MARCH 1973
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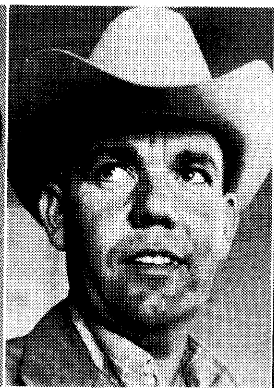
JOURNAL OF RANGE MANAGEMENT

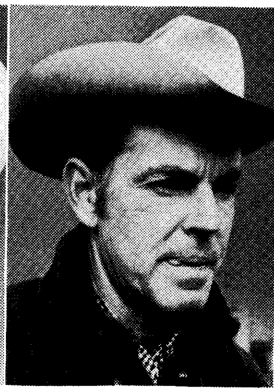
SOCIETY FOR RANGE MANAGEMENT

Jerry Winfrey, Rising Star, Texas
217 steers
Irrigated Coastal Bermuda
2.9 steers per acre, 118 days
A.D.G.—1.59 lb.
545 lb. beef per acre
20.12¢ per pound of gain

Marvin Knopp, Dighton, Kansas
75 steers
Sudan pasture
3-1/2 steers per acre, 90 days
A.D.G.—1.78 lb.
490 lb. beef per acre
11.8¢ per pound of gain



Wendell Kent, Sweetwater, Texas
400 steers
Sudan hay
180 days
A.D.G.—2.25 lb.
12.8¢ per pound of gain



Harry Lynn, South Coffeyville, Oklahoma
701 steers and heifers
Native bluestem range
2.8 acres per steer, 210 days
A.D.G.—1.59 lb.
119 lb. beef per acre
19.38¢ per pound of gain

Joe Ellis, Kaufman, Texas
900 steers
Coastal Bermuda
3 steers per acre, 129 days
A.D.G.—1.93 lb.
747 lb. beef per acre
18.13¢ per pound of gain

Average starting weight of 2,293 head . . . 350 lb.
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Average cost per pound of gain . . . 17.56¢

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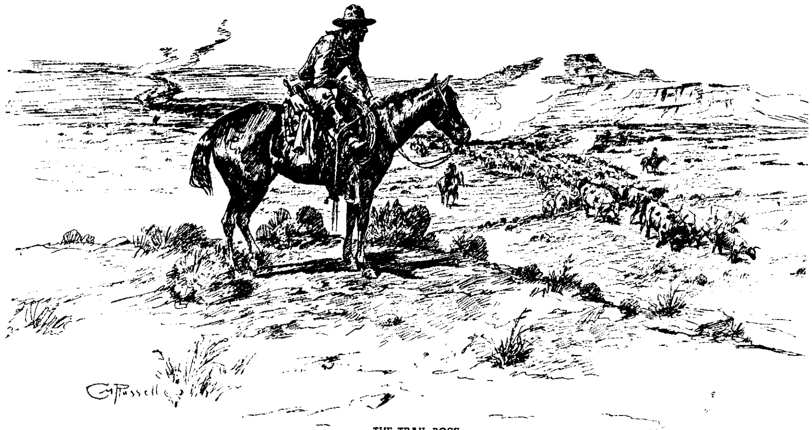
CATERPILLAR

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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The Quest for Excellence

FLOYD E. KINSINGER

Someone once said that talk is cheap because the supply is always greater than the demand. Thus, I do not intend to bore you with a long, detailed explanation of your Society's activities and of the many programs we have developed and are developing. If you have been faithfully reading *Rangeman's News,* you are already aware of the more important happenings. Nevertheless, since it is customary for the out-going president to report to the membership on the "state of the Society," I do feel obligated to share just a few highlights of this past year.

The Society is affiliated with or maintains liaison with nine other societies and organizations. This includes the recently established liaison with the Weed Science Society of America, out of which relationship has emerged a group called *ICOMPT* –Intersociety Committee on Plant Terminology. Mr. Tom Eaman is our representative to this committee, while Dr. James A. Young is SRM's liaison to WSSA.

Dr. Jack F. Hooper has been appointed to represent the Society for Range Management on the National Research Council, and Dr. Carlton Herbel recently succeeded Dr. Wesley Keller as our representative to the American Society of Agronomy.

Effective liaison with these other societies and groups requires attendance at meetings, preparation of reports, correspondence, familiarization with the goals and objectives of each organization, and a host of other physical and mental demands. It is not a task to be taken lightly, and we have been blessed this past year with representatives who were dedicated to furthering the interests of the Society.

The Society has 19 Sciential Committees preparing summary reports of the principles and problems pertaining to numerous aspects of rangeland management and use. These reports are in various stages of completion, but in the near future I anticipate a steady stream of highly informational and educational bulletins. I believe every member, as well as many others, will want this entire series for his library. During this past year, I have appointed three additional Sciential Committees: Rangeland Plant Physiology, Rangeland Economics and Sociology, and Rangeland Mine Reclamation.

I had the privilege of attending many Section meetings in 1972 and I am tremendously impressed with the dedication of our members and the quality of Section meetings and programs.

Our 14 standing committees have been most productive and I really cannot say enough about them and about how proud I am of their accomplishments. Some of the things our committees are doing are readily apparent, but the tremendous amount of time and effort they expend and the accomplishments they attain are generally not well-known by the rank-and-file membership until a policy statement is approved by the board of directors or a new or better program or product is presented. Unless you have served the Society as a committeeman, it is difficult to comprehend the amount of dedicated effort that goes on behind the scenes before some tangible result is apparent.

