the research, authors were professor of plant ecology, Botany Department, Hebrew University, Jerusalem, Israel; head of Division of Sheep, Agricultural Research Organization, Beit-Dagan; and range officer and manager of the Migda site, Gilat Experiment Station near Be'er Sheva, Israel, Naphtali Tadmor has since passed away.

The study is a contribution from the Agricultural Research Organization, Israel, 1973 Series No. 262-E.

This project was carried out by a team of researchers and technicians. Those active in certain aspects included, besides the authors, N. Seligman, M. Guttman, S. J. Ellern, P. Yonatan, and Y. Ast of the Agricultural Research Organization; M. Vachnish of the Faculty of Agriculture; M. Forti, A. Degen, and the late M. Morag of the Negev Institute of Arid Zone Research; B. Yogev, A. Brigitt; H. Takhan, Salim, and Suleiman Aldanfiri of the Ministry of Agriculture; L. Shanan, consulting water engineer; and H. van Keulen and C. T. de Wit from the Agricultural University of Wageningen, as well as numerous students. Without the splendid teamwork and help of people from many disciplines this project could not have been undertaken.

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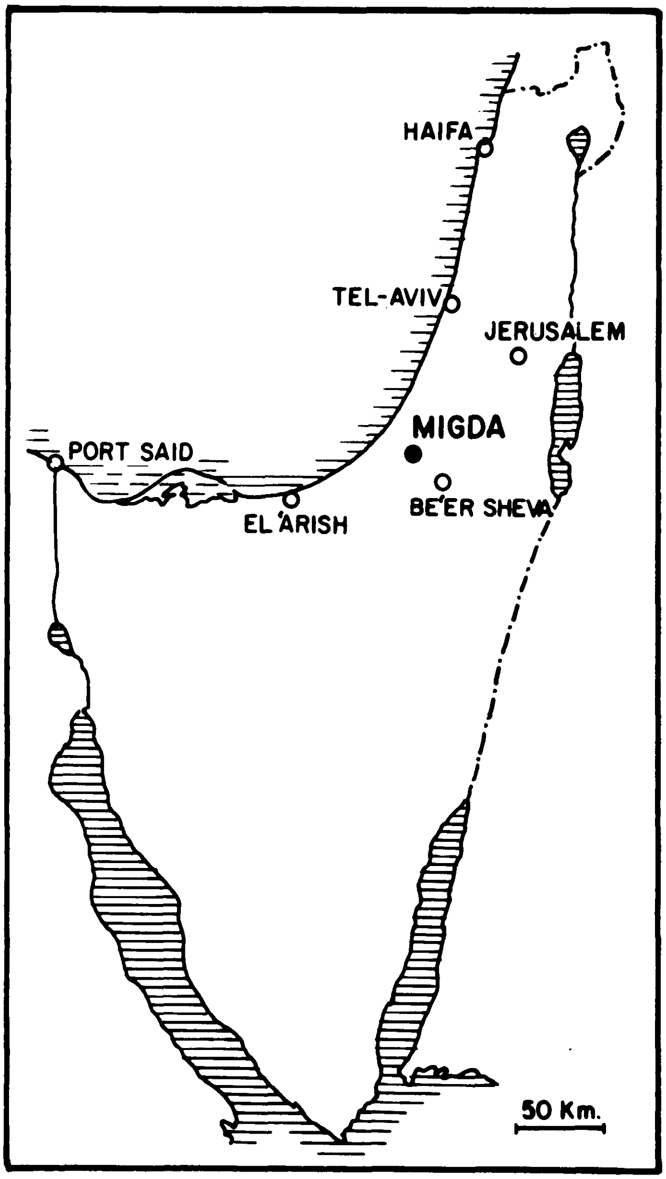

Fig. 1. *Map of Israel showing location of the Migda Experimental Site.*

long., 31°22′ lat., 100 m altitude a.s.l.) near Beersheba in the Northern Negev desert of Israel (see Fig. 1).

Climate

This is a winter rainfall area with rain coming between October and April; 60% of the annual precipitation is concentrated in December and January. Due to the Mediterranean climatic seasonality, rainfall and growing seasons are always referred to as 1962/63, 1963/64, i.e., from October 1962 to September 1963, etc. There are extreme rainfall fluctuations between years—42 mm in 1962/63, 412 mm in 1964/65—but without discernible periodicity. Long-term (110 years) cycles seem to exist with 20 years moving averages reaching 20% above and below the long-term mean (Shanan et al., 1967). The pattern of rainfall distribution within a single season greatly influences vegetation development. Temperatures are mild in winter. The coldest month is January with mean minimum, daily mean, and mean maximum temperatures of 7.6°C, 12.6°C and 18.1°C. There are 20 to 30 nights of frost, with the soil surface temperature dropping to −1 to −4°C. Temperatures are high in summer. The hottest month is August with mean minimum, daily mean, and mean maximum temperatures of 20.2°C, 26.8°C and 33.5°C.

Soil

The soil is a deep sandy loam (loess) plain 10-20 m deep. Soil physical constants (moisture retention curve) are given in Figure 2. "Field capacity" is about 16% per weight and "wilting point" about 5%. Bulk density is 1.35. This gives an available moisture range of 11% per weight or 15% per volume—i.e., 150 mm of available water are temporarily stored per meter depth. This equals 150 l/m^2 or 1500 m^3/ha. In this 250-m rainfall area, wetting thus is usually not deeper than 150 cm and soil moisture seldom exceeds the rooting depth of the annual vegetation. On the impact of rain drops, this structureless loam forms a crust (Hillel, 1969) and infiltration decreases rapidly to 3.4 mm/hour (Tadmor and Shanan, 1969). This causes runoff on even slight slopes.

On flat land, most of the runoff from 1 m^2 accumulates in slight depressions of an adjoining square meter. Runoff and "run on" thus seem to be a major source of the enormous spot-to-spot variation in vegetation development characteristic of the area.

Pasture Vegetation

The native vegetation is an abandoned cropland vegetation, consisting predominantly of herbaceous annuals. The grasses, *Brachypodium pinnatum, Elymus geniculatus, Hordeum murinum, Phalaris paradoxa, Stipa capensis*; the legumes, *Medicago polymorpha* and *Trigonella arabica;* the crucifers, *Erucaria boveana* and *Reboudia pinnata,* and the compositae, *Anthemis melaleuca* and *Centaurea iberica*, are the predominant plants. Seasonal development of this vegetation (Fig. 3) depends wholly on the rains. Before the rains start, grazed areas may be completely bare. After the onset of rains

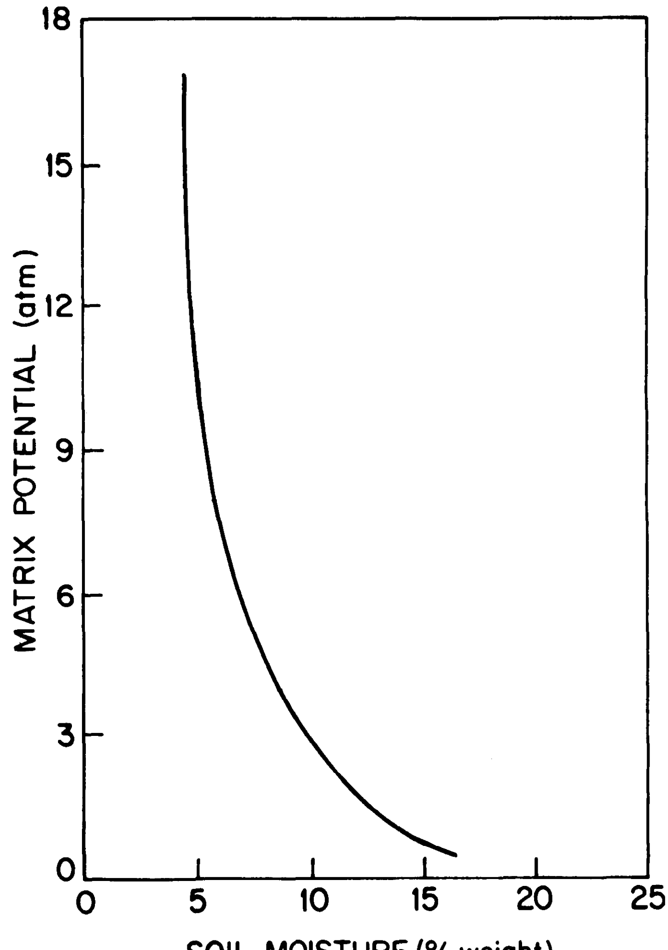

Fig. 2. *Soil moisture retention curve, Migda sandy loam soil.*

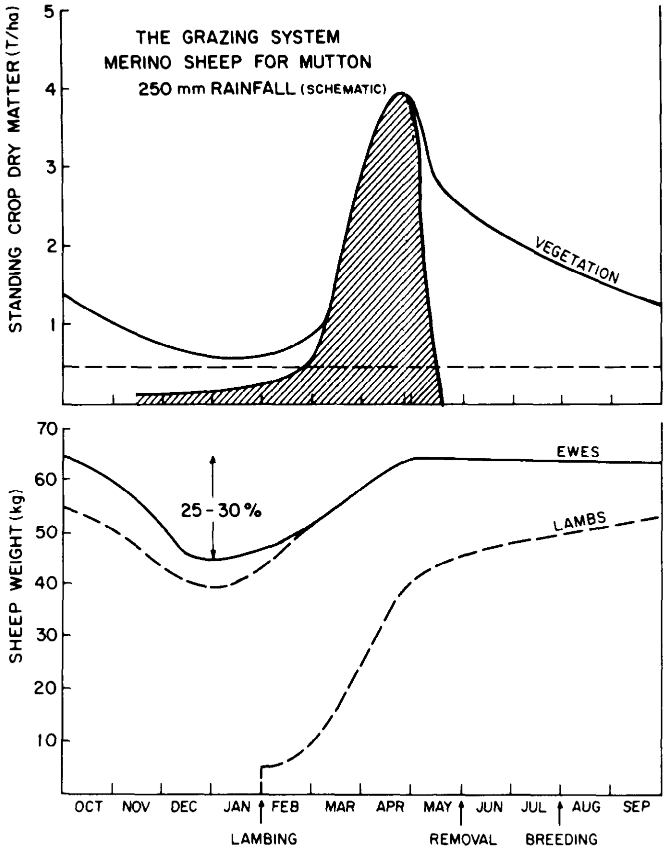

Fig. 3. *(Upper) Seasonal development of annual pasture in Migda. Stripped area denotes green forage. During the rest of the year vegetation is stem-cured hay. (Lower) Ewe weight fluctuations and lamb development adapted to the forage seasonality. Both parts are semischematic abstractions as extreme variation occurs between years.*

between October and November, germination and emergence take place after 5-15 days, depending on temperature, when about 150 days/degrees have been reached (Tadmor et al., 1968). The density may at first be about 500-700 seedlings/m^2, and with successive rains it increases gradually to 3000-5000 seedlings/m^2. Vegetation development is very slow in cold December and January. When there are no early October rains, the soil may stay relatively bare till mid-February. With rising temperatures in February, vegetation development is gradually accelerated and may reach peak growth rates of 17 g/m^2/day (i.e., 170 kg/ha/day) in March, if soil moisture permits. The period of plant development varies from 5 weeks to 5 months between November and March, depending on the seasonal rainfall. In late spring (March-April) peak dry matter yields of 200-400 g/m^2 (2-4 ton/ha dry matter) are reached. The vegetation then dries up and remains as stem-cured hay until decomposing the following winter. Directly after maturing, a 20-30% decrease of standing crop occurs, due to seed scattering and physical breaking up of leaves. Gradual weathering continues during summer, a process not yet well understood but perhaps due to grasshopper and vole activity.

Materials and Methods

Experimental Layout

The project described in this paper was designed as a stocking rate experiment on the four main pasture types of the region. Subsequently, it developed also into an arid ecosystem study and as a validation site for crop and pasture growth models. Of the area described, 200 ha (about 500 acres) were fenced and then subdivided into first 18, then 42 subplots of 0.1 to 12 hectares size, each grazed at different stocking rates.

Three vegetation types were artificially established in part of the plots and were compared to the above described annual native vegetation. These types were: seeded legumes; wheat and/or barley seeded for pasture; and planted salt bush. They form with native pasture the four main blocks of the experiment.

Establishment – 1962-1964 (2 years)

The experimental area was subdivided and fenced, soil and vegetation surveys were carried out; legumes, barley, oats and wheat sown and salt bush planted. Water supply was installed, as well as runoff-plots. Vegetation measurements were carried out.

Preliminary Grazing (Phase I) – 1964-1967 (3 years)

Sheep were introduced and a preliminary series of grazing experiments were carried out with stocking rates of 0.6 and 1.2 ha/sheep under year-round grazing. During this phase it became apparent that possible stocking rates were closer to the higher rate. This formed the basis for the planning of the main phase. Both disturbed and undisturbed plant development and secondary production were monitored in this first phase.

Main Grazing (Phase II) – 1967-1972 (5 years)

This was the main experimental period. Six stocking rates were applied to each vegetation type, ranging from 0.2-1.0 ha/sheep in the native pasture.

Sheep

Closed flocks of breeding ewes were maintained throughout each phase of the experiment. Fixed numbers of sheep (6-20) were kept in fenced paddocks. Yield was measured annually in terms of lamb production with wool a secondary product. Yields were calculated on a per ewe and per land area basis. German Mutton Merino hoggets (yearlings) were introduced in 1964/65 and used for both grazing phases on the native pasture. There were 12 ewes in each plot (10 adult and 2 hoggets) kept as closed flocks. Replacements were made as necessitated by deaths or by management or breeding requirements, resulting in occasional small deviations in the flock composition of a plot in a certain year (e.g., 11 ewes and 1 hogget, or 9 ewes and 3 hoggets). All calculations were related, however, to a number of 12 ewes. Sheep were kept outdoors throughout the years. New lambs born in each plot were used as replacements for culled animals and natural death. The breeding seasons commenced at the middle of August so that lambing would coincide with the beginning of pasture growth (Fig. 3). An artificial (milk) feeder system was introduced to save lambs born when vegetation was insufficient to support ewe milk production. No supplementary concentrates were given throughout the years except during late pregnancy in the 1966/67 drought. When sheep reached the "crashing point" towards the end of the season on the high stocking rate plots, the animals were removed to reserve plots and maintained at the same body condition until the onset of the next season. In these cases, sheep production figures were corrected to that fraction of the year during which grazing actually took place.

The Measurement System

The following measurements were carried out at the Migda site:

Climate

Rainfall was measured in 28 rain gauges, 4 recording rain gauges and 24 small orifice tube-gauges, all well dispersed over the experimental area.

Temperature was recorded by a thermohydrograph and maximum-minimum thermometers at the nearby (8 km) Gilat

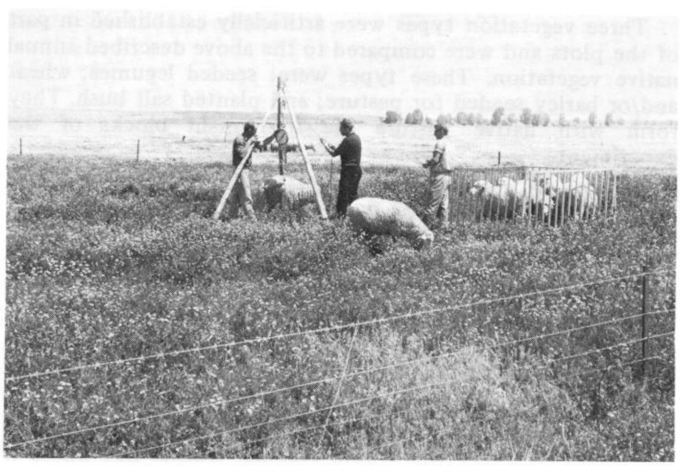

Fig. 4. *Weighing Mutton Merino sheep in the corner of a "legume" field, in the spring of a "good" year (280 mm of rain with good distribution). The native pasture in the background is dominated by the white flowers of* Trigonella arabica *and* Anthemis melaleuca. *(Note the light aluminum hurdles used to enclose the sheep.)*

Experiment Station in the same topographic conditions. Soil temperatures were recorded 25 km away in Beersheva in an identical soil type by the Meterorological Service.

Radiation, humidity, evaporation (class A pan), wind, and cloudiness were all recorded daily in Gilat.

Soil Water Balance

Thirty small runoff plots (5-80 m^2) measured runoff of bare soil, vegetation covered soil, and under various soil surface treatments (Tadmor and Shanan, 1969). Two plots were equipped with simultaneous rainfall and hydrograph recorders which plot rain and runoff intensity on the same chart.

Soil moisture changes were monitored (since 1971) by Neutron moderation in 250 access tubes at a depth of 220-240 cm every 2 weeks and after each rainfall in the growing season and every 3-4 weeks in the dry summer. Soil surface moisture was measured gravimetrically every 1-2 days directly after a rainfall and then weekly till the next shower.

Soil surface evaporation was measured by gravimetric sampling from bare plots.

Plant Biomass and Production

Germination and seedling survival studies of the major plants were carried out in the laboratory (Tadmor et al., 1963-71).

Plant biomass (above ground) was sampled at first periodically and since 1970/71 at 2-week intervals in the growing season, and 4 to 5-week intervals in the dry season. Sampling was done by clipping above-ground biomass to the ground in representative samples (10-40 per plot). Since 1971/72, a double sampling technique was employed. Biomass was estimated visually (dry matter or fresh weight) in a large number of quadrats (400 per plot). This estimate is calibrated by harvesting a subsample of 10-40 quadrats. The resultant regression (linear or logarithmic) is excellent, with $r = 0.96$ to 0.97 obtained by trained technicians. This large scale, nondestructive sampling was found to be well suited to the annual, highly heterogenous herbaceous sward.

Animal Population

All ewes were weighed 3 days after lambing, at the end of the green pasture season, at shearing and several times (at 4 to 5 week intervals) during summer and autumn. Occasionally the whole flock was weighed also in other seasons. Lambs were weighed at birth, at fortnightly intervals until weaning, and at monthly intervals from weaning to sale.

A subjective technique (0-5 scores) as suggested by Jeffries (1961) was used for estimating body condition.

Mating and lambing dates were recorded as well as disease and mortality of ewes, with causes of death whenever known. Details of lamb disposal and fate were also recorded.

Table 1. Rainfall (mm), peak yields (ton/hectare) of "native" vegetation and dry matter production (kg) per m³ of rainfall.

Year[1]	Amount of rain[2]	Yield of native vegetation: Fresh matter	Yield of native vegetation: Dry matter	Dry matter production per m³ of rainfall
1962/63	42 (b)	no germination	0	0
1963/64	377 (g)	13.4	3.4	0.9
1964/65	413 (g)	10.4	3.1[3]	0.7
1965/66	218 (b)	10.3	3.0	0.7
1966/67	282 (g)	15.9	3.6	1.3
1967/68	308 (b)	11.3	2.8	0.9
1968/69	224 (b)	9.4	2.6	1.2
1969/70	170 (b)	–	0.9	0.5
1970/71	238 (b)	4.6	1.1	0.5
1971/72	350 (g)	6.6	(3.6)[4]	1.6
1972/73	258 (b)	–	3.5	1.4

[1] In this winter rainfall area, the agricultural year is considered from October of one year to September of the following year, hence 1962/63, 1963/64, etc.
[2] (g) for good intraseasonal distribution, (b) for bad.
[3] After effect of no grazing in 1963/64, resulting in decomposition of large amounts of accumulated mulch, after all the nitrogen had been spent by the 1963/64 crop.
[4] In the same year, an ungrazed plot yielded 5.8 ton/ha following the plowing in of 4 years of accumulated sheep droppings.

Results and Discussion

Primary Production

Data on rainfall and on plant development are shown in Table 1. These yields are much higher than those indicated in some California reports from considerably higher rainfall areas (Hutchinson and Kotok, 1942; Heady, 1957 and 1961). The extreme variability of the rainfall is clearly demonstrated. Dry matter yields vary from 1 to 4 ton/ha in all but exceptional years. It may be seen that fluctuations in yield and dry matter herbage exceed the rainfall fluctuations by a factor of about 3:1. This is due to the all-important effect of rainfall distribution. Many small rains only wet the upper soil layers and a relatively large proportion of rain (up to 20-30% of the annual total) may be lost through direct soil surface evaporation. Too heavy rains may result in runoff or deep percolation beyond the root zone. For the mean total of 250 mm prevalent in this region, the ideal would seem to be a 100-mm October-November rain, falling in 3-4 days, followed in monthly intervals by 3 or 4 50-mm rains, each falling over a 2-3 day period till the middle of March. As an example of the influence of rainfall distribution, compare the consecutive years 1966/67 and 1967/68. The lower rainfall in 1966/67 with an almost ideal rainfall distribution resulted in optimal yields, whereas, due to recurring droughts in mid-season, the higher rainfall in 1967/68 yielded less.

Fertilizer Application

This annual vegetation reacts very strongly to fertilizer application. Fertilizer application may raise the total dry matter yield of the native pastures in all years 2 to 4 times (Tadmor et al., 1966-1970). Fertilizer application was *not* carried out in the grazing plots, but in small (10 x 10 m) trial plots replicated 8-12 times. Fertilizer application was effective in all years, dry or wet. It was found that two thirds of the maximum response is reached with about 120 kg N applied as NH_4NO_3 or $(NH_4)_2SO_4$ per hectare. Maximal yields are at 200 kg N/ha. Fertilizer application is economic in wet years, when the basic yield is high. In such years pasture yields may be trebled to 8-15 tons/ha dry matter. In drought years, however, when yields are basically low, the immediate result is not economical notwithstanding the increase in yields. However, in this arid climate, the nitrogen fertilizer is not leached out of the root zone and remains stored in the soil till the following season or seasons. The soil can thus serve as a nitrogen bank; increased yields show up in subsequent years. Fertilizer application to the arid range under these conditions is always economically justifiable (Tadmor et al., 1970). These aspects form the basis of a current investigation into the nitrogen cycle of arid pastures. Disked-in sheep droppings can have the same effect as fertilizer.

Lamb Production

Preliminary Trial (1964-1967)

The key to economic pasture utilization lies in the proper assessment of an optimum stocking rate (Chisholm, 1965). The aim of the first experimantal stage was to arrive at an approximation of the carrying capacity of the area. Results of the third year of this stage (Table 2) show that production per animal was slightly higher under the lower stocking rate. The difference was, however, small and statistically not significant. The higher stocking rate resulted in a substantially higher production per unit pasture area (x 1.5). This conclusion formed the basis for the higher stocking rates applied during the second stage of the experiment.

Main Phase (1967-1972)

The interrelationship of rain, vegetation, body weight, and fertility will be dealt with in detail elsewhere. The present article will discuss only the main performance parameters.

Results are presented in Table 3 and Figure 5. The results dramatically demonstrate the complexity of the grazing system. Lamb yields are a product of fertility, lamb survival, and growth rate. All three vary with the stocking rate. However, other things being equal, fertility depends mainly on the body condition of the sheep during the breeding season, i.e., the preceding year. Lamb survival and growth rate depend on pasture conditions in the current year. The situation is further complicated by the diversity of rain distribution from year to year. To arrive at meaningful production figures, such an experiment must be run for several consecutive years.

It is thus pointed out that performance in the first year of the experiment is largely a result of the history of the sheep in the year before the onset of the experiment, so that true treatment effects actually begin to show from the second year on.

Table 2. Lamb production in 1966/67 (third year of first stage).

Parameter	Stocking rate (ha/ewe) [1] 0.6	1.2
Lambing rate[2]	0.69	0.75
Lamb's daily weight gain in the green season (g)	322	343
Lamb yield/ewe (kg)	27.4	39.9
Lamb yield/hectare (kg)	46	33

[1] There were two replicates to each stocking rate, 8 ewes in each replicate.
[2] Average number of lambs born per ewe in the flock.

Table 3. Sheep body weight (kg) fluctuations during 1968/69 at different stocking rates (ha/head).

Stocking rate	Month of weight recording 12/68	1-2/69[1]	5/69	9/69	12/69
0.2	39.3	43.6	56.4	47.2	41.0
0.3	43.7	49.1	63.6	57.8	45.0
0.4	45.8	47.6	63.0	57.3	46.5
0.6	44.9	47.4	59.6	55.5	46.0
0.8	49.7	51.8	62.2	63.7	52.5
1.0	52.5	49.6	67.7	65.5	56.0

[1] 3 days after lambing.

The years 1967/68 to 1969/70 were drought years of varying degrees; this accounted for a gradual overall reduction in productivity during this period. The 0.2 ha/ewe plot was badly overgrazed and had to be discontinued after 2 years.

Lambs Born per Ewe

The average number of lambs born per ewe in the flock (Fig. 5) fluctuated considerably from year to year, particularly under the two extreme (lowest and highest) stocking rates. A least-square analysis of variance, however, has shown that the year effect was not significant. This may indicate that all year effects were of relatively little importance, at least at the beginning of the breeding season in August and September, and that real shortage of food occurred, during summer, only under the highest stocking rate of 0.2 ha/ewe.

The apparent "optimum curve" of fertility may be of true significance. The overall quadratic regression was highly significant ($P<0.01$). Under the 1.0 ha/ewe, the vegetation may have matured earlier than under heavier stocking rates, thus developing certain deficiencies. The ewes in this plot were very heavy (70-80 kg at the beginning of the breeding season). If this postulation is correct, then it may also explain a recovery of fertility, which was observed in 1970/71 following the 1970 drought, when probably less surplus feed was formed during the vegetation growing season.

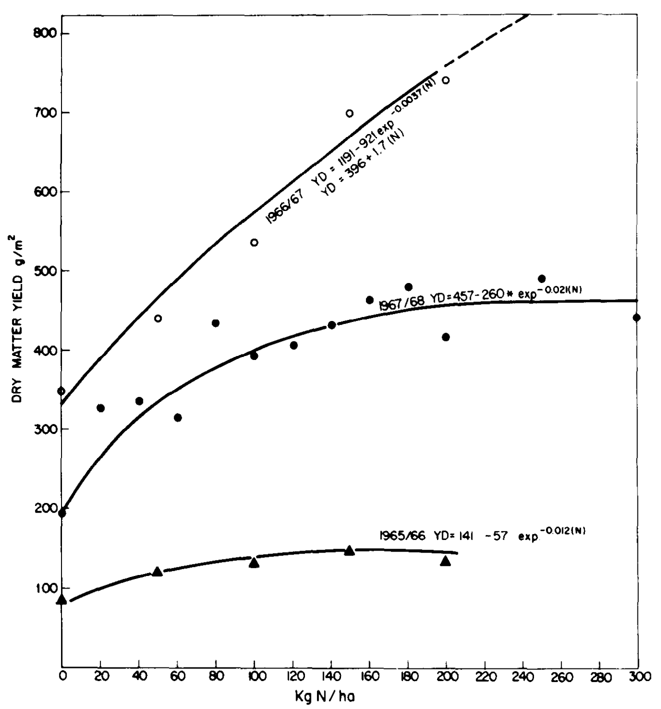

Fig. 5. *Effects of fertilizer application on native pasture in 3 types of rainfall years.*

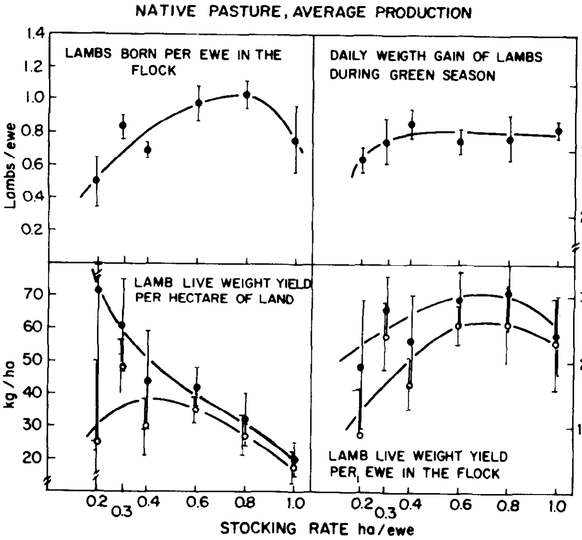

Fig. 6. *Five years' average relationships between stocking rates and different parameters describing lamb production. (Full circles = five years' averages; open circles = first year excluded.)*

Yield per Animal vs. Yield per Unit Area

Within certain limits, yield per animal rises with reduced stocking rates, whereas yield per unit land area decreases. This is clearly demonstrated in the present results (Fig. 5). Optimum economic production depends on land/sheep value relationships and on prices of supplementary fodder. In high rainfall areas, land value is usually high and the optimum will, therefore, fall close to the point of maximum production per unit land area. The same may be true for a small country like Israel, where pasture lands are scarce and all land values are high. In other low rainfall areas land is cheaper and the optimum economic production will move closer to maximum production per animal.

In evaluating the results it must again be stressed, that those of the first year were greatly affected by the pre-experimental history of the sheep. All plots were grazed under relatively light stocking rates (first phase) and 1967 was one of the best years recorded in a long period. Results excluding the first year are, therefore, also given in Figure 5. A calculation of the optimum from the present experiment will have to await the accumulation of additional results. It seems, however, that with very limited supplementary feeding, the optimum will be close to 0.6-0.8 ha/ewe. This is relatively high in comparison with similar rainfall areas in the world and may be explained by the high yield of the vegetation. Macfarlane (1968) cited much lower yields of dry matter per hectare for 250 mm rainfall areas. It is impossible to compare the results of lamb production with those appearing in literature, as all the available reports on lamb production deal with areas of higher rainfall.

The low per-ewe yields in 1968/69 and in 1969/70 are partly due to the fact, that during these drought years it was feared that the lamb burden would endanger the subsequent ewe fertility to a degree that would mask stocking rate effects. It was, therefore, decided to transfer a number of the lambs immediately after birth to an artificial rearing unit and, in these cases, both ewe and plot were credited only with the newly born lamb. The lambs that were left to be suckled showed that the pasture (and the ewes) could easily support the production of 15-20 kg lambs, (weaning at 6-8 weeks). In the succeeding seasons only mismothered lambs were sent to the artificial rearing unit.

The present experiment was made to assess the unsupported productive capacity of the area. No supplementary feeding was given and no management manipulations were made. Productivity of the area concerned would probably be greatly increased by various means such as the introduction of a more fertile breed of sheep, together with appropriate management procedures, i.e., supplementary feeding during late pregnancy and artificial rearing and early weaning of the lambs.

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Beef Production on Native Range, Crested Wheatgrass, and Russian Wildrye Pastures

SYLVESTER SMOLIAK AND SYDNEY B. SLEN

Highlight: *Weight gains per acre of yearling steers on continuously grazed Russian wildrye were 96.2 lb, or six times the gain of 16.0 lb on native range over a 6-year period. Crested wheatgrass, native range, and Russian wildrye grazed in a rotation or free-choice system reduced the acreage requirement to 15 acres per animal-unit for 6 months from 28 acres required for native range and increased beef production per acre by 55 to 66%. The vegetation on each of the three pasture types was maintained in a more productive condition when they were grazed in rotation in individually fenced fields than when they were grazed free-choice as a single unit. Crested wheatgrass and Russian wildrye effectively extended the grazing season.*

Crested wheatgrass [*Agropyron cristatum* (L.) Gaertn. and *A. desertorum* (Fisch.) Schult.] and Russian wildrye (*Elymus junceus* Fisch.) are the most commonly used species for range reseeding in the Northern Great Plains. (Grazing studies conducted by various research institutions have shown that these grasses are well adapted for pasture use. Some grazing trials have deferred the use of native range during the spring by providing crested wheatgrass pasture (Sarvis, 1941; Williams and Post, 1945; Lang and Landers, 1960; Lodge, 1963; Whitman et al., 1963; Smoliak, 1968). Other studies reported benefits from grazing Russian wildrye during late summer and fall resulting from the provision of a more nutritious feed compared to that on native range (Lang and Landers, 1960; Rogler et al., 1962; Jefferies et al., 1967; Smoliak, 1968; Rogler and Lorenz, 1970). Further advantages of utilizing seeded pastures to complement native range are the extension of the grazing season and the reduction in the pasture acreage requirement (Lodge, 1970).

This study was initiated in 1967 to determine the productivity of native range and seeded pastures when grazed continuously, in rotation, or free-choice by yearling steers.

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Methods

The study was conducted from 1967 to 1972 at the Agriculture Canada Research Substation, Manyberries, Alta. Four grazing treatments were studied. They were: (1) native range grazed continuously for 6 months; (2) crested wheatgrass, native range, and Russian wildrye grazed in rotation; (3) crested wheatgrass, native range, and Russian wildrye grazed free-choice; and (4) Russian wildrye grazed continuously for 6 months. In the rotation, crested wheatgrass was grazed in the spring for about 2 months, native range during the summer for 1½ months, and Russian wildrye in the fall for about 2½ months. In the free-choice grazing system, the three types of pasture were enclosed as one field, thus allowing the yearling steers their preference throughout the 6-month grazing season.

The fields used in the rotation and free-choice system had been grazed by sheep in a previous study (Smoliak, 1968). Nearby fields of native range and Russian wildrye were used for the continuously grazed treatments. Two replications of the free-choice grazing system were possible, while one replicate was available for the rotation and the continuously grazed native range and Russian wildrye treatments. Replication of land was sacrificed in favor of larger numbers of animals per treatment with replication obtained over grazing seasons or years.

Yearling steers were placed in each treatment in early May and removed in late October. Grazing began when leaf height of crested wheatgrass averaged 4 inches and terminated in 180 days, or when the steers on any treatment lost weight between three consecutive weighings. Stocking rates (Table 1) were set to provide an average forage utilization of 55% on native range and 75% on seeded pastures. In each of the study years, 8 head of yearling steers were allotted to the rotation system, 10 head to the free-choice grazing system, and 7 head to the continuously grazed native range. In 1967, 1971, and 1972, 9 head were allotted to the continuously grazed Russian wildrye, and in 1968, 1969, and 1970, 12 head were used.

The native range used in this study has been described previously (Smoliak, 1965). The crested wheatgrass and the Russian wildrye grazed in rotation or free-choice were sown in 1955 in 6-inch rows. The continuously grazed Russian wildrye pasture was seeded in 1961 in 18-inch rows (Fig. 1).

Table 1. Stocking rates and pasture acreages of various treatments at the Manyberries Research Substation, 1967-1972.

Parameter and treatment	Pasture: Native range	Russian wildrye	Crested wheatgrass
Stocking (acre/AUM)[1]			
Rotation	4.7	1.6	1.6
Free-choice	4.7	1.6	1.6
Continuous	4.7	0.83	–
Area of pastures (acres)			
Rotation	40	21	19
Free-choice	50	27	23
Continuous	130	35	–

[1] Acres per Animal Unit Month.

Fig. 1. *Russian wildrye pasture seeded in 18-inch rows was more productive and more heavily stocked than when seeded in 6-inch rows.*

The steers were weighed biweekly after being penned overnight without feed and water. Initial weights averaged about 490 lb in early May.

Herbage was harvested from 10 caged and 10 adjacent grazed 9.6-ft^2 areas in each pasture at the end of each grazing season. Dry matter yields were used to estimate forage production and consumption. Estimates of ground cover were obtained by the point-quadrat method (Clarke et al., 1942). A total of 2,100 points were taken in each pasture type in June 1966 and 1973.

Annual precipitation near the grazing trial averaged 13.0 inches for the 6 years (1967-1972) of the trial, compared with the 44-year average of 12.4 inches. Annual precipitation during the study was 16.9 inches in 1967; 12.5 inches in 1968; 9.6 inches in 1969; 13.9 inches in 1970; 12.4 inches in 1971; and 13.1 inches in 1972.