It is obvious that the 1973 Annual Meeting Committee has done its job and done it extremely well. It is equally obvious that the Awards Committee and Nominating Committee selected excellent candidates for recognition and to serve as officers.

At this meeting we also can see the fruitful efforts of the Student Affairs Committee in the Student Conclave, Youth Range Forum, Range Plant Contest, and other student activities.

You have seen the "new" *Journal of Range Management* and the first Sciential Committee report–*Rangeland Hydrology* –so it is quite apparent the Publications Committee has been constructively active.

The Society has experienced a year of unprecedented growth in membership, and my gratitude goes to all of you on the Membership Committee and to all those who recruited new members and helped reinstate suspended members.

Information about the symposium to be sponsored by our Society at the forthcoming meeting of AAAS-CONACYT in Mexico City will appear in an early issue of *Rangeman's News.* This program has been developed by the International Affairs Committee, which also is reaching out into other international aspects of range resources management. For example, it is giving direction to the establishment of an Australian Society for Range Management, preparing a training workshop for range managers in Argentina, and is giving consideration to ways and means of promoting an International Congress on Range Management.

These are but a few of the more important activities and programs your Society has become involved in. Some committees I have not even mentioned because time will not permit more discussion, but they, too, have been extremely active and productive and you will see the fruits of their efforts as time passes. Realizing that I have been necessarily brief about committee activities, I suggest that those of you inter-

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Address by the retiring president of the Society for Range Management at the 26th Annual Meeting, February 8, 1973, Boise, Idaho.

ested in more detail should corner the committee chairman and ask him about his committee's work.

I want to publicly announce my sincerest appreciation to all my committee chairmen and committee members. They have been aggressive, creative, and dedicated—a bunch of "Young Turks"—and my long hours of agonizing over committee organization and selection of committee members has paid off many times in moving the Society forward.

Ladies and gentlemen, this has been an exciting year for me and the Society, and it is most rewarding to belong to an organization such as this. In my travels around the Sections, I find a bubbling enthusiasm, a renewed vitality, an increasing interest, and a strong desire to become more involved in Society affairs. This is a healthy, growing Society, which is beginning to flex its muscle in many areas. And what a privilege it is to be associated with such fine people! The professional contacts made at Section meetings and meetings such as this are invaluable. Many lasting friendships develop, grow, and become firmly established. Knowledge and information is exchanged; old friendships are renewed and new ones made; decisions are made; and the voice of the Society is being increasingly heard throughout the land.

I know of no other organization that is composed of members who are, at once, so heterogeneous in background and experience, yet so dedicated to a cause, so united in seeking common goals, and so warm, friendly, and compassionate in their relations with each other. There is a bond of fellowship here that can *never* be broken. The biblical reference that states "Ye are the salt of the earth" must surely have had people like you in mind.

A new Society for Range Management is taking shape before our eyes. Our Society is much different than it was twenty, ten, or even five years ago, and the future is happening *today!* In reading an account of the work of the Manned Spacecraft Center, a statement was made that greatly impressed me: it was to the effect that the remarkable *engineering* feats of the space program were made possible only because, many years ago, some individuals "imagineered" into the future. I could not help thinking that, since "imagineering" is just as important in *our* scientific world, we as professional and practical resource managers need to do some additional "imagineering" for the years ahead. For those who follow us we need to identify opportunities and responsibilities now, to stretch our imaginations, stir our consciences, and think creatively about our work in a rapidly changing world.

The outstanding characteristic of the years ahead will be rapid change. Tomorrow will move at a faster pace. If we expect to compete in the marketplace of ideas, we must keep pace or face a diminishing role in the closing years of this century. We must make it clear that livestock grazing on the rangelands of the world is not only a significant source of food and fiber but also a universal and powerful tool for multiple use management of rangeland ecosystems. Never before has the need for man's "imagineering" been as apparent as it is today. Happily, SRM members are more and more unshackling their imaginations to think of new approaches for service, for developing the better way, for expanding our horizons, and for reaching out for the things we once thought were beyond our reach. Resource managers, administrators, conservationists, biologists, ranchers, students, teachers—literally any and every occupation—can be used in a specific area of service to do the work in today's complex environment.

If we were to look back in time to the beginning of our Society, we would note that all significant advances in our brief history have resulted from dedicated members and officers surrendering a portion of their time and lives to what the profession would have them do. "Imagineering" in the past has led us to where we are now. "Imagineering" for the years ahead will take account of the future that is happening *today!*

Just as important as "imagineering" into the future is the continuing *quest for excellence.* Every letter of the word "quest" can be used to develop a program of excellence: *Q* for *quality* of professional life; *U* for *unity* of purpose in the goals pursued; *E* for *excellence* in the goals pursued; *S* for *steady* pursuit of the goals; and *T* for *total commitment* for that goal.

The *quality* of a professional organization depends on the quality of the professional life of each individual member. An organization can only be as good as its individuals working collectively. Those who have no ethical professional standards, jealously exercise prerogatives, hold biased and uncompromising positions, and approach new programs with a negative attitude do not contribute to the quality professional life of an organization.

Unity of purpose keeps an organization from being weakened by indecisive and fractured programs. Most certainly we have our differences; but once all voices have been heard and the goal is established, then it behooves all members to pursue that goal without deviation. Thus, the pursuit is more likely to be successful, past failures are placed in perspective, present powers and capabilities are maximized and focused on the issue, and the vision of the goal is clarified.

The phrase "quest for excellence" contains one magnificent word that tells what it is really all about; that word is *excellence.* Second rate goals have no place in our Society. As a matter of fact, one of our major goals is the pursuit of excellence in all our programs.