The data on steer gains were analyzed by the method of least squares for unequal subclass numbers, using initial weight as a covariate. As there were no differences in gains in the two replicates of the free-choice grazing system, the means are reported in this study. Tukey's test was used to test for significance of differences between treatments. Comparisons termed "different" imply statistical significance at the 0.05 level of probability.

Results

During the 6 years (1967-1972), yearling steers gained significantly more liveweight on continuously grazed Russian wildrye than those on the rotation or free-choice systems (Table 2). Liveweight gains of steers on continuously grazed native range (297.8 lb) were similar to those of steers on Russian wildrye (317.2 lb) and on the free-choice system (266.5 lb), but were significantly greater than those of steers on the rotation system (248.5 lb). During the spring grazing season, steer gains were greatest on the continuously grazed Russian wildrye and lowest on crested wheatgrass on the rotation system. During the summer grazing period, there were no differences in steer gains on the various pastures. During the fall grazing season, steers on the continuously grazed native range and Russian wildrye pastures gained significantly more liveweight than those on the free-choice system or on the Russian wildrye on the rotation system.

Table 2. Average initial weight and seasonal and total gain (lb) of yearling steers on four grazing treatments, 1967-1972.

Measurement	Continuous native range	Rotation	Free-choice	Continuous Russian wildrye
Initial weight	495.6 a[1]	490.2 a	492.2 a	495.4 a
Spring gain	143.5 ab	131.4 b	141.6 ab	156.8 a
Summer gain	82.5 a	76.2 a	84.6 a	83.9 a
Fall gain	71.8 a	40.9 b	40.3 b	76.5 a
Total gain	297.8 ab	248.5 c	266.5 bc	317.2 a

[1]Means followed by the same letter do not differ significantly within rows at the 5% level (Tukey's test).

There were no differences in the initial weight of the steers on the various treatments. However, there were differences in initial weight between years. The initial weights averaged 497.4 lb in 1967; 427.6 lb in 1968; 464.4 lb in 1969; 462.9 lb in 1970; 520.7 in 1971; and 535.8 lb in 1972.

Steer gains per acre were significantly greater on Russian wildrye pastures than on the other pastures (Table 3). Over the 6-year period, steer gains per acre on Russian wildrye averaged 96.2 lb, which was six times that on native range pastures (16.0 lb). Gains per acre on the rotation (24.8 lb) and free-choice (26.6 lb) grazing system were about 1.5 times the gains on native range pastures, but these differences were not significant. When adjusted for initial weight, year differences in gain per acre were not significant but the treatment × year interaction was significant and is attributed to variations in precipitation during the season of plant growth, which affected feed quality.

The lower gains per acre in 1971 and 1972 reflected the lower total liveweight gains. Liveweight gains of the steers averaged 273.8 lb in 1967; 350.3 lb in 1968; 304.1 lb in 1969; 320.2 lb in 1970; 209.6 lb in 1971; and 217.8 lb in 1972. The liveweight gains of the steers during 1971 and 1972, the last 2 years of the study, were significantly lower than during the first 4 years. In 1971, the steers lost weight during the last 4 weeks of the trial. During this period, the steers lost on the average 37.6 lb on the continuously grazed native range, 53.0 lb on the rotation, 43.9 lb on the free-choice grazing system, and 14.8 lb on the continuously grazed Russian wildrye. During the last 2-week period in 1972, the steers lost on the average 12.8 lb on the rotation and 1.2 lb on the free-choice grazing system, but gained 8.9 lb on continuously grazed native range and 18.2 lb on Russian wildrye.

Forage production estimates from clipped plots indicate considerable variation in dry matter production and utilization among pasture types and years (Table 4). The Russian wildrye pasture produced about twice as much dry matter when seeded in 18-inch

Table 3. Beef production (lb/acre) from yearling steers on four grazing treatments, 1967-1972.

Year	Pasture season	Continuous native range	Rotation	Free-choice	Continuous Russian wildrye
1967	May 11-Nov. 9	15.7	26.1	24.5	84.5
1968	May 2-Oct. 30	18.1	32.6	35.5	125.4
1969	May 1-Oct. 30	18.0	27.6	29.2	110.3
1970	May 12-Oct. 27	18.9	28.4	31.1	115.1
1971	May 6-Oct. 27	12.7	18.2	19.1	67.7
1972	May 11-Sep. 28	12.8	16.0	20.6	74.2
Mean	May 7-Oct. 25	16.0 b[1]	24.8 b	26.6 b	96.2 a

[1]Means followed by the same letter do not differ significantly at the 5% level (Tukey's test).

rows (1,120 lb/acre) as when seeded in 6-inch rows (480 lb/acre). Average dry matter yields were 305 lb/acre on native range and 750lb/acre on crested wheatgrass.

Utilization of forage during the study period ranged from 49 to 95% on native pastures, 31 to 87% on crested wheatgrass, and 49 to 97% on Russian wildrye (Table 4).

Forage production declined and utilization increased on each pasture type and on each grazing system during the trial. The highest yields on native range were recorded in 1968 and on crested wheatgrass and Russian wildrye in 1967. The lowest yields were recorded in all fields in 1972, the last year of the study.

The steers made greater use of native range when grazed free-choice than they did on native range grazed continuously or during the summer when grazed in a rotation. More crested wheatgrass was consumed when grazed in a rotation than when grazed free-choice. Equal amounts of Russian wildrye were consumed when grazed in a rotation or free-choice.

The basal area of the grasses on the three pasture types under three grazing systems did not vary greatly between 1966 and 1973 (Table 5), except on the rotation crested wheatgrass where a 30% reduction was recorded. The native range pastures grazed free-choice showed a decrease in basal area of needleandthread (*Stipa comata* Trin. & Rupr.) and the wheatgrasses (*Agropyron* spp.) and an increase of Junegrass (*Koeleria cristata* (L.) Pers.). Blue grama (*Bouteloua gracilis* (HBK) Lag.) remained rather constant in basal area on all native range pastures. The basal area of forbs and shrubs decreased on all native range pastures, on the crested wheatgrass grazed free-choice, and on the Russian wildrye pastures grazed in rotation and free-choice, but increased on the crested wheatgrass pasture grazed in rotation. There was a decrease in basal area of Russian wildrye when grazed continuously or free-choice, but a slight increase when grazed in a rotation system.

Discussion

Russian wildrye and crested wheatgrass, two introduced grasses, have been effective in increasing beef production. Established pastures of Russian wildrye produced from five to seven times as much gain per acre as did native range when grazed by yearling steers during a 6-month grazing season. The combination of crested wheatgrass, Russian wildrye, and native range produced from 1.3 to 1.8 times as much gain per acre as native range.

The low gains per acre recorded for the yearling steers on the rotation and the free-choice grazing systems may reflect the lower production and availability of feed. The decline in forage production from 1967 to 1972 may be attributed in part to prior grazing by sheep for a 10-year period and in part to dry conditions in the spring season. Total precipitation in March, April, and May was less than normal from 1968 to 1972 (long-term average is 3.3 inches).

The steers with a free-choice generally preferred native range to crested wheatgrass. Native range grazed free-choice was more heavily utilized than when grazed in rotation or continuously. Crested wheatgrass grazed in rotation was more heavily utilized than when grazed free-choice. Russian wildrye was heavily utilized in both the rotation and the free-choice system of grazing. This suggests that better control of grazing was obtained when the three pasture types, crested wheatgrass, native range, and Russian wildrye, were fenced separately and grazed in a rotation. In a previous study, Smoliak (1968) showed that sheep rotated themselves on the various pasture types.

Table 4. Dry matter production (lb/acre) and utilization (%) of forage on three pasture types under four grazing treatments, 1967-1972.

		Native range			Crested wheatgrass		Russian wildrye		
Year	Measurement	Continuous	Rotation	Free-choice	Rotation	Free-choice	Continuous	Rotation	Free-choice
1967	Production	465	420	445	1,070	1,120	2,260	690	610
	Utilization	57	49	54	58	31	47	56	49
1968	Production	465	515	510	685	925	815	635	585
	Utilization	56	63	62	82	45	77	73	82
1969	Production	330	315	310	660	700	760	610	445
	Utilization	60	56	70	71	67	90	90	95
1970	Production	200	215	220	735	805	1,155	485	365
	Utilization	70	61	66	71	65	90	81	74
1971	Production	260	190	210	595	655	1,080	345	410
	Utilization	77	75	86	77	69	89	92	91
1972	Production	135	130	120	480	605	660	325	290
	Utilization	75	82	95	87	82	92	97	95
Mean	Production	310	300	305	705	800	1,120	515	450
	Utilization	66	64	72	74	60	81	82	81

Table 5. Changes in basal area (%) of vegetation on three pasture types under four grazing treatments, 1966-1973.

Pasture type and species	Continuous		Rotation		Free-choice	
	1966	1973	1966	1973	1966	1973
Native range						
Blue grama	3.8	3.8	3.3	3.3	3.2	3.4
Needleandthread	3.2	3.1	3.8	3.7	3.1	2.3
Junegrass	0.9	1.5	0.8	1.1	0.9	1.8
Wheatgrasses	1.4	1.0	0.5	0.4	1.0	0.5
Other grasses and sedges	1.8	1.3	3.2	2.3	1.6	1.7
Total	11.1	10.7	11.6	10.8	9.8	9.7
Forbs and shrubs	2.2	2.0	2.8	2.3	1.9	1.7
Crested wheatgrass						
Crested wheatgrass	–	–	11.1	7.7	10.3	9.1
Other grasses	–	–	0.0	0.0	0.0	0.0
Forbs and shrubs	–	–	0.3	0.8	0.3	0.0
Russian wildrye						
Russian wildrye	9.8	8.2	9.9	10.6	10.0	8.6
Other grasses	0.0	0.0	0.7	0.1	0.1	0.1
Forbs and shrubs	0.0	0.0	0.8	0.0	0.4	0.0

Under the rotation and free-choice grazing system, the acreage requirement for a 6-month grazing period was reduced to 15 acres per animal-unit compared to 28 acres required on continuously grazed native range. The continuously grazed Russian wildrye, in 18-inch rows, provided 5.0 acres per animal-unit for 6 months of grazing.

Stocking rates on Russian wildrye pastures varied from 0.83 to 1.6 acres per AUM, depending on row spacing and forage production, and were from about 3 to 5.5 times heavier than on native range. The Russian wildrye seeded in 18-inch rows produced more dry matter and had a greater carrying capacity than when seeded in 6-inch rows. This confirms the results of Rogler and Lorenz (1970) who showed that dry matter, beef production, and stocking rates were greater on Russian wildrye seeded in 36-inch rows compared to solid stands seeded in 6-inch rows.

The results of this study indicate that both Russian wildrye and crested wheatgrass are suitable for range reseeding and are effective in reducing the acreage requirement and extending the grazing season. Trlica and Cook (1972) concluded in their study of carbohydrate reserves in the two grasses that "both crested wheatgrass and Russian wildrye are physiologically adapted for fall or early spring grazing and possibly for spring-fall range." Our study suggests that crested wheatgrass should be grazed during the spring period, while Russian wildrye should be grazed in the fall or throughout the grazing season.

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The Physiology of Eating and the Energy Expenditure of the Ruminant at Pasture

P. O. OSUJI

Highlight: *Large areas of the world are marginal lands and extensive grazing of moderately good or poor pastures is the major avenue for producing meat and milk. As the world population increases, the future supply of meat and milk for man would of necessity have to come from the utilization of existing marginal lands in grazing systems.*

Conventional estimates of the energy required for maintenance have been made with animals housed indoors in respration chambers. Animals at pasture walk longer distances, and usually up gradients and ingest herbage of usually low dry matter content. Consequently, they spend considerably more time eating and foraging for food than conventionally housed animals. These extra muscular activities, over and above those observed indoors, might increase the maintenance energy requirements of animals on range by 25-50%.

It is suggested that this increased requirement might be due to the energy cost of eating, walking to graze, and the "work of digestion" done by the gut in handling bulky pasture materials.

The energy requirements of animals indoors have been estimated by the use of direct calorimetry (Pullar, 1969; Blaxter, 1967; Benzinger and Kitzinger, 1949; Braman, 1933) or indirect calorimetry (Blaxter, 1967; Blaxter et al., 1954; Kleiber, 1935; Flatt et al., 1958; Wainman and Blaxter, 1958, 1969), and by the comparative slaughter technique (Lofgreen, 1965). However the energy requirements of the free ranging animal have been more difficult to estimate because of the complications of environmental factors. Indications are that animals on range have maintenance requirements appreciably higher than those indoors.

Blaxter (1967) reported that activity by sheep at maintenance and in a thermoneutral environment would increase their total energy expenditure by 11%. For cattle he suggested that they expend about 15% more energy out-of-doors than indoors. Other workers determined the maintenance requirements of animals at pasture from the intake of digestible organic matter required to maintain them at constant liveweight. Corbett et al. (1961) found that when cows were strip-grazed, their maintenance requirements did not differ greatly from what would be expected indoors. The average cow required 12.1 Mcal metabolizable energy (ME) per day. Reid (1958) reported that the maintenance needs of average dairy cows at pasture was 18.6 Mcal/day. Wallace (1955) found that dairy cows at pasture required 21.1 Mcal/day for maintenance. Similar values by Hutton (1962) ranged from 18.4-25 Mcal/day. Some of these estimates would indicate that cows at pasture have maintenance needs 50 to 100% greater than similar cows indoors.

The increased requirements of sheep at pasture have ranged from about 25% (Langlands et al., 1963; Coop and Hill, 1962) to about 100% (Lambourne and Reardon, 1963). Values for penned sheep were 1.6 Mcal/day (Langlands et al., 1963) and 1.4 Mcal (Coop, 1962). However the outdoors maintenance requirements reported by the various workers were 2.3 to 2.7 Mcal ME/day (Coop and Hill, 1962) and 2.1 Mcal/day (Lambourne and Reardon, 1963). Blaxter (1967) suggested that such high maintenance requirements for sheep at pasture might be due to increased costs of body movement at pasture, the effects of the outdoor environment, or errors due to the measurement of organic matter intake. It is suggested that the increased energy expenditure at pasture might be due to increased overall costs associated with grazing, especially the costs of walking to and harvesting the herbage, which depend on the availability of pasture and environmental stresses (Osuji, 1973).

Recently Young and Corbett (1972) developed methods for estimating the energy requirements of sheep at pasture. They used either a "Mobile Indirect Calorimeter" (Corbett et al., 1969) or the carbon dioxide entry rate technique (Young et al., 1969). With these apparently improved techniques the energy requirements of sheep at pasture were 60 to 70% greater than those for housed sheep of similar body weight (Yougn and Corbett, 1972). These values are all closer to the estimates of maintenance energy requirement at pasture based on digestible organic matter intake than those obtained from measurements made in calorimeters and adjusted to account for the increased activities of animals at pasture.

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Graham (1964, 1965) reported that the energy expended in muscular work by a sheep at pasture could be up to six times that of a housed sheep due to standing, walking, eating, the energy cost of rumination, and the secretory activities associated with feeding (Ustjanzew, 1911; Graham, 1962, 1964; Agr. Res. Council, 1965; Young, 1966; Osuji, 1971; Webster, 1972). The energy cost of eating has been said to constitute an appreciable part of the extra maintenance requirement of the grazing animal (Osuji, 1971; Webster, 1972). The muscular activities of prehension and mastication plus the secretory activities associated with feeding are essential components of this complex. Therefore, the study of the marked changes associated with eating, especially their contributions to the total heat increment of an animal, may lead to a better understanding of the physiology of forage utilization, particularly with regard to energy requirements and the effect of the physical form of the diet on the productivity of ruminants.

Studies of the physiological changes associated with feeding in animals at pasture are very difficult. Therefore, Osuji (1973) attempted to study in the calorimeter the changes associated with the ingestion of fresh herbage and the same material dried. It was hoped that this would give a clue as to such changes in animals eating the same fresh material in the field. It was found that the ME requirement of sheep given fresh grass was 12% higher than that of sheep given dried grass.

Energy Cost of Muscular Activity

Standing vs Lying

When an animal is fasted in a respiration chamber, the energy the animal expends in minor movements (standing, drinking, and scratching) is usually very small (Blaxter, 1967). In cattle, Forbes et al. (1927) found, as did Blaxter (1967), that under the conditions obtainable in respiration chambers, the activity of cattle was much the same whether they were fed or fasted. Fasting steers spent on average 7.2 hours/24 hours standing as compared to 7.8 hours for the fed animal.

It is difficult to ascertain to what extent the levels of activity in animals observed in respiration chambers reflect their activity under normal feeding conditions or under range or pasture conditions where the area available for movement is greatly increased, especially when pasture availability is limited. With both cattle and sheep, there is a linear increase in grazing time as pasture availability decreases (Lofgreen et al., 1957; Arnold, 1960).

Not surprisingly, these reports show that animals grazing poor or sparse pastures spend more time standing and walking about than do conventionally housed animals. The increased energy expended by an animal at pasture over that expended in a calorimeter depends, therefore, on the energy cost of the different activities at pasture and the time spent in pursuit of them additional to that in the calorimeter. Young and Corbett (1972) in a recent experiment showed that as pasture availability decreased from 2800 to 370 kg/hectare, grazing time increased from 8.2 to 12.3 hours.

Estimates of the increased energy cost of standing over lying made in respiration equipments are summarized in Table 1.

Table 1. Energy cost (kcal/kg/hour) of standing over lying.

Species	Energy cost of activity	Reference
Sheep	0.06	Osuji (1973)
	0.12	Hall and Brody (1933)
	0.07	Joyce and Blaxter (1963)
	Metabolism increased by 70%	Pullar (1962)
	0.38	Armsby and Fries (1915)
	0.34	Graham (1964)
	0.12	Webster and Valks (1966)
Cattle	0.09	Hall and Brody (1933)
	0.12	Forbes et al. (1927)
	0.06	Blaxter and Wainman (1962)
	0.10	McLean (1962)

Walking

The energy cost of horizontal locomotion has been determined by various workers for various species of animals. Clapperton (1961, 1964) found that the energy cost of horizontal walking in sheep increased with speed and was on average 0.59 cal/horizontal kg meter. Values of 0.54 for man (Smith, 1922), 0.58 for the dog (Lusk, 1931), and 0.39 cal/horizontal kg m for the horse (Brody, 1945) have also been reported. Clapperton (1961) with sheep found that the energy cost of vertical work decreased with speed but was independent of gradient. He found a value of 6.45 cal/vertical kg m. This could be compared to 6.92 cal/kg vertical m found for man by Lusk (1931). The amount of food given to the sheep had no effect on the cost of work.

Since the work of ascent is about 10 times as costly as walking on a horizontal plane (Clapperton, 1961) it suggests that an animal grazing a hill pasture expends more energy walking to find the herbage in addition to the other muscular activities. In an area where animals face drought conditions for a greater part of the year and have to travel long distances to graze or drink, the energy cost of walking could be high. Such problems are experienced for example by the nomadic Fulannis and Masai who herd their cattle across the rangelands of Africa.

Energy Cost of Eating

The Agricultural Research Council of the United Kingdom (1965) stated that the heat increment of feeding in ruminants is in the main accounted for by the heat of fermentation and the energy cost of metabolizing the volatile fatty acids (VFA). The energy cost of eating they considered was negligible. In other words, the energy cost of grazing, as distinct from the energy cost of standing and walking to graze, should be no different from the energy cost of eating the same amount of food energy when provided in a convenient and readily accessible form in a calorimeter. As indicated earlier, this conclusion now seems unlikely (Osuji, 1971; Webster, 1972); it is probable that grazing is energetically more expensive than eating prepared and accessible food, and the cost of grazing may explain the differences between published accounts of the maintenance energy requirement of the grazing animal.

It has been shown that the energy cost of eating is a direct function of the time spent eating (Osuji, 1973). Therefore, animals at pasture spending 8 to 10 hours (Tribe, 1949; Hughes and Reid, 1951; Arnold, 1960; and Graham, 1965) per day eating would expend an appreciable amount of energy as a direct consequence of eating. Therefore, it is of interest to include in an examination of the factors contributing to the total heat increment of feeding an estimate of the energy cost of eating.

Estimates of the energy cost of eating have been reported by Ustjanzew (1911), Blaxter and Joyce (1963), Graham (1964), Young (1966), Webster (1967), Webster and Hays (1968), and Osuji (1971, 1973). These have been gathered together in Table 2.

Table 2. Estimates of the energy cost (cal/kg/min) of eating.

Animal	Feed	Cost	Reference
Sheep	Long timothy hay	14.7	Ustjanzew (1911)
"	Timothy hay (wet) soaked	13.42	"
"	Long clover hay	14.73	"
"	Dry pea or lucerne	12.35	"
"	Green lucerne	11.08	"
"	Red clover (green)	7.01	"
"	Oat grain	15.15	"
"	Lucerne hay	10.94	"
Ox	Hay	7.06	Dahn (see Ustjanzew (1911)
Sheep	Cut grass	9.0 (4.9-13.2)	Graham (1964)
"	Uncut sward	9.0 (4.0-16.4)	"
"	Chopped dried grass	10.3	Osuji (1973)
"	Pelleted dried grass	4.4	"
"	Fresh pasture grass	7.5	"
"	Lucerne chaff	5.4-12.4	Young (1966)
"	Wheaten chaff	8.08	"
"	Concentrate	6.4-7.0	"
"	Dried grass	22.0	Webster (1967)*
"	Alfalfa/brome hay	13.8 (11.7-15.5)	Webster and Hays (1968)
"	Chopped alfalfa		Christopherson (1971)
"	Brome grass hay	8.05	"

*Estimate based on heart rate used as an index of heat production.

Ustjanzew (1911) using mask and tracheostomy techniques measured the respiratory exchange of sheep which were fasted for 13 to 14 hours and then offered various types and preparations of food. The energy cost of eating hay was the same whether it was fed in the long form or chopped and steamed. Metabolic rate during the course of the meal increased by 60%.

The energy expended during consumption of green feed (pea haulms and lucerne) was greater than that during the consumption of an equivalent amount of dry matter fed as hay. This was due mainly to the increased amount of time that the sheep required to achieve the same dry matter intake when eating fresh material.

Graham (1964) dug small areas of turf from pasture and relaid them on the floor of a respiration chamber. Sheep were allowed to graze this material for 1-2 hours. Prepared meals were offered to the sheep between grazing periods. He found that the rates of food intake varied with types of food. Sheep weighing about 40 kg ate 0.5-1 kg of fresh herbage (60-120 g DM) per hour when grazing and 2-3 kg cut fresh herbage (300-400 g DM) and 400-800 g hay per hour; i.e., the rate of eating during grazing was lower than the rate of eating comparable cut fresh grass. Not surprisingly, when sheep were offered poor pasture or given prepared food *ad lib,* their rate of intake was very low; but when given small meals after long periods without food they had the fastest eating rate. The rate of energy expenditure during eating was not affected by the size of meals or by the length of time between them. It was suggested that there was "*a tendency* for the cost of any given activity to vary in the same direction as the rate of intake." This statement should not necessarily be taken to mean that the energy cost of activity (eating) is directly related to the rate of eating. Graham's experiments were not particularly designed to answer this question. Graham (1964) estimated the energy cost of grazing as 0.54 kcal/hour/kg wt (range, 0.29-0.79). The corresponding value for eating prepared meals was 0.54 (range, 0.24-0.98).

Blaxter and Joyce (1963) reported that the increased metabolic rate (50-60%) associated with eating in sheep did not continue into the post prandial period. They partly ascribed this to the excitement of animals anticipating their regular feed. However, Osuji (1973) found that heat production during the 2 yours preceding feeding was often not significantly different from the base line values.

Young (1966) offered diets of various types to sheep and found that the increased energy expenditure per gram of diet ingested varied with the type of diet. The energy cost of eating (cal/kgw/g) was 0.3-0.6 for a concentrate diet and 1.2-1.9 for lucerne or wheaten chaff diet. The rates at which the foods were eaten were about 12 g/min for the chaff and more than 40 g/min for the concentrate diet. His results would, therefore, show contrary to Graham's (1964), that the energy cost of eating was inversely proportional to the rate of eating. Young (1966) also attributed the initial rapid rise in the metabolic rate of the sheep when food was given to psychic factors and claimed that during eating there was a slight increase in respiratory frequency, but this may have been an artefact.

He also used sheep fitted with oesophageal fistulas and found that when the sheep were sham-fed such that 77% of the food was recovered from the oesophageal fistula, there was no difference in the metabolic rate between normally and sham-fed sheep. This finding thus discounted the possibility that the presence of food in the rumen acted as the metabolic stimulus. Young therefore concluded that the increased heat productions observed during eating originate mainly from the act of prehension and mastication.

Webster and Hays (1968) have reported that the increased metabolic rate associated with eating is not mediated through the sympathetic nervous system. They showed that propranolol (a beta-adrenergic blocking agent) almost totally inhibited cardioacceleration in sheep following exposure to a moderate cold stress but only slightly reduced the cardioacceleration observed in sheep during feeding.

Table 3. The daily energy expenditure of a 50 kg sheep at pasture compared to that of a similar sheep kept indoors.

	Duration of activities		Energy cost of activities				
			Housed		Grazed		Cost of activity in kcal/kg body wt.
Activity	Unit of measure	No.of units	Unit of measure	Total cost	Unit of measure	Total cost	
Eating (chopped dried grass)	hour	1	kcal/day	31.0	–	–	0.62/hour
Grazing (fresh pasture)	"	9		–	kcal/day	202.5	0.45/hour[1]
Ruminating	"	8	"	12.0	"	12.0	0.03/hour
Standing							
Housed	"	2	"	6.0	–	–	0.06/hour
Grazed	"	12	–	–	"	36.0	0.06/hour
Walking							
Housed	km/day	1	"	29.5	–	–	0.00059/m
Grazed	km/day	6.1	–	–	kcal/day	180.0	0.00059/m
Total energy cost of muscular work			"	78.5	"	430.5	
Resting metabolic rate[2]			"	1200.0	"	1200.0	
Total daily energy expenditure							
Amount			"	1278.5	"	1630.5	
Increase in energy expenditure due to:							
(1) Muscular activity			%	6.6	%	35.9	
(2) Eating/grazing			"	2.6	"	16.9	
(3) Ruminating			"	1.0	"	1.0	
(4) Standing and walking			"	3.0	"	18.0	

[1] From Osuji (1973).
[2] Resting metabolic rate = Basal metabolic rate (BMR) + heat increment of feed at maintenance.

Young (1966) also estimated that the energy cost of eating for housed animals accounts for 2-3% of their daily energy expenditure. For free ranging animals grazing for 8 to 9 hours a day, the energy cost of eating could constitute an appreciable part of the maintenance requirement (Osuji, 1971; Webster, 1972). The contribution of eating to the daily energy expenditure of an animal grazing poor pasture would be considerably greater, since it has been reported (Arnold, 1960) that the time spent grazing is greatly increased when animals graze very poor pasture. Graham (1964) reported that a sheep grazing poor pasture has a maintenance requirement 40% greater than that of a caged animal.

This estimate agrees more closely with the predictions of increased energy requirements of sheep out-of-doors made on the basis of organic matter intake (Coop and Hill, 1962; Langlands et al., 1963; Lambourne and Reardon, 1963). But it is considerably in excess of the value of about 15% referred to by the Agr. Res. Council (1965) on the basis of Blaxter's (1967) prediction of the allowances for extra muscular activities out-of-doors. This did not include the energy cost of eating, as this was considered negligible. There is, therefore, a strong suggestion on the basis of the foregoing arguement that the energy cost of eating makes a significant contribution to the energy requirements of animals, especially those at pasture.

Results from recent experiments (Osuji, 1973) indicate that eating definitely results in increased heat production in ruminants as has been observed by other workers. The precise relationship between eating and heat production, especially in relation to the effect of the physical form of the diet, has not been clearly defined.

The trials reported by Osuji (1973) suggest:

1) that eating is associated with an increase in heat production and the increased rate often varies with the physical form of the diet but does not seem to vary with the size of the meal;

2) because dried roughage diets take longer to eat, the increase in heat production associated with their ingestion is considerably greater. Pelleting has the effect of markedly increasing the rate of food intake, and since pelleting reduces the particle size of a diet, the eating of pelleted diets does not result in appreciable increases in heat production attributable to trituration during eating;

3) when fresh grass is given to sheep, their rate of intake of dry matter is much slower, even though they eat an equivalent weight of wet matter more rapidly. This is mainly because of the enormous amount of water in the herbage which they must ingest to attain the same level of dry matter intake as that from dried grass. Consequently, the energy cost of eating (cal/g DM) the same grass is about twice as great when the fresh than when the dried grass is given;

4) the energy cost of eating varies directly with the time spent eating ($r = 0.86$). For animals eating, for example, 8 hours a day at pasture, the energy cost of eating would contribute significantly to maintenance requirement. These observations could also explain the low energy costs associated with the eating of prepared meals by housed animals, as these usually consume their day's meal in 1-2 hours.

The same experiments showed that the energy cost of rumination is very small. Therefore, the value of rumination to animals that chew the cud might lie in the great saving in energy during rumination as opposed to eating. For example, the energy cost of eating for a sheep at pasture eating for 16 hours instead of for 8 hours a day, would amount to 22% of the maintenance energy requirement. By eating for only 8 hours, the sheep would at least halve this amount of energy expenditure.

On the basis of calorimetric estimates it has been calculated that a grazing animal would need 10-15% more energy for maintenance than the housed one (Blaxter, 1967). This allowance was made for the increased muscular activity of the grazing animal, mainly standing and walking. However, allowing for activities like standing, walking, and rumination does not explain the wide discrepancies between the maintenance energy requirement of the housed compared to the free-grazing animal. It is suggested that the energy cost of eating *per se* could partly explain such discrepancies. Webster (1972) and Graham (1964) have reported that the energy cost of eating could account for 25-50% of the extra maintenance requirement of the grazing animal.

It is also probable that the "work of digestion" involved in handling the bulky fresh grass might account for an appreciably high fraction of the total heat increment of feeding observed in ruminants. Osuji (1973), for example, found that visceral heat increment due to aerobic gut metabolism in sheep accounted for about 66% of the increased heat production of the portal drained viscera disregarding the type and physical form of diet.

Table 3 attempts to summarize the contribution of various factors to the increased energy requirement of sheep at pasture as compared to the housed animal. This table clearly shows that the sheep at pasture has a maintenance requirement about 30% higher than that of a comparable animal indoors. This extra requirement is due to the muscular activities of eating, rumination, standing, and walking. While energy expenditure due to eating (foraging?) amounts to about 50% of the total expenditure due to muscular activity in the grazing animal, the corresponding percentage for the housed animal eating a prepared meal is 39%. The contributions of the other activities, except standing and walking, are not appreciable when compared to the eating component.

The maintenance requirement of the animal at pasture has been said to be 25-100% higher than that of a similar animal indoors. This is within the range (30%) calculated in Table 3. It is however being suggested that the "work of digestion" i.e., the work done by the gut in "handling" the bulky pasture material could be the other major component of the increased energy expenditure of the free ranging animal (Osuji, 1973). This is an area that needs further study.

Fluid and Electrolyte Changes during Eating

Dobson et al. (1966) reported that when sheep were changed from high potassium (K), low sodium (Na) grass to hay and diets of medium K and Na contents, the excretion of Na in the urine fell and there was a net retention of Na. When the animals were returned to the grass diet, the Na retained during the previous regime was rapidly lost in the urine. They ascribed these changes to the water and electrolyte content of the gut and suggested that the different physical forms of the diets and their different osmotic activities might have played some part. Stacy and Warner (1966) showed that the rate of absorption of Na from the rumen into the blood was influenced by the potassium concentration of the rumen fluid. The rumen has been said to dominate the response of the animal to changes in the electrolyte content of the diet. When potassium chloride (KCl) was added to a maintenance diet (700 m-eq/day), the K content of the rumen increased and the Na content decreased, due possibly to an increased absorption of Na across the rumen wall (Warner and Stacy, 1972a). Warner and Stacy, (1972b) also found that when saliva was replaced by a synthetic solution, the rate of water movement across the rumen wall was a linear function of the osmotic pressure and concluded that the rate of K and Na absorption tended to depend on the immediate nutritional state of the animal. The morphology of the rumen eqithelium underwent extensive changes when the rumen contents were made highly hypertonic.

During feeding, an increased volume of fluid leaves the plasma and extracellular fluid space (ECF) and enters the gut. Stacy and Warner (1966) reported an increase of 0.29-0.85 liters/hour in the flow of fluid from the ECF to the rumen during the consumption of dry feed and ascribed this to an increased salivary flow. A decrease of 10% in the ECF volume was noted by Ternouth (1968) in sheep given 350 g of lucerne chaff. He ascribed this to an increased salivary flow and to the transfer of plasma fluid across the rumen wall during eating. Blair-West and Brook (1969) showed a rapid fall in the plasma volume of sheep within 15 minutes of starting to eat. Plasma volume in sheep given 1 kg of chopped alfalfa-brome hay declined sharply by 300 ml at the beginning of the meal and recovered slowly after feed was removed. Changes in ECF volume estimated from thiosulphate disappearance was variable but showed a significant fall of 1-1.5 liters during eating (Christopherson and Webster, 1972).

Blair-West and Brook (1969) showed that plasma renin concentration rose throughout the duration of a meal and indicated that the renin-angio-tensin system was activated during eating, leading to retention of Na and water when appreciable quantities of fluid were being lost from the ECF to the gut. Feeding has also been shown to stimulate the release of the antidiuretic hormone in sheep.

While it is difficult to make any precise quantitative estimates of the effects of the quantity and quality of food eaten on the flow of electrolytes into and out of the gut, it is clear that these effects are considerable. Webster (1972) therefore postulated that the increased metabolic rate associated with eating could be attributed to these marked increases in the rate at which body fluids were redistributed between the extravascular and vascular compartments and the lumen of the gut. The association of angio-tensin with active transport suggests a possible hormona stimulus to thermogenesis during eating. Because of this, it seems that the effect of eating fresh grass on fluid and electrolyte changes in animals needs more researching.

Cardiovascular Changes Associated with Eating

Heart rate is known to be related to oxygen consumption (Brody, 1945; Webster, 1967) and this relationship has been used to predict the metabolic rates of animals (Blaxter, 1948; Webster, 1967; Brockway and McEwan, 1969). Webster (1967) used the heart rate to predict the metabolic rate of sheep during eating and exposure to cold. Within limits, the relationship between heart rate and oxygen consumption could in some animals, be used to predict energy expenditure. In three out of four sheep the errors associated with the prediction were less than 10%. However in the experiments of Brockway and McEwan (1969) heart rate could not be used adequately as a predictor of energy expenditure in sheep during eating because of the large errors associated with the prediction equations.

Marked increases in the heart rate of sheep during eating have been reported (Young, 1966; Webster, 1967; Webster and Hays, 1968; Berzins, 1969; Christopherson and Webster, 1972). Ingram and Whittow (1962) also reported an increased heart rate during eating in cattle. Young (1964) attributed the initial increase in heart rate in sheep to the release of adrenaline. The increased heart rate associated with eating was not abolished by beta-adrenergic blockade. It was concluded, at that time, that the cardioacceleration during feeding could not be attributed to excitement (Webster and Hays, 1968). Hays and Webster (1971) later showed that most of the increase in heart rate observed when sheep ate a meal in a thermoneutral environment could be attributed to reduced vagal inhibition. When the stimulatory effects of colds and eating were superimposed, heart rate was often considerably higher than 110 beats/minute, the intrinsic rate of the denervated sheep's heart, even when sympathetic cardioaccelerator fibres were blocked with propranolol. Hays and Webster (1971) suggested from these observations that at this time heart rate was accelerated in part by a non-autonomic factor, possibly angio-tensin, known to be released during eating (Blair-West and Brook, 1969).

During eating both arterial and venous CO_2 tensions and free plasma HCO_3 increased while blood pH decreased; (Christopherson and Webster, 1972) arterial oxygen tension (PO_2) did not change significantly during eating but venous oxygen tension (PvO_2) fell significantly. The fall in oxygen (O_2) saturation of venous blood was related to the decline in pH. The arteriovenous difference in oxygen content increased from 4.4 ml/100 ml before feeding to 6 ml/100 at the end of the meal.

The beginning of the meal was associated with a significant increase in haematocrit and this persisted and only declined slowly afterwards. Blood haemoglobin increased from 8.6 to 9.4 g/100 ml but this was attributed entirely to the increase in haematocrit levels. Cardiac output increased by 17% and stroke volume declined throughout the meal from 67 to 52 ml per heart beat (Christopherson and Webster, 1972).

Apparently eating is associated with a lot of cardiovascular changes. It is to be expected therefore that increased activity by these various systems during eating will contribute to the elevated metabolic rate associated with eating. Therefore for animals on range, the increase in the activities of these systems would be considerably greater and these would increase their maintenance requirement appreciably. Additional increases are suggested as coming from the increased "work of digestion" involved in the handling of the bulky pasture materials.

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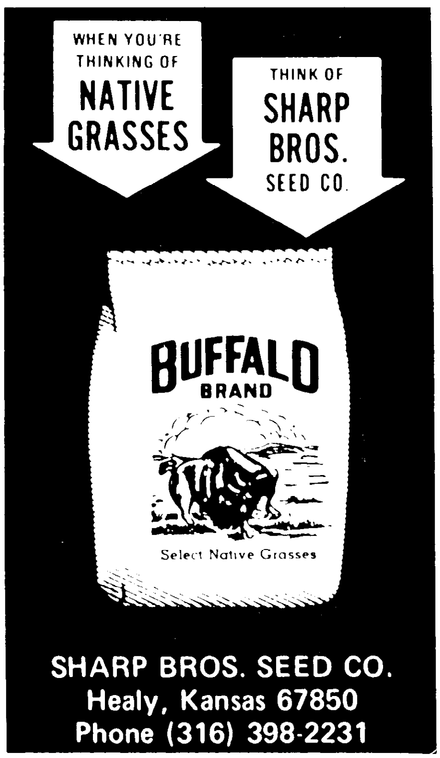

Forage and Cattle Responses to Different Grazing Intensities on Southern Pine Ridge

H. A. PEARSON AND L. B. WHITAKER

Highlight: *Over a 10-year span, grazing intensities of 35, 49, and 57% use of the current year's growth did not affect total forage yields on southern pine range. However, yields started to decline when the young pines were about age 9. Calf crops were highest from cows grazing lightly and lowest with heavy stocking; calf weaning weights and daily gains did not differ because of stocking rates. Highest total returns per calf were received from cows grazing lightly. Greatest returns per acre were from herds grazing heavily.*

Southern pine forests provide substantial quantities of forage after timber harvest and until reforestation appreciably shades out the understory plants. Grazing varies from heavy to light, but livestock responses to grazing intensities have not been well defined. This research assesses effects of grazing regimes on the production efficiency of beef breeding herds. Findings pertain to some eight million acres comprising the western portion of the longleaf-slash pine type, where bluestem grasses predominate in the understory.

Study Methods

Area

The three-unit, 1,600-acre, study area is on the Palustris Experimental Forest in central Louisiana. Annual precipitation averages 58 inches. Soils are mainly deep, medium-textured, and slowly permeable; but some are coarse-textured and permeable. Topography varies from poorly drained flats to rolling hills with slopes up to 10%.

The longleaf pine forest had been cut prior to 1935, and when the study began only scattered pines and oaks were present. Slender bluestem (*Andropogon tener* (Nees) Kunth) and pinehill bluestem (*A. divergens* (Hack.) Anderss. ex Hitchc.) were the dominant herbaceous species. Other prominent species were fineleaf bluestem (*A. subtenuis* Nash), paintbrush bluestem (*A. ternarius* Michx.), Elliott bluestem (*A. elliottii* Chapm.), big bluestem (*A. gerardii* Vitm.), and several panicums (*Panicum* spp.). Carpetgrass (*Axonopus affinis* Chase) occurs on heavily grazed areas. The main shrub is southern waxmyrtle (*Myrica cerifera* L.)

In 1961 and each of the next 3 years, 25% of the area was regenerated to slash pines (*P. elliottii* Engelm. var. *elliottii*). About 17% of each unit was planted with 1-year-old seedlings (908 per acre), and 8% was direct-seeded with 1 lb per acre. Prescribed burning prepared the land for pine regeneration and drew cattle away from the newly regenerated land. Prescribed burning resumed on regenerated areas when trees were age 5 or older. The effects of grazing on pine regeneration were reported in detail by Pearson et al. (1971). In brief, heavy grazing caused loss of about 18% of the planted pines; however, more than 550 well-distributed trees survived at age 5. Seeded stands under all grazing regimes and planted stands under light and moderate grazing were not affected.

Cattle Management

Cows were typical crossbred native piney-woods cattle. The majority showed evidence of Brahman breeding while the remainder were mixtures of other beef and dairy breeds. Purebred bulls (Hereford or Shorthorn) were mated with the native cow herds for December through March calving; calves were weaned and marketed in mid-August when about 210 days old.

Cattle diets were supplemented mainly for protein and mineral deficiencies (Duvall and Whitaker, 1963; Duvall and Hansard, 1967; and Pearson and Whitaker, 1972). About 400 pounds of cottonseed cake were hand-fed each animal from November through May; salt and steamed bonemeal were provided free-choice year round. Grass hay, fed during periods of inclement winter weather, averaged 260 lb per animal year.

Grazing Treatments

In the summer of 1960, three yearlong treatments of grazing intensity were randomly applied to contiguous range units, two of 580 acres each and one of 440 acres. Stocking rates calculated to atain light, moderate, and heavy grazing were 26, 20, and 13 acres per animal. These rates were projected to give intensities of about 30, 45, and 60% utilization of the current year's available forage.

Between May 1960 and May 1963, one-quarter of each range unit was rotationally prescribe-burned each year. Cattle prefer to graze areas most recently burned, since forage quality is improved (Duvall and Whitaker, 1964). The number of acres of burned range per cow-year remained relatively constant throughout the study, with greatest acreages under light stocking and least under heavy stocking.

Measurements

Forage production and utilization were determined from clusters of four plots, each 9.6 ft^2 in area. One plot in each cluster was caged and its yield was taken as a measure of forage production. The other three plots were grazed plots, and their mean yield was subtracted from that of the caged plot to calculate forage utilization. Between 35 and 40 clusters of plots were systematically distributed over the grazing units and were relocated annually.

Analyses

Since grazing treatments were unreplicated, results of this study are not suitable for statistical analysis. Standard deviations of forage yield means were computed within years. Regression analyses of yearly forage yield means give some indications of the overstory-understory relationships following pine regeneration. Calf responses under the various grazing regimes were evaluated by covariance analysis[1] with age of calf and dam as covariates.

Results and Discussion

Herbage

Herbage yields varied greatly among years. In 1961-62

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[1] Analyses were conducted by Dr. J. W. Turner, Department of Animal Science, Louisiana State University, Baton Rouge, presently at the Department of Animal Science, Mississippi State University, State College.

Table 1. Herbage production (lb/acre) by years under three grazing intensities.

Year	Grazing intensity		
	Light	Moderate	Heavy
1961-62	2154	2033	2732
1963	2006	1841	2356
1964	1696	1819	2320
1965	1609	1918	2201
1966	1804	1932	2203
1967	1701	2024	2028
1968	2068	2388	1979
1969	2015	2382	2536
1970	1518	1840	1597
1971	1284	1232	1310
1972	1093	815	860
Average	1723	1839	2011

production averaged from 2,000 to 2,700 lb/acre in the three range units (Table 1), with standard deviation for pasture yields averaging 600 lb. Yields on all units were above 1,600 lb until the 1969-70 growing season, but declined to 1,300 lb during 1970-71 and 900 during 1971-72. Apparently, the timber stand did not appreciably decrease the yields until trees were about 9 years of age. Regression analysis of yearly means indicates reductions in herbage production after tree age 8 (Fig. 1). A definite decline was noted under the oldest stand of pine–age 9–with light and heavy grazing (Fig. 2). At tree age 11, herbage yields were 496, 744, and 356 lb/acre under the light, moderate, and heavy grazing intensities. Areas with younger trees partially compensated these low herbage productions in the older stands; consequently, cattle numbers were not reduced during the first 10 years following regeneration. However, cattle numbers were decreased about 10% on all pastures during the 11th year.

Herbage responses were probably related to both site and growing treatment (Table 1). Heavy grazing initially had the highest yields; however, a slight downward trend was noted until 1968. Yields with moderate grazing were initially lowest but demonstrated a slight upward trend after 1963. Yields with light grazing declined through 1964 then trended upward. These increases with light and moderate grazing were partially due to hardwood control during 1963-64. However, herbage yields–possibly influenced by grazing intensity–were greater with moderate grazing after 1963 than with light grazing. Duvall and Linnartz (1967) reported that grazing stimulates yields on pine-bluestem range.

Botanical composition changed somewhat with grazing; for instance, pinehill bluestem decreased with heavy grazing while carpetgrass increased (Pearson and Whitaker, 1974).

Years since prescribed burning did not affect the 10-year average herbage yields (Table 2). Possibly without burning, the pine needle cast would have reduced the production sooner. However, nonburned comparisons were not available.

Stocking levels provided 10-year forage utilization of 35, 49, and 57% on the light, moderate, and heavy grazing intensities (Table 2). Yearly fluctuations of forage utilization under light intensity ranged from 29 to 41%; moderate 41 to 57; and heavy 47 to 65. Total yields apparently were not affected since production remained unchanged until tree competition reduced yields.

Burned range received higher utilization than unburned (Table 2). During 1963 when burning had occurred only 3 years, similar utilization results on the lightly grazed unit

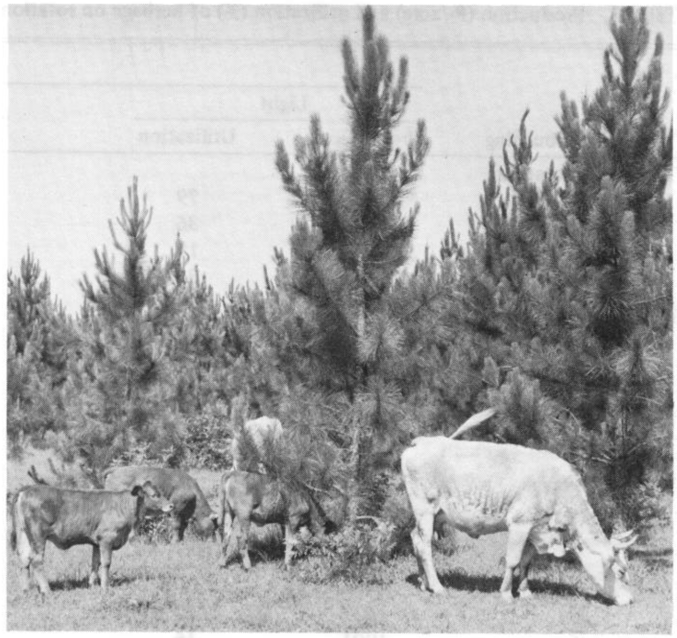

Fig. 1. *Cattle grazing among pines 7 years of age.*

occurred as previously reported (Duvall and Whitaker, 1964). Utilization increased with grazing intensity. Consequently, utilization of the 3-year rough was 34 and 42% on moderate and heavy intensities and 19% on light intensity.

Herbage production with light stocking also responded as previously reported (Duvall and Whitaker, 1964). Yields were lower on first-year rough than on 3-year roughs. Moderate and heavy grazing reacted differently, but reasons are not apparent from these data.

Utilization was again examined after the fourth burn. These results differed from those reported by Duvall and Whitaker (1964) and the 3-year burn results in this study. Utilization was higher on the burned portion but was highly variable thereafter. When utilization with years since burning was averaged, it did not change between the second and fifth year (Table 2). Apparently cattle prefer the newly burned forage but are not highly selective when a variety of forages with different burning ages are in the pasture.

Cattle

Fluctuations in cow weight, calf crops, and calf weaning weights are indicative of the nutritional status of the range and feeding program. Random selection and potential productivity of the cow herds were assumed to be the same for all grazing

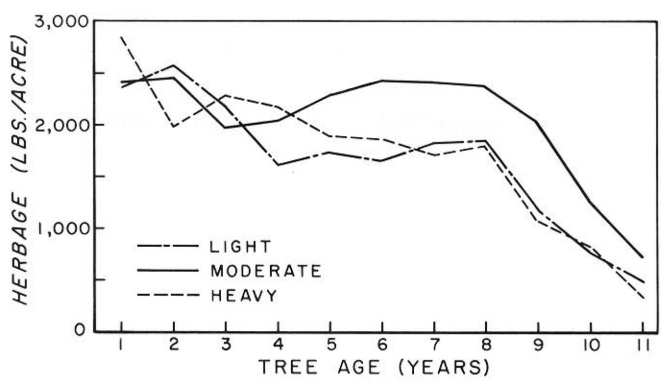

Fig. 2. *Herbage production under 1961 regenerated pines and three grazing intensities.*

Table 2. Production (lb/acre) and utilization (%) of herbage on rotation-burned range.

	Grazing intensity					
	Light		Moderate		Heavy	
Years[1] since burning	Production	Utilization	Production	Utilization	Production	Utilization
Three-year rotation[2]						
1	1289	79	1771	87	2469	93
2	1955	36	1163	41	2488	50
3	2575	19	2477	34	1977	42
Average	2006	32	1841	46	2356	57
Four-year rotation						
1	1174	51	2080	72	2041	88
2	1280	41	1593	40	2155	56
3	2031	29	1591	27	2585	40
4	2184	40	1979	29	2361	57
Average	1696	38	1819	41	2320	56
Ten-year average						
1	1566	68	2052	78	2120	81
2	1640	31	1546	49	2090	60
3	1762	26	1945	43	1982	48
4	1605	30	1777	40	2040	55
5	1627	27	1689	33	1894	55
6	1901	16	2158	38	2213	42
Average	1786	35	1941	49	2126	57

[1] Data apply to herbage produced after burning.
[2] One-fourth of each range unit rotation burned annually.

intensities. Although cows on lightly grazed pastures were heaviest, cow weights did not differ appreciably among grazing intensities (Table 3).

Cows grazing lightly had the highest annual percent calf crop weaned, while those grazing heavily had the lowest. Average percent calf crops were 82, 73, and 70 for the light, moderate, and heavy intensities. Calf crops varied from 65 to 95% for light stocking; 61 to 89 for moderate; and 58 to 79 for heavy.

Calves from light grazing were slightly heavier at weaning than from the other two grazing treatments. Steers (441 lb) weaned heavier than heifers (418 lb). Daily weight gains from April through weaning in August were similar for all grazing intensities—about 1.74 pounds.

Brahman breeding in cows apparently affected weaning weights of calves. Cows with none, one-quarter, one-half, and three-quarters Brahman had calf weaning weights of 416, 421, 436, and 444 lb. Calves from cows with one-half and three-quarters Brahman breeding weaned heavier than calves from cows with no Brahman, regardless of grazing intensity.

The selling price per pound was essentially identical on calves sold at weaning; however, returns per calf differed—highest returns were received from the lightly grazed pasture (Table 3). The calf market price varied between $16 and $35 per hundred pounds during the 10 years. Steers brought better prices and returns than heifers. Calves with highest amounts of Brahman breeding had greatest returns ($108.94), attributable to heavier weaning weight. Southern forest grazing showed greatest returns per cow ($89.35) from herds grazing lightly and greatest returns per acre ($5.55) from herds grazing heavily.

Table 3. Cattle statistics (1961-71) under three grazing intensities.

	Grazing intensity		
	Light	Moderate	Heavy
Cow weights (lb)	819	778	788
Calf crop (%)	82	73	70
Calf weaning weight (lb)	444	419	421
Calf sale weight (lb)	427	403	404
Price/cwt ($)	25.60	25.27	25.51
Returns/calf ($)	108.96	102.15	103.14
Returns/cow ($)	89.35	74.57	72.20
Returns/acre ($)	3.44	3.73	5.55

Current prices greatly enhance returns. Using the $42 per hundred weight received in 1972, returns would be $147.06 per cow with light grazing and $9.14 per acre with heavy grazing. Economic implications regarding costs and returns with the various grazing regimes were reported by Pearson and Whitaker (1973).

Returns from cattle grazing will decline as the tree crowns close and forage yields diminish. Some increase will occur when the trees are thinned, perhaps at ages 15 to 18 years. When commercial harvest commences, economic considerations will involve integrated management for timber and livestock.

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Vigor of Idaho Fescue Grazed under Rest–Rotation and Continuous Grazing

RAYMOND D. RATLIFF AND JACK N. REPPERT

Highlight: *The vigor of Idaho fescue in northeastern California was compared on plots grazed by two different approaches: one full 5-year cycle of rest-rotation grazing, at Harvey Valley; and repeated continuous grazing, at Grays Valley. Vegetative shoot lengths and numbers of flower stalks served as indicators of vigor. Vigor was higher on the Harvey Valley plots. The full-use treatments of rest-rotation grazing did not measurably reduce vigor, nor did the rest treatments improve it. Production of flower stalks appeared to depend on adequate spring precipitation and was not synchronized with the seed production phase of rest-rotation grazing. Continuous grazing at moderate intensity did not reduce plant vigor during the 5-year study period on the Grays Valley plot.*

The results suggest that moderate, continuous grazing permits Idaho fescue to maintain its vigor. But because rest-rotation grazing disrupts an apparent relationship between grazing use and precipitation, it may hold Idaho fescue vigor at a higher level than can continuous grazing.

At Harvey Valley, in northeastern California, a test of rest-rotation grazing has been underway since 1954. The grazing prescription is keyed to the growth and reproduction requirements of Idaho fescue (*Festuca idahoensis* Elmer), an important herbaceous component of range vegetation in the western United States. The species begins growing about April 1, shows flower stalks by the end of May, flowers and reaches full height growth in early July, and produces ripe seeds in early August.

The Harvey Valley allotment is divided into five range units. Each range unit receives each of five treatments in rotation over a 5-year period. As a whole, the allotment is stocked to obtain moderate use. The treatments and their intended purposes are (a) continuous full use (June 1 to October 31) to maximize livestock production, (b) rest the full season to permit recovery of plant vigor, (c) rest to mid-season to permit seed production followed by full use the second half of the season to plant seed, (d) season-long rest to permit seedling establishment, and (e) moderate use to mid-season followed by rest the second-half to aid establishment of new plants. "Full use" means 66% consumption of the current forage crop; "moderate use" means 33%.

Idaho fescue was expected to be more vigorous at Harvey Valley than on allotments where repeated continuous grazing was practiced. After 10 years of rest-rotation grazing, this expectation was confirmed (Ratliff et al., 1972).

But to understand more fully how rest-rotation grazing affects the vigor of Idaho fescue, we needed answers to such questions as: Is vigor maintained at a higher level with rest-rotation than with continuous grazing? Do the full-use treatments adversely affect vigor? Does season-long rest improve vigor? Is flower stalk production greatest during the seed production phase? And does additional continuous grazing adversely affect vigor? This paper reports a study that points to some answers.

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Methods

Three 1/2-acre plots were set up on sites that have the same basic potential to produce and sustain a given plant community. Therefore, we could logically expect any difference in plant vigor to reflect the effects of the grazing regime. One plot, on the Grays Valley allotment, was under moderate, continuous grazing; the other two plots, on the Harvey Valley allotment, were in different range units, in different sequences of rotation under rest-rotation grazing.

The three plots were on hair sedge (*Carex exserta* Mkze.)-bunchgrass sites, where Idaho fescue is a major component. Total basal cover of live plants and of Idaho fescue in 1966 was statistically equal on all three plots. The combined average, by point quadrat, was 13.2% for live plants and 2.9% for Idaho fescue. But basal cover of other grasses was statistically greater on both Harvey Valley plots (3.3% for 1 and 2.4% for plot 2) than on the Grays Valley plot (1.2%). While the amounts of grasslike plants (5.8%) were the same on the Grays Valley plot as on Harvey Valley plot 1, on Harvey Valley plot 2 basal cover of grasslike plants was 7.3%. A greater basal cover of forbs on the Grays

Table 1. Average length (ft) of vegetative shoots of Idaho fescue and overall means, northern California, by year of sampling and plot.

Plot no. and allotment	1966	1967	1968	1969	1970	Means[1]
Harvey Valley-1	0.51	0.48	0.50	0.49	0.54	0.50 a
Harvey Valley-2	0.49	0.48	0.44	0.48	0.45	0.47 a
Grays Valley	0.38	0.38	0.36	0.33	0.40	0.37 b
Means[2]	0.46	0.44	0.43	0.43	0.46	

[1] F ratio from analysis of variance = 37.6 with (2, 8) degrees of freedom. Means followed by the same letter are not significantly different at the 5% level of probability, according to Duncan's multiple range test.
[2] F ratio from analysis of variance = 0.8 with (4,8) degrees of freedom; no significant differences.

Valley plot (2.8% as compared to 0.6 and 0.5 on Harvey Valley plots 1 and 2) largely offset its lower amounts of other grasses and grasslikes.

Twelve lines across the width of each plot were randomly selected with the imposed restriction that four fell on each third of the plot. Along each line, five sample points were randomly selected, providing 60 observations per plot per year. The nearest ungrazed Idaho fescue plant (with at least one flower stalk) to the sample point was the one measured. Each plot was sampled each year for 5 years, starting in 1966,–completing one rotation of treatment under rest-rotation grazing. At the start, two sets of lines and two sets of sample points were selected. Thereafter, the particular sets of lines and sampling points used for a plot were determined each year by chance.

Each year we recorded our vigor observations before any significant amount of grazing occurred on the plots. Rarely was the nearest plant to a sampling point grazed. Therefore, current grazing did not materially affect the vigor observations. The percentage of Idaho fescue plants grazed was estimated in October each year.

The hypothesis of equality among plot means and among year means was tested by standard analysis of variance procedures (Dixon and Massey, 1957). Duncan's multiple-range test (LeClerg, 1957) was used to detect differences among the means.

We studied two indicators of vigor: (a) length of vegetative shoots (basal leaf fascicles), and (b) number of flower stalks per plant. For ease in sampling, the longest vegetative shoot was the one measured, and each plant observed was required to have at least one flower stalk, thereby assuring mature plants for our study.

We consider vegetative shoot length to reflect vigor free of moisture stress caused by competition and, therefore, vigor as related to grazing. Mueggler (1970) found that "leaf length" was affected more by intensity of clipping than by reduction of competing vegetation. Therefore, if soil moisture is adequate, the effect of competition on vegetative shoot growth would be nil. Hurd (1959) also agrees on the value of basal leaf height as a reliable index to vigor of Idaho fescue plants – provided herbage weight is accepted as the combined vigor expression. He found that leaf height and herbage weight were closely correlated. Mueggler (1970) found that reducing competing vegetation around Idaho fescue plants increased the number of flower stalks and that clipping also affected the number of stalks, but not as drastically as Hormay and Talbot (1961) had reported.

For the 5 years of this study, we found a near-perfect correlation (r = 0.996) between spring precipitation and flower stalk numbers (Fig. 1). And from a number of precipitation gages in and around Harvey Valley, we know that the amounts and distributions of precipitation were similar on the three plots. Therefore, the number of flower stalks produced should reflect the effects of grazing and the relative amounts of competing vegetation on vigor of Idaho fescue.

Results

Vegetative Shoot Length

Vegetative shoots did not differ significantly in length between the two Harvey Valley plots, but they were longer than those on the Grays Valley plot (Table 1). Therefore, over the 5-year period, vigor of Idaho fescue fared better under rest-rotation than under continuous grazing, but the treatments did not measurably affect vigor on the Harvey Valley plots. Nor did additional continuous grazing cause plants to lose vigor on the Grays Valley plot.

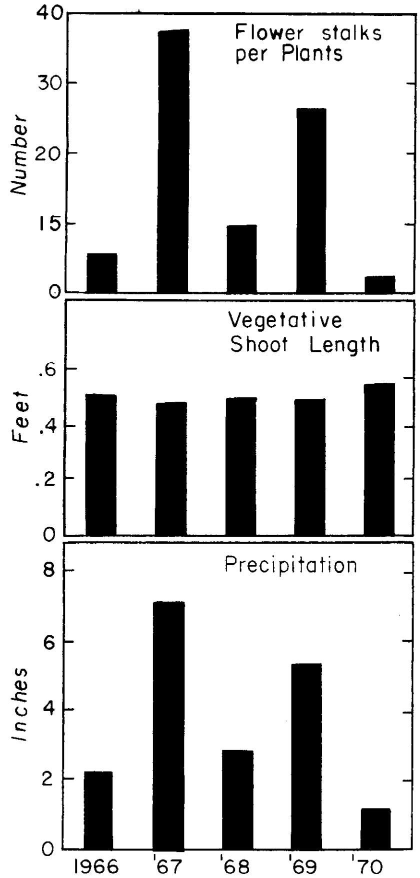

Fig. 1. *High production of Idaho fescue flower stalks depends upon adequate spring precipitation, but vegetative shoot production shows no such dependence.*

Flower Stalk Numbers

Plots did not differ significantly in number of flower stalks produced per plant (Table 2), but differences in flower-stalk numbers between years

Table 2. Average number of flower stalks per Idaho fescue plant and overall means, northern California, by year of sampling and plot.

Plot no. and allotment	1966	1967	1968	1969	1970	Means[1]
Harvey Valley-1	5.5	37.2	9.5	26.2	2.7	16.2
Harvey Valley-2	18.9	18.9	9.0	31.4	3.1	16.3
Grays Valley	9.1	9.5	9.1	30.0	4.0	12.3
Means[2]	11.2 bc	21.5 ab	9.2 bc	29.2 a	3.3 c	

[1] F ratio from analysis of variance = 0.44 with (2, 8) degrees of freedom; no significant differences.
[2] F ratio from analysis of variance = 5.70 with (4, 8) degrees of freedom. Yearly means followed by one or more like letters are not significantly different at the 5% level of probability, according to Duncan's multiple range test.

Table 3. Percent of Idaho fescue plants grazed and scheduled grazing treatment for season preceding measurement of vigor indicators, northern California, by year of measurement and plot.

Plot no. and allotment	1965 % use	1965 T[1]	1966 % use	1966 T	1967 % use	1967 T	1968 % use	1968 T	1969 % use	1969 T
Harvey Valley-1	20	A	82	B	0	C	24	D	0	E
Harvey Valley-2	0	C	92	D	0	E	28	A	94	B
Grays Valley	76	F	92	F	57	F	81	F	31	F

[1] Treatments: A = moderate use first half, rest second half; B = continuous full use; C = season-long rest; D = rest first half, full use second half; E = season-long rest; F = moderate, continuous use (Grays Valley).

were significant. Some within-plot variation was probably related to grazing use the previous year, but most of it was caused by differences in spring precipitation. These differences masked the effects of grazing to the extent that we could find no clear relationship between grazing use and flower stalk numbers for any of the plots.

On the basis of this single indicator—flower stalk numbers—it would appear that Idaho fescue plants on the Harvey Valley plots did not differ in vigor from those on the Grays Valley plot. However, pussytoes (*Antennaria dimorpha* Nutt.) comprised all the forb cover on the Grays Valley plot. Because it occurs in rather compact patches and precedes most grass and grasslike plants in the succession, pussytoes does not compete with Idaho fescue as much as the other grasses and grasslikes. Further, the basal covers of other grasses and grasslikes were greater on the Harvey Valley plots. Competition was, therefore, probably greater on the plots under rest-rotation. And because as many flower stalks were produced there as where competition was likely less, vigor of Idaho fescue plants could be considered relatively greater on the plots under rest-rotation grazing.

Use of Idaho Fescue

On the Grays Valley plot, an average of 67.4% of the Idaho fescue plants were grazed by October (Table 3). Averages for Harvey Valley plots 1 and 2 were only 25.2 and 42.8%, respectively. A comparison of use on the Grays Valley plot with precipitation (Fig. 1) indicates that the percentage of plants grazed under continuous grazing is negatively correlated with spring precipitation. There is also an indication that use of Idaho fescue occurs earlier when spring precipitation is low. For example, 86% of the Idaho fescue plants in 1966 but only 16% in 1967 were grazed by mid-August on the Grays Valley plot.

Discussion and Conclusions

Continuous grazing did not further reduce Idaho fescue vigor on the Grays Valley plot. Basal cover measurements of Idaho fescue on the three plots were equal in 1966, and Idaho fescue took more use without deteriorating on the Grays Valley plot than it received on the Harvey Valley plots. Continuous grazing, therefore, appears to be more effective in controlling competing vegetation than it is damaging to Idaho fescue.

Fullest use of Idaho fescue plants on the Grays Valley plot appears to occur when spring precipitation is low and grazing most damaging. Conversely, use appears lighter (also later) when spring precipitation is high and conditions are most favorable for plant growth, seed production, and seedling establishment. Thus, given reduced competition and "rest periods" afforded by favorable moisture, Idaho fescue can apparently maintain its vigor and reproduce under moderate, continuous grazing.

However, our results suggest that rest-rotation grazing has some advantages over continuous grazing. Vigor of Idaho fescue was significantly higher on both Harvey Valley plots than on the Grays Valley plot. Idaho fescue plants on the Harvey Valley plots received rest independent of precipitation. Rest-rotation grazing thus disturbs the relationship between grazing use and precipitation, which may be an important factor on continuously grazed allotments; and, therefore, may hold Idaho fescue vigor at a higher level than can continuous grazing.

It appears, however, that range managers cannot key seed production into a set program of rest-rotation grazing. Flower stalk production on the Harvey Valley plots was not synchronized with the seed production phase of rotation—except by chance. Rather, flower stalk production depends on spring precipitation. Further, the full use treatments did not reduce nor did full-season rest improve Idaho fescue vigor on the Harvey Valley plots.

These results lead to two suggestions; First, by 1966 when this study was started, Idaho fescue plants at Harvey Valley may have already reached their maximum vigor. If vigor was at a maximum, the effects of a later rotation would be less obvious. Second, the range manager can capitalize on the high vigor of Idaho fescue and the relationship between spring precipitation and flower stalk production. During years of adequate precipitation, most range units at Harvey Valley could be lightly stocked until seeds ripen, thereby assuring ample seed on units scheduled for full use. Concentrating livestock in these units after seed ripens should result in more seed being trampled into the soil, more seedlings the following year, and more rapid improvement in range conditions.

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Influence of Cattle and Big Game Grazing on Understory Structure of a Douglasfir–Ponderosa Pine–Kentucky Bluegrass Community

WILLIAM C. KRUEGER AND A. H. WINWARD

Highlight: *A Douglasfir-ponderosa pine-Kentucky bluegrass community was studied 14 years after grazing by cattle and big game, by big game, and no cattle or big game grazing. Heavy season-long use by cattle and big game resulted in apparent retrogression. The herbaceous component of the community was substantially changed by cattle and big game grazing but not by big game grazing alone. Grazing by cattle and big game and big game only had similar effects on the browse components of the community.*

Use of plant communities by different animal species has long been known to influence development of vegetation aggregates. The influence of any particular animal species on plant community structure is in part a function of time, season, and intensity of use. This study was designed to measure the relative impact of grazing by cattle (*Bos taurus*), and mule deer (*Odocoileus hemionus hemionus*) and Rocky Mountain elk (*Cervus canadensis nelsoni*) on a Douglasfir-ponderosa pine-Kentucky bluegrass (*Pseudotsuga menziesii-Pinus ponderosa-Poa pratensis*) community in northeastern Oregon.

Study Area

The study was conducted in the foothills of the Wallowa Mountains on the Hall Ranch portion of the Eastern Oregon Experiment Station. The 2,000 acre Hall Ranch has been grazed by livestock for over 100 years. A range survey in 1956 indicated much of the ranch was in poor condition. Since then the ranch has been grazed only by cattle and wildlife.

The entire Hall Ranch has been logged at various times since the 1870's. According to ring counts of stumps present in the Douglasfir-ponderosa pine-Kentucky bluegrass community studied, the most recent logging in this stand occurred in the 1930's.

The Douglasfir-ponderosa pine-Kentucky bluegrass stand studied is representative of large acreages in the foothills of mountain ranges in eastern Oregon and Washington and much of northern Idaho. The study area was located on a 5-8% southwest facing slope at an elevation of 3,950 ft. Records for 1963-1971 indicated annual precipitation varied from 19-32 inches coming principally as snow and rain in the cold winter months and rain in spring and fall. The soil type was Hall Ranch loam and has been described in detail by Walton (1962). According to the key in Daubenmire and Daubenmire (1968), this site was a *Pseudotsuga menziesii-Physocarpus malvaceus* habitat type.

Observations[1] of big game use since 1956 indicated the area received continuous, light mule deer use from early May into December, at which time snow depth forced the deer to move onto winter ranges. Rocky Mountain elk used the site from early April to early May and then moved to summer range. Both species of big game occasionally used the study site in mild winters.

Since 1956, cattle have grazed the Hall Ranch from late May until late October or mid-November depending on occurrence of autumn snows. The Douglasfir-ponderosa pine-Kentucky bluegrass community was grazed by cows and calves as needed. In some years the community received as little as 2 months' use and in others was used throughout the grazing season but use was heavy in all years.

Utilization records[1] from 1961-1967 classified grazing by cattle, elk, and deer collectively into five classes: no use—no evidence of utilization or sign of livestock during the current season; light—less than 50% utilization on Kentucky bluegrass; moderate—about 50% utilization on Kentucky bluegrass; heavy—more than 50% utilization on Kentucky bluegrass and some palatable herbage left; very heavy—almost all vegetation grazed off that can be utilized by the animals. The observations indicated use had been heavy to very heavy over the 7 years of examination.

Methods

In 1958 a game and cattle exclosure and a cattle exclosure each 1 acre in size were constructed in the Douglasfir-ponderosa pine-Kentucky bluegrass community (Fig. 1). Sampling was conducted in 1972 following 14 years of grazing treatment. The grazing treatments were: no grazing, big game grazing, and cattle and big game grazing.

Changes in plant community structure were estimated using frequency measurements for all plant species present in each treatment. Presence of plants in 10 plots 1 X 2 ft was recorded at 10-ft intervals along each of four 100-ft transects in each treatment. Frequency of rodent mounds was also recorded for each transect. Each transect began at a randomly selected point and ran perpendicular to the slope.

Canopy cover of shrubs was measured by line intercept of six 100-ft transects. Canopy cover of trees was measured with a model C forest densiometer.

Differences in both frequency and cover were statistically

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[1] File data, Agricultural Experiment Station Project 429, Rangeland Resources Program, Oregon State University. Data collected by Drs. J. A. B. McArthur and D. W. Hedrick, formerly professors of range management.