To achieve excellence has never been easy. If we made the quest only when it was easy or when we enjoyed success, the goal would never be reached. *Steady* pursuit of the goal, overcoming all obstacles with persistent effort, is the key to success. Men scale high mountains only in a steady climb that may be described as joyous agony—joyous because of advancement toward a goal, agonizing because of the physical and mental effort required. But steadily they climb toward their goal.

A wise man once observed that the person who really excels in the enterprise or profession to which he is *totally committed* usually does not realize that he is an authority or an expert. This may be due in part to the complexity of further knowledge in any area of human endeavor, particularly so in our profession. But it is more apt to be because such a person is so totally committed to his goal that he has lost sight of himself and sees only that for which he strives. He is totally committed!

When the first ape-like man discovered he could pick up an inanimate object and put it to use gathering food, or defending himself, or just scratching an itch, the use of technology was established as a human characteristic. Superior intelligence has made man dominant among Earth's creatures and resources. The ability to organize and utilize the random arrangement of natural resources has taken humanity from the primitive level of the cave, where each day presented a challenge to survival, to the level of modern civilization. Today, however, serious questions have been raised concerning the quality of life that has developed with modern civilization. And in some circles, technology is accused of being the major villain for a host of environmental and social problems. As a result, many young people who wish to pursue humanistic and humanitarian goals believe that a career in physical sciences or engineering would be inconsistent with their hopes, ideas, and ideals. Let me say to you young people in our audience today: I commend you for choosing a profession in natural resource management because, perhaps in no other profession can you combine technology with your ideals for serving mankind and maintaining a quality environment.

What is needed to solve so many of today's urgent social problems—environmental pollution, the distribution and depletion of natural resources, poverty and urban blight, disease, the demand for more energy, population control, and so much more—is *not* a flight from the present into the illusions of the past. If anything, poverty, injustice, war, and environmental abuse were more acute then than they are today. What is really needed is people who are skilled in the modern techniques of resource management—researchers, range scientists, biologists, ecologists, planners, technicians—skilled workers who bring with their skills a heightened sensitivity to human needs. Rejection of technology is not the answer, rather we need technology with a heart. This Society is unique in having both the technical skills for modern natural resource management and a high degree of sensitivity to the needs of mankind. To apply our skills, our knowledge, and our humanitarian ideals to that 40 percent of the earth's land area which is rangeland will be a contribution of monumental magnitude to the quality of life.

In closing, I encourage each of you to "imagineer" into the future and continually to quest for excellence in all our programs, recognizing that the ultimate test of our worth and the ultimate fruits of our efforts will be found on the land itself.

I have thoroughly enjoyed serving as your president and I shall remember the privilege as one of the most memorable occasions of my life. It has been an awesome task but I have had a dedicated board of directors to guide me and I have been inspired by my experiences in working with them. My agency, the Bureau of Land Management, has been most generous in permitting me to devote time and travel to fulfill my obligations and has given me unwavering support during my term of office. And last and most important, I must publicly express my sincerest gratitude to a man without whose devoted help, guidance, and council the job would have been so much more difficult. I speak, of course, of our invaluable and tireless executive secretary, Francis T. Colbert. To him and his very able staff go the thanks of this Society.

To our members from Canada, I say God bless you in your management of the magnificent prairie resources of that country; to our members from Mexico and other Latin American countries, I say God bless you in your work to improve your lands and the social and economic conditions of your people; and to our members from the United States and throughout the world, I say God bless you in your untiring efforts to achieve proper management of all rangeland resources. May this chain of international good will and cooperation be strengthened and lengthened in the years ahead.

THESIS: UNIVERSITY OF CALIFORNIA

Large Scale 70 mm Aerial Photographs for Evaluating Ecological Conditions, Vegetative Changes, and Range Site Potential. David H. Carneggie, Ph.D., Wildlife Resource Science. 1972.

On three dates during the 1967 summer growing season, very large scale 70 mm aerial photographs were obtained of established range plots in Harvey Valley Range Allotment. The Harvey Valley Range is a perennial sagebrush-grassland located in northeastern California near the town of Susanville. Color and color-infrared film were exposed in 1967, and again on a single date in July of 1968 and 1969. The objectives for obtaining and analyzing the aerial photographs were: (1) to determine the accuracy of detecting and identifying range plants on very large scale color and color-infrared photographs; (2) to develop techniques for measuring plant parameters (plant numbers, cover and size) directly on the aerial photographs, and to determine the accuracy for making such measurements; and (3) to determine the extent tc which large scale aerial photographs can be used as a sampling tool for evaluating ecological condition, observing and measuring within and between season vegetational changes, and assessing range site potential.

Detailed interpretation and measurement of the aerial photography was performed by various skilled interpreters and the results support the thesis that large scale aerial photographs are a valuable sampling tool for range resource analyses. Quantitative interpretation tests have demonstrated that many of the dominant shrub species could be detected and identified at an accuracy level above 90%. The color-infrared photos were moderately better for plant species identification than the color photos. They were much better, however, for evaluating plant health and the amount of living versus dead or decadent foliage. Color photos were slightly better for identifying a few species during the autumn. The time for detecting and identifying the greatest number of plant species is during July when the plants have nearly reached the stage of peak foliage development or when the plants were phenologically unique because of their flowers, leaf color, or health of foliage.

The absolute number of plants at a site cannot be determined by means of photo analysis. This is because very small juvenile plants can not be resolved and because some plants are obscured by adjacent plants or their shadow. However, the relative change in plant numbers, plant size, and plant composition can be determined by analysis of photographs taken on different years over the same site.