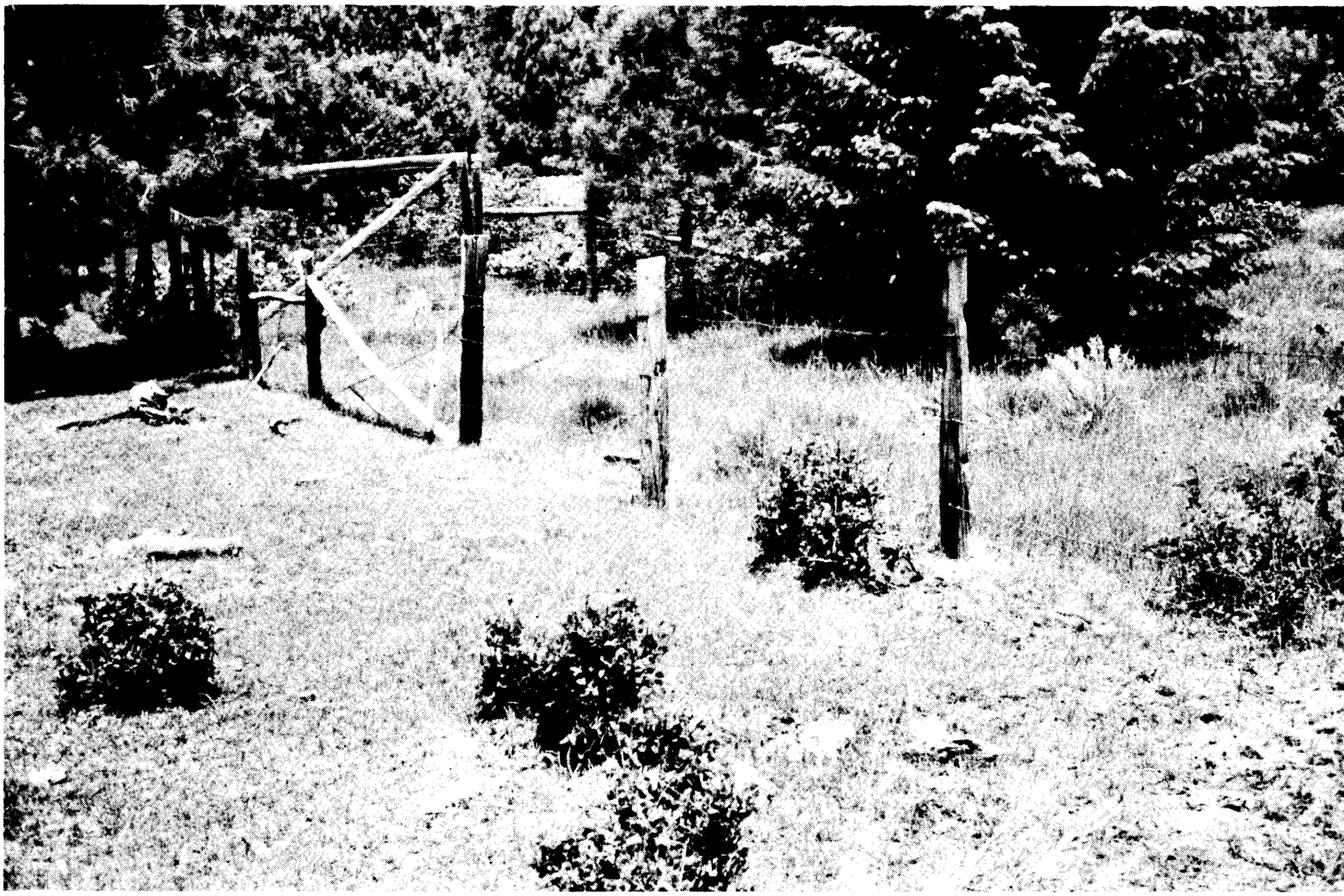

Fig. 1. *Exclosures in the Douglasfir-ponderosa pine-Kentucky bluegrass community. Cattle and big game dual grazing is in foreground, cattle exclosure in middle and big game exclosure in upper left.*

analyzed with chi-square techniques. Plant species with less than 10% frequency or 1% cover as a maximum value for any of the three treatments were not evaluated. Throughout the paper the term significant refers to $P<0.05$.

Results

Frequency

Frequency of grasses and sedges indicated that heavy to very heavy season-long use had a significant impact on some species (Table 1). Grazing by big game had no significant influence on frequency of perennial grasses or sedges. Elk sedge (*Carex geyeri*) was significantly lowest in frequency, with a value of 8% in the area grazed in common by big game and cattle as compared to treatments that had no cattle grazing influence. Treatments that excluded cattle grazing resulted in frequency greater than 40% for elk sedge. Junegrass (*Koeleria cristata*) did not occur in transects sampled in the portion of the community grazed in common by cattle and big game. Frequency of Junegrass in the area where cattle grazing was excluded was significantly greater than in the area where cattle grazing was permitted and ranged from 12 to 15%. Kentucky bluegrass and Columbia needlegrass (*Stipa columbiana*) frequencies were not significantly different in the three treatments. However, since Kentucky bluegrass had a frequency near 100% for all treatments, a smaller plot size may have reflected differences in response not identifiable with the sampling procedure used.

Table 1. Average frequency (%) of major plant species after 14 years of grazing by cattle and big game, big game, and no grazing.

	Grazed by		
Plant species	Game and cattle	Game	No grazing
Grasses and sedges			
Columbia needlegrass	10[a][1]	15[a]	5[a]
Elk sedge	8[a]	42[b]	50[b]
Junegrass	0[a]	12[b]	15[b]
Kentucky bluegrass	98[a]	100[a]	100[a]
Forbs			
Blueleaf strawberry	30[a]	40[a]	25[a]
Dandelion	28[a]	0[b]	0[b]
Fleabane	12[a]	0[b]	0[b]
Heartleaf arnica	0[a]	0[a]	12[b]
Moss	30[a]	10[b]	2[b]
Rose pussytoes	12[a]	0[b]	2[ab]
Sheep sorrel	80[a]	35[b]	12[c]
Tortula	28[a]	15[a]	2[b]
Western yarrow	88[a]	68[b]	58[b]
White clover	78[ab]	82[a]	62[b]
Woods strawberry	12[a]	18[a]	10[a]
Annuals			
Cheatgrass	0[a]	2[ab]	12[b]
Autumn willowweed[2]	18[a]	18[a]	30[a]
Bigleaf sandwort	12[a]	0[b]	2[ab]
Douglas knotweed	0[a]	5[ab]	15[b]
Littleflower collinsia[3]	22[a]	15[a]	18[a]
Browse			
Snowberry	15[a]	20[a]	40[b]

[1] Treatment means within species followed by different letters are significantly different at the 0.05 level.
[2] *Epilobium/paniculatum.*
[3] *Collinsia parviflora.*

Table 2. Average cover (%) of major browse species after 14 years of grazing by cattle and big game, big game, and no grazing.

Plant species	Grazed by		
	Game and cattle	Game	No grazing
Ninebark	0.9^{ab} [1]	2.2^{a}	0.6^{b}
Oceanspray	0.6^{a}	0^{a}	3.4^{b}
Snowberry	0^{a}	3.0^{b}	15.7^{c}
Snowbrush	0^{a}	0^{a}	7.3^{b}

[1] Treatment means within species followed by different letters are significantly different at the 0.05 level.

Frequency of most perennial forbs increased under grazing. The relative impact of heavy grazing by cattle and big game was greater than that of lighter utilization by game alone. Western yarrow (*Achillea millefolium*), fleabane (*Erigeron pumilus*), dandelion (*Taraxacum officinale*), and mosses (class: Musci), except tortula (*Tortula ruralis*) were significantly higher in frequency when the stand was open to grazing by cattle and big game than when grazed by big game alone or protected from grazing. Big game grazing alone had no effect on these species when compared to no grazing.

Rose pussytoes (*Antennaria rosea*) did not show a distinct response to grazing but was most frequent under cattle and game grazing and least frequent under treatments that excluded cattle grazing. Frequency of white clover (*Trifolium repens*) was significantly higher on areas grazed by big game alone (82%) than on areas not grazed (62%). Frequency on areas grazed by cattle and big game was intermediate (78%) and not different from either. Sheep sorrel (*Rumex acetosella*) frequency increased markedly on grazed areas, from 12% with no grazing to 35% with big game grazing, and 80% with cattle and big game grazing. All treatments were significantly different from each other. Other perennial forbs, blueleaf strawberry (*Frageria virginiana*) and woods strawberry (*F. vesca*), showed no significant response to grazing.

Annual forbs generally showed no change in frequency under the different grazing treatments. Bigleaf sandwort (*Arenaria macrophylla*) was the only annual forb that increased significantly under cattle and big game grazing compared to lighter grazing by big game alone. There was no significant change in bigleaf sandwort between the cattle and big game grazing treatment. Douglas knotweed (*Polygonum douglasii*) and cheatgrass (*Bromus tectorum*) had significantly different frequencies for the three grazing treatments. Both plants grew on disturbed soil of rodent mounds, and changes in frequency for these species was related directly to rodent activity and only indirectly to grazing treatments.

The only browse species of sufficiently general distribution to examine with the frequency technique was snowberry (*Symphoricarpos albus*). No difference in snowberry frequency was noted for cattle and big game grazing versus no cattle grazing. Under no grazing the frequency doubled to 40%, so it would appear that grazing by either cattle or big game significantly retarded the spread or development of snowberry.

Rodent mound frequency was highest in the area of no grazing at 30%. The area grazed by big game had 20% frequency of rodent activity and the area grazed by cattle and big game showed 8% rodent mound frequency.

Cover

Canopy cover of trees was 9% for Douglasfir and 6% for ponderosa pine.

Because of the low frequency of most browse species, it was felt cover provided a more meaningful measure of relative amounts of these plants in the community (Table 2). Snowbrush (*Ceanothus velutinus*), oceanspray (*Holodiscus discolor*), and ninebark (*Physocarpus malvaceus*) showed no significant differences in cover between the area grazed by cattle and game and that grazed by big game only. Snowbrush and oceanspray were both well represented in the area with no grazing. Cover of ninebark was greatest in the area grazed by big game when compared to cattle and big game grazing or no grazing.

Snowberry cover was significantly different for all grazing treatments ranging from a high of 16% under no grazing to a low of 0% under cattle and big game grazing. Grazing by big game alone resulted in 3% cover of snowberry.

Production

The exclosures were sampled for production of herbaceous and woody vegetation in 1959 the year after construction (Walton, 1962). At this time, Kentucky bluegrass made up most of the yield averaging about 600 lb/acre. Elk sedge produced 160 lb/acre and perennial forbs 60 lb/acre, so it appeared the site had a substantial amount of elk sedge and some perennial forbs at the time the exclosures were established. Perennial forbs were not separated by species in his study.

Discussion

It appeared the 14 years of continuous heavy grazing by cattle and big game resulted in retrogression within the plant community. Frequency of grasses generally decreased and frequency of forbs generally increased under heavy dual grazing, compared to light big-game grazing. Elk sedge appeared to have decreased substantially, but no direct comparison between production in 1959 and frequency in 1972 can be made. However, frequency of elk sedge and Junegrass was different enough between the cattle-grazed area and the areas not grazed by cattle to suggest retrogression had occurred on the site. Daubenmire and Daubenmire (1968) also found Kentucky bluegrass increased in dominance under heavy grazing.

It is possible that protection from cattle grazing since 1958 resulted in secondary succession within both exclosures, which would further emphasize differences between plots grazed heavily by cattle and big game and those grazed lightly by game or not grazed by cattle and big game.

Generally, the impact on herbaceous vegetation was most pronounced when cattle and big game grazed in common. Grazing by big game alone resulted in minor impacts on the herbaceous component of the understory. This does not imply that herbaceous vegetation was not important forage for big game. Big game populations have not been large enough to exert a significant impact on structure of the herbaceous component of this community. Walton (1962) reported annual production on this site was 98% herbaceous material.

Both cattle and big game had similar effects on the browse component of the community. Frequency and cover of browse were significantly reduced either by grazing cattle and big game together or by big game grazing. In 1959-1960 browse made up only 2% of the annual forage production (Walton, 1962). A small portion of forage available for use was browse, and so the relative impact of grazing on these plants would be expected to be greater than for herbaceous vegetation. The significantly lowered browse frequency and cover on grazed versus ungrazed areas suggested these plants sustained heavy use over the 14 years of study but does not imply that browse was important for production of cattle or big game because of the relatively small amount available.

It seems logical to expect that the herbaceous component of the Douglasfir-ponderosa pine-Kentucky bluegrass community could be maintained by judicious cattle grazing management. The browse component of this community will probably be suppressed by game regardless of livestock management programs.

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Biology and Impact of a Grass Bug *Labops hesperius* Uhler in Oregon Rangeland

J. G. TODD AND J. A. KAMM

Highlight: *Wintering eggs of a univoltine plant bug* Labops hesperius *Uhler in rangeland seeded to intermediate wheatgrass hatched in late March. The subsequent nymphs stayed in the litter during the day and crawled on the leaves to feed at night. Adults began to appear in late April. Females had a 2-week preoviposition period and thereafter laid diapausing eggs in dry culms of various grasses. The feeding injury produced by a density of 120 bugs per 0.96 ft^2 reduced the nutritive value of intermediate wheatgrass about 18% midway through the growing season, but by the time the grass matured, the reduction due to feeding injury was only 2%. However, the impact of feeding injury on rangeland productivity varies with the time of utilization, annual rainfall, and drought. Management practices that reduce the food supply of the bugs and the availability of the straw preferred for oviposition seem a promising method of reducing the impact of feeding injury and the density of bugs.*

Seeding of native rangeland in the semiarid regions of western North America with introduced wheatgrasses has greatly increased forage production during the past 30 years. However, the occurrence and density of populations of *Labops hesperius* Uhler[1] (no approved common name but often referred to as Labops, black grass bug, or wheatgrass bug) in seeded areas has closely paralleled this modification of the rangeland ecosystem (Mills, 1939; Denning, 1948; Armitage, 1952; Knowlton, 1967; Bohning and Currier, 1967). The acreage of rangeland infested with this and other plant bugs is difficult to estimate, but in Utah alone 200,000 acres were damaged in 1965 (Knowlton, 1967). Little is known about the biology of these plant bugs in rangeland other than general observations concerning the seasonal occurrence and the feeding injury caused by the bugs. Nevertheless, the bugs extract the plant sap from the leaves during their feeding activities and may reduce yields 50 to 60% (Bohning and Currier, 1967; Knowlton, 1967).

This investigation was therefore made to study the biology and behavior of *L. hesperius* in Baker County, Oregon. Laboratory and field tests were also conducted to assess the degree of feeding injury produced by the bugs.

Study Areas and General Methods

Two sites with different physical characteristics were used for study. Site I was located on an eastward slope (elevation 3200 ft) that was cleared of sagebrush in 1949 and seeded to intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.). In 1972, the plant cover was dominated by intermediate wheatgrass with minor amounts of bulbous bluegrass (*Poa bulbosa* L.), Kentucky bluegrass (*Poa pratensis* L.), and scattered plants of big sagebrush (*Artemisia tridentata* Nutt.). Site II was located on rolling terrain close to timberline (elevation 4200 ft). It was seeded with a mixture of grasses in 1959, and by 1972 the plant cover was dominated by intermediate wheatgrass and pubescent wheatgrass (*Agropyron trichophorum* (Link) Richt.) with minor amounts of alfalfa (*Medicago sativa* L.), bulbous bluegrass, and big sagebrush. Both sites are among the more productive improved rangelands in Baker County, which has an annual precipitation of 14 to 20 inches. A 1–2 inch layer of litter was typical of both sites due to light grazing. Daily temperatures were monitored at site I with a thermograph.

The technique for sampling population densities of *L. hesperius* depended on the developmental stage. A 0.96-ft^2 circular quadrat was used for sampling. Quadrat locations were selected at random. Egg counts were obtained by collecting all straw in the quadrat and splitting the straws to expose the eggs. Counts of nymphs and adults were made by placing an open cylinder of sheet metal over the quadrat and then collecting them with an aspirator. Another sampling method was also used to determine the density of bugs whereby the

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[1] Hemiptera: Miridae.

bugs were collected by sweeping the foliage with a standard 15-inch insect net. The number of bugs per sweep refers to the number collected as the net traveled in a 180° arc.

Herbage was clipped at ground level in circular quadrats of 9.6 ft^2, oven dried for 24 hours at 130° F, and then weighed to obtain yield data. Samples were analyzed for the percentage crude protein and ash (Horwitz, 1965), cell-wall constituents (Van Soest and Wine, 1967), and acid-detergent fiber (Van

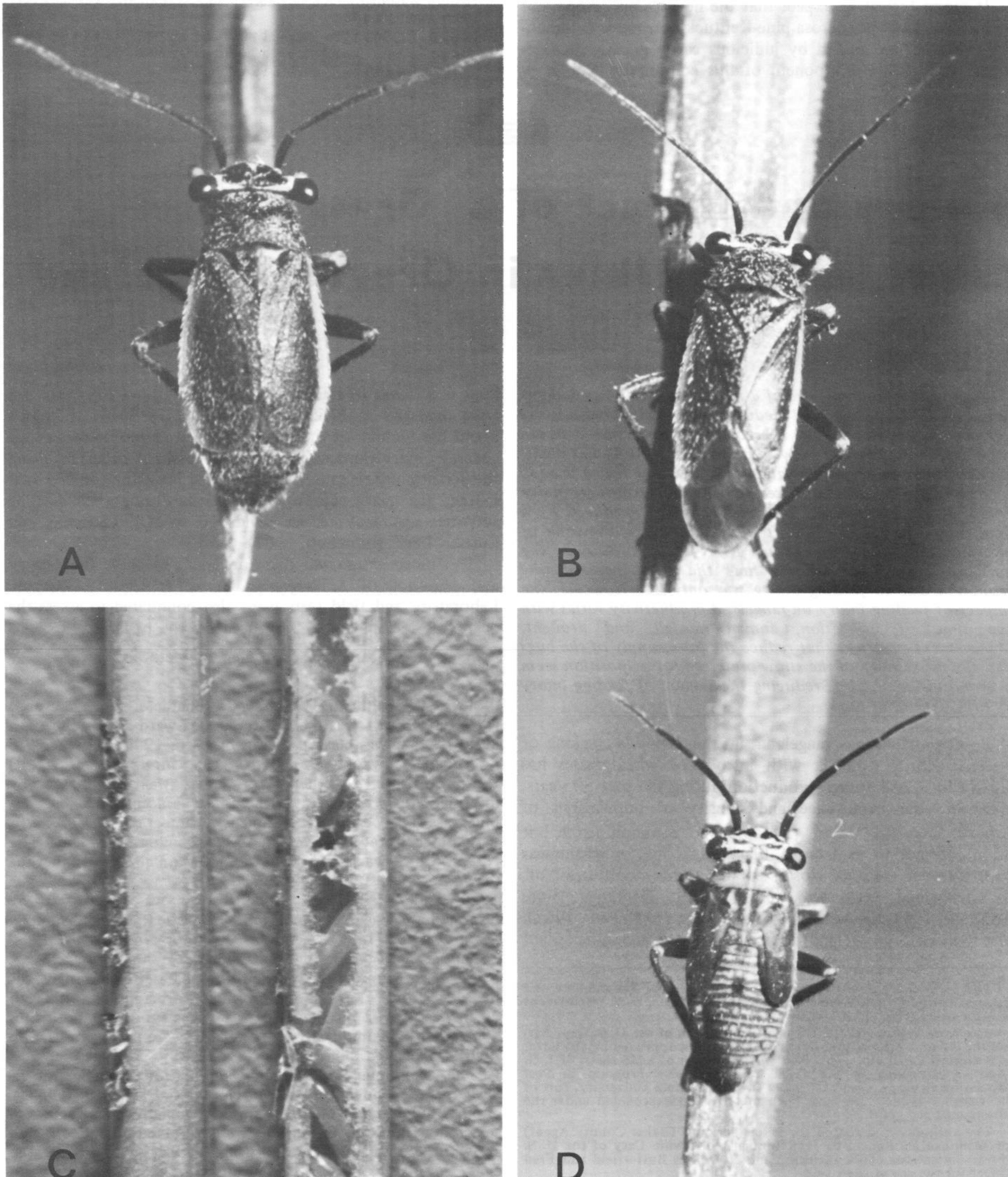

Fig. 1. *Life stages of the* Labops hesperius. *A. Brachypterous female. B. Macropterous female. C. Straw cut in half to show eggs. D. Fifth-instar nymph.*

Soest, 1963) by the Department of Animal Science, Oregon State University. All values are expressed on an oven-dry basis.

Results

Description of Life Stages

The adult bugs are predominantly black and have a white lateral stripe along the outer margin of the wings. Both sexes have a short, broad head with widely spaced and stalked eyes. Adults are about 1/4 inch long and about 1/16 inch wide. Males are always macropterous, but females may be either macropterous or brachypterous (Fig. 1 A, B). The elongate eggs are circular in cross section, slightly curved longitudinally, with a laterally compressed operculum at one end (Fig. 1 C). The eggs are white when laid but gradually turn light brownish-orange. Nymphs are light grey but have mottled brown and black markings on the legs, thorax, and head, so to the naked eye they appear different shades of greyish-brown (Fig. 1 D). Nymphs pass through five stadia.

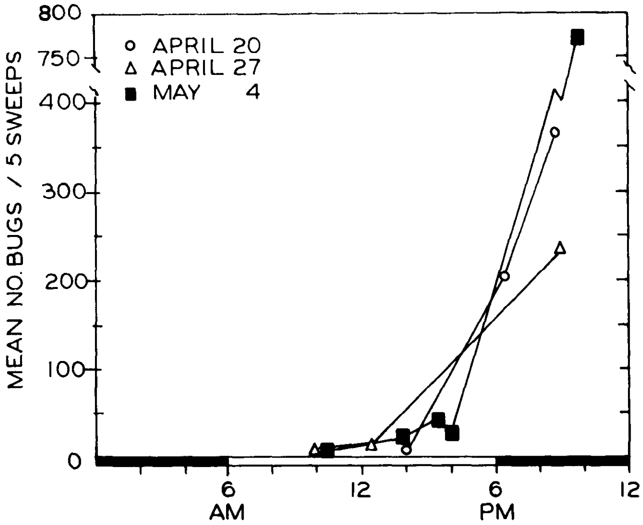

Fig. 2. *Number of nymphs of* Labops hesperius *collected from intermediate wheatgrass at different times of day.*

Seasonal Development

Wintering eggs of *L. hesperius* began to hatch in late March. The nymphs remained on the ground beneath the straw and litter during the day. They crawled up on the leaves and fed primarily at night (Fig. 2). However, larger nymphs and adults fed both day and night. Bugs at both sites developed rapidly despite the relatively cold temperatures (Fig. 3). The first adults appeared in late April, and the maximum density of adults occurred 2 weeks later (Fig. 3 and 4). The duration of the life cycle at both study sites was essentially the same, except the eggs hatched 1 week later at the higher elevation, probably due to colder temperatures.

The duration of the preovisposition period was determined by dissecting 25 females from each site once a week by using methods previously described (Kamm and Ritcher, 1972). Oocytes were visible as white spots within the follicles of the ovaries after 1 week, but no mature eggs were found until 2 weeks after adult emergence; mating was also observed at this time. Thereafter, ovarian development proceeded rapidly, and the abdomens of females became greatly distended. The number of eggs within the ovaries was maximum in early June but declined thereafter, indicating that oviposition was in progress (Fig. 5). However, the females at site I contained considerably more eggs than the females at site II, which could indicate a difference in fecundity between the populations. Therefore, the straw in five quadrats from each site was dissected to estimate fecundity based on the number of eggs laid in the straw. The results showed that females at site I laid an average 21 eggs compared with 9 eggs per female at site II. We attribute the lower fecundity at site II to a shortage of food, since twice as many bugs were present at site II (Fig. 3 and 4) and feeding injury to the grass was more severe than at site I. No evidence of a second generation was observed at either site.

The phenology of many plant bugs and their host are often synchronized; that is, maturation of the grass coincides with oviposition by the insect. In contrast, *L. hesperius* had completed oviposition when many grasses (including wheatgrasses) were still vegetative, so most straw used for oviposition was one or more years old. Field tests were conducted to determine the species of grass and the portion of

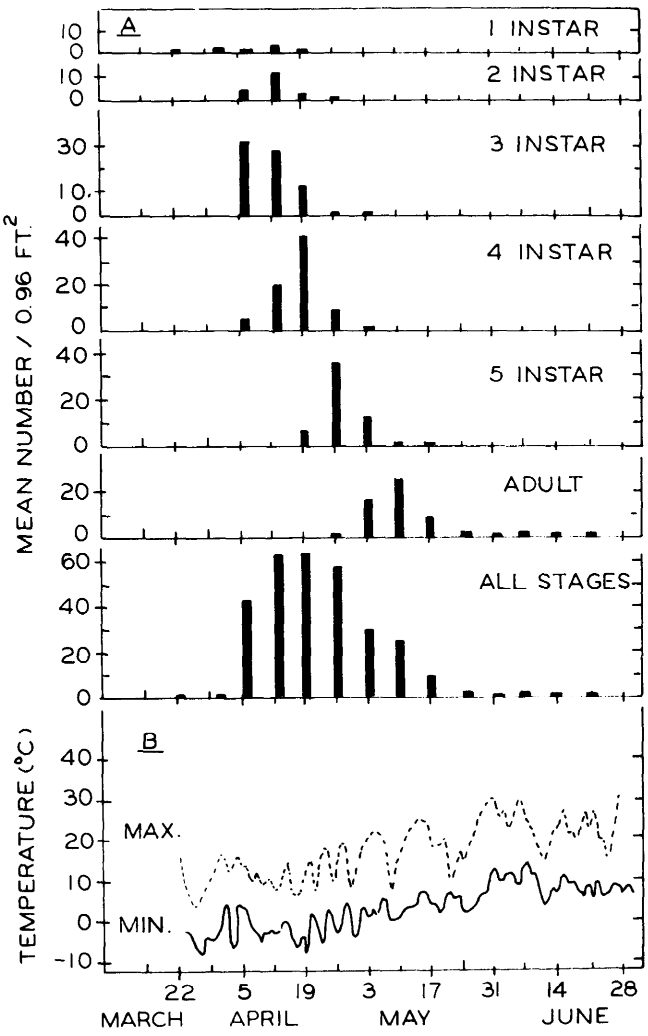

Fig. 3. *A. Seasonal occurrence and density of life stages of* Labops hesperius *at site 1 (5 samples per collection date). B. Daily temperature.*

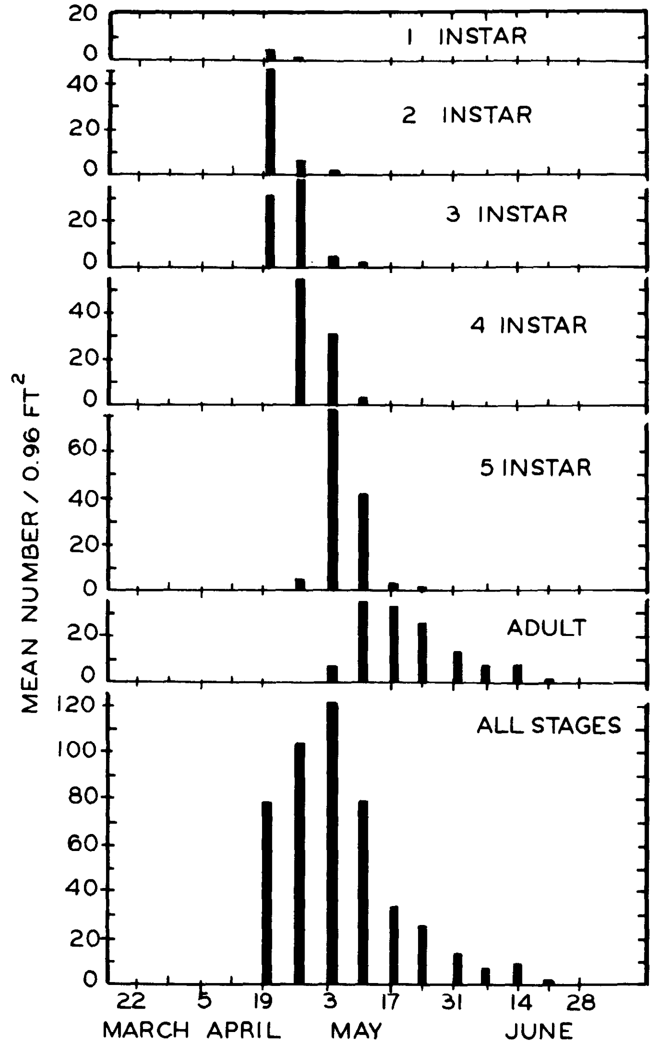

Fig. 4. *Seasonal occurrence and density of life stages of* Labops hesperius *at site 2 (5 samples per collection date).*

the culm used for oviposition. First, the fallen straw was removed leaving only the green leaves of intermediate wheatgrass and negligible amounts of short pieces of straw produced the previous year. Then 500 adults (sex ratio was 1.8 females to 1 male) were introduced into each of six cages and provided with dry whole culms of a single species of grass. In addition, 500 adults were confined with only whole green culms, and another 500 adults were caged on only stubble and short broken straws (1-3 inches) of intermediate wheatgrass. Egg counts were made from a sample of straw taken from each cage after the adults had died (Table 1).

The dry culms of crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith), intermediate wheatgrass, and bulbous bluegrass were readily used for oviposition, and most eggs were laid between the inflorescence and the distal node. No eggs were laid in green culms and relatively few were laid in the stubble and broken culms of intermediate wheatgrass. Since many eggs were laid in bulbous bluegrass we decided to determine the preferred oviposition host in a field situation. At the time of this test, the wheatgrass was still vegetative, but the bulbous bluegrass had produced dry, mature culms that were available for oviposition. The culms in 30 quadrats were collected at random from site II; 99.5% were intermediate wheatgrass and 0.5% were bulbous bluegrass. However, 27% of the 3,152 eggs recovered were found in bulbous bluegrass. Clearly, the early maturing bulbous bluegrass was preferred for oviposition despite the great abundance of old straw of intermediate wheatgrass.

Habitat and Host Range

L. hesperius was found in habitats that varied from the native sagebrush-grass communities of the high desert to mountain parks near the timberline. Populations of bugs were relatively sparse in areas of native vegetation, but dense populations were invariably associated with modified rangeland reseeded to wheatgrasses. Bugs were observed to feed on the following plants: crested wheatgrass, intermediate wheatgrass, pubescent wheatgrass, bulbous bluegrass, Kentucky bluegrass, cheatgrass (*Bromus tectorum* L.), quackgrass (*Agropyron repens* (L) Beauv.), bluebunch wheatgrass, California brome (*Bromus carinatus* Hook and Arn.), orchardgrass (*Dactylis glomerata* L.), Idaho fescue (*Festuca idahoensis* Elmer), barley (*Hordeum vulgare* L.), Junegrass (*Koeleria cristata* (L) Pers.), Sandberg bluegrass (*Poa secunda* Presl), rye (*Secale cereale* L.), and Lemmon's needlegrass (*Stipa lemmonii* (Vasey) Scribn.). The degree of feeding injury varied among species, and the list is probably

Table 1. Number of eggs laid by *Labops hesperius* in 100 culms of each of 6 species of grass.

Plant species	Straws with eggs (%)	Number of eggs between: Inflorescence and distal node	Distal node and penultimate node	Penultimate node and base of plant	Total
Crested wheatgrass: whole culm	11	121	39	0	160
Bluebunch wheatgrass: whole culm	19	204	0	0	204
Cheatgrass: whole culm	2	0	14	0	14 [a]
Idaho fescue: whole culm	2	18	0	0	18 [a]
Bulbous bluegrass: whole culm	64	4508	1160	0	5768 [b]
Intermediate wheatgrass:					
Whole culm (dry)	30	336	40	0	376
Stubble (1-3")	3				32
Broken straw	7				52
Whole culm (green)	0				0

[a]Calculated from a sample of 50 straws.
[b]Calculated from a sample of 25 straws.

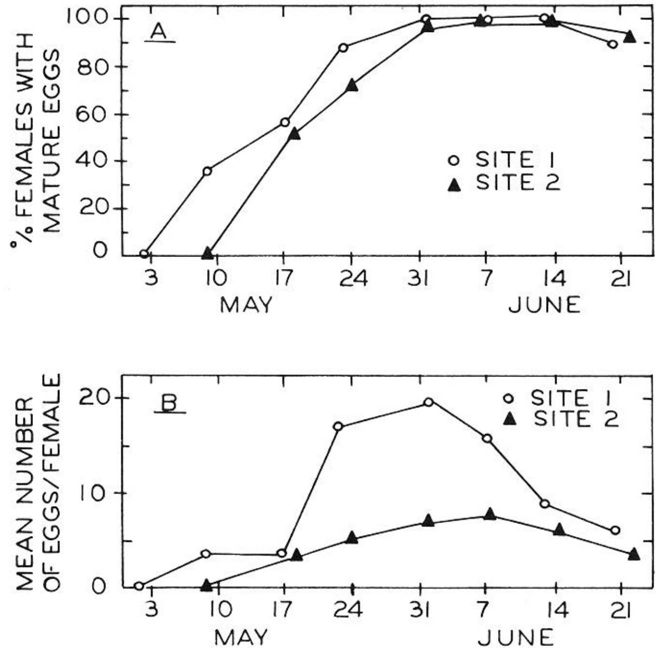

Fig. 5. *A. Cumulative percentage of females that had ovaries with mature eggs. B. Mean number of eggs per female (from dissection of ovaries).*

incomplete. Many grasses are satisfactory as food in early season; but thereafter grasses, such as wheatgrass, which remain green during oviposition are essential to meet the food requirements of the adults.

Feeding Injury

Nymphs and adults of *L. hesperius* sucked plant juices from the leaves and thereby produced small irregular white spots. When such feeding punctures were numerous, the leaves gradually turned yellow and then white around the feeding punctures. The impact of feeding injury on the yield and nutritional value of the forage was assessed in a block of field plots, half of which were sprayed with insecticide[2] (Cygon®, 1 lb/acre) April 26. Forage samples were removed from both sprayed and unsprayed plots on May 22, when the contrast in feeding injury between plots was greatest (Fig. 6). By May 22, the feeding injury in the unsprayed plots reduced the dry weight yield 13% but increased crude protein 2%, cell-wall constituents 6%, acid-detergent fiber 5%, and ash 0.5% (Table 2). This increase in the cell-wall constituents reflects an equivalent decrease of 6% in the cell contents. Since the estimated digestibility of the cell-wall constituents of grasses is 25% and that of the cell contents is 98% (Van Soest and Moore, 1965), the 6% decrease in cell contents represents an approximated decrease in digestibility of about 5%. However, the acid-detergent fiber is part of the cell-wall constituents, so the 5% increase was, in fact, a relative increase due to the removal of the cell contents by the bugs. Similarly, the increase of ash was a relative increase due to the removal of the cell contents. The 2% increase of crude protein may also be relative, but we are not certain because the crude protein includes portions of both the cell contents and cell-wall

[2] Mention of a pesticide does not constitute recommendation or endorsement by the U. S. Department of Agriculture.

Table 2. Dry weight (g/9.6 ft²) and chemical constituents (%) of intermediate wheatgrass injured by feeding of *Labops hesperius* at site II, Baker, Oregon.

Date sampled and treatment	Dry weight	Chemical constituents: Crude protein	Cell-wall constituents	Acid detergent fiber	Ash
May 22, 1972					
Sprayed	99*	11.28*	62.08*	34.80*	10.84*
Unsprayed	86	12.87	68.33	39.38	11.22
July 31, 1972					
Sprayed	247	4.37	60.85*		
Unsprayed	244	4.55	62.39		

*Significantly different at $P < 0.05$.

constituents (Van Soest and Moore, 1965). Rautapaa (1970) reported a similar increase in protein of wheat due to the feeding injury of the plant bug *Leptopterna dolobrata* (L.). We estimate the combined effects of the decrease in yield and the reduction in percent cell contents to represent a loss of forage value of about 18% midway in the growing season.

After the adult *L. hesperius* had laid eggs and died, summer rainfall produced a lush growth of grass, so another series of forage samples was taken to determine the impact of feeding injury on forage production at the end of the growing season. Only the dry weight yield, crude protein, and cell-wall contents were determined at this sampling. The yield for July 31 was more than that for May 22, but no significant difference was found between sprayed and unsprayed plots (Table 2). The crude protein was about the same in both treatments, but the cell-wall constituents were 2% greater in the untreated plots. Thus, our estimate of the total loss of nutritive value of the forage was about 2% when the grass was mature.

Aspects of Cultural Control

In our first tests *L. hesperius* was observed to oviposit in the upper portions of culms; relatively few eggs were laid in the stubble and broken culms of intermediate wheatgrass (Table 1). We therefore evaluated removal of straw as a method of reducing the density of bugs. In July 1971, a hay

Fig. 6. *Intermediate wheatgrass with feeding injury by* Labops hesperius *(left) and no injury (right). May 18, 1972.*

crop was removed from a 40-acre field of intermediate wheatgrass adjacent to site II, which was left undisturbed. The management practices on these field was the same prior to 1971. Both fields were sampled along parallel transects on May 20, 1972, to estimate the number of adults and again on June 14 to estimate the number of eggs laid by these adults. In the field where the hay was removed, a mean density of 20 adults produced a mean of 45 eggs per quadrat; in the undisturbed field, 44 bugs produced a mean of 230 eggs per quadrat. Analysis of the data with the Wilcoxon two-sample test indicated that significantly fewer adults ($P < 0.05$) were present in the field that produced the crop of hay, but the number of eggs in the two fields was not significantly different. However, the outcome may have been different in the absence of bulbous bluegrass because nearly half the eggs in the field used for hay production were in straws of bluegrass produced the season after the hay was removed.

In yet another test, burning of grass litter to destroy wintering eggs and nymphs was evaluated by burning randomly selected portions of a field of wheatgrass in early April. On May 4 the burned and unburned plots had an average of 7 and 92 nymphs per sample, respectively, and the number of eggs laid in the burned and unburned plots by June 30 was 2 and 30 eggs per sample, respectively. Clearly, burning had destroyed the spring population and also eliminated most of the straw used for oviposition. In fact, the only eggs found in the burned area were in straw of bulbous bluegrass that grew after the field was burned.

Discussion

Dense infestations of the univoltive plant bug, *L. hesperius*, were usually associated with established seedings of crested and intermediate wheatgrass. However, the feeding injury produced by a maximum density of 120 bugs per quadrat (0.96^2 ft) reduced the nutritive value of intermediate wheatgrass about 18% midway in the growing season but only 2% by the time the grass was matured and dry. In other words more than half the forage produced during the 1972 season grew after the bugs had died, so the impact of the feeding injury was less than 9% for the season. Thereafter the nutritive components decreased 7% further during normal curing of the grass and thus, at maturity, only a 2% loss was attributable to feeding injury of the bugs. We are aware of the accuracy and limitations of the analytical techniques used to determine forage quality and the assumptions made in assessing our data in practical terms. Nevertheless in terms of forage utilization, yield would have been reduced 9% when used for spring pasture but only 2% when reserved for fall pasture. However, in years of scant rainfall, the grasses make little or no growth after the bugs die. Then the loss would be close to 18%, assuming utilization as spring pasture. The impact of feeding injury of *L. hesperius* on rangeland productivity, therefore, varies with time of utilization, annual rainfall, and drought. In fact even greater losses may occur in years of acute drought.

The forage loss attributed to the feeding activity of *L. hesperius* often does not justify the use of insecticide. However, cultural or management practices designed to reduce the straw preferred for oviposition may prove useful in reducing population densities the following year. Certainly in some rangeland the presence of early maturing grasses such as bulbous or Sandberg bluegrass may reduce or prevent an effective management program, but these grasses are not present in all seedings of wheatgrass. The practice of rotation grazing whereby a pasture is grazed one year and rested the next may increase the population of bugs by allowing the accumulation of the straw used for oviposition. We believe that grazing trials should be explored as a management practice to reduce the food supply of the bugs and the straw available for oviposition.

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Contour-Furrowing and Seeding on Nuttall Saltbush Rangeland of Wyoming

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Highlight: *A Nuttall saltbush (*Atriplex gardneri*) site in the Big Horn Basin of Wyoming was contour-furrowed and seeded to crested wheatgrass (*Agropyron cristatum*) by the Bureau of Land Management in 1957 as part of a range improvement and watershed management program. In 1962 total herbage production on the treated area was 972 lb/acre compared to 412 lb/acre for untreated range. Greater production was due to both the yield of crested wheatgrass and improved vigor of Nuttall saltbush. By 1972 total production of the treated area declined to 590 lb/acre but was still 54% greater than the control. Coincident with decreased production, foliage cover of crested wheatgrass decreased by 74% and Nuttall saltbush 50%, part of which can be attributed to reduced waterholding capacity of the furrows by about 30% from their original capability. The untreated native range produced 384 lb/acre in 1972, which was not appreciably different from production 10 years previously. Likewise, foliage cover percentages remained relatively stable.*

Contour-furrowing and seeding is a widely used method of range manipulation. These procedures have improved rangelands by increasing availability of moisture, decreasing soil erosion from wind and water, and increasing forage production for livestock and wildlife. Many rangelands of semiarid western Wyoming, with impermeable soils and average annual precipitation values as low as 4 to 6 inches, have been treated with contour-furrowing and seeding. Significant forage increases have often resulted.

The Bureau of Land Management, during the 1950's and 1960's initiated a number of range improvement and watershed management projects on the Fifteen-mile drainage north of Worland in the Big Horn Basin of northcentral Wyoming. A total of 25,000 acres were treated with an expenditure of more than $35,000. The Burnt Wagon project was initiated in 1957 and completed in 1962.[1] Included in this project were contour-furrowing and seeding crested wheatgrass (*Agropyron cristatum*) on 81 acres (Fig. 1) as well as subsequent fencing, stockwater development, and livestock management changes.

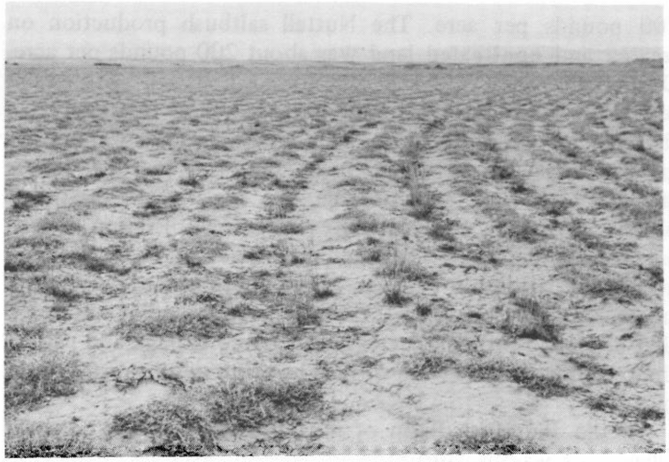

Fig. 1. *General view of the Burnt Wagon study area showing crested wheatgrass and Nuttall saltbush vegetation in contour-furrowed area during July 1972, 15 years after the establishment of the treatment.*

The following report is an evaluation of the Burnt Wagon contour-furrowing and seeding operation.

Review of Literature

Although a number of reports exist which describe contour-furrowing on native rangelands of the western United States, few incorporate reseeding. Additionally, most publications concerned with rangeland seedings do not include contour-furrowing as a seedbed preparation method. The combined operations have, in general, resulted in favorable vegetation production responses primarily because of reduced water runoff, increased soil moisture, and enhanced microhabitat growing conditions (Vallentine, 1972).

Results from contour-furrowing and seeding on shortgrass rangelands in eastern Wyoming have been favorable when furrows were no more than 2 ft apart and at least 4 to 8 inches deep (Barnes, 1952; Rauzi, 1968). Furrows spaced five to ten ft apart were ineffective because only a small portion of the total area was treated, resulting in little or no difference on herbage production.

An area near Fort Peck, Montana, was contour-furrowed and seeded to crested wheatgrass (Branson et al., 1962). After 10 years, vegetation measurements were obtained to determine responses. Before treatment the area had a sparse stand of Nuttall saltbush (*Atriplex gardneri*) and plains pricklypear (*Opuntia polyacantha*). After furrowing and seeding there was a satisfactory stand of crested wheatgrass which yielded 500 to

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[1] Records on file in the District Office, Bureau of Land Management, Worland, Wyoming.

Table 1. Precipitation (inches) recorded at the Burnt Wagon Study Area.

Year	Total annual	Spring period
1961	6.37	2.55
1962	6.54	3.90
1963	7.44	5.00
1964	6.27	4.63
1965	5.50	2.00
1966	4.14	1.07
1967	7.94	4.20
1968	9.16	3.74
1969	4.42	2.20
1970	4.37	2.10
1971	6.71	2.37
1972	6.48	1.45
Mean	6.28	2.93

700 pounds per acre. The Nuttall saltbush production on treated and nontreated land was about 200 pounds per acre. During the same study, it was found that soil of medium texture was the most favorable for mechanical treatment. On fine and very fine soils, plant production increases were not as great as on soils of medium to medium-fine textures. These latter soils were more suitable for mechanical treatment because of their better capability for water infiltration, as well as interrelated high waterholding capacity. There was no apparent relationship between pH and response to mechanical treatment in the study by these authors, although it was noted that contour-furrowing increased moisture storage and caused the transport of salts from surface layers to depths of 60 cm or more.

In the Big Horn Basin of northcentral Wyoming, crested wheatgrass was broadcast on pitted plots established with an eccentric one-way disc (Fisser, 1964). Adequate stands of crested wheatgrass were present 4 years after treatment on the pitted plots.

Range condition of saltbush range has been investigated by Fisser (1964). Excellent condition Nuttall saltbush range had approximately 10% cover of this half-shrub on heavy and impermeable soils. On lighter textured soils, saltbrush on excellent condition sites sometimes had more than 20% cover. Some decreaser species such as western wheatgrass (*Agropyron smithii*), Indian ricegrass (*Oryzopsis hymenoides*), and winterfat (*Eurotia lanata*) were occasionally present but usually in small quantities. As condition classification decreased the saltbush clumps became smaller and broken down.

Description of Study Area

The study area was located in Washakie County in the Big Horn Basin, approximately 18 miles northwest of Worland, Wyoming. Elevation is 4,252 ft above sea level. Topography is rolling with numerous drainages dividing the area, many of which are deep and sharply cut. The immediate study location was on nearly level upland with a slope of less than 5%.

The major geological unit of this area is the Willwood formation which consists of some 2500 feet of variegated shale and white and yellow sandstones (Van Houten, 1944). Soils of the area are predominately Greybull series, which are shallow clay loams, light colored, and classified as calcic lithosol of the sierozem zone (Soil Conservation Service, 1962).

A 20-year average of climatic conditions recorded by the U.S. Weather Bureau from 1941 to 1960, representing seven stations in the Big Horn Basin, was presented by Vosler (1962). Precipitation averaged 6.5 inches annually while average annual temperature was 45.2°F. For the Worland Station, Nichols (1964a) summarized the long term climatic records and revealed that average annual precipitation from 1914-1962, was 7.76 inches. Almost 50% occurred during the months of April, May, and June. Annual precipitation values exhibited extreme variation and ranged from a low of 2.27 inches to a high of 13.57 inches. Average annual temperature was 44.6°F with June, July, and August the three warmest months.

At the Burnt Wagon study area, precipitation averaged 6.28 inches annually from 1961 through 1972 (Table 1). Average precipitation during the spring period from April 15 through June 30 was 2.93 inches, almost 50% of the total annual moisture regime. In spring 1962 3.90 inches occurred, but only 1.45 inches were recorded in 1972.

The most common vegetation type in the Burnt Wagon area is dominated by Nuttall saltbush. Some rather ephemeral perennials such as leafy musineon (*Musineon divaricatum*) are occasionally abundant, but usually the saltbush type of the area presents an aspect of low productivity and much bare soil.

The study area was located in the Burnt Wagon pasture, a unit of some 25,000 acres with a history of summer cattle use, winter sheep use, and continuous year-around use by wild horses. As administered by the Bureau of Land Management, grazing rates were established at 1,523 AUMs of cattle for a 2-month period, 302 AUMs of sheep for 2 months during winter, and 80 to 120 AUMs of horses for year-around use.

Some water pits and reservoirs were established but livestock distribution is still inadequate. A large proportion of the grazing use of the area has occurred on the contour-furrowed and seeded areas resulting in some overuse of crested wheatgrass and Nuttall saltbush.

Methods and Procedures

The contour-furrowing and crested wheatgrass seeding operation was accomplished with an Arcadia Model B contour-furrowing machine in 1957. Furrows were 10 to 12 inches deep, 5 ft apart, with dams spaced at about 10-ft intervals to hold water within each furrow segment.

Estimates of vegetation cover, composition, and production were obtained in 1962 (Nichols, 1964b), 5 years after the initial furrowing and seeding treatment, and in 1972. Methods and procedures were identical. Sampling was conducted along permanently staked transects 50 ft in length. Ten transects were established in the native rangeland and ten in the contour-furrowed and seeded area.

Table 2. Frequency (%) of occurrence of seeded and native site vegetation (1962 and 1972).

	1962		1972	
Species	Native site	Seeded site	Native site	Seeded site
Nuttall saltbush	42	36	38	19
Crested wheatgrass	–	78	T	43
All others	51	16	38	23

Table 3. Foliage cover (%) of seeded and native site vegetation (1962 and 1972).

	1962		1972	
Species	Native site	Seeded site	Native site	Seeded site
Nuttall saltbush	12	11	9	5
Crested wheatgrass	–	23	T	6
All others	7	3	6	3
Total	19	37	15	14

Cover and composition data were obtained by utilizing a line transect adaptation of the Levy and Madden (1933) point frame procedure. The point frame contained ten pins spaced at 2-inch intervals. The point frame was positioned adjacent to the transect line in a sequential series of 30 contiguous settings to provide 300 point readings for each transect. All forage hits were recorded and later calculated as percentages of cover, composition, and frequency.

Herbaceous forage production was estimated by clipping ten quadrats, 1 foot X 10 feet, in each of the two areas. Locations of the plot frames were determined by restricted random selection for placement adjacent to the permanent transects. Collection of field data was made during the first week in July, both in 1962 and 1972, when the important species were mature but before senescense and decomposition.

Nuttall saltbush and crested wheatgrass were clipped and weighed separately. All species were grouped into three categories—perennial forbs, perennial grasses, and annual forbs—because each species individually contributed relatively little to the total production of the site.

In 1972, depth of furrows were determined by measuring 25 subsamples located by restricted random sampling.

Results

Prominent vegetation changes occurred with the 1957 establishment of crested wheatgrass in the contour-furrowed site. Evaluation and interpretation of the data obtained in 1962 and subsequently in 1972 showed that changes also occurred during the latter 10 year period.

Percent frequency of occurrence of crested wheatgrass declined by almost one-half from 78 to 43% (Table 2). Although the frequency values of Nuttall saltbush remained relatively stable on the native nontreated site, they decreased by half on the seeded site from 36 to 19%. An increase of other species was recorded on the seeded site.

Foliage cover percentages on the native site exhibited a minimal decrease (Table 3), which probably resulted from the arid situation which occurred during spring, 1972. The very significant decrease of foliage cover on the seeded site reflects a concomitant decrease of furrow waterholding capacity. The mean depth of furrows was 4.6 inches, with values ranging from 3.0 to 6.0 inches. Waterholding capacity of the furrowed area in 1972 was estimated to be 25 to 30% of the original furrows constructed in 1957. While the saltbush cover only decreased by about half, the crested wheatgrass decreased by 75%. In addition, it is of interest to note that saltbush cover in 1962, 5 years after treatment, was essentially the same in both the native and treated sites. In 1972 the cover percentage of saltbush on the native site had decreased by 25%, but decreased by 54% on the furrowed and seeded site.

Although 1962 was a moist spring year and 1972 rather dry, the native site vegetation cover composition values (Table 4) were almost identical, with Nuttall saltbush comprising 60% of the vegetation. The remainder consisted primarily of tansyleaf aster (*Machaeranthera tanacetifolia*) and leafy musineon with small amounts of grasses, half shrubs and forbs. On the seeded site, although the saltbush remained relatively constant and comprised about one-third of the cover composition, the percentage value of crested wheatgrass decreased from 62% to 43% while the values of all other species increased from 8% to 21%. This increase was caused by increased amounts of leafy musineon, bluebur stickseed (*Lappula redowskii*), and bottlebrush squirreltail (*Sitanion hystrix*). These native species are better adapted to arid environments than crested wheatgrass and represent a shift to more xeric conditions caused by the decreased waterholding capacity of the furrows.

Table 4. Cover composition (%) of seeded and native site vegetation (1962 and 1972).

	1962		1972	
Species	Native site	Seeded site	Native site	Seeded site
Nuttall saltbush	63	30	60	36
Crested wheatgrass	–	62	1	43
All others	37	8	39	21

Table 5. Herbage production (lb/acre) of seeded and native site vegetation (1962 and 1972).

	1962		1972	
Species	Native site	Seeded site	Native site	Seeded site
Nuttall saltbush	266	475	280	145
Crested wheatgrass	–	481	–	334
All others	146	16	104	111
Total	412	972	384	590

Herbage production on the native nontreated site, both in 1962 and in 1972, was about 400 lb/acre (Table 5). The slightly greater production of all other species in 1962 as compared to 1972 reflects the better moisture conditions during the spring of the earlier year. Production of ephemeral annual and perennial forbs is of little importance as livestock forage, however, because of early shattering and desiccation, unless it is used during its relatively short growth period.

Although herbage cover of Nuttall saltbush in 1962 was similar for both sites, production was much greater on the seeded site because of increased plant vigor and more robust growth on the furrowed site. The 972 lb/area production exhibited on the seeded site in 1962 reflects the impact of increased waterholding capacity by furrows. Also, cultivation effects may have released nutrients and improved the soil environment, resulting in significantly greater saltbush production, as well as comparably greater crested wheatgrass yields.

By 1972 the herbage cover of Nuttall saltbush on the seeded site had decreased by 54%, from 11% cover to 5%. Production of saltbush had decreased very significantly from 475 to 145 lb/acre. This decrease appeared to be a function of three factors: (1) several concurrent years (1969-1972) of below-average precipitation especially during spring; (2) decreased waterholding capacity of the furrows, allowing greater runoff and moisture loss; and (3) competition for limited water between Nuttall saltbush and crested wheatgrass.

The decrease of crested wheatgrass production from 481 lb/acre in 1962 on the seeded site to 334 in 1972 indicates a concomitant relationship. Since the crested wheatgrass decreased only by about 30% while Nuttall saltbush decreased by almost 75%, it appears that crested wheatgrass is well adapted to the site, can compete effectively with the native vegetation, and can maintain good production levels even during periods of limited moisture.

Summary

A Nuttall saltbush range area was contour-furrowed and seeded with crested wheatgrass in 1957. Vegetation data obtained in 1962 showed a very marked response to the

improvement program with increased production, a result of improved vigor of Nuttall saltbush and the introduction of crested wheatgrass. Additional waterholding capacity by furrows was the primary stimulus for improved production.

By 1972, when the most recent data were obtained the furrows had been sufficiently filled to reduce the waterholding capacity by 25-30% their original capabity. Nevertheless, forage production of crested wheatgrass was still over 300 lb/acre. Although Nuttall saltbush production was lowest on the contour-furrowed and seeded site, total herbage production was still maintained at a level significantly greater than on the nontreated native rangeland.

The rate at which the furrows continue to fill is expected to decrease in the future. There is a high probability that production on the treated site will remain higher for at least another 20 years.

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Vegetation Response Following Spraying a Light Infestation of Honey Mesquite

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Highlight: *Vegetation change was evaluated for 4 years following aerial application of 2,4,5-T + picloram (1:1) at 0.56 kg/ha to semiarid rangeland with a light canopy cover of honey mesquite (12%) and sand sagebrush (2%). Stand reductions of woody plants exceeded 95% at 4 years after treatment whether in grazed or ungrazed pastures. Forage production increased on areas with brush control and protection from grazing only in years of average or above-average rainfall. However, sprayed, ungrazed areas produced during the study period an average of 3 kg/ha/year more grass for each centimeter of precipitation received than did untreated, ungrazed areas. At the end of the study, areas sprayed and protected from grazing supported more grasses of fair to good grazing value than did unsprayed areas.*

The Soil Conservation Service (Smith and Rechenthin, 1969) indicated over 16 million ha of Texas rangeland were infested with light to moderate stands (less than 25% of canopy cover) of honey mesquite (*Prosopis glandulosa* Torr. var. *glandulosa*). In the Rolling Plains, a part of the Great Plains region, many of the light to moderate stands are the result of massive disturbance of dense stands of large, single-stemmed honey mesquite. Honey mesquite growth form following initial control efforts is usually a multi-stemmed, bushy plant that is not susceptible to mechanical methods such as chaining and is only temporarily controlled by shredding (Fisher et al., 1969) (Fig. 1). The small, bushy, honey mesquite is not easily controlled by prescribed burning (Britton and Wright, 1971). Rootplowing is not practiced in much of the Rolling Plains because of shallow soils, rough terrain, investment costs and variability in the semiarid climate.

A 1965 study indicated that aerially spraying honey mesquite with 50% or greater canopy cover using 0.56 kg/ha of 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] applied in about 40 to 50 liters/ha of a diesel oil: water emulsion (1:3 or 1:4) was profitable in the Rolling Plains (Workman et al., 1965). However, the value of spraying light to moderate stands of honey mesquite has been questioned on the basis that control results in little or no additional forage production and small, scattered plants present no significant management problem.

Success from aerial applications of 2,4,5-T is strongly influenced by site factors such as soil temperature (Dahl et al., 1971) and physiological

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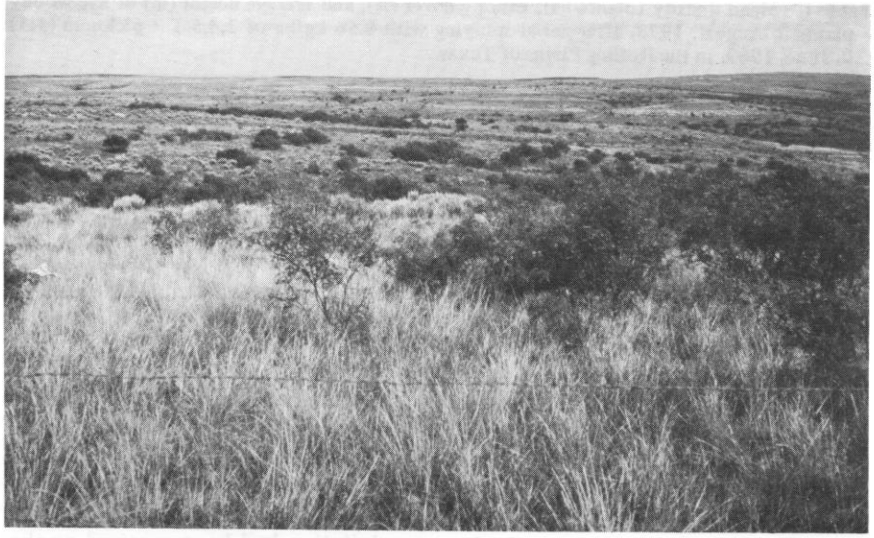

Fig. 1. *Much of the honey mesquite infestation on Texas rangeland, especially in the Rolling Plains, is composed of multi-stemmed, bushy plants that are difficult to control except by aerial spraying.*

conditions such as internal moisture stress (Meyer et al., 1972). Recently workers have combined 2,4,5-T with herbicides such as dicamba (3,6-dichloro-*o*-anisic acid) or picloram (4-amino-3,5,6-trichloropicolinic acid) in an effort to increase the level of honey mesquite control and to broaden the spectrum of phytotoxicity to associated undesirable species (Scifres and Hoffman, 1971). Control of honey mesquite by the 2,4,5-T + picloram combination is evidently governed by the same environmental factors which regulate 2,4,5-T effectiveness (Meyer et al., 1972; Sosebee et al., 1973). Sosebee et al. (1973) also reported that trees taller than about 2.5 m were more difficult to kill than smaller plants with aerial sprays of 2,4,5-T + picloram.

In efforts to develop more effective herbicides and herbicide combinations, researchers have concentrated almost solely on response of the target species. Relatively few studies in the study area have emphasized reaction of the total plant community to herbicide application. The objective of this research was to evaluate the reaction of a rangeland community with a light infestation of honey mesquite and sand sagebrush (*Artemisia filifolia* Torr.) to aerial application of 2,4,5-T + picloram.

Materials and Methods

Two watersheds, 3.5 and 4 ha in area and less than 0.6 km apart, were chosen for study. The watersheds were typical Rolling Hill range sites (Scifres et al., 1974) with south to southeasterly exposure and about 5% slope. The surface 2.5 cm of the Carey sandy loam had pH 7.1 and contained 1.1% organic matter, 66% sand, and 14% clay.

On June 9, 1969, the triethylamine salts of 2,4,5-T + picloram were aerially applied in a 1:1 commercial formulation at 0.56 kg/ha total herbicide in 47 liters/ha of a diesel oil:water emulsion (1:4) to one watershed. The other watershed was not treated. In early July, 1969, an exclosure of about 0.32 ha in area was constructed in the center of each watershed.

Numbered stakes were placed along the upper fence and along one side of each exclosure such that their intersection formed a sampling point in a stratified scheme. Fifty-four points were randomly selected for sampling each year from 1969 through 1973. To compensate for slope effects, the watersheds were divided into three equal portions downslope and 18 points randomly drawn from each strata for sampling each year. During August of each year from 1969 to 1973, broadleaved species were counted, standing herbaceous vegetation was clipped at 2.5 cm stubble height, and mulch was hand collected at each sampling point from 0.25 m^2 quadrat. Standing vegetation, sorted into grasses and broadleaves, and mulch were oven-dried and weighed. Within 2 m either side of each quadrat harvested for yield, at least two samples were taken for botanical composition. Botanical composition was determined using basal intercepts from 10-point inclined sampling frames.

Canopy cover and density of honey mesquite and sand sagebrush were estimated using belt transects 1.5 m wide and 25 m long. At each sampling date, 12 transects were evaluated in the exclosures (four randomly located in each of the three sampling strata) and in an adjacent area beginning 9 m from the exclosure fences. Other undesirable species of minor importance in the area were observed for reaction to the spray.

Population attributes were compared between sprayed and untreated areas using a *t*-test. Influence of time on change of vegetation attributes was evaluated by regression analyses.

The range was stocked continuously during the study period with cows and calves at 1 AU/7 to 8 ha. The study area was within 0.15 km of a watering facility, which may have induced higher use than in other areas of the range.

Results and Discussion

Brush Control

Honey mesquite canopy was reduced by over 90% within 30 days after aerial spraying. The other primary woody component, sand sagebrush, did not defoliate but demonstrated typical, morphological responses to the growth-regulator herbicides (stem epinasty and dieback from the tips) at 1 month after treatment. At the time of treatment, canopy cover of honey mesquite was estimated to be about 12%, and sand sagebrush cover was about 2%. Canopy cover of these species increased slightly over the 4-year study period in the unsprayed plots (Table 1). Total canopy cover, reduced drastically by the spray, was less than 1% at 4 years after herbicide application. Density of honey mesquite and sand sagebrush did not change in the unsprayed areas over the study period but was reduced to about 32 live plants/ha on the sprayed watershed. The reduction in honey mesquite density, about 97%, was higher than normally expected from the spray. In the same area, Fisher et al. (1972) reported an average of about 50% reduction in number of live plants, regardless of growth form, with the same treatment from 1968 to 1970. Also, Sosebee et al. (1973) indicate that plants of the stature of those in our study are more difficult to control than larger plants.

Regrowth honey mesquite plants in treated areas were only about 0.3 m shorter than the average of the untreated population 4 years after spraying (Table 1). Kill of original topgrowth by the herbicide caused regrowth honey mesquite plants to develop over six stems per parent plant, whereas untreated plants averaged less than four stems per plant.

Less prevalent undesirable species, plains pricklypear (*Opuntia polyacantha*) Haw.), tasajillo (*O. leptocaulis* D.C. var. *leptocaulis*) and Jeff Davis cholla (*Opuntia davisii* Engelm. & Bigd.) were completely eliminated by the spray. No seedlings of woody or succulent plants were observed during the four growing seasons following spraying. The area has evidently reached a successional stage where disturbance of the ground cover would be necessary for invasion of honey mesquite seedlings (Scifres et al., 1971).

Table 1. Mean density (plants/ha), canopy cover (%), and average height (m) of live woody plants in August, 1973, after aerial spraying with 0.56 kg/ha of 2,4,5-T + picloram (1:1) in June, 1969, in the Rolling Plains of Texas.

Species	Treatment	Density	Canopy cover	Height
Mesquite	None	659	12.3	1.31
	Sprayed	17	0.2	1.01
	Difference[a]	*	*	N.S.
Sand sagebrush	None	259	3.8	0.52
	Sprayed	15	0.2	0.49
	Difference[a]	*	*	N.S.

[a]Asterisks indicate means of sprayed and unsprayed populations significantly different and "N.S." indicates no significance at the 95% level of probability.

Herbage Production

Long-term average annual rainfall for the area is 56 to 76 cm (Gould, 1969). During the year of treatment, the area received about 70 cm of precipitation.

Pretreatment evaluation showed no difference between watersheds in herbage production. Primary grasses at the time of spraying were buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), hooded windmillgrass (*Chloris cucullata* Bisch.), Hall's panicum (*Panicum halli* Vasey), Japanese brome (*Bromus japonicus* Thunb.), and Wright's threeawn (*Aristida wrightii* Nash). There was little change in production of herbage the first 90 days following herbicide application. Total standing yield was about 900 kg/ha of oven-dry herbage in the sprayed exclosure and about 975 kg/ha in the untreated area in August following spraying the previous June. However, grasses yielded only 120 kg/ha dry matter in the untreated area (12% of the total production) whereas 258 kg/ha (about 29% of the total) were harvested from the sprayed exclosure. The difference in total herbage production the year of spray application was accounted for in control of broadleaved species, primarily prairie pepperweed (*Lepidium densiflorum* Schrad.), Texas croton (*Croton texensis* (Klotzch) Muell. Arg.), prairie paintbrush (*Castilleja purpurea* (Nutt.) G. Don) and common broomweed (*Xanthocephalum dracunculoides* (D.C.) Shinners). Over 200 kg/ha less herbaceous, broadleaf dry matter were harvested on the sprayed watershed as compared to the untreated area after 90 days.

Annual precipitation during 1970 was less than 29 cm (about 40 to 50% of the annual average). Treatment effect evidently was completely masked by low rainfall and the high air temperatures which often exceeded 38°C during the summer months. Herbage yield averaged only 390 and 450 kg/ha total dry matter in the exclosures and less than 100 kg/ha was produced as grasses. Rainfall increased to over 56 cm during 1971, and herbaceous vegetation responded accordingly. However, there was little difference between sprayed and unsprayed areas in total herbage production. Grass yields averaged 380 and 485 kg/ha dry matter in untreated and sprayed areas, respectively, under complete protection. In 1972, about 60 cm precipitation was recorded. In the exclosures, about 750 kg/ha of oven-dry grasses were harvested from the sprayed area whereas the untreated exclosure produced about 680 kg/ha.

Highest herbage production for the study period was recorded in 1973, with the greatest differences recorded between sprayed and unsprayed exclosure (Table 2). Over 40 cm of precipitation had been received on the study area by time of the August harvests. Production of broadleaves was greater in grazed than in protected areas, but there was little influence due to spraying.

Trends in mulch accumulation followed the same pattern as with herbage production in 1973. Based on protected areas only, regression analysis was used to isolate the influence of rainfall on herbage production. For every centimeter of precipitation received annually, the sprayed, ungrazed area produced 21.8 kg/ha of oven-dry grasses. The untreated, ungrazed area produced 18.3 kg/ha of grasses for each centimeter of precipitation received annually. Difference in slopes of the regression lines was significant at the 90% level of probability. Thus, in a year of "average" rainfall, treatment of the light honey mesquite infestation resulted in a 230 kg/ha increase in grass production.

Vegetation Composition

By 1973, the least amount of bare ground (17%) was contacted in the area sprayed and protected from

Table 2. Mean production (kg/ha, oven-dry) of herbage and mulch in August, 1973, after aerial application (0.56 kg/ha) of 2,4,5-T + picloram (1:1) in June, 1969, to semiarid rangeland and subsequent protection from grazing or continuous grazing in the Rolling Plains of Texas.

Treatment	Herbage		
	Grasses[a]	Broadleaves[a]	Mulch[a]
Sprayed, protected	1092 a	199 b	1284 a
Sprayed, grazed	492 c	255 a	875 b
Unsprayed, protected	839 b	134 b	1028 b
Unsprayed, grazed	834 b	248 a	591 c

[a]Means within a column followed by the same letter are not significantly different at the 95% level using t-test as a criterion.

Table 3. **Basal contact (%) of grasses grouped by grazing value and total intercepts by broadleaves on aerially sprayed and unsprayed watersheds supporting light infestations of honey mesquite which were protected from grazing or grazed from June, 1969, to August, 1973, in the Rolling Plains of Texas.**

		Watershed treatments			
		Unsprayed		Sprayed	
Species	Grazing value	Grazed	Protected	Grazed	Protected
Grasses					
Blue grama	Good	1.4	5.2	6.8	7.4
Buffalograss, Hall's panicum, hooded windmillgrass, tall dropseed, Texas wintergrass	Fair	5.6	7.2	10.0	13.6
Burrograss, Japanese brome, sand dropseed, Wright's threeawn	Poor	8.0	4.0	5.9	2.9
Total grasses		15.0	16.4	22.7	23.9
Total broadleaves		0.8	0.2	0.2	0.6

grazing. The greatest amount of bare ground (35%) occurred in the area not sprayed and grazed continuously. Percentage of ground covered by mulch varied from 48 to 59% among the experimental areas with greatest cover in the exclosures.

Four years after spraying, the desirable forage species, blue grama (*Bouteloua gracilis* (Willd ex. H.B.K.) Lag. ex Griffiths) was present in 1973 and not encountered in 1969 were tall dropseed (*Sporobolus asper* (Michx.) Kunth. var. *asper*) and Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.). The latter, a cool season species, occurred only in sprayed areas which were protected from grazing. Two species of poor grazing value, burrograss (*Scleropogon brevifolius* Phil.) and sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray), were also encountered in 1973 but were not present in other years. Wright's threeawn was present in all study areas but in greatest abundance (5.6% basal contacts) and highest vigor in areas unsprayed and grazed continuously for the 4-year study period. It constituted 1% or less of the basal contacts in other study sites.

Four years after spraying, the broadleaved species contacted were in similar proportions as mentioned for the year of spraying, with the addition of silverleaf nightshade (*Solanum elaeagnifolium* Cav.), scurfy side (*Sida lepidota* Gray), prairie spiderwort (*Tradescantia occidentalis* (Britton) Smyth), and Maximilian sunflower (*Helianthus maximiliani* Schrad.). Residues from 0.28 kg/ha of picloram can be expected to persist in soils of the study area for 60 to 90 days after application (Bovey and Scifres, 1972). These residues prevent establishment of many broadleaved species during the season of spraying. Accordingly, the broadleaf population in this study, based on density, was completely restored within the second season following spraying.

These data indicate that reduction in competition from light stands of honey mesquite in semiarid environments such as that of the Rolling Plains can result in increased grass production if rainfall is the long-term average or greater. Since the disturbed stands are usually not composed of plants of great stature and probably do not present a mechanical problem, increased efficiency in managing and handling livestock following spraying would be discounted as a benefit. However, honey mesquite control did result in vegetation more desirable for grazing. Controlling such stands is also necessary for maintenance of initial brush control levels.