The best technique for estimating shrub cover involved counting dots from a clear plastic dot-grid which was placed over the shrubs seen on the enlarged aerial photographs. An absolute estimate of shrub cover can not be made because many small shrubs can not be seen. Small shrubs, however, do not contribute greatly to the estimate of total shrub cover. A reliable estimate of the relative change in shrub cover can be determined from the aerial photographs taken on two or more different years. This parameter can be used as an indicator of changes within a plant community. Although vegetative change detection was the primary emphasis in the dissertation, changes in other surface features (soil, rodents, litter) were evaluated using the very large-scale (approximately 1/600) photography.

Returns from Southern Forest Grazing

H. A. PEARSON AND L. B. WHITAKER

Highlight: *Over a 10-year span, commercial herds grazing bluestem forest ranges in central Louisiana provided data on the returns from good cattle and range management. With labor cost excluded, per-cow returns on the investment were from 14 to 18%, with the best return from light stocking. Returns per acre of range varied from $1.88 under light stocking to $2.67 under heavy use.*

For perhaps 10 years after pine regeneration becomes established, forests in the southern Coastal Plain contain substantial volumes of forage. Bluestem grasses (*Andropogon* spp.) are the chief component, but a large variety of forbs and other grasses contribute. Nutritional values are good in spring and early summer; and if the cattle receive supplemental feed at other seasons, they can be kept on the range all year.

Large numbers of cattle are grazed on this forage—usually in small herds and at a low level of management (Fig. 1). The majority of cattlemen do not own enough land to support a herd of profitable size, and therefore must arrange for additional grazing on neighboring timbered tracts. Many forest owners grant grazing rights free of charge, and some assess a small fee to be paid either in cash or by the construction of fences or other improvements.

Research has shown that pines, even those in seedling stages, are not seriously damaged when grazing is properly managed (Pearson et al., 1971). Some practices serve both cattle and timber interests. For example, prescribed burning is useful in manipulating forage utilization by cattle and also aids in controlling undesirable hardwoods, reducing hazard from wildfire, and preparing seedbeds for pine (Halls et al., 1964).

This paper reports costs and returns from a reasonably high level of herd and range management. The data are from three privately owned herds that grazed from 1961 through 1971 on the Palustris Experimental Forest in central Louisiana.

The authors are principal range scientist and range technician, Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture at Pineville, Louisiana.

Manuscript received March 2, 1972.

Grazing returns per acre varied from $1.82 to $2.67 annually. To the cattle owner, these values should be an inducement to improve his management practices. To the manager of forest land, they suggest that the forage may be a source of income while the pines are growing to sizes at which they can be marketed.

While some southern range cattle are maintained in part on improved pasture, the present herds were typical of many others in that they had recourse only to native forage.

Herd and Range Management

Most cows were Brahman crossbreeds, which appear to be the most efficient producers on southern forest range (Duvall and Halls, 1963; Whitaker et al., 1970).

Bulls were high-quality Shorthorns or Herefords which were replaced when their breeding efficiency declined, generally about age 9. The breeding season was limited to late winter and spring. Calves dropped from late November through February are old enough to utilize all the milk the cows produce when the native grasses begin to grow in the spring. Calves were marketed in August to permit cows to regain thrift before winter.

The cattle were sprayed or dusted three or four times annually for control of external parasites. Calves were vaccinated for blackleg, and bull calves were castrated at no later than 3 months of age.

The ranges were on areas from which the old-growth longleaf pine had been cut some years previously and which were planted or seeded to slash pine (*Pinus elliottii* var. *elliottii*) over the period of the study. Areas to be regenerated were prescribe-burned in the year before pines were established. They were then protected from fire until the trees were 5 to 6 years old, after which they were burned on a 3-year rotation. Grazing was heaviest on newly burned areas, because fires remove dead plant material and stimulate new growth that is high in protein (Campbell et al., 1954). Thus rotational burns served in lieu of temporary fencing to control cattle distribution over the range.

Herbage yields throughout the study averaged nearly 2,000 lb./acre annually. Three stocking rates were tested: 26, 20, and 13 acres per cow. These rates were considered to represent light, moderate,

Fig. 1. *Brahman crossbreed cattle grazing a 2-year-old slash pine plantation in central Louisiana.*

and heavy grazing. Utilization averaged 35, 49, and 57%. Each herd was assigned to one range and to one grazing intensity throughout the decade of study. Although yearly fluctuations occurred, neither grazing intensity nor pine growth reduced herbage yields sufficiently to necessitate reductions in cattle numbers.

Since range forage is notably deficient in nutrients after the growing season ends, about 400 lb. of cottonseed cake (41% crude protein) was fed each cow during late fall, winter, and early spring (Duvall, 1969; Pearson and Whitaker, 1972). About 260 lb. of grass hay per cow was fed in late winter or on cold, rainy days. Steamed bonemeal and salt were provided free-choice all year; intakes averaged 17 and 21 lb., respectively.

Costs and Returns from Cattle

As land costs are logically charged to timber interests, this presentation considers mainly the direct expenses for grazing. These are designated investment and operational costs. Investments include fences, water supplies, corrals, animals, equipment, and supplies. Operational costs include such items as feed, rotation burning, and care of bulls.

The three ranges differed somewhat in size but approximated a section each. Since range area was fixed, herd size varied with stocking rate. All values given here have been adjusted for herds of a size to graze 640 acres at the specified intensities of use. Some costs varied with herd size and others were largely independent.