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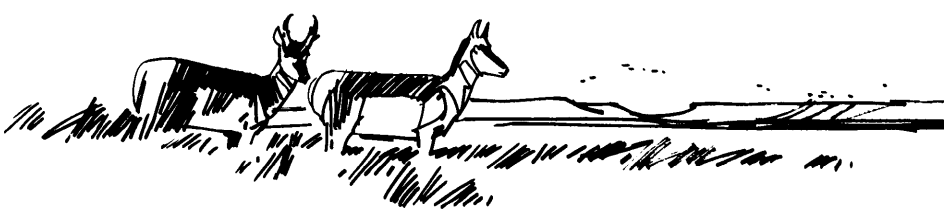

Diurnal Variations of Nonstructural Carbohydrates in the Individual Parts of Switchgrass Shoots at Anthesis

STEVEN B. GREENFIELD AND DALE SMITH

Highlight: *Switchgrass (*Panicum virgatum *L.) was harvested at early anthesis in the field at Madison, Wisconsin, during 1972. Shoots were separated into the inflorescence, individual green leaf blades, green leaf sheaths, and internodes at 6 am, 12 noon, 6 pm, and 12 midnight during 3 days. All tissues were analyzed for percentages (dry wt) of reducing and nonreducing sugars, total sugars, starch, and total nonstructural carbohydrates (TNC). Diurnal trends were clearest in the inflorescence, leaf blades, and the upper sheaths and internodes, but they were not always statistically significant. The trend was an increase of nonreducing sugar, total sugar, and starch percentages from 6 am to 6 pm and then a decrease to 12 midnight. Diurnal change in reducing sugar percentage was small in all plant parts. Basal sheaths and internodes tended to increase in percentage of starch and TNC from 6 am to 12 midnight. These are storage parts, and presumably carbohydrates were being translocated continuously from upper parts to these lower sinks for storage, especially after 6 pm. These data indicate that pasturing in the evening might provide advantages insofar as energy concentration in herbage is concerned. The highest content of energy occurred in the inflorescence of all the individual shoot parts. Diurnal trends of elemental concentrations in the shoot parts also were determined and were found to be largely nonsignificant.*

Diurnal changes in nonstructural carbohydrates in the herbage of grasses have been studied most often for the introduced, cool-season (temperate-origin) species, where fructosan is the principal nonstructural polysaccharide accumulated (Smith, 1973). Few studies have been conducted on the diurnal changes in warm-season (tropical-origin) grasses, where starch is the principal nonstructural polysaccharide, and these were made on annuals. Studies of corn (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench) leaf blades by Miller (1924) in Kansas showed that total sugar percentages began to increase between 4 and 6 am, reached a maximum sometime between noon and 5 pm, and then decreased until daylight the next morning. Variation was due mostly to sucrose, since reducing sugar percentages remained fairly constant. Starch reached maximum percentages later in the day than did total sugars, underwent little change to midnight, and then decreased rapidly until daylight. In contrast, Eisele (1938) in Iowa found that both reducing sugars and sucrose (mg/g, dry wt) increased between 4 am and 4 pm in corn leaf blades, but changes in starch were not significant. Recently, Lechtenberg et al. (1973) found virtually no diurnal change in free glucose or fructose concentrations in sudangrass (*Sorghum sudanense* Stapf.) herbage, but sucrose increased from 1.8% (dry wt), and starch from 6.6%, at 6 am to 5.8 and 8.8%, respectively, at 6 pm. Half the daily increase in carbohydrate disappeared between 6 pm and midnight. Trends in leaves and total herbage were similar. No data was found for warm-season perennial grasses, such as switchgrass (*Panicum virgatum* L.) and other native species.

The current work was initiated to ascertain the diurnal fluctuations of nonstructural carbohydrate fractions in each individual part of switchgrass shoots. Shoots were sampled during 1972 when they were at early anthesis.

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Materials and Methods

The switchgrass used was a clonal line that had been transplanted in rows 45 cm apart with 30 cm between plants in the row. The clone was an ecotype native to a river-bank area near Madison, Wisc. The Miami silt loam at date of tissue collection in 1972 had a pH of 6.6, and contained 112 kg/ha of available P and 304 kg/ha of exchangeable K. Nitrogen, as ammonium nitrate, was applied

Table 1. Temperature (°C) and net radiation at times of tissue sampling during 1972.*

Date	Time of day	Air temperature	Wm^{-2}**	fc**	Climatic description
July 29	6 am	17.0	40	800	20% cloudy all day
	12 noon	25.0	360	10,000	
	6 pm	23.0	40	800	
	12 midnight	20.0	0	0	
July 30	6 am	18.5	36	700	20 to 40% cloudy during
	12 noon	27.0	425	11,800	afternoon
	6 pm	27.5	84	1,600	
	12 midnight	19.0	0	0	
Aug. 9	6 am	9.5	30	540	Cloudy (40%) during late
	12 noon	19.5	416	11,600	afternoon
	6 pm	21.0	45	950	
	12 midnight	14.0	0	0	

*Readings made at 80 cm above soil surface.
Wm^{-2} = Watts/square meter; fc = footcandles.

broadcast in early spring at 138 kg/ha.

Shoots of switchgrass were collected when they began to flower (early anthesis) during three sunny days on July 29, 30, and August 9, 1972. Shoots were collected at 6 am, 12 noon (N), 6 pm, and 12 midnight (MN) of each day. Light intensity and air temperature measurements at the field site were recorded during each sampling time at 80 cm above soil level (Table 1). The days selected for sampling were warm and sunny. Adequate soil moisture prevailed during the period of sampling.

Table 2. Dry weights (mg) of shoot parts and the inflorescence and stem lengths (cm) of switchgrass.

Shoot part[b]		Weight[a]	Length[a]
Inflorescence		640.6	26.3
Internode	1	138.7	20.5
	2	177.4	15.4
	3	168.9	10.1
	4	169.0	7.1
	5	127.5	4.2
	All	781.5	57.3
	LSD[c]	22.1	4.1
Leaf blade	1	95.2	–
	2	140.8	–
	3	133.0	–
	4	110.9	–
	5	81.5	–
	All	561.6	–
	LSD	21.4	–
Leaf sheath	1	91.2	–
	2	108.8	–
	3	97.0	–
	4	71.8	–
	5	51.3	–
	All	420.1	–
	LSD	15.0	–
Total shoot		2403.8	83.6

[a]Statistical analyses based on days as replicates with each day the mean of 4 sampling times.
[b]Numbered from top to bottom of the shoot.
[c]LSD 0.05 among individual internodes, leaf blades, and leaf sheaths.

At each sampling, approximately 35 shoots of switchgrass of uniform height and development were selected. Shoots were severed at soil level and immediately taken to the laboratory.

Each shoot was separated into inflorescence and each individual green leaf blade, green leaf sheath, and internode. Yellow and dead leaf blades and/or sheaths were discarded, but these were mainly the oldest, basal ones. Length of each internode and the inflorescence was recorded. The separated tissues for each sampling time were dried 48 hours at 70° C and weighed. Tissues were then ground to 40-mesh size, bottled, redried for 12 hours at 70° C, and the bottles sealed.

Tissues were analyzed for reducing and total sugars after extraction with 80% ethanol. Nonreducing sugar values were obtained by subtracting reducing sugar values from those for total sugars. The ethanol residues were treated with takadiastase enzyme solution for starch as described by Smith (1969). Total nonstructural carbohydrate values were obtained by addition of the total sugar and starch values. Reducing power for the different fractions was determined by copper reduction-iodine titration, and the results expressed as glucose (70° C).

Elemental analyses were made on the inflorescence, and the first (top), third, and fifth leaf blade, leaf sheath, and internode. Nitrogen (N) was analyzed by Kjeldahl to include both the organic and inorganic forms. The other elements (P, K, Ca, Mg, Cu, Fe, Zn, B, Mn, and Al) were determined by direct-reading emission spectroscopy.

The data were analyzed statistically as a randomized complete block design, using sampling times as treatments and days as replicates. Significant diurnal trends were calculated at the 0.05 level using orthogonal polynomial coefficients.

Results

Shoot Part Weights and Internode Lengths

Average length of the inflorescence was 26.3 cm, while the uppermost internode was the longest internode: 20.5 cm (Table 2). Internodes became progressively shorter down the shoot. The second leaf blade, leaf sheath, and internode (numbered top to bottom) were heaviest among these respective tissues. The inflorescence made up

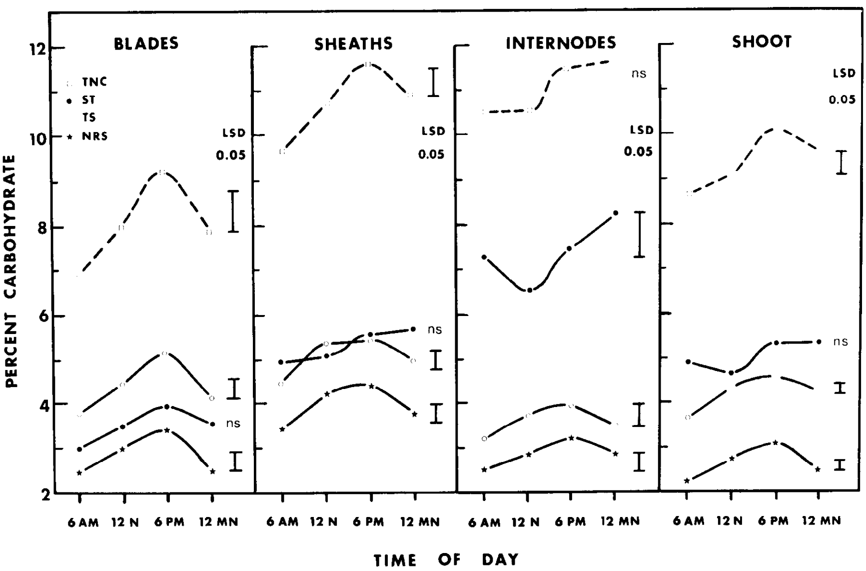

Fig. 1. *Diurnal changes in percentages (dry wt) of nonreducing sugars (NRS), total sugars (TS), starch (ST), and total nonstructural carbohydrates (TNC) in the total leaf blades, leaf sheaths, internodes, and shoot of switchgrass.*

27%, leaf blades 23%, leaf sheaths 17%, and internodes 33% of the total shoot dry weight.

Carbohydrate Concentrations

Concentrations in each individual shoot part are shown in Table 3, and for all leaf blades and sheaths, internodes, and the whole shoot in Figure 1. Diurnal changes in reducing sugar (RS) percentages were very small, and they were not significant (0.05 level) in the inflorescence or leaf sheaths (Table 3), except for the top leaf sheath. Changes in the internodes were significant for internodes 1, 2, and 4, and for the total internodes; increasing from 6 am to 12 noon, plateauing to 6 pm, and then decreasing. The most consistent diurnal changes in RS occurred in the leaf blades. Percentages in all blades, except blade 4, increased significantly from 6 am to 6 pm and then decreased.

Diurnal changes in total sugar (TS) percentages mostly reflected those of nonreducing sugars (NRS). Changes in both sugar fractions were significant at the 0.05 level, except for those of NRS in internodes 2, 3, and 4, and of TS in the inflorescence and internode 2. Percentages increased from 6 am to 6 pm, and then decreased, for all shoot parts, except that percentages were similar in the lower three internodes at 12 noon, 6 pm, and 12 midnight.

Diurnal changes in starch percentage were not significant at the 0.05 level, except for the top leaf blade and leaf sheath and the top and third internode (Table 3), and in the total internodes (Fig. 1). Even so, starch percentages increased from 6 am to 6 pm, and then decreased in the inflorescence, all leaf blades, and the top leaf sheath and internode. The second and third sheaths had similar starch percentages at 6 pm and 12 midnight, but highest percentages in the bottom two sheaths, total sheaths, and all internodes, except the top internode, occurred at 12 midnight.

Diurnal changes in total nonstructural carbohydrates (TNC) were significant at the 0.05 level for all leaf blades and sheaths (Table 3), except for the fourth blade and lower two sheaths. Percentages of TNC increased from 6 am to 6 pm and then decreased to 12 midnight. Diurnal changes in TNC in the inflorescence and internodes were not significant (0.05 level), except for the top internode. Even so, the highest TNC percentages in the inflorescence and top two internodes occurred at 6 pm, but the lower three internodes (Table 3), and total internodes (Fig. 1), were highest at 12 midnight.

Percentages of NRS, TS, and TNC in the total shoot increased from 6 am to 6 pm and then decreased to 12 midnight (Fig. 1). There was no significant diurnal change in starch percentage, but it did reach a high at 6 pm and remained at this level until 12 midnight. No diurnal change in RS percentages was detectable in the total shoot.

Carbohydrate Content

The inflorescence, total leaf blades, total leaf sheaths, total internodes, and total shoot of switchgrass contained the highest content (mg/part) of each carbohydrate fraction at 6 pm. Leaf blade and leaf sheath 3 yielded the

Table 3. Diurnal changes in percentages (dry wt) of nonstructural carbohydrates in the individual shoot parts of switchgrass.*

Time of day	Inflo-rescence	Leaf blades 1	2	3	4	5	Leaf sheaths 1	2	3	4	5	Internodes 1	2	3	4	5
							Reducing sugars									
6 am	2.8	1.2	1.2	1.5	1.4	1.6	0.9	1.0	1.5	1.4	1.5	0.8	0.9	0.9	0.5	0.4
12 noon	2.6	1.4	1.4	1.8	1.6	1.8	1.2	1.2	1.5	1.3	1.5	1.1	1.1	1.0	0.6	0.4
6 pm	2.6	1.4	1.5	1.9	1.7	1.9	1.3	1.2	1.6	1.4	1.5	1.1	1.1	0.9	0.6	0.4
12 midnight	3.0	1.3	1.4	1.8	1.6	1.8	1.1	1.1	1.5	1.2	1.3	0.8	0.7	0.8	0.5	0.4
LSD 0.05	n.s.	0.2	0.1	0.1	n.s.	0.1	0.3	n.s.	n.s.	n.s.	n.s.	0.3	0.2	n.s.	0.1	n.s.
							Nonreducing sugars									
6 am	1.1	2.0	2.3	2.5	2.7	2.6	2.4	3.7	3.6	4.3	3.2	1.4	2.9	3.2	2.8	1.7
12 noon	1.5	2.7	3.0	3.0	3.1	2.9	2.8	4.7	4.6	5.0	3.6	1.9	3.2	3.7	3.1	2.0
6 pm	1.9	3.2	3.5	3.7	3.6	3.3	3.6	4.7	4.8	5.4	4.1	2.0	4.0	3.8	3.3	2.1
12 midnight	1.4	2.3	2.6	2.8	2.6	2.6	2.5	4.1	4.0	4.7	3.8	1.4	3.6	3.8	3.2	2.0
LSD 0.05	0.2	0.3	0.4	0.5	0.6	0.4	0.4	0.7	0.5	0.6	0.5	0.7	n.s.	n.s.	n.s.	0.2
							Total sugars									
6 am	3.9	3.2	3.4	4.1	4.1	4.2	3.3	4.7	5.0	5.6	4.7	2.2	3.8	4.1	3.3	2.0
12 noon	4.0	4.1	4.4	4.8	4.7	4.7	4.1	5.9	6.0	6.3	5.1	3.1	4.3	4.6	3.6	2.4
6 pm	4.5	4.6	5.0	5.6	5.4	5.2	4.9	5.9	6.4	6.8	5.6	3.2	5.1	4.7	3.9	2.5
12 midnight	4.4	3.6	4.0	4.5	4.2	4.4	3.6	5.2	5.5	6.0	5.1	2.2	4.3	4.6	3.6	2.4
LSD 0.05	n.s.	0.4	0.5	0.5	0.4	0.4	0.4	0.9	0.6	0.4	0.4	0.8	n.s.	0.5	0.4	0.2
							Starch									
6 am	3.4	2.8	2.6	3.4	3.3	3.5	4.4	4.8	5.8	5.3	5.1	3.9	4.5	8.0	9.5	9.8
12 noon	3.2	3.2	3.1	4.0	3.5	3.7	4.7	4.8	5.9	5.4	5.3	3.8	4.8	8.0	9.1	8.9
6 pm	3.6	4.4	3.8	4.6	3.2	4.1	5.2	5.5	6.9	5.5	5.4	4.4	4.9	8.7	9.8	10.0
12 midnight	3.3	3.6	3.6	4.1	3.5	3.4	4.9	5.5	6.8	6.0	5.8	3.7	5.3	9.1	11.2	11.4
LSD 0.05	n.s.	0.7	n.s.	n.s.	n.s.	n.s.	0.4	n.s.	n.s.	n.s.	n.s.	0.3	n.s.	0.3	n.s.	n.s.
							TNC									
6 am	7.3	6.0	6.0	7.5	7.4	8.3	7.7	9.5	10.8	10.9	9.8	6.0	8.3	12.1	12.9	12.0
12 noon	7.2	7.3	7.5	8.8	8.2	9.5	8.8	10.7	12.0	11.7	10.4	6.9	9.2	12.4	12.7	11.3
6 pm	8.1	9.1	8.8	10.2	8.6	10.1	10.1	11.4	13.3	12.3	11.1	7.6	10.0	13.4	13.7	12.6
12 midnight	7.7	7.2	7.6	8.6	7.7	9.0	8.6	10.7	12.4	12.0	10.9	5.8	9.6	13.7	14.8	13.7
LSD 0.05	n.s.	0.7	0.6	1.1	n.s.	1.0	0.7	0.8	0.9	n.s.	n.s.	0.7	n.s.	n.s.	n.s.	n.s.

*Numbered top to bottom of shoot.

highest content of each carbohydrate fraction among these respective parts, except that leaf blade and leaf sheath 2 were slightly higher than blade or sheath 3 in content of RS. Internodes 2 and 3 were highest, and similar, in content of RS, NRS, and TS among the internodes. However, internode 4 was highest in content of starch and TNC.

Elemental Concentrations

The inflorescence, and the first (top), third, and fifth leaf blade, leaf sheath, and internode were analyzed for concentrations of N, P, K, Ca, Mg, Cu, Fe, Zn, B, Mn, and Al. Diurnal trends of these elements were statistically nonsignificant (0.05 level), except for N in leaf blade 3, Al in leaf blade and leaf sheath 5, and Ca in internode 1. Concentrations in these significant cases increased from 6 am to 12 noon and then decreased to 12 midnight, but Al in leaf sheath 5 was highest at 6 pm. Diurnal trends of elemental concentrations also were nonsignificant for the most part even when calculated at the 0.10 level of probability.

Discussion

Diurnal trends of nonstructural carbohydrates in the total shoot and total leaf blade tissues of switchgrass were similar to those that have been noted in annual grasses, i.e. corn, sorghum, and sudangrass (Miller, 1924; Eisele, 1938; Lechtenberg, et al., 1973). Percentages of total and nonreducing sugars, starch, and TNC increased from early morning to late in the afternoon and then decreased. Diurnal changes in reducing sugar percentage were small. These data support a conclusion made by Lechtenberg et al. (1973) with sudangrass that pasturing in the evening might provide nutritional advantages, at least from the viewpoint of energy concentration in herbage.

Use of only the total shoot, total leaf blades, total leaf sheaths, or clum masked many of the diurnal changes in carbohydrates that occurred in the parts that make up each of these parameters. Although diurnal changes in reducing sugar percentages were small in all shoot parts, the changes were significant in the total leaf blades and total internodes, while they were not in the total shoot. Even so, diurnal changes in reducing sugar percentages were not significant in leaf blade 4 nor in internodes 3 and 5.

Diurnal changes in total sugar percentages were due primarily to fluctuations in nonreducing sugars (sucrose). With percentage of nonreducing sugars, diurnal changes were not only significant in the total shoot, but also in all of its parts, except in internodes 2, 3, and 4. On the other hand, diurnal changes in starch percentage were not significant in the total shoot, total leaf blades, and total sheaths, but this masked the significant changes that occurred in the top leaf blade and sheath. In contrast, diurnal changes in starch percentage were significant in the total internodes, but were significant only in individual internodes 1 and 3.

Percentages of TNC showed the changes in the sum of the nonstructural carbohydrate fractions (sugars plus starch). Diurnal trends in TNC percentage were significant in the total shoot, but this masked the fact that TNC trends were not significant in the inflorescence or total internodes, nor in each individual internode except the top one. Diurnal changes in TNC were significant in the total leaf blades and sheaths, but not in leaf blade 4 nor in the bottom two leaf sheaths.

This investigation indicated that diurnal changes in sugar percentages were due primarily to changes in nonreducing sugars, as also noted by others (Miller, 1924; Lechtenberg et al., 1973; Smith, 1973), and that significant diurnal changes in nonreducing sugar percentage occurred in all plant parts except in some individual internodes. Percentages increased from 6 am to 6 pm and then decreased to 12 midnight. In contrast, significant diurnal changes in starch percentage, the predominant nonstructural polysaccharide, were limited primarily to the upper leaf blade, leaf sheath, and internode, where the highest level also occurred at 6 pm. Although not statistically significant, the diurnal trend of starch percentage in the lowest sheaths and internodes was for a continuous increase from 6 am to 12 midnight. These bottom parts of the switchgrass shoot are storage organs, so that sugars probably were being translocated continuously from the upper leaves for storage as starch in the bottom leaf sheaths and internodes, especially after 6 pm.

Certain plant parts were analyzed by emission spectroscopy for elemental concentrations and by Kjeldahl for total nitrogen. Diurnal changes in concentrations of these elements for the most part were not statistically significant.

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Nutritive Quality of Nitrogen Fertilized and Unfertilized Blue Grama

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Highlight: *Fertilization with 40 lb of nitrogen per acre generally increased crude protein content of blue grama plants during the growing season but not during the dormant season. However, because of increased dry matter yield under fertilization, total protein on the fertilized area exceeded that on the unfertilized area by 37 lb/acre during the dormant season. Fertilization decreased content of ash, silica and acid detergent fiber and had little effect on ether extract, cell wall constituents, acid detergent lignin, carotene content or in vitro dry matter digestibility or content of individual mineral elements of blue grama. Results indicated very little improvement in nutritive quality of blue grama during early spring stress period when cows are lactating and forage quality and quantity are low.*

Many studies have shown that nitrogen fertilization increases herbage production under conditions throughout the Great Plains where precipitation is sufficient for plants to utilize the added nitrogen. In New Mexico Dwyer (1971) reported that grass production was increased from about 500 lb/acre on the control to over 1200 lb/acre on plots fertilized annually with 60 lb N/acre over a 6-year period.

Nitrogen fertilization may also have additional benefits in improving the nutritional qualities of range forage. Dee and Box (1967) reported that all rates of nitrogen fertilizer, from 33 to 300 lb/acre, increased the protein content of blue grama growing in the Texas panhandle even in the dormant period. With the cost of supplemental feed climbing steadily, an improvement in nutritive content of blue grama could have widespread economic benefit.

The objective of this study was to compare chemical composition of fertilized and unfertilized blue grama collected over a three-year period at four stages of maturity.

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Procedures

Samples of blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) were collected randomly from nitrogen-fertilized (40 lb of urea nitrogen/acre applied in June) and unfertilized native range pastures at the Fort Stanton Cooperative Range Research Station near Capitan, New Mexico. Vegetation consists of open grasslands dominated by blue grama on mesas and pinyon-juniper and wavy leaf oak (*Quercus undulata*) on slopes and ridges. Average annual precipitation is just over 15 inches with about 60% falling from June through September.

Samples were collected by clipping plants approximately 1 inch above ground at four stages of maturity as described by Harris (1970). These stages were late vegetative, which was from beginning of stem elongation to period when heads were just emerging from boot; full bloom to dough; ripe seed; and stem cured, when seeds had been cast. Samples were deposited in air-tight plastic bags, placed in a cooler containing dry ice, and transported to the Animal Nutrition Laboratory at New Mexico State University. One portion of each sample was oven dried at 65°C and ground through a 20-mesh screen in a micro-Wiley mill. The second portion was freeze dried and ground through a 20-mesh screen in a micro-Wiley mill while frozen with liquid nitrogen. This portion was analyzed for carotene, acid detergent lignin, and acid detergent fiber.

Chemical analyses were made using the following procedures: dry matter, ash, ether extract, carotene, and Kjeldahl nitrogen by methods of the A.O.A.C. (1965); cell wall constituents by the method of Van Soest and Wine (1967); silica by the method of A.O.A.C. (1965) with modifications as described by Boggino (1970); acid detergent fiber and lignin by the method of Van Soest (1963); and in vitro dry matter disappearance by the method of Tilley and Terry (1965) with modifications described by Boggino (1970).

Statistical analysis of data included an analysis of variance using a mixed model to determine significance of differences among years, dates, and fertilizer levels as main effects. When a significant difference was found, individual means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1960). All statistical comparisons are at the 5% level of significance unless otherwise stated.

Results

The ash content of unfertilized blue grama was significantly less ($P < 0.01$) than that of fertilized blue grama when averaged across maturity stages, but the stem cured stage was the only individual comparison which showed a significance difference. There appeared to be little seasonal trend in ash content of either fertilized or unfertilized blue grama. The silica content was also significantly lower for fertilized plants compared to unfertilized plants, and was significantly lower at all maturity stages except for the full bloom to dough stages (Table 1).

Fertilization apparently had little influence on ether extract content of blue grama. The content of fertilized plants was 2.3% compared to 2.1% for unfertilized plants averaged over maturity stages.

Fertilization increased the crude protein content of blue grama col-

Table 1. Average chemical composition of fertilized and unfertilized blue grama at four stages of maturity collected over a 3-year period at the Fort Stanton Cooperative Range Research Station, New Mexico.

	Stages of maturity and fertilization treatments									
	Late vegetative		Full bloom to dough		Ripe seed		Stem cured		Mean	
Constituent	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.
Ash (%)	9.6 a[1]	10.4 a	9.8 a	11.0 a	10.9 a	11.5 a	9.6 a	14.1 b	10.0 a	11.8 b
Silica (%)	5.0 a	6.4 b	6.3 a	7.1 a	7.2 a	8.3 b	8.5 a	12.9 b	6.7 a	8.7 b
Ether extract (%)	2.8 a	2.3 a	2.5 a	2.4 a	2.2 a	2.1 a	1.6 a	1.6 a	2.3 a	2.1 a
Crude protein (%)	15.7 a	10.6 b	10.9 a	8.2 b	6.8 a	5.6 a	4.1 a	3.3 a	9.4 a	6.9 b
Cell wall constituents (%)	69.7 a	72.1 a	71.5 a	71.8 a	72.1 a	70.7 a	78.7 a	73.5 a	73.0 a	72.0 a
Acid detergent fiber (%)	36.8 a	39.2 a	39.6 a	41.1 a	43.1 a	48.6 a	49.0 a	51.2 a	42.1 a	44.3 b
Acid detergent lignin (%)	4.9 a	4.7 a	4.9 a	5.1 a	5.9 a	5.6 a	6.7 a	6.6 a	5.6 a	5.5 a
Carotene (Mg/Kg)	163.0 a	140.0 a	141.0 a	121.0 a	23.0 a	19.0 a	5.0 a	2.0 a	83.0 a	70.0 a

[1] Means with same letter are not significantly different ($P < 0.05$) within a maturity stage.

lected during the growing season (late vegetative to dough stage) but not in the ripe seed or stem cured stage (Fig. 1). Crude protein contents declined ($P < 0.01$) with advancing maturity for both fertilized and unfertilized plants as many other studies have shown.

At any stage of maturity there were no significant differences between fertilizer treatments in either content of cell wall constituents, acid detergent lignin or fiber. The fertilized plants contained significantly less acid detergent fiber than unfertilized plants (Table 1). Acid detergent lignin increased in a stepwise fashion with advancing stage of maturity. Cell wall constituents and acid detergent fiber showed no trend during the growing season although they were higher at the stem-cured stage than in earlier stages.

The carotene content of both fertilized and unfertilized blue grama declined sharply with advancing stage of maturity (Table 1). However, there was no significant difference in carotene content between fertilized and unfertilized blue grama.

The differences in dry matter digestibility between fertilized and unfertilized plants at every stage of maturity were not statistically significant (Fig. 1). Dry matter disappearance decreased markedly from the full bloom stage to the stem-cured stage for both fertilized and unfertilized plants.

Nitrogen fertilization did not influence the levels of phosphorus, potassium, magnesium, sodium, manganese, iron, boron, zinc, strontium, barium, or molybdenum (Table 2).

The copper content of nitrogen-fertilized blue grama was greater than that of unfertilized, whereas the calcium and aluminum content of the unfertilized blue grama exceeded that of the fertilized blue grama.

Differences in mineral composition at different stages of maturity were significant only for phosphorus ($P < 0.01$) and potassium ($P < 0.001$). Although there was considerable variation for the other minerals at different stages of maturity none of the differences betwen fertilized and unfertilized plants were significant. For both phosphorus and potassium, highest levels were at the late vegetative stage, thereafter decreasing with advancing maturity. Levels of both minerals were lowest at the ripe seed stage of maturity. The full-bloom to dough and the stem cured stages were intermediate in both cases.

Discussion

From a nutritional standpoint, range fertilization would be most beneficial if increases in protein content were maintained during dormancy since other studies (Thetford et al., 1971) show that cattle diets are adequate in protein content during the

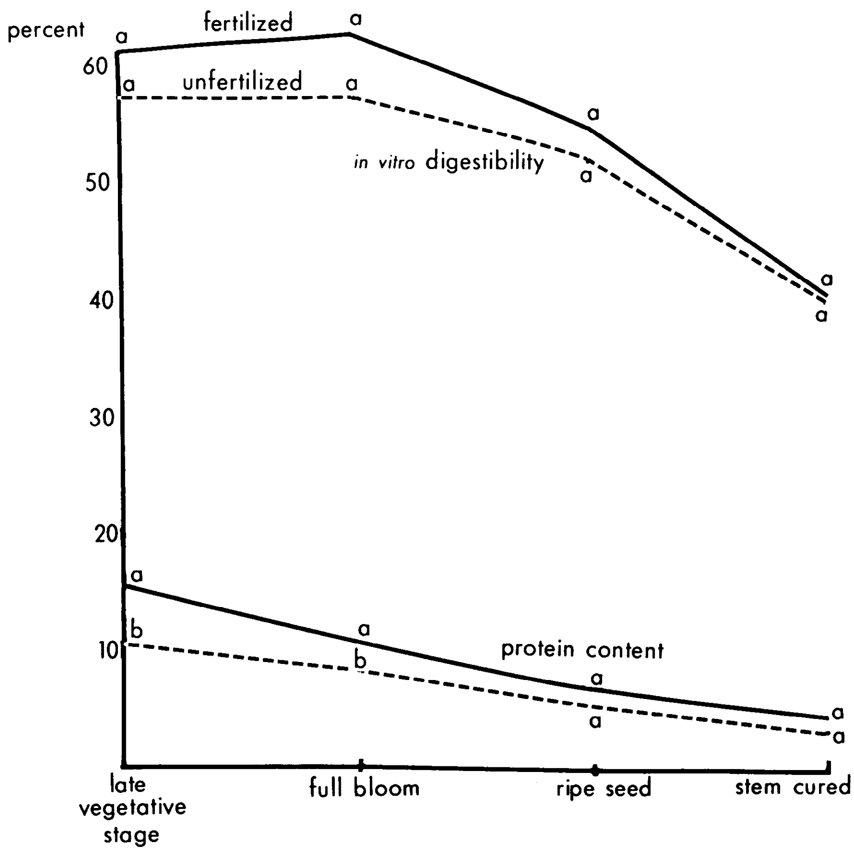

Fig. 1. *In vitro dry matter disappearance and protein content of fertilized and unfertilized blue grama at four stages of maturity. Means with same letter are not significantly (P < 0.05) different within a maturity stage for either protein content or in vitro dry matter disappearance.*

Table 2. Average mineral composition at different stages of maturity for unfertilized blue grama (across years).

Mineral	Late vegetative		Full bloom to dough		Ripe seed		Stem cured		Mean	
	Unfert.	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.	Fert.
Percent of dry matter										
Phosphorus	0.38	0.34	0.31	0.31	0.25	0.26	0.17	0.18	0.28	0.27
Potassium	1.12	1.26	0.78	0.96	0.58	0.69	0.31	0.39	0.70	0.83
Calcium	0.38	0.38	0.40	0.36	0.37	0.39	0.35	0.24	0.38*	0.34
Magnesium	0.14	0.11	0.14	0.16	0.07	0.09	0.12	0.05	0.12	0.10
Sodium	0.015	0.007	0.018	0.028	0.005	0.007	0.010	0.007	0.012	0.012
mg/kg of dry matter										
Manganese	39	39	41	45	45	54	49	44	44	46
Iron	280	202	221	200	241	246	285	159	257	202
Boron	23	21	24	19	26	21	23	14	24	19
Copper	6	8	6	7	6	7	6	7	6	7*
Zinc	22	22	28	27	26	28	21	22	25	24
Aluminum	671	425	550	470	565	495	533	271	580*	415
Strontium	47	49	47	39	39	44	33	33	41	41
Barium	40	24	28	22	30	27	35	26	33	25
Molybdenum	1.37	1.07	1.16	1.31	1.17	1.28	1.59	1.03	1.32	1.18

Stages of maturity and fertilization treatments (column groups: Late vegetative, Full bloom to dough, Ripe seed, Stem cured); Mean.

*Corresponding means for treatment groups are significantly different, $P < 0.05$.

growing season and early part of the dormant season. In much of the Southwest, the period of stress for cattle is spring, when both quantity and quality of forage is low and cows are often nursing calves. Although measurements of protein content were not precise enough in this study to show real differences between fertilized and unfertilized blue grama during dormancy, other studies show a distinctly higher protein content in fertilized blue grama compared to unfertilized plants during the dormant season (Dee and Box 1967; Adi, 1969). Convergence of protein curves for fertilized and unfertilized blue grama (Fig. 1) can be explained partially by the greater contribution of culms on fertilized plants (Banner, 1969; Kelsey et al., 1971; Pieper et al., 1973).

Effects of nitrogen fertilization cannot be evaluated entirely in terms of percentage composition figures. At the time of peak standing crop, over 73 lb of protein/acre were present in fertilized blue grama compared to less than 50 lb/acre for unfertilized blue grama. During the late dormant period, about 50 lb of protein/acre were available in fertilized blue grama compared to only 13 in unfertilized blue grama (Pieper, 1973). These figures reflect production differences as well as differences in protein composition on ungrazed herbage. Other studies have also indicated increased herbage production as well as intake of digestible and metabolizable energy by sheep fed hay from fertilized pastures (Kelsey et al., 1973). Additional studies are needed to determine intake and digestibility of nitrogen fertilized blue grama rangeland under range conditions. In this regard limited data indicated that beef heifers may not lose as much weight during the winter on fertilized rangeland as on unfertilized (Dwyer and Schickedanz, 1971).

The phosphorus and calcium contents of blue grama were sufficient to meet the requirements of dry pregnant or lactating beef cows except for the phosphorus content during the ripe seed stage (N.R.C., 1970). For lactating cows the phosphorus content was slightly deficient and the calcium content was borderline at the ripe seed stage. This would indicate the need for phosphorus and calcium mineral supplement after blue grama has reached maturity if the content in the grazing animal's diet approximates these amounts.

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Influence of Nitrogen on Irrigated Buffalograss Yield and Protein Content

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Highlight: *Buffalograss (*Buchloe dactyloides*), a shortgrass dominant in many plant communities throughout the Great Plains, was irrigated and fertilized with four rates of ammonium nitrate. Yield and crude protein were determined on six dates throughout the growing season. The highest nitrogen level (120 kg/ha) increased dry matter yield 130% while 30 kg/ha of nitrogen only increased yield 23% over the control. Peak crude protein concentration (16.71%) of herbage from the 120 kg of N/ha treatment was observed on July 8, while maximum crude protein (9.26%) in nonfertilized herbage was found a month earlier. In all fertilized treatments, peak protein yield preceded peak herbage yields by at least 1 month. Loss of proteins from herbage was greater in those plots receiving the higher rates of nitrogen than on those plots receiving lower nitrogen applications. It is important that grassland managers be aware of the "quality vs quantity" interaction when making management decisions. Based on results from this study, we can not recommend fertilization and irrigation of buffalograss range.*

Many studies have reported the effects of fertilization on native forages. Usual objectives of these studies were to increase herbage yields or forage quality. Increased forage production, resulting from fertilization, may be due to a change in species composition which, in some cases, is toward more desirable species (Rumburg and Cooper, 1961) or in some cases to less desirable forage species (Johnston et al., 1967).

Burzlaff et al. (1968) reported that application of commercial fertilizer, especially nitrogen, increased yields of the dominant forage species. In addition to increased productivity and change in species composition, nitrogen and phosphorus fertilization also increased the crude protein content of native forages (Dee and Box, 1967). Rodgers and Box (1967) asserted that native grasses in the southern High Plains of Texas seldom contained adequate protein in the winter to sustain livestock production.

Dudley (1953) reported that when a nonirrigated buffalograss monoculture was fertilized with 30 and 60 lb of nitrogen per acre, yields ranged from 806 lb/acre of forage in the control plot to over 1,600 lb/acre of forage where 60 lb of N had been added.

Near Amarillo, Texas, ammonium nitrate was applied to a native bluegrama range at rates up to 800 lb of N/acre. Irrigation water was applied to facilitate maximum herbage response. In this study, Lehman et al. (1968) found that blue grama could produce at least 7,500 lb/acre/year of oven-dry forage. They maintained, however, that this species was a relatively inefficient user of water when compared to improved forages.

In an earlier study we found that irrigation and nitrogen fertilization were detrimental to carbohydrate reserve concentrations in root and crown tissues of buffalograss. These results showed that photosynthate was used to facilitate increased yields and stolon and seed development at the expense of the root and crown system. This study, then, reports on the productivity and crude protein content of buffalograss herbage as affected by differing nitrogen applications under irrigation treatments.

The reader should be aware that water for irrigation in this part of Texas is becoming a limiting resource. The authors in no way imply that rangeland fertilization and irrigation are economically feasible at this time. Current costs of fertilizer and the uncertainty of livestock prices make cultural practices seem impractical on this type of range. However, when more favorable price structures are a reality, data from research are needed to help land managers make good decisions.

Methods and Procedures

This study was conducted at the Texas Tech University Center located 24 km northeast of Amarillo, Texas. Plots were on a fair condition, deep hardland range site with buffalograss predominating.

The soil of the study area is a Pullman silty clay loam, which is the soil type of about 4/5 of Carson County and 4.8 million hectares in northwest Texas (Coover et al., 1953). Infiltration and water percolation rates are slow.

In early April, 1971, pelleted ammonium nitrate was broadcast with a "whirlwind" spreader at rates of 0, 30, 60, 90, and 120 kg/ha of N onto a 10 m^2 plots. Plots were in a completely random grid with three replications of each treatment.

The 1971 rainfall was periodically supplemented with sprinkler irrigation to facilitate a maximum herbage response. Throughout this study 70 cm of water were received on all plots.

On June 10, July 8, August 11, September 18, October 19, and November 27, herbage yields were taken at ground level from two, 0.1 m^2 plots in each replication. Samples were dried in a forced air oven at 70°C for 24 hours prior to weighing. They were then ground in a Wiley Mill to pass through a 40-mesh screen and stored in air-tight containers.

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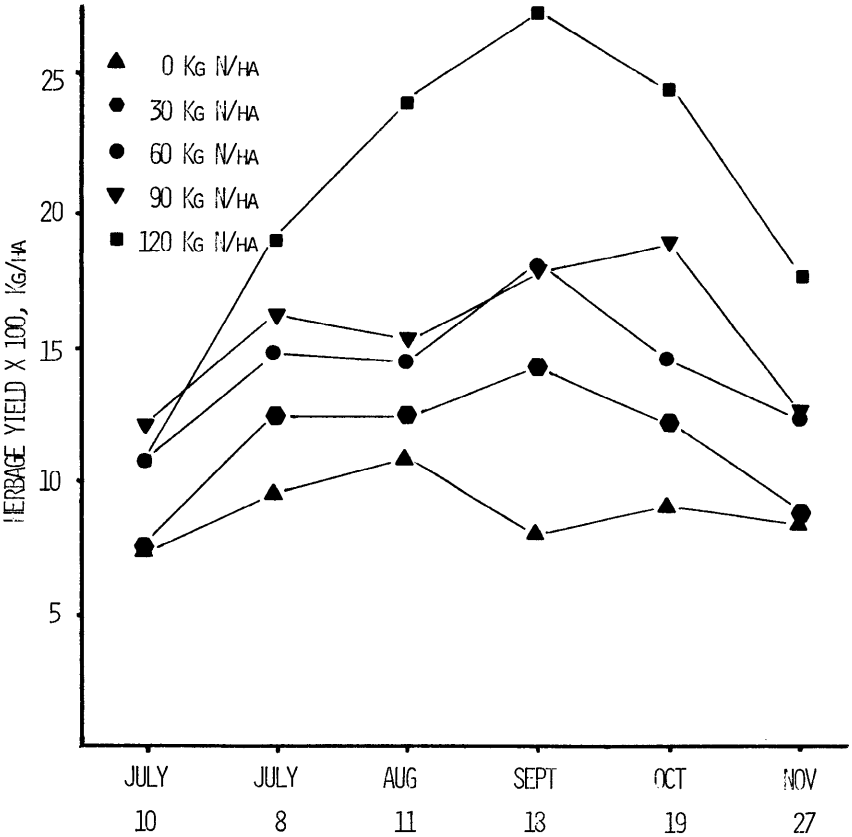

Fig. 1. *Herbage yield of nitrogen treated and irrigated buffalograss on a deep hardland range site in the Texas High Plains near Amarillo, Texas.*

Nitrogen determinations for crude protein were obtained by the automatic Dumas Combustion method using a Coleman Model 29 A Nitrogen Analyzer. This method of N determination yields results comparable to the more conventional Kjeldahl Method (Morris et al., 1969).

Data were analyzed as a split-plot factorial with sampling dates as whole units and fertilizer rates as the subunit in this analysis. Duncan's multiple range test was used to compare all means. Level of precision used was 0.05.

Results

Herbage Production

Nitrogen fertilization increased yields at all application rates and on nearly all sampling dates (Fig. 1). The highest N level–120 kg of N/ha–increased dry matter yield 130% over the control, while the lowest N rate–30 kg of N/ha–increased yields 23%. There was no difference in average yields for the August and October sampling dates, while yields on all other dates were different from each other. Peak standing crop in the 120 kg of N/ha treatment–2,787 kg/ha–was obtained on September 18. Peak standing crop on the nonfertilized plots, however, was obtained 5 weeks earlier.

Herbage Protein Concentration

The crude protein concentration within the herbage increased with each increase in N rate (Table 1). When considering the seasonal averaged protein concentration, no difference was found between the 30 and 60 kg of N/ha treatments. All other N rates produced herbage with higher protein levels. Similarly, all fertilized buffalograss herbage contained more protein than did the control treatment. No difference was found in herbage protein on the June and July sampling dates, while protein levels in herbage collected on all other dates were significantly different.

Peak crude protein concentration–16.71%–of herbage from the 120 kg of N/ha treatment was observed on July 8; maximum crude protein in the nonfertilized herbage–9.26%–was a month earlier. Protein levels of herbage from all treatments declined after July 8.

Fertilization, under optimum soil moisture conditions, dramatically increased the herbage protein yield on this site (Fig. 2). The 120, 90, 60, and 30 kg of N/ha rates produced 263, 134, 80, and 46% more protein, respectively, than did the control.

Discussion

Results from this study demonstrate that the quantity and quality of buffalograss herbage can be increased with N and water applications. Efficiency of dry matter production was also increased with N additions. However, maximum herbage yields were not obtained with our rates of application as evidenced by luxuriant growth on the borders of plots where fertilizer had spilled in the weighing process.

The loss of herbage protein from August 11 to September 18 was of major concern. It is generally assumed that maturing short grass species do not lose proteins as readily as taller grasses. Our data show that nearly 100% decrease in nitrogen concentration occurred in this time period when 90 or more kg of N/ha were applied. In the control and 30 kg of N/ha treatments, only 17% of the protein was lost in this same period. This differential loss of nitrogen from the herbage poses an important

Table 1. Average crude protein concentration (%) of irrigated and fertilized buffalograss herbage sampled throughout the growing season near Amarillo, Texas.

Nitrogen application rate[1]	Crude protein						
	June 10	July 8	Aug. 11	Sept. 18	Oct. 19	Nov. 27	Avg
0	9.26	8.47	7.98	6.64	4.84	2.68	6.65 a
30	11.83	11.88	8.13	6.57	5.53	2.66	7.77 b
60	12.33	11.62	8.31	5.72	5.51	2.80	7.78 b
90	12.08	13.62	12.80	6.57	5.97	3.24	9.05 c
120	13.25	16.71	15.30	7.68	6.26	4.56	10.63 d
Avg	11.75 a[2]	12.46 a	10.50 b	6.71 c	5.62 d	3.19 e	

[1] Fertilizer applied as NH_4NO_3, April, 1971.
[2] Protein concentrations in rows or columns followed by same letter are not different at the 0.05 level of significance.

question—why? Perhaps the most tenable answer is that this area received about 15 cm of rainfall between August and September 18. Until this date most water was artificially applied by irrigation. Phenologically the plants had progressed from the early to hard seed stage of development with little change in leaf tissue coloration. It seems logical, then, that substantial portions of the nitrogen passed into the atmosphere or into the soil. The Lehman et al. (1968) study with irrigated and fertilized blue grama on the same soil series disregarded soil N accumulation or leaching losses.

Other avenues of N losses are as gases into the atmosphere, accumulation of N in root material, and other chemical reactions. Wullstein and Gilmour (1964) warned that interpretations regarding soil N losses are incompletely understood. They further asserted that gas analysis was needed in nitrogen balance studies.

To support the hypothesis that gaseous loss of N was high in this study, unpublished data of microbial populations on a site near our study area showed the soil fauna to dramatically increase after the heavy, late summer precipitation. In addition, we have found blue grama-buffalograss litter decomposition rates to exceed net photosynthesis for this time period. Thus, denitrification and the gaseous loss of N as molecular nitrogen (N_2), nitrous oxide (N_2O) or nitric oxide (NO) are assumed to be major contributors to low N recovery rates in grassland ecosystems. Further testing of this hypothesis is needed.

In the control (0 N), peak protein and herbage yield occurred on the same date whereas all fertilizer

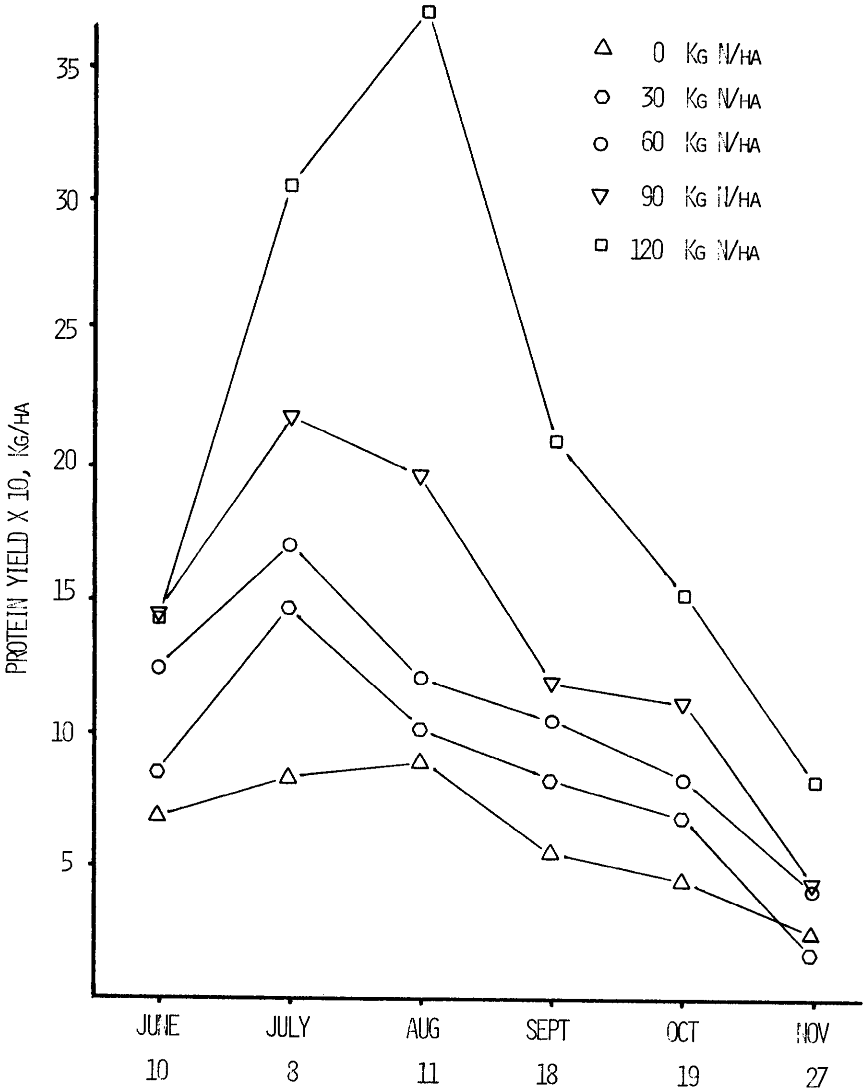

Fig. 2. *Total crude protein yield of irrigated and nitrogen treated buffalograss harvested from a deep hardland range site near Amarillo, Texas.*

treatments showed maximum protein yield occurring at least 1 month earlier than maximum herbage yield. Whitehead (1970), in England, similarly reported the rate of N uptake by grasses to be greatest in the vegetative state. Further, he stated that N yield in the herbage reached a peak just before ear emergence. Our data revealed that peak protein yield of buffalograss fertilized with 30, 60, and 90 kg of N/ha corresponded to the male flowering stage of development. In the nonfertilized and 120 kg of N/ha treatment, peak protein yield was obtained 1 month later or at the early seed stage of development. Reasons for this lag are not known.

Table 2. Total available carbohydrate concentration (mg/g) of irrigated buffalograss reserve tissues[1] sampled on six dates in 1971.

Nitrogen application rate[2]	Sampling date						
	June 16	July 16	Aug. 18	Sept. 17	Oct. 19	Nov. 27	Avg
0	101[3]	165	113	111	118	132	120 ab[4]
30	85	151	102	110	118	132	113 acd
60	84	131	93	99	118	137	106 cd
90	81	132	80	102	132	129	106 d
120	79	104	71	95	130	138	99 e
Avg	86 ab	136 cd	91 ab	103 e	123 f	133 cd	

[1] Reserve tissues include living crown and root tissue to a depth of 10 cm.
[2] Kg/ha of actual nitrogen applied in April, 1971.
[3] Averaged total available carbohydrate concentration expressed as mg/g of dry plant tissue.
[4] Means in any column or row not sharing a common letter are significantly different ($P < 0.05$) from all others.

Management Implications

Range managers traditionally have assumed that a moderate grazing intensity is necessary to sustain both plant and animal vigor. Maximum livestock profits/ha are usually lower at this intensity than when heavy grazing is used. Our data (Figs. 1 and

2) show that grassland managers can not generally obtain maximum protein and herbage yields simultaneously on fertilized and irrigated buffalograss range.

If Fig. 2 was superimposed on Fig. 1, we would see that all fertilizer treatment herbage and protein yield curves intersect. It is apparent that where these curves intersect, we have optimized the quantity vs quality of forage concept. Unfortunately, buffalograss was approaching the hard seed stage of development which corresponded to low carbohydrate reserves (Table 2). When over 30 kg of N/ha was added, reserve carbohydrates decreased an average of 33% from the early seed to hard seed growth stage. The concept of optimizing the quantity vs quality of forage can not be achieved without possibly damaging the plant by harvesting at this time. To solve this dilemma, and if maintenance of plant vigor as measured by these reserves is considered important, we believe it is necessary to either delay the harvest until herbage is mature—mid October—or harvest the herbage in mid July at the late anthesis-early seed stage of development.

The ultimate question, then, must be asked. Can we justify fertilizing irrigated or dryland buffalograss range? First, our observations of fertilized but nonirrigated buffalograss show little herbage production response. Similarly, nonfertilized and irrigated buffalograss yields are not substantially increased. Second, if irrigation and fertilizers are available, more productive forages are available to the ranchman. Third, in this part of the state, cool season perennial forages are needed to complement the native-warm season blue grama-buffalograss ranges. In view of this, we can not recommend the treatments used in this research on those sites dominated by buffalograss. Perhaps on other soils or in other locations, these treatments might be feasible.

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Infiltration Rates and Sediment Production of Selected Plant Communities in Nevada

W. H. BLACKBURN AND C. M. SKAU

Highlight: *Infiltration rates and sediment production of 29 plant communities and soils on five rangeland watersheds were studied in central and eastern Nevada. Three inches per hour of simulated rainfall was applied to soil initially dry and to soil initially at field capacity. Infiltration rates and sediment production for the various plant communities and soils varied considerably within and between watersheds. Highest infiltration rates and lowest sediment production occurred on sites with well-aggregated surface soils free of vesicular porosity.*

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Effective management of rangeland watersheds in the Great Basin depends largely on the plant cover and infiltration rates of associated soils to control sediment production and peak floods from intense summer thundershowers. Few studies are available for the Great Basin (Jager, 1972; Gifford and Coltharp, 1972; Gifford et al., 1970; Gifford and Tew, 1969; Gifford and Skau, 1967; Woodward, 1943). Related studies stress the importance of plant cover type in other western regions (Branson et al., 1970 and 1965; Brown, 1965; Box, 1961; Rowe and Reimann, 1961; Rauzi and Zingg, 1956).

This study reports results of infiltration and sediment production for a broad range of plant communities occurring in Nevada.

Methods

Twenty-eight study sites were selected within the watersheds (Table 1). Nine sites were located within the Duckwater Watershed, six within the Coils Creek Watershed, six within the Steptoe Watershed, and seven within the Pine and Mathews Canyon Watersheds. Study sites were selected for their accessibility, repetition over large areas in the Great Basin, and vegetation and soil properties. Each site was located on a typical area with a different plant community and/or soil.

A water application rate of 3 inches per hour for a duration of ½ hour was applied to two antecedent moisture conditions: soil surface horizon initially air dry and soil surface horizon initially at field capacity. There were six replications for each treatment, except for some sites at Duckwater where eight were used. For all variable plots, six replications were used for dune interspace and six for coppice dunes.

Data were subjected to analysis of variance to compare infiltration rates and sediment production by treatment for each watershed.

In the Great Basin, summer thunderstorms usually occur on dry

Table 1. Study sites description.

Watershed	Location	Elevation	Climate	Geology and soils	Dominant vegetation
Duckwater	30 airline miles south and east of Eureka, mostly in White Pine County, Nevada. Site: 100 square miles Blackburn et al. (1968)	Highest peak is around 7,300 ft and the basin outlet is 4,800 ft	Annual precipitation 7.8 to 13.7 inches, mostly as snow. Temperature at the lower elevations ranges from a low of −34°F to a high of 99°F with a mean annual temperature of 43°F	Volcanics and sedimentaries, i.e., tuff, basalt, andesites and limestone. Aridisols, and Entisols, i.e., Torrifluvents, Durorthids, Haplargids, Durargids and Natragids	Black sagebrush (*Artemisia nova*) Big sagebrush (*Artemisia tridentata*) Shadscale (*Atriplex confertifolia*) Winterfat (*Eurota lanata*) Green rabbitbrush (*Chrysothamnus viscidiflorus*) Utah juniper (*Juniperus osteosperma*) Singleleaf pinyon (*Pinus monophylla*)
Coils Creek	32 airline miles northwest of Eureka in Eureka County, Nevada. Site: 48 square miles Blackburn et al. (1969a)	Highest peak is around 8,400 ft and the basin outlet is 6,500 ft	Annual precipitation 8.8 to 14.8 inches, mostly as snow. Temperature ranges from a low of −26°F to a high of 110°F with a mean annual temperature of 47°F	Volcanics and sedimentaries, i.e., basalt, shale, sandstone and limestone. Entisols and Aridisols or Mollisols, i.e., Torriorthents, Camborthids, Haplustolls, Haploxerolls, Durixerolls, and Argixerolls	Low sagebrush (*Artemisia arbuscula*) Big sagebrush Snowberry (*Symphori carpos longiflorus*) Utah juniper Singleleaf pinyon Sandberg bluegrass (*Poa secunda*) Bluebunch wheatgrass (*Agropyron spicatum*) Woolly wyethia (*Wyethia mollis*) Squirreltail (*Sitanion hystrix*) Arrowleaf balsamroot (*Balsamorhiza sagittata*) Diffused phlox (*Phlox diffusa*)
Steptoe	24 airline miles southeast of Ely in White Pine County, Nevada. Site: 45 square miles Heinze et al. (1966)	Highest peak is around 9,081 ft and the basin outlet is 7,100 ft	Annual precipitation is 12 inches, mostly as snow. Temperature ranges from a low of −26°F to a high of 97°F with a mean annual temperature of 44°F	Limestone. Aridisols or Mollisols, i.e., Camborthids, Haplargids, Durargids, and Argixerolls	Big sagebrush Bitterbrush (*Purshia tridentata*) Utah juniper Singleleaf pinyon Bluebunch wheatgrass Crested wheatgrass (*Agropyron desertorum*)
Pine and Mathews Canyon	18 airline miles southeast of Caliente in Lincoln County, Nevada. Site: 66 square miles Blackburn et al. (1969b)	Highest peak is around 6,700 ft and the basin outlets are approximately 5,600 ft	Annual precipitation 11.9 to 21.8 inches mostly as snow during winter or rain in late summer. Temperature of the basins range from a low of 0°F to a high of 101°F with a mean annual temperature of 50°F	Volcanics and old lake bed sediments, i.e., andesite, tuff, ignibrite, tuffaceous clay, sand and silt. Aridisols or Mollisols with a few Entisols, i.e., Torriorthents, Durargids, Haplargids, Argixerolls, and Haploxerolls	Big sagebrush Black sagebrush Rubber rabbitbrush (*Chrysothamnus nauseosus*) Serviceberry (*Amelanchier alnifolia*) Utah juniper Singleleaf pinyon Intermediate wheatgrass (*Agropyron intermedium*) Squirreltail

soil, although some occur on soil that is at or near field capacity. A 3-inch per hour storm was used to simulate the exceptional thunderstorm and to assure that maximum site infiltration rate was exceeded, under both moisture conditions.

The infiltrometer and methods of application are described by Blackburn et al. (1974).

Basically, infiltration was defined for any point in time as the difference between total water applied and total runoff. Two types of runoff plots were used: 3 by 3-foot and variable. Regular plots were situated so the same mean percent coppice dune that occurred on the site also occurred in the plot. Coppice dune is the area of accumulation of litter and soil under shrubs and bunch grasses. Variable plots were located to contain approximately 100% dune interspace area or coppice dune area. Variable plots were used only on sites that demonstrated obvious dune interspace and coppice dune differences.

Sediment production was determined from a 900-ml runoff sample and other sediment trapped in the collection apparatus. Suspended sediment was allowed to settle in the laboratory and the water was drained off. Samples were then oven dried, weighed, and converted to sediment in tons per acre.

Results

Highest infiltration rates and lowest sediment production were observed in the Steptoe Watershed. Conversely, the lowest infiltration rate and highest sediment production were found in the Duckwater Watershed. Infiltration rates were lower and sediment production higher when the soil was initially at field capacity. Highest infiltration rates and lowest sediment production occurred in the coppice dunes; the opposite was true for the dune interspace areas regardless of plant community or soil (Table 2). Throughout the study, $P = 0.05$ was accepted as significant.

Infiltration

Duckwater Watershed.

Infiltration rates were significantly higher ($P = 0.05$) for the singleleaf pinyon/Utah juniper and black sagebrush communities than for all other communities except black sagebrush and big sagebrush/green rabbitbrush. Conversely, the lowest infiltration rates were in the winterfat community. Infiltration rates in the winterfat community were significantly lower than those in all other communities except shadscale.

Coils Creek Watershed.

The snowberry/big sagebrush/bluebunch wheatgrass/woolly wyethia community had the highest infiltration rate, and it was significantly higher than those of all other units except big sagebrush/bluebunch wheatgrass/arrowleaf balsamroot community. Lowest infiltration rates occurred in the low sagebrush/Sandberg bluegrass/squirreltail community.

Steptoe Watershed.

Singleleaf pinyon/Utah juniper community consistently had the lowest infiltration rates, and this rate was significantly lower than all other communities except crested wheatgrass (seeded big sagebrush/bluebunch wheatgrass site), initially dry. Infiltration rates for communities plowed and seeded to crested wheatgrass were not

Table 2. Mean infiltration rate (inches/hr) and sediment production (tons/acre) for the plant communities in each watershed.[a]

Watershed and plant community	Infiltration rate: Dry[b]	Infiltration rate: Field capacity[b]	Sediment production: Dry[b]	Sediment production: Field capacity[b]
Duckwater				
Singleleaf pinyon/Utah juniper	2.85[a]	2.79	0.003	0.003
Black sagebrush	2.70[ab]	2.05[a]	0.140[bc]	0.266[ab]
Big sagebrush/green rabbitbrush	2.40[bc]	1.52[ab]	0.642[a]	0.666[a]
Big sagebrush	2.16[cd]	1.42[b]	0.262[abc]	0.359[a]
Black sagebrush/shadscale	2.10[cd]	1.49[b]	0.386[abc]	0.508[a]
Shadscale/winterfat	1.98[cd]	1.58[b]	0.235[abc]	0.243[ab]
Utah juniper	1.97[de]	1.71[b]	0.122[c]	0.071[b]
Shadscale	1.75[e]	1.26[bc]	0.594[ab]	0.673[a]
Winterfat	1.38	0.87[c]	0.552[ab]	0.522[a]
Coils Creek				
Snowberry/big sagebrush/bluebunch wheatgrass/woolly wyethia	2.68[a]	2.39[a]	0.22[c]	0.32
Big sagebrush/bluebunch wheatgrass/arrowleaf balsamroot	2.60[ab]	2.36[a]	0.25[bc]	0.37[c]
Singleleaf pinyon/Utah juniper/low sagebrush/Sandberg bluegrass	2.42[b]	1.87[b]	0.42[abc]	0.62[bc]
Low sagebrush/Sandberg bluegrass	2.40[b]	1.82[b]	0.63[a]	1.25[a]
Big sagebrush/Sandberg bluegrass/diffused phlox	2.39[b]	1.73[b]	0.38[bc]	0.87[ab]
Low sagebrush/Sandberg bluegrass / squirreltail	1.97	1.62[b]	0.48[ab]	0.58[bc]
Steptoe				
Big sagebrush/bluebunch wheatgrass	2.87[a]	2.41[a]	0.14[a]	0.13[abc]
Crested wheatgrass (seeded big sagebrush/bluebunch wheatgrass site)	2.82[a]	2.47[a]	0.07[ab]	0.21[abc]
Big sagebrush/bitterbrush/bluebunch wheatgrass	2.82[a]	2.35[a]	0.08[ab]	0.36[ab]
Big sagebrush	2.78[a]	2.69[a]	0.01[b]	0.07[c]
Crested wheatgrass (seeded big sagebrush site)	2.69[ab]	2.23[a]	0.04[ab]	0.09[bc]
Singleleaf pinyon/Utah juniper	2.55[b]	1.79	0.20[a]	0.52[a]
Pine and Mathews Canyon				
Black sagebrush/intermediate wheatgrass	2.84[a]	2.31[a]	0.04[a]	0.23[a]
Utah juniper	2.54[ab]	1.97[ab]	0.05[a]	0.16[ab]
Big sagebrush/crested wheatgrass	2.50[ab]	2.05[a]	0.22[a]	0.35[a]
Utah juniper/crested wheatgrass	2.46[ab]	2.38[a]	0.06[a]	0.02[c]
Singleleaf pinyon/Utah juniper/black sagebrush/serviceberry	2.41[ab]	2.14[a]	0.38[a]	0.54[a]
Utah juniper/big sagebrush/squirreltail	2.21[b]	1.95[ab]	0.04[a]	0.03[bc]
Big sagebrush/rubber rabbitbrush	2.09[b]	1.29[b]	0.40[a]	0.45[a]

[a]Means followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple range test. All comparisons are made within column and within watershed.

[b]Antecedent moisture condition.

significantly different from rates of their undisturbed counterparts.

Pine and Mathews Canyon Watersheds.

Black sagebrush/intermediate wheatgrass and Utah juniper/crested wheatgrass communities exhibited the highest infiltration rates. Big sagebrush/rubber rabbitbrush communities had the lowest infiltration rate, and this rate was significantly lower than for black sagebrush/ intermediate wheatgrass, Utah juniper/ crested wheatgrass, singleleaf pinyon/ Utah juniper/black sagebrush/ serviceberry and its railed and seeded counterpart (big sagebrush/crested wheatgrass), field capacity.

Sediment Production

Duckwater Watershed.

Largest quantities of sediment came from the big sagebrush/green rabbitbrush, shadscale, and winterfat communities and the smallest quantities from Utah juniper and singleleaf pinyon/Utah juniper communities. Sediment production from the singleleaf pinyon/Utah juniper community was significantly smaller than for other communities sampled.

Coils Creek Watershed.

Largest quantities of sediment were produced from the low sagebrush/ Sandberg bluegrass and low sagebrush/ Sandberg bluegrass/squirreltail communities. Smallest quantities of sediment came from big sagebrush/bluebunch wheatgrass/arrowleaf balsamroot and snowberry/big sagebrush/bluebunch wheatgrass/woolly wyethia community. Sediment production was significantly smaller than for low sagebrush/Sandberg bluegrass and low sagebrush/Sandberg bluegrass/squirreltail communities, soil initially dry.

Steptoe Watershed.

Singleleaf pinyon/Utah juniper community consistently produced more sediment than other sampled communities. Least sediment came from big sagebrush and crested wheatgrass (seeded big sagebrush site) communities. Communities that had been plowed and seeded to crested wheatgrss showed no significant difference nor trend in sediment production from their unseeded counterparts.

Pine and Mathews Canyon Watersheds.

Big sagebrush/rubber rabbitbrush and singleleaf pinyon/Utah juniper/ black sagebrush/serviceberry communities produced the largest quantities of sediment. Lowest sediment production communities were Utah juniper/crested wheatgrass, black sagebrush/intermediate wheatgrass, and Utah juniper/big sagebrush/ squirreltail. Communities railed and seeded or chained and seeded (big sagebrush/crested wheatgrass, black sagebrush/intermediate wheatgrass and Utah juniper/crested wheatgrass) showed no significant difference in sediment production from their unseeded counterparts (big sagebrush/ rubber rabbitbrush, singleleaf pinyon/ Utah juniper/black sagebrush/ serviceberry, and Utah juniper/ squirreltail). However, the trend was for larger quantities of sediment from untreated sites.

Discussion

Substantially higher infiltration rates and sediment production were observed on coppice dunes than on dune interspace areas. Thus, the extent and morphology of the dune interspace surface soil essentially control infiltration rates of the various soils. Dune interspace areas with a vesicular surface horizon have a lower percent carbon, a higher pH, a higher bulk density, a higher percent silt, and shallower surface horizon than the coppice dunes. Structure in the dune interspace areas is massive or platy as compared to granular in coppice dunes. Infiltration rates are negatively related to vesicular horizons. The strength of this relationship is dependent on vesicular horizon morphology (Blackburn, 1973). These surficial vesicular horizons develop in arid and semiarid areas of sparse vegetation cover (Volk and Gyeger, 1970) and tend to increase with the removal of herbaceous vegetation in the interspace area by overgrazing. More specifically, soils involved in vesicular development are classified as Aridisols, Torrifluvents, or Torriorthents. These vesicular horizons are very unstable when nearly saturated (Miller, 1971), which accounts for the absence of vesicular porosity in the better aggregated coppice dunes and dune interspace soils. This unstableness also accounts for the larger sediment production from dune interspace areas and from soils that are initially at field capacity. The surface soil reaches saturation quicker on soils initially at field capacity, thus the time required to erode dispersed soil particles in longer.

Infiltration rates and sediment production for the various plant communities and soils varied considerably within and between watersheds. Soils in the Steptoe Watershed generally had the highest infiltration rates and lowest sediment production. The Duckwater Watershed soils generally exhibited the lowest infiltration rates and hightest sediment production. However, the variation was high among plant communities; for example, in the Duckwater Watershed the singleleaf pinyon/Utah juniper community had the hightest infiltration rate and the winterfat community the lowest rate of all sites studied.

The two plant communities in Steptoe Watershed that were plowed and drilled to crested wheatgrass showed no significant ($P = 0.05$) difference nor apparent trend in infiltration rates or sediment production as compared with their untreated counterparts. Three plant communities, however, at Pine and Mathews Canyon Watersheds that were railed and seeded or chained and seeded showed a trend of higher infiltration rates and lower sediment production for treated sites as compared to untreated counterparts. Of the three treated communities only the older treatment that had been railed and seeded in 1954 showed a significantly higher infiltration rate than its untreated counterpart. These results indicate that time is required for a vegetation conversion treatment to significantly affect infiltration rates. If dune interspace soil surface is well aggregated and free of a vesicular horizon before treatment, a significantly larger infiltration rate or significantly lower sediment production for the treated site may never be realized.

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An Analysis of Range Conservation Academic Training

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Highlight: *A survey of range professionals employed by federal agencies was found to be an effective means for determining educational needs of range managers. Eighteen western universities produce essentially all Range Conservationists employed by federal agencies and two of these universities combined produce more than one-third of these professionals. Only 57.5% of the Range Conservationists in 1969 had BS degrees in range science, while 42.5% received sufficient course credits in range to qualify them for Civil Service appointments. Most Range Conservationists believed that ecology was the most important basic subject matter, while range management courses were most important for training as Range Conservationists. Respondents indicated that experience was helpful but not as essential as proper academic training.*

In 1969, 1,605 questionnaires[1] were sent to range conservation employees who were currently employed by the Forest Service (FS), the Bureau of Land Management (BLM), or the Soil Conservation Service (SCS). The survey was taken from employees qualified by these agencies under the Range Conservationists or Range Examiner Civil Service Series. These employees qualified for range positions by either receiving a BS degree in range science or range management, or by having the minimum course credits in range. This minimum number of credits has varied from as low as 6 semester credits to as much as 12 semester credits during the past few years.

The present Civil Service Occupational Series under which these range conservationists have served include: 401–General Biological Series (Ecologist); 454–Range Conservationist; 457–Soil Scientist; 460–Professional Forester; and 486–Professional Wildlife Biologist.

The results of this survey should be useful to university personnel involved in range education, as well as to land management agencies, for determining educational needs in range management and perhaps in natural resource management in general.

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[1] Williams, R. E. 1970. Range conservationist need for education: Rangeland action agency's views. Paper presented at the 1970 Annual Meeting, Society for Range Management, Denver, Colorado, February 12, 1970.

Universities and Range Degrees

The data in Table 1 shows the number of individuals graduating from 18 colleges or universities that offered major coursework in range science or range management prior to 1967. Students from these schools could also meet Civil Service standards without obtaining a degree in range science or range management. Thus, students with and without degrees in range science qualified under the Civil Service Series as Range Conservationists and were employed by the SCS, the BLM, and the FS. The data show that two universities (Utah State University and Colorado State University) produced almost 43% of the Range Conservationists who held BS degrees in range science and about 29% of the Range Conservationists who did not have degrees in range science. It is of interest to note that only 57.5% of these employees received BS degrees in range, while 42.5% received enough course credits in range to qualify for Civil Service appointments as Range Conservationists. The data listed in Table 1 include only 1,409 of the total of 1,605 respondents because 196 did not list a degree major.