Investment Costs

At present, fence materials cost approximately $275 per mile. This sum allows for four strands of barbed wire with posts 40 feet apart and wire stays between all posts. Labor and equipment to build the fence cost approximately $150. If $25 is added for unexpected expenses, the total per mile is $450. Four miles of perimeter fence (enclosing one section) cost about $1,800 or $72, $56, and $37 per cow for light, moderate, and heavy grazing (Table 1).

Since the ranges initially included no watering facilities, ponds were installed at an approximate cost of $350 each, or $14, $11, and $8 per cow for light, moderate, and heavy use. Treated-board corrals, 6 feet high and with two or more working pens to handle a one- or two-bull herd, cost $350.

Though many of the cattle had been purchased for less, a value of $130 per head is realistic on today's market. Bulls cost about $450 apiece and served 25 to 30 cows, or $18 per cow regardless of grazing intensity.

Other investment expenses included feed troughs, storage sheds, veterinary supplies, and a vehicle charge. These outlays were estimated to be $23, $19, and $15 per cow for light, moderate, and heavy grazing intensities.

Depreciation on the initial investment (including replacement of fence posts and wire) was considered as maintenance and included under operational expenses.

Operational Costs

In forest grazing, much of the labor is part time; occasionally several men are needed, but on many days no work is required. Off-season and sparetime labor can be used efficiently. On the average, one man-month of labor is sufficient to maintain 25 cows for a year (Halls and Duvall, 1961). The operating expense of labor is not included in our tabulation but would vary with size of the herd. In 1961 Halls and Duvall estimated annual labor costs for a 25-cow herd at $13 per cow. On the Texas Experimental Ranch, estimated labor cost per cow was $11.25 (Kothmann et al., 1970)

Range supplements were the biggest operating expense, averaging $20.67 per cow annually, regardless of grazing intensity (Table 1).

Grazing fees ($1.20 per cow year) are omitted from the table, since they were not based on actual forage value.

Prescribed burning was considered to cost $0.99 per acre (Yoho et al., 1969). Since about half the expense was chargeable to tree growing, costs per cow approximated $3.47, $2.48, and $1.49 under the three grazing intensities. Costs of two forage surveys each year were estimated at $25 per survey or $2, $1.67, and $1.14 per cow.

A special pasture and additional supplemental feed were necessary for the bulls during nonbreeding periods. Costs to maintain and replace bulls approximated $4 per cow. Cows generally produce for 10 to 12 years. The difference between the selling price of a cow and the cost of her replacement was about $20, or $2 per cow when prorated over 10 years.

Miscellaneous operating costs included death losses, vehicle operation, taxes, and upkeep of fences, corrals, troughs, and equipment. The total for these items was $8.25 per cow.

Returns

Calf crops averaged 82, 73, and 70% with light, moderate, and heavy grazing. Corresponding 10-year average calf weights were 444, 419, and 421 lb. at 7 months. Gross annual returns per cow averaged $89.35 for light grazing, $74.57 for moderate grazing, and $72.20 per cow for heavy grazing (Table 1). The lower calf crops at the higher stocking rates probably reflected forage intakes. That is, the animals were evidently forced to eat less palatable and less nutritious forage.

Subtracting the operating expenses from the gross annual returns leaves $48.96 per cow for light grazing, $35.50 for moderate grazing, and $34.65 for heavy grazing—or 18, 14, and 16% net return on the initial investments, respectively. If the cost of labor is included in the operating expenses, an additional $13 per cow would be subtracted from the

Table 1. Investments, operating costs, and returns (dollars) per cow for cattle grazing forest range.

Item	Grazing intensity		
	Light	Moderate	Heavy
Investment			
Fencing	72.00	56.00	37.00
Water facilities	14.00	11.00	8.00
Corrals	14.00	11.00	8.00
Cow	130.00	130.00	130.00
Bull	18.00	18.00	18.00
Miscellaneous	23.00	19.00	15.00
Total	271.00	245.00	216.00
Operation (per year)			
Feed	20.67	20.67	20.67
Range burning	3.47	2.48	1.49
Forage survey	2.00	1.67	1.14
Care of bull	4.00	4.00	4.00
Cow replacement	2.00	2.00	2.00
Miscellaneous	8.25	8.25	8.25
Total	40.39	39.07	37.55
Returns (per year)			
Gross	89.35	74.57	72.20
Net	48.96	35.50	34.65

net return for light grazing, $11 for moderate grazing, and $9 for heavy grazing. Including labor, the returns on investment are 13, 10, and 12%, respectively.

Discussion

If the expense of labor is included, returns on the investment were 13, 10, and 12% for light, moderate, and heavy grazing. Still greater returns are possible. Certain per-head costs decrease in larger operations. For example, a storage shed serving 25 cows costs about $300, while a shed for twice this number would cost only $400. Labor costs can be lowered by increasing herd size and perhaps by use of liquid and range-block supplements.

If labor charges are excluded, net returns per acre of range were $1.88, $1.82, and $2.67 for the three grazing intensities. These values may be of interest to the landowner who is considering the lease of grazing rights. While leases are always a matter of negotiation in the light of local conditions, a fee equal to 10% of net returns per acre may not be unreasonable when herd and range are carefully managed.

The ranges in this study were almost fully productive throughout the decade. Now the tree crowns are beginning to close on some portions, and forage growth will diminish. Some increase will occur when the trees are thinned, perhaps at ages 15 to 18 years; but until the stands are harvested, forage will average perhaps half the present rate of 2,000 lb./acre. Consequently, cattle numbers must be decreased or additional acreage provided. Per-acre returns from cattle will decline accordingly.

Still under the proviso of careful management, heavy grazing yields highest returns per acre of range and does not damage timber unduly. For reasons not entirely clear, the heavy-grazing herd in the present study had the poorest calf crops and lighter calves at market time. Perhaps increased supplementation or rearrangement of the feeding schedule would have increased beef production.

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Evaluating Zones of Utilization

E. WILLIAM ANDERSON AND WILBUR F. CURRIER

Highlight: *A method of checking utilization has been devised and tested on public and private rangelands. It involves mapping and evaluating zones of utilization within a pasture or grazing unit. It presents guidelines for determining how grazing resources are being used and what needs to be done to improve efficiency: identifying areas that need special attention, analyzing economic aspects, adjusting livestock numbers, and recording progress over a period of years. The procedure is relatively simple, inexpensive, meaningful, and easily used by resource managers on horseback, in a jeep or helicopter, or afoot. It requires only the usual equipment found on a ranch.*

Grazing distribution problems within range pastures or grazing units are common. They are caused by such factors as topography, location of fences and salt, distances between watering places, grazing system used, kinds of grazing animals, weather, and shade location (Williams, 1954). In addition, range pastures often include variable combinations of range sites and plant communities on which utilization is seldom uniform. Zones of utilization, herein called use zones, usually result where such factors either concentrate or restrict grazing. As a result, forage on some areas within the pasture may remain unused, while at the same time, other areas are abused. Resolving these situations by corrective management is what practical range management is all about.

The process of investigating and evaluating the pattern and degree of grazing use within a range pasture is known as a management check. Timely management checks, including those made to check progress during the grazing season, provide guidelines for determining needed adjustments and additional treatments. Periodic management checks should be an integral part of each grazing system. They provide an easy measure of accomplishment and are especially useful if done in successive years. The rancher or resource user should participate because he is the key person in respect to private resources and can be deeply concerned with public resources.

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The authors are grateful for the collaboration of many co-workers and ranchers and the encouragement to present this procedure for widespread consideration. Special acknowledgement is given Waldo R. Frandsen, regional range conservationist (retired), Soil Conservation Service, U. S. Dep. of Agr., Portland, Ore., for his significant role in developing, testing, and applying this procedure in various parts of the West.

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The purpose of this paper is to present a procedure for making and using a management check of a range pasture under practical operating conditions. The procedure involves judging classes of utilization on key species, mapping use zones within a pasture, and evaluating these zones and other data to determine the effects that the current grazing system and existing facilities and improvements collectively are having on the resources within the pasture.

Review of Literature

Utilization checks have long been a standard procedure in range management. Many of the methods for doing this are better adapted to collection of research data by scientists than to use by practicing resource managers. Studies of utilization have dealt primarily with detailed techniques of sampling, measuring, and estimating. Emphasis has been placed on accuracy of data and reliability of sampling. In most studies, the degree of utilization has been expressed in terms of percentage of total herbage that has been removed. Only in a few recent instances have reports mentioned mapping and analysis of use zones within a pasture.

Thorough reviews of range utilization studies have been made by Heady (1949) and Hedrick (1958). They include excellent lists of references not duplicated in this paper except for specific citation.

Campbell (1937) noted the need for something besides an acceptable measurement of forage utilization. He emphasized that the real problem was one of interpreting these measurements. Deming (1939) proposed nine classes of utilization and a system for recording on a map certain spot locations that had been observed. His method is probably the earliest recorded basis for further development of the use-zone concept. Pechanec and Stewart (1949) proposed observation of key areas within a grazing unit where examination of the whole range was not feasible. This is currently accepted as being appropriate if range management is not intensive enough to warrant an overall appraisal.

Humphrey (1949) preliminarily reported on the use-zone concept during its early developmental stages. He digressed into the use of flexible proper-use factors for each key species according to range condition class. This was not widely accepted because of problems inherent in proper-use factors. Hickey and Garcia (1964) mapped use zones to illustrate changes that take place in the grazing pattern when pastures are grazed by different classes of livestock. They interpreted the varying zones as presenting a problem of variable grazing patterns. They did not interpret these zones, however, as guidelines to corrective management. Kingery (1963) reported on mapping classes of utilization according to existing range site and condition class delineations and indicated that such reports were helpful in making management adjustments. Smith (1967) mapped use zones representing grazing patterns in relation to vegetational types. He thoroughly discussed the problems associated with use zones although he did not interpret these zones as presenting solutions to the corrective management needed. Anderson (1967) presented a 5-year case history (1949 through 1953) of how mapped use zones and their interpretation were used to improve grazing efficiency through additional improvements and corrective management in a planned grazing system. Reynolds and Martin (1968) mapped use zones within a pasture and interpreted them as presenting solutions to problems of grazing distribution that include additional water and salt locations, fencing, and supplemental feeding.

Chronologically, these reports represent a growing awareness of the importance for periodically mapping zones of utilization within a range pasture and interpreting them to solve problems of grazing distribution. As range management becomes more intensified, there will probably be a greater need for this technique in respect to alternative solutions for obtaining planned use of the total resource.

Use Classes

Number of Classes

Deming used nine classes; others used seven. Experience has proven this to be too many for practical range management because observers spend too much time trying to decide which class applies. A minimum of three classes should be used as they present the fewest, but not necessarily the easiest, choices.

Five classes are preferred by the authors for most situations. After the central class representing safe use and the two extremes representing no use and severe use are defined, the remaining two classes are "in-betweens." They provide an opportunity to rate situations that do not qualify for one of the three basic classes. Because of this feature, five classes seem to present the easiest choices to make except for those people who are "splitters."

Names of Classes

Some thought should be given to naming of classes. For example, the name "proper" has been used widely for the central use class. This name has weaknesses that are worth considering because, if range is not used to a "proper" degree, it must therefore be used improperly. Heavy grazing may be entirely proper, biologically, under certain circumstances such as when a deliberate attempt is being made to clean up old weathered growth accumulated during a previous period of nonuse or deferment. Heavy grazing for a short period of time also might be economically proper under certain circumstances. Of course, repeated or prolonged abuse of the resource would not be proper, safe, or judicious. On the other hand, too little use might be just as improper as is severe use.

A better name for the central class is SAFE. Any other class, therefore, could be relatively unsafe economically, biologically, or both.

Five classes of utilization are recommended. Preferred names of these classes are NONE, LIGHT, SAFE, HEAVY, and SEVERE. Names of classes, however, are not as important as what they represent.

Description of Classes

If use zones are to be mapped within a range pasture, the differentiating characteristic for classes should be the degree of use on key forage species.

Key forage species vary according to range site and ecological condition of the plant community, kind of grazing animal, season of use, and management objectives. Safe degree of use for a key species also can vary. For example, when cattle graze a range during the growing season on which bluebunch wheatgrass (*Agropyron spicatum* Pursh.) is the key forage species, 4 to 6 inches of foliage, or about 35% to 65% of the current year's growth, should be left on this species toward the end of the growing season. This provides for sufficient green leafage to maintain root and shoot growth during the remainder of the growing season. If this key species is allowed to mature before grazing takes place, maintaining root and shoot growth is not involved. Then only about 3 to 4 inches of foliage needs to be left because this amount provides sufficient litter and stubble to reduce evaporation, protect growth buds, catch snow moisture, protect the plant crowns from freezing, and retard erosion and frost heaving (Anderson, 1969). The size of the plant canopy, however, influences the depth to which moisture penetrates (Ndawula-Senyimba et al., 1971). In dry climate areas this factor should be given special consideration in determining the amount of stubble to be left.

On some kinds of range, the total herbage produced consists of a wide variety of species having approximately equal forage value for the kinds of grazing animals and season of use involved. Under these conditions, the significance of key forage species is reduced and it is practical to judge degree of utilization on the basis of a mass of vegetation rather than of a key species. For example, safe degree of use of some kinds of mountain meadow sites can be represented by an average 3- to 4-inch stubble on the portion of the plant community that produces the bulk of the forage.

Use-class descriptions also should contain brief accessory characteristics that help in the decision-making process of selecting the appropriate use class. The following illustration represents the kind of descriptions that have been used successfully for rangeland and grazed forest sites by the authors:

Use class	Degree of use	Description
None	0–15%	Very little or no use of key forage plants.
Light	16–35%	Key forage plants lightly to moderately used. Practically no use of low-value forage plants.
Safe	36–65%	Key forage plants used about right for the season of grazing and sites involved. Some use of low-value forage plants.
Heavy	66–80%	Key forage plants closely cropped. Low-value forage plants generally being grazed. Trampling damage may be evident.
Severe	Over 80%	Key forage plants grubbed. Low-value forage plants carrying the grazing load and closely cropped. Trampling damage may be evident.

Judging Degree of Utilization

The first step in judging degree of utilization is to decide which is the key species for the range site and ecological condition involved, kind of grazing animals, season of use, and management objectives. The second step is to decide what is the safe percentage of herbage that can be removed and thereby the desirable amount of stubble to be left on the key species in order to most nearly achieve the management objectives. Clipping several ungrazed plants of key species to simulate SAFE use establishes what safe degree of use looks like. The third step is to clip plants of key species to represent and demonstrate what SEVERE use looks like. The amount of grazing allowable in the NONE class is then established in a similar manner to complete the standards for the three major use classes. As previously stated, the other two classes are "in-betweens" for which standards need not be developed.

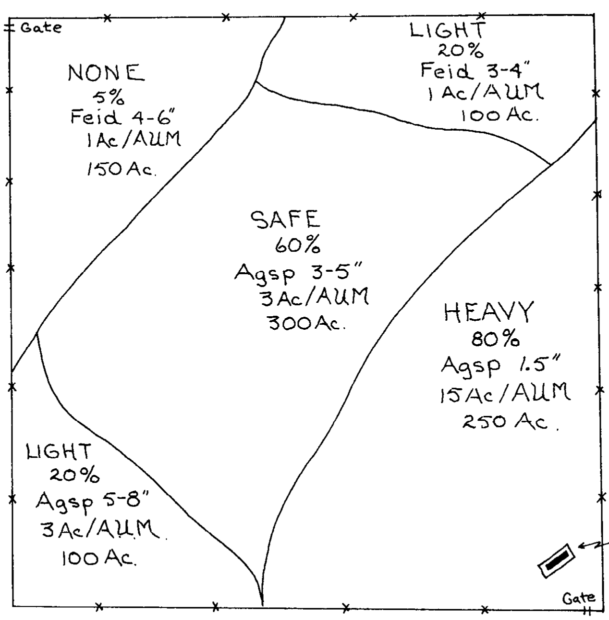
If naturally ungrazed areas on which to establish a visual yardstick for judging use in terms of stubble-left are not likely to be available, ungrazed check areas can be created by erecting wire cages prior to the grazing season.

A grazed range usually looks ragged because of varying degrees of utilization on portions of a single plant and from plant to plant. As a procedure, estimating average stubble-left for an area does not stress accuracy because it is not needed for this type of field procedure; consistency of judgment is more important.

Mapping Use Zones

The best kind of base on which to map use zones is a clear aerial photo map showing range sites or vegetational types and physical features such as fences, water, and roads. Other kinds of maps, including roughly sketched maps, can be used (Fig. 1). The mapping procedure involves traversing the range pasture with sufficient coverage to obtain a general concept of how the key species have been utilized and the pattern of this utilization. Since features such as topography, rockiness, range sites, vegetational types, and distance from water affect grazing patterns, these features also are helpful in denoting the extent of use zones and mapping their boundaries.

The mapping of use zones usually begins at the entrance to the range pasture. The first step is to record on the map the name of the use class applicable to that location. Other information that should be recorded for each mapped use zone while it is being traversed includes name(s) or symbol(s) of the key species, average stubble left, and average percentage of utilization. It is also important to record for each mapped use zone the estimated initial stocking rate expressed in acres per animal unit month (AUM).



LEGEND: SAFE – Use class
60% – % use of key species
Agsp 3-5" – Key species – stubble left
3 Ac/AUM – Estimated initial stocking rate for use zone
300 Ac – Size of use zone

Fig. 1. *Sketch map of a 1,000-acre pasture illustrating a typical pattern of utilization as represented by use zones and data recorded during the management check.*

Mapping proceeds as the pasture is traversed. When another use zone is observed, the name of the new use class and approximate boundary of the zone is recorded on the map together with the other information. Further traversing extends boundaries of use zones until the entire pasture has been completed at which time the approximate number of acres within each use zone is recorded on the map as illustrated in Figure 1.

In some situations of intensive management or public land administration, it may be desirable to be more explicit about the degree of utilization than is represented by a broad use class. Such information may be needed for making important management decisions such as stocking adjustments because, for example, there is significant difference between 35% and 55% utilization, both of which may be grouped in the same use class. In such situations, mapped zones representing relatively narrow increments of percent utilization, within practical limits, will portray an intensive pattern of grazing on the map. Such narrowly defined zones then can be grouped according to the five use classes for evaluation purposes.

Timeliness

Periodic management checks, without mapped zones, made while "riding" during the grazing period are beneficial for observing use zones as they develop. These observations provide for adjusting livestock distribution at an early stage so as to reduce development of excessively used and unused areas.

Management checks in which use zones are mapped should be made at or near the end of the grazing period. An exception is made if the grazing period coincides with early stages of forage growth such as occurs in a turn-in pasture. In this situation, the management check should be made at the end of the primary growing season for key forage species. This is because only a portion of the total forage crop exists during the early-growth period. The amount of herbage remaining after early grazing can be compared with ungrazed production only after the primary growing season has ended. At this time, regrowth on grazed plants can be compared with ungrazed plants.

Data Analysis

Figure 2 illustrates a data sheet used in conjunction with the use-zone map to provide a basis for evaluating the situation and formulating plans to install needed facilities and corrective management.

As illustrated, a serious problem of grazing distribution exists within this pasture even though the actual grazing use was only 68% of the estimated amount available (276 AUMs used, 405 available). About 25% of the available forage in this pasture received SAFE use, and this use zone represents 30% of the pasture area. Of the available forage, 37% essentially was unused (NONE zone), and this represents only 15% of the acres in the pasture. Grazing was lighter than SAFE on 70% of the forage crop, and this represents 35% of the pasture area. Although 35% of the pasture area was grazed more closely than SAFE, these acres produced only 5% of the forage crop.

Efficiency of grazing use of the forage in this pasture at the time of the management check is 25%, which is the proportion of the total available forage that was grazed to a SAFE degree. To improve grazing efficiency, highest priority should be given to increasing grazing use of the forage being wasted (NONE zone) and reducing grazing use on forage being destroyed (SEVERE zone). Significant problems also exist in the LIGHT and HEAVY zone, and these should not be neglected. A near-perfect grazing efficiency usually is impractical for most range pastures. It can be achieved, however, under conditions of level topography, uniform plant community, adequate and well-distributed water, and relatively small-sized pastures. Based on judgment and taking into account a feasible water development in the NONE zone, the potential grazing efficiency for this pasture was estimated to be 85%, or 345 AUMs of grazing, which establishes a goal.

It is important to note that analysis of the management check emphasizes the proportion of total available forage in AUMs, rather than acres, in each use class. Available forage is the logical basis on which to make decisions involving investments and corrective management if cost-return aspects are important to the decision-making process. This is because forage can be transformed into marketable products useful to humans, and in this way used to offset investments and expenses. Acres are important, however, for expressing the extent of a problem and judging potential improvement area by area.

Economic Aspects

Evaluation of a management check involves making decisions on needed improvements and on corrective management. The management check is useful for predicting benefits accruing from investments as illustrated by the following simple hypothesis.

Assume that it is practical to pipe water into the NONE use zone, which produces 150 AUMs of forage not now being

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US DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
OREGON

GUIDE FOR DETERMINING DEGREE OF RANGE USE

USE CLASS DESCRIPTIONS

NONE	Very little or no use
LIGHT	Key forage plants lightly to moderately used. Practically no use of low-value forage plants.
SAFE	Key forage plants used about right for the season of grazing and the sites covered. Some use of low-value forage plants.
HEAVY	Key forage plants closely cropped. Low-value forage plants generally being grazed. Trampling damage may be evident.
SEVERE	Key forage plants grubbed. Low-value forage plants carrying the grazing load and closely grazed.

PASTURE RATING

USE CLASS	APPROXIMATE ACRES IN