Federal land agency administrators were among those polled, and 26% of these felt that a range degree qualified individuals to handle assignments that dealt with resource and environmental problems other than those traditional in range management. Additionally, 71% of these administrators indicated that a formal degree in range was not necessarily a major factor which qualified individuals to solve these problems. The remaining three percent said that a range degree did not qualify individuals in any way to deal with these nontraditional problems.

Membership in Professional Societies

As might be expected, the majority of these employees were members of the Society for Range Management (SRM) (Table 2). However, only 69.5% of those persons who had BS degrees in range science were members of the SRM, while only 58% of the Range Conservationists who did not have a range degree were members. Approximately 50% of the BLM Range Conservationists were members of the SRM, whereas the SCS and FS had 72 and 67% of their Range Conservationists as members of SRM, respectively (Table 2). Range Conservationists who had met the requirements by coursework other than a BS degree in range had a higher percentage of membership in other professional Societies such as the Soil Conservation Society, Society of American Foresters, Wildlife Society and others (Table 2).

Subject Matter Training

Information presented in Tables 3 and 4 indicated that ecology and range management courses were given as the most beneficial in the Range Conservationist's training. These courses were also suggested as the most important in updating a Range Conservationist for the responsibilities he is expected to meet in his position. Ecology was listed as the most important basic subject matter received in their range training with basic range management courses listed second in importance (Table 3). A greater percentage of the more recent graduates responded that they needed more range management, which is in contrast to a greater percentage of the earlier graduates who said that more ecology was needed in the range curriculum. This could have resulted from fewer ecology courses being available to earlier graduates. However, all respondents, regardless of when they graduated, indicated that basic ecology was the most important discipline required in their training (Table 3). More training was suggested in plant physiology and botanical sciences by respondents who had more than 4 years of service.

There were several interesting contrasts among personnel in the various federal land management

Table 1. Universities attended for BS degrees in range science or where training in range management was sufficient to qualify the employee for a Range Conservationist or Range Examiner position. Data are presented in actual numbers except in last two columns.

Schools	SCS Range sci. degree	SCS Non-range degree	BLM Range sci. degree	BLM Non-range degree	FS Range sci. degree	FS Non-range degree	Combined Numbers Range sci. degree	Combined Numbers Non-range degree	Combined Percent Range sci. degree	Combined Percent Non-range degree
Ariz., Univ. of	8	3	5	9	8	3	21	15	2.6	2.5
Calif., Univ. of	3	1	3	2	3	2	9	5	1.1	*
Colo. State	19	21	9	17	78	50	106	88	13.1	14.7
Fort Hays Ks. State	1	16	1	12	0	1	2	29	*	4.8
Idaho, Univ. of	21	3	25	12	25	21	71	36	8.8	6.0
Montana State	11	5	15	14	5	8	31	27	3.8	4.5
Montana, Univ. of	21	5	11	14	37	23	69	42	8.5	7.0
Nevada, Univ. of	0	0	1	5	1	0	2	5	*	*
N. Mex. State	12	4	17	6	21	5	50	15	6.2	2.5
N. Dak. State	0	4	0	4	0	0	0	8	*	1.4
Oregon State	3	4	5	3	3	5	11	12	1.4	2.0
S. Dak. State	2	3	4	0	2	0	8	3	1.0	*
Sul Ross	5	9	1	2	0	0	6	11	*	1.9
Texas A&M	38	12	5	1	9	1	52	14	6.4	2.4
Texas Tech	11	8	4	2	3	1	18	11	2.2	1.9
Utah State	29	8	89	10	124	65	242	83	29.8	13.9
Washington State	1	7	7	2	9	7	17	16	2.1	2.7
Wyoming, Univ. of	5	2	16	14	11	9	32	25	3.9	4.2
Other universities	39	47	13	35	12	61	64	153	7.9	25.6
Total	229	162	231	174	351	262	811	598	100.0	100.0

*Less than one percent (1%).

agencies as to what was important in a range management curriculum for a BS degree. The range degree and non-range degree specialists employed by SCS and FS expressed a common view that basic ecology was the most important discipline. The range degree employees of BLM likewise thought that ecology was decidedly most important, but non-range science degree employees of BLM working as Range Conservationists thought that range management was more important than ecology.

There was little or no difference in responses from persons holding range degrees and other degree specialists when averaged over all land management agencies as to importance of the six basic subject matter areas (Table 3). However, the average percent of respondents within each agency listing the six disciplines indicated that a marked difference existed among the three agencies. The BLM and SCS respondents indicated that 70 and 80%, respectively, thought that the six disciplines were important regardless of the degree that the Range Conservationist held. These are in contrast to the 56% of the FS Range Conservationists who felt that these subjects were the most important. The remaining percentages indicated that other courses were as important or more important than those included in the six disciplines listed in Table 3.

Courses or subject matter areas considered to be highly important in carrying out the assignments of a Range Conservationist, regardless of their employing federal agency, were: first, range management; second, ecology; and third, plant taxonomy (Table 4).

The non-range degree range employee thought that plant taxonomy should have been required in his formal education. Apparently, field experience made up for a great many of his educational deficiencies, but plant taxonomy, plant ecology, and grazing management appeared to remain a void (Table 4).

The trends expressed in Table 4 suggested that range specialists with other degrees had different deficiences than specialists with range degrees. These deficiencies could have been the result of differences in academic training and job assignments. In any case, these data suggested that several years of experience were gained before the

Table 2. Range Conservationists' membership in professional societies. Data expressed as a percent of 1,605 respondents.

	SCS		BLM		FS		Combined	
Societies	Range science degree	Non-range degree	Range science degree	Non-range degree	Range science degree	Non-range degree	Range science degree	Non-range degree
Soc. for Range Manage.	77.3	67.3	50.6	49.4	76.9	58.0	69.5	58.0
Soc. of Amer. Forest.	*	3.1	2.2	5.2	17.9	40.5	8.5	20.1
Soil Conserv. Soc.	56.3	67.9	3.9	1.1	2.0	2.7	17.9	19.9
Amer. Soc. of Agron.	–	1.9	*	*	–	–	*	*
Ecol. Soc. of Amer.	2.6	2.5	*	–	–	1.5	*	1.3
Wildlife Soc.	1.3	2.5	5.2	13.2	8.3	16.4	5.4	11.7
Amer. Inst. Biol. Sci.	1.7	1.2	*	*	*	2.7	*	1.7
Amer. Forest. Ass.	–	–	*	1.1	2.6	4.2	1.4	2.1

*Less than one percent (1%).

Table 3. The six courses or subject matter areas listed as most important in the range management curriculum. Data expressed as a percent of respondents stratified by years of service in the agencies.

	Years of service							
	1–4		5–8		9–12		Combined	
Courses	Range science degree	Non-range degree	Range science degree	Non-range degree	Range science degree	Non-range degree	Range science degree	Non-range degree
Ecology	23.1	17.3	22.6	23.6	27.7	30.5	24.6	24.2
Range manage.	18.8	17.3	12.3	11.5	9.7	8.4	13.5	12.1
Plant taxonomy	11.5	18.2	9.4	12.2	9.0	9.9	10.0	13.1
Plant physiology and botany	12.1	9.0	17.0	17.5	15.4	10.7	15.0	12.9
Soils	3.6	4.5	3.3	2.7	2.6	1.5	3.2	2.8
Agrostology	3.6	*	3.3	2.0	1.9	*	3.0	1.3

*Less than one percent (1%).

Table 4. Shortcourses listed as being most useful in carrying out Range Conservationist assignments. Data expressed as a percent of all respondents.

	Years of service							
	1–4		5–8		9–12		Combined	
Subject area	Range science degree	Non-range degree	Range science degree	Non-range degree	Range science degree	Non-range degree	Range science degree	Non-range degree
Range manage.	16.4	9.1	13.2	12.8	14.4	13.8	14.3	12.1
Ecology	6.6	4.5	6.6	9.5	10.3	8.4	7.7	8.0
Plant taxonomy	4.8	7.3	3.3	4.7	5.2	6.1	4.3	5.9
Range economics	4.2	2.7	2.4	5.4	4.5	3.8	3.6	4.1
Watershed manage.	4.8	5.5	1.9	1.4	3.2	2.3	3.2	2.8
Wildlife manage.	3.0	4.5	4.7	3.4	*	–	3.0	2.6
Recreation manage	1.2	1.8	2.8	*	3.2	*	2.4	1.0
Economics and adm.	1.8	–	2.8	2.0	3.2	1.5	2.6	1.3
English	1.2	1.8	*	2.7	4.5	1.5	2.1	2.1
Soil and water sci.	6.1	4.5	4.2	6.1	5.2	8.4	5.1	6.4
Communications	*	–	–	1.4	–	*	*	*

*Less than one percent (1%).

range employee realized the importance of some of the subject matter areas that are common to range management.

There were some differences in opinions among range employees within the three federal land management agencies as to a need for continuing education. There were also differences between those who had attained degrees in range and those who did not have range degrees with respect to continuing education in range management. The Range Conservationists of BLM and FS, regardless of the degree held, thought that specialized courses were absolutely essential to update Range Conservationists. SCS Range Conservationists holding a degree in range science thought that these kinds of courses were important but not essential; while SCS Range Conservationists without a range degree thought that such courses were essential. For example, short courses most frequently listed were: range management, ecology, watershed management, and wildlife management in that order. In general, the majority of Range Conservationists said that specialized courses were essential in continuing their education. Contrary to present-day thinking, communication needs were not listed as being important by the respondents.

Table 5. Years of experience in federal agencies for employees originally employed as Range Conservationists with and without range science degrees. Data expressed as a percentage of respondents.

Years of experience	SCS Range science degree	SCS Non-range degree	BLM Range science degree	BLM Non-range degree	FS Range science degree	FS Non-range degree	Combined Range science degree	Combined Non-range degree
2	6.1	3.1	5.6	2.9	2.3	5.0	4.3	3.8
3	9.6	5.6	6.9	8.0	6.6	3.4	7.5	5.4
4	7.9	8.0	5.2	9.8	3.1	5.7	5.1	7.5
5	5.2	5.6	3.9	5.2	7.4	5.0	5.8	5.2
6	4.8	2.5	9.1	5.7	6.3	5.0	6.7	4.5
7	3.9	1.2	9.1	12.6	7.7	6.1	7.0	6.7
8	4.8	2.5	13.0	14.9	3.7	7.6	6.7	8.4
9	1.3	3.7	5.6	5.7	6.6	5.3	4.8	5.0
10	4.8	4.3	6.5	2.9	5.7	10.3	5.7	6.5
11	2.6	4.9	5.2	4.0	6.3	5.3	4.9	4.8

Experience and Training

Most respondents indicated that experience along with formal education was essential in qualifying them for fulfilling their assignments as Range Conservationists. According to this survey, more than 50% of the range specialists in the FS and the SCS believed that experience along with formal education made them highly qualified for their job. On the other hand, slightly more than 40% believed that experience along with education was only somewhat helpful for qualifying them. The remaining percentage was intermediate in this respect.

Only about one-third of the Range Conservationists in BLM thought that experience along with formal education highly qualified them for their positions, while two-thirds felt experience along with their education was only slightly beneficial. When averaged over all agencies, it was found that considerably more individuals with a degree in range said that their experience along with their academic training was essential for carrying out their responsibilities than those without range degrees. This contrast was surprising, since it would appear that Range Conservationists without a range science degree would benefit markedly more from experience than the range degree specialist.

A majority of the respondents indicated that an advanced degree in range at either the MS or PhD level was not essential or even desirable as an aid in carrying out present assignments or possible future assignments. However, the majority of respondents did indicate that additional formal education or short courses would contribute substantially in assisting them in present and future assignments in rangeland environments.

Most respondents said that experience in several geographical regions was very helpful in preparing them for their present position, but only about one-fourth said it was essential. For the most part, all employees of each agency responded about the same way with respect to this kind of experience.

Employment and Years of Experience with Agencies

Most respondents suggested that experience with more than one land management agency was of only minor importance as an aid in their assignments now or assignments anticipated in the future.

As illustrated in Table 5, there were some years when all federal land management agencies employed more Range Conservationists than others. There were also years when one agency employed far more Range Conservationists than other agencies. Furthermore, it is interesting to note that during some years all agencies employed more Range Conservationists without BS degrees in range than with range degrees. In some years these federal agencies employed almost twice as many Range Conservationists without BS degrees in range science as the range degree specialists (Table 5).

Conclusions

Range professionals over the years have had difficulty in identifying their specific expertise and likewise the subject matter which is essential in training them for their job. This is partially a result of changing knowledge and problems, but may also be a result of inadequacy in the training which is necessary for managing the biological system through a holistic approach. This survey has shown that Range Conservationists feel that basic coursework should emphasize ecology, but general curriculum coursework should emphasize range management. These results indicated that basic ecology should be the foundation of academic training, while applied courses in range management are necessary building blocks to complete a well-rounded education to be employed as a rangeland manager.

MANAGEMENT NOTES

Elk and Bison Management on the Oglala Sioux Game Range

RALPH S. COLE

Highlight: *The Oglala Sioux Indians have recently instituted a range management program involving the production of native game animals for fee hunting. The unique combination of natural habitat, native game animals, and American Indian guides has attracted hunters and resulted in returns that compare favorably with domestic livestock operation.*

The Oglala Sioux Indians in southwest South Dakota instituted in 1970 a range management program involving the production of native game animals for recreation fee hunting. They have two forest-parkland pastures of about 4,000 acres each. These pastures are enclosed by game fences of heavy woven wire, 7.5 feet high. This paper is concerned with these two pastures, referred to as the game range. The Indians also have a 20,000-acre badlands pasture enclosed by natural barriers and a heavy barbed-wire cattle fence.

The game range is a land of rugged topography located near Allen, S. Dak. Its plant cover includes ponderosa pine (*Pinus ponderosa*) forests, open parklands, and savannahs. The steep-sided drainages have good stands of deciduous trees, including bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), and American elm (*Ulmus americana*), and deciduous shrubs including chokecherry (*Prunus virginiana*), skunkbush sumac (*Rhus trilobata*), and American plum (*Prunus americana*). The drainage bottoms have perennial streams.

Between 1970 and 1973, 165 elk (*Cervus canadensis*) and 95 bison (*Bison bison*) obtained from the National Park Service were stocked. Mule deer (*Odocoileus hemionus*), whitetail deer (*Odocoileus virginianus*) and pronghorn (*Antilocapra americana*), naturally occurring within the game range, are managed for increasing populations under limited, special permit hunts.

In January, 1973, 214 elk and 109 bison were counted. This represents an increase of 49 elk and 14 bison during a period when 40 cow elk, 15 bull elk, and 7 bull bison were harvested by hunters. Populations and harvest data were not available for deer and pronghorn.

The 1973 hunting fees charged by the Indians for trophy male animals are: elk–$1,200; bison–$1,200; deer–$375, and for one pronghorn and one deer–$550. They expect to sell all they have planned for harvest, which attests to hunter acceptance.

Quality hunting is a major goal of management. The male elk, bison, deer, and pronghorn are allowed to reach trophy dimensions before they are hunted. Quality of the hunt is further enhanced by limiting the number of hunters permitted at any one time and by the other services provided to hunters. Female animals are harvested, or live trapped and moved, to keep the range properly stocked.

The game range is managed by Sioux Indian rangers. Technical guidance is provided by wildlife biologists of the Bureau of Indian Affairs. Personnel of the U. S. Fish and Wildlife Service have also provided technical counseling.

The Soil Conservation Service (SCS) helped develop a range management plan in conjunction with the Oglala Sioux Tribe's participation in the United States Department of Agriculture's Great Plains Conservation Program. The plan is centered on monitoring the composition of plant communities and the vigor of forage plants. This is accomplished using permanent browse photo points and step transects to determine forage use (Fig. 1).

Observations of forage used by elk, bison, deer, and pronghorn on Wind Cave National Park, South Dakota, under similar conditions of confinement, indicate that elk graze both herbaceous and woody plants. Bison and pronghorn take primarily herbaceous plants while deer primarily use wood plants, especially during winter.

The management goal of the Indian game range provides for the sustained production of all classes of forage plants with utilization determinations keyed to the plants considered most important. As the complexity of this operation changes, so may the concern for particular plant species change. Currently, the key browse species on the game range is chokecherry, and the key grasses are little bluestem (*Andropogon scoparius*) on shallow

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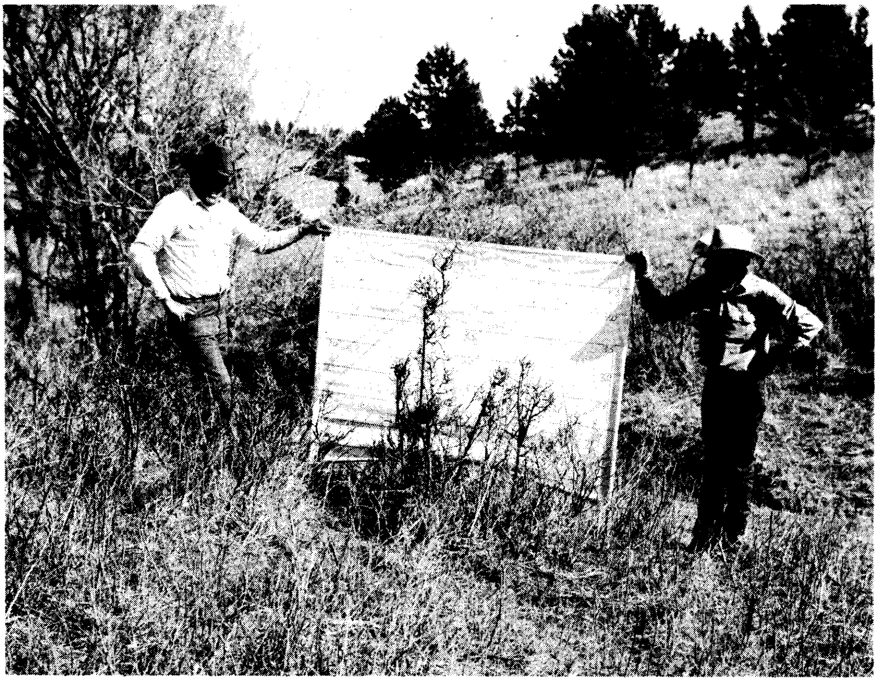

Fig. 1. *Leo Dubray and Russel Loudhawk, Indian rangers, obtaining browse utilization information at permanent photo point.*

soils and western wheatgrass (*Agropyron smithii*) on deeper soils.

The status of these key forage species provides a basis for exercising a number of options for managing the four species of big game—elk, bison, deer, and pronghorn. Economics as related to hunter preference, the population dynamics of each game species, and the competition for forage and space among game species, along with the management complexities concerning both animals and forage resources, will undoubtedly require that adjustments in the overall management plan be made in the future.

The Department of Wildlife and Fisheries Sciences of South Dakota State University has set up transects to determine plant use and is also making stomach analyses to determine plant use by animal species.

Licensing of hunters is coordinated with state authorities. In this instance, through the cooperation of the Department of Game, Fish, and Parks, legislation was passed permitting special hunting seasons, regulations, and licenses for the game range.

It appears that native game animals produced for fee hunting may bring as good a financial return to the Indians as would domestic livestock. Examining a hypothetical comparison of elk and cattle is quite interesting. Elk are fee hunted at $1,200 for bulls and $200 for cows, or an average of $700. A 100-elk herd would provide 25 harvestable animals annually. At $700 each, the return would be $17,500. Using the same amount of range for domestic livestock, 86 cows and 3 bulls could be grazed for 9 months. They should produce 75 calves weighing 450 pounds each. If the calves brought 65 cents per poumd, this would be a gross return of $21,937. Subtracting $3,440 for cost of hay for 3 months and $830 for bull costs, the return for cattle is $17,667 compared to $17,500 for elk.

There are other costs to each kind of production such as labor costs for feeding cattle, labor costs for guiding hunters, and equipment and facilities depreciation and maintenance in either activity. A factor of considerable importance, not included in the preceding comparison, is the high initial investment for a game fence, which runs from $6,000 to $10,000 per mile. Maintenance costs of either kind of fence would be similar.

Although this may be a suitable activity for the Oglala Sioux, it would be difficult to say what the opportunity for others might be to develop a similar operation—particularly if it were necessary to acquire habitat where not only the range would be satisfactory but where an esthetically pleasing hunt could be offered. It is also interesting to speculate what problems might occur if a source of free or low cost elk or bison for initial stocking were not available.

One Ranch Family's Adaptation to Changing Resource Demands and Social Values

GORDON STANLEY

Highlight: *Southwest Oregon was quite primitive when Mr. Stanley's grandfather began ranching there in 1880. Grazing was the primary use of the land, and the pioneer ranchers resented all government regulation. When Stanley and his brother took over in the 1940's they began to feel the pressure of increased demands on the land. Recently they actively participated in the development of the Big Butte Coordinated Management Plan involving federal grazing land, private timber company land and their base property. Through this type of planning their grazing is planned so as to avoid conflict with other uses and to enhance some uses.*

Ninety-four years ago my grandfather established the family in the business of raising meat. At the same time he developed a land usage philosophy that was to guide the operation for 60 years to come. He had to take into consideration the scarcity of money (which has continued over the years), the difficulty of producing hay, and the necessity of having enough feed for the cattle year-round. Not only the cattle would eat, but so would his family. Thus his use, and in some years, his overuse, of the land was a direct economic necessity.

For the next 60 years our business, then run by my father and my uncles, followed the basic tenets laid down by grandfather. With the coming of mechanization, however, they were able to develop the land, particularly patented land, with their goal, of course, to produce more pounds of meat per acre of land.

In my grandfather's time the population of the Rogue River Valley, just north of the California border in

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The author is a cattle rancher, Eagle Point, Oregon.

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southwestern Oregon, was small. So quite naturally there were few users of the land and consequently plenty of land for all. By contrast, in the late 1940's when my brother and I took over the business, the population had doubled many times over. No longer was there enough land for everyone to use for a single purpose. The pressure was already beginning to build for multiple uses of land formerly used only for grazing cattle. Timber production was rapidly becoming big business. This meant roads into land never easily accessible before. Hunting and fishing were no longer for sheer necessity. Now they were sports with many participants. Other recreations, such as camping, boating, hiking and the like, were growing by leaps and bounds. Then too, as the population grew, the watershed was of increasing importance. Each of these groups pulled for its goals with the cattleman where he had always been, but now it was smack dab in the middle of progress.

We felt the pressure of these stepped-up demands on the land and yet still another on which our economic security directly hinged. We could no longer continue to operate and support our families with the small bunch of cattle that had carried the family in years past. We just had to expand to stay in business. That meant more cow units and more land. While we were expanding, we developed a sensitivity to criticism and a growing awareness of one clear fact: if we hoped to continue to use the land, we had to develop a more viable system, allowing for our use without interfering with other uses and at the same time develop more and better forage.

Any and all government regulation in my grandfather's time was met with reluctant compliance and deep resentment by nearly all of those highly individualistic pioneer ranchers. Times have changed and so have we. Now we actively are involved with planning and writing controls that we can live and work with without hesitancy and ire.

From this approach evolved the "Big Butte" coordinated management plan. Besides the Stanley brothers, the planners include two other ranchers who also run on our range, two timber companies—Medford Corporation and Boise-Cascade Corporation—the Oregon State Wildlife commission, the U.S. Forest Service, the Bureau of Land Management, and the Soil Conservation Service. The plan itself incorporates 140,000 acres of varying types of ownership and management. All aspects of the land and its usage were studied and evaluated to determine where conflicts existed and where improvements were needed. On the basis of this evaluation, a superior type of grazing system was implemented.

One resulting change in our favor, we believe, is the flexible entry date as opposed to the fixed date. Now we are allowed access to rangeland according to feed and conditions. Already we have seen improvement, even in a very dry year, in the condition of our cattle. We are sure, too, that we will soon see improvement in range conditions.

Because of this planning, we are now in a position to do more in the way of range improvement than before possible. In this first year of implementation, for instance, we have done more in the way of fencing and water development than would have been normal over a 5-year period. As a result of this plan, we have initiated a system whereby we can plant grass in timber-producing areas, greatly enhancing the forage without adversely affecting timber production. On the slope of a porous volcanic mountain, we have developed three watering ponds to service a grazing area never used before for lack of water. The list of additional improvements for completion in the near future is long, but all parties are enthusiastic and anxious to finish as soon as possible on a priority basis.

An added plus to the working of the plan is the total cooperation of all those involved. We had a reasonably good relationship with the various agencies before, but I believe cooperation and understanding has greatly improved. Participant reaction has been tremendous, with each one giving just a little instead of pulling for its own course. The timber companies and ranchers both agreed to give consideration to an enhanced environment for the wildlife on their lands. In the past, the production of timber was the only point of concentration for the timber companies with little thought for range. Our attitude for years toward game and wildlife has been one of tolerance because we could do nothing else. Our thinking has changed as a result of this plan. We instituted a method for the manipulation of feed, water, and other factors to manage the deer herds as we would manage our cattle.

The plan is working and has caused us to continue to broaden our outlook. Still another outgrowth of this type of overall planning was the leasing of a ranch in the milder climate of California for our cattle to winter on. This move will have a dramatic effect to the betterment of our entire operation.

Aesthetically, we have always been concerned about what our total effect on the land will be. It is our sincere hope that when we have had our day the land will be undepleted and unscarred. I would hope that our properly planned use can help us to accomplish our end, that of helping to feed a demanding society, while also improving conditions for all the other demands put on the land.

The demise of the family-type operation, because the younger generation sees no future in most agricultural fields, is becoming an increasing concern. In order to save our way of life for our children and make it feasible for them to continue, we, the cattlemen, must take the initiative. A progressive attitude in our time may have an effect on whether or not they will continue. The land must be productive and available for grazing use tomorrow, as well as today, so that they will have a reasonable chance to achieve economic security. It is my belief that this type of coordinated planning and management can give more security of tenure than anything done so far. While there are many uncertain variables in the economics of the cattle business, the asset of a well-planned and managed range is the key factor to keeping a ranch solvent.

As a consequence of my changing attitudes, I strongly feel that it is imperative that we publicize to the greatest degree the efforts and results of these efforts that have been made in planning and management of grazing lands. There are two groups, or publics, we need to reach. First, there are all others who graze the land and are not now involved in good practices with the aim of immediately enlisting their efforts in a proper direction. The second group is the general public, in particular the concerned environmentalists who are now so intense in their efforts to eliminate grazing from public lands.

The public does have the right to know how the public land is being managed. We need to tell and show these people that the land can be managed in such a way as to insure its retaining productive capability, its cover and wildlife habitats, its scenic, recreational and aesthetic values and still produce adequate supplies of red meat for the demanding consumer.

BOOK REVIEWS

A Study of the Agroclimatology of the Highlands of Eastern Africa. By L. H. Brown and J. Cocheme. Tech. Note No. 125, World Meteorological Organization. U. S. distribution by Unipub, Inc., P. O. Box 433, New York, N. Y. 10016, 197 p., 1973, $13 paperback.

Technical Note No. 125 is the third agroclimatological publication of this joint organization. These publications report on investigations of basic climatic agricultural potentials of countries for increasing food production with improved agricultural practices. In this report, the authors have concentrated on accumulating, analyzing, and describing basic climatic factors of and the current agricultural crops in the Ethiopia, Kenya, Uganda, and Tanzania highlands.

Beginning with a basic description of the global air circulation that affects these countries, the authors describe modifications of the basic model and rain-producing mechanisms. With these background data they describe, in greater detail and in more practical terms, local climatic patterns of the various subdivisions of the area.

Orographic influences and the seasonal pattern of rainfall for the subareas of the highlands are attacked with vigor and great detail. After this discussion, the authors concentrate on estimating water availability, using Penman's equation, and discuss the water budget for the areas of concern. The final chapter on climatic aspects explores patterns and amounts of solar radiation for the region and the effect of solar radiation on crops and the heat budget.

Elevation varies from 1,500 to 3,000 meters, and precipitation from 250 to 1,500 mm. The natural vegetation is described in broad associations that are extremely complex and strongly zonal.

With this region's great variability in climate, the authors suggest that, except for plants susceptible to frost-killing, all plants grown elsewhere in the world could find a home here. Because of the great number of crops possible and currently grown, seven of the more important crops are discussed in terms of current production practices, economic and agricultural value, existing disease problems, and potential increases through improved practices. The crops discussed are coffee, tea, pyrethrum, maize, tef, wheat, and barley. The first three are cash crops, and the cereals are the primary staple food crops of the residents.

This report will interest (a) students of agroclimatology, (b) students of the South African continent, and (c) those anticipating tours of duty in these areas relative to economic and agricultural development. For the latter, the digestion of a report such as this would be a necessity.

If a reader is looking for agronomic soils information, this report will not provide it. The paucity of soils information and impact is perhaps best illustrated by, "The vegetation reflects the climate wherever the nature of the soil does not make it impossible. . . ." Soil requirements of the crops discussed are only briefly described. Subregions of this immense highland area (83 million hectares) are described in considerable detail; unfortunately the accompanying map does not permit the reader to locate himself readily to the areas being discussed. Nevertheless, the authors have done a commendable job in accumulating, synthesizing, and assessing a large amount of data, sometimes from scattered locations, into a comprehensible and very informative manuscript.—*F. A. Sneva*, Burns, Oregon.

Economics and Management Planning of Range Ecosystems. By Donald A. Jameson, Sandy D'Aquino, and E. T. Bartlett. A. A. Balkema, Postbus 1675, Rotterdam. Distributed in U.S. by Lawrence Verry, Mystic, Conn. 06355. 244 p., 1974. $9.50. Paperback.

The spring of 1974 marked the addition to range management literature of a badly needed and long awaited text in range economics. However, both the title and the glowing description by the Netherlands publisher overstate what the book actually delivers. The book is composed of twelve chapters and two detailed programming appendices. Chapters 1-6 consist of an introduction to basic economic concepts, a survey of the market system, and a treatment of production economics principles (factor-product, factor-factor, and product-product). Although presented in a straightforward manner complete with range examples, these six chapters do contain numerous errors in graphical displays and a few conceptual mistakes which will undoubtedly confuse students and irritate instructors.

Chapter 7 treats cost-effectiveness, program planning and budgeting, and benefit-cost analysis. This section is largely out of date with undue emphasis placed on Senate Document 97 written back in 1962. No mention is made of the U.S. Water Resources Council "Standards for Planning Water and Related Land Resources," which has been circulated in draft since 1970 and which appeared in final form in the *Federal Register* in mid 1973. Although the economic success of any private or public range project hinges entirely on the interest rate used for discounting purposes (cost of borrowing or forgone uses of capital), no mention of either interest rates or the process of discounting is made in Chapter 7. Four chapters later discounting is briefly mentioned but only within the context of the uncertainty that makes stochastic programming necessary.

Chapters 8-12 are a clear and concise treatment of linear programming, sensitivity analysis, stochastic programming, and simulation techniques using examples from a range livestock operation. One gets the impression that the authors viewed Chapters 1-7 as a necessary but uninteresting portion of the book and that the bulk of their talents and energy was concentrated on the final five chapters. The two appendices strengthen the material presented in Chapters 8-12 by displaying the details of the computer program used for linear programming along with several subroutines employed in these chapters.

The book might best be used as a supplement to junior or senior lecture courses in range economics. It is not well suited to self teaching, and independent readers with little background in production economics will find it difficult. The over-use of professional jargon tends to cloud several important concepts. In the preface, for example, the authors mention that the "effects of ecological inputs on the resource base" will be treated in the last two chapters of the book. In reading these two chapters the reader discovers that "ecological inputs" consist of the number and kind of livestock grazing a given range area and that the "effects on the resource base" are changes in range condition and corresponding changes in carrying capacity. Specialized jargon has already developed to the point that range people sometimes have difficulty communicating with *other disciplines.* The barrage of specialized terms encountered in the book will likely lead to communication difficulties *within* the range profession as well. Economics and programming terms are defined as they are first encountered in the text, but a glossary of important terminology would have made the job of assimilating new terms much easier.

In summary, the book does partially fill an important void in range management literature. After experiencing the frustrations of using Leftwich, Heilbroner, and other well-known microeconomics texts as references for senior courses in range economics, I have found draft copies of this book to be very helpful. Most range and other natural resource students relate much easier to production economics explained in terms of cattle and sheep AUMs than to the typical "guns and butter" textbook examples. In its present form the book lacks polish and fails to anticipate reader difficulties in comprehending complex concepts. This may be due to insufficient student exposure prior to publication. However, in spite of the criticisms mentioned, for $9.50 this book offers a package for which there is currently no alternative.— *John P. Workman,* Logan, Utah.

Weeds of Eastern Washington and Adjacent Areas. By Xerpha M. Gaines and D. G. Swan, with color illustrations by H. Clinton Keller. Camp Na-Bor-Lee Assoc., Davenport, WA 99122. 349 p., 1972. Paperback, $6.95; hard cover, $11.95.

This modestly titled book covers a range of weedy species that extends far beyond adjacent areas. A majority of these weeds are of Eurasian origin, but are now common to the northern United States and southern Canada.

The book is arranged in sections on a taxonomic system of families, with a brief description of family characteristics. Species are arranged alphabetically within families by scientific name, with the common name approved by the Weed Science Society of America preceding the scientific name. The origin of the plant, its general distribution, and sidelights of interesting information on the plant are often included in a supplementary paragraph. The style of the addenda is that of a former era, which lends a historical aura to the book. A black-and-white photo of the seed accompanies the text. There is one species per page, and on the facing page is a color illustration of the mature plant, emphasizing distinguishing features.

The book is not a taxonomic treatment of weeds, although it is arranged along taxonomic lines. It has a page of "quick references" for aid in identification and a glossary of line drawings and explanations of necessary taxonomic terms. The design and format are well suited for agricultural producers and their agribusiness allies and for use as a quick reference for county agents and others interested in weed identification. The authors have avoided technical terms and described each plant so that, with the aid of the color illustration, it could be identified. The reader with an interest solely in range problems will note a scarcity of weeds that are primarily range problems, but a great many are problems on both range and cultivated agricultural areas.—*W. C. Robocker,* Pullman, Washington.

A Selected Bibliography on Southern Range Management, 1968-1972 has been issued by the Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, New Orleans, Louisiana. This bibliography is the third of a series compiled by the Committee on Range Bibliography of the Southern Section, Society for Range Management. Authors are H. A. Pearson and G. L. Wolters, Southern Forest Experiment Station, Pineville, Louisiana; C. E. Lewis, Southeastern Forest Experiment Station, Marianna, Florida; and G. E. Probasco, North Central Forest Experiment Station, Columbia, Missouri. It lists over 950 publications dealing with the forest ranges of the South, and with the livestock and wildlife utilizing this vast resource. The list brings up to date the coverage of publications useful to the diverse interests of land managers, stockmen, conservationists, scientists, teachers, and students. The first bibliography appraised all literature that had accrued through 1961. The second spanned the years 1962-1967.

The southern range area is considered to extend from easthern Oklahoma to Virginia, and from southern Kentucky and Missouri to the Gulf of Mexico. Because pasture commonly augments the diets of cattle that subsist chiefly on range forage, pertinent publications on supplemental pastures are included. Contents of the bibliography span from range plants to wildlife management.

Copies of the bibliography—Forest Service Technical Report SO-3—are available from the Southern Forest Experiment Station, 701 Loyola Avenua, New Orleans, Louisiana 70113.

New Publications

The **Science Calendar 1975** (printed on 10 by 13-inch glossy-white paper) has 12 "out-of-the-ordinary" color photographs (suitable for framing) bound with appointment calendars of individual months. These pages are ring bound for over/under display of a photo and calendar month. Significant sicentific events and people are commemorated by brief notes printed in date blocks. The claendar is sponsored by the National Science Teachers Association and published by: Charles Scribner's Sons, 597 Fifth Avenue, New York, N.Y. 10017. $3.95.

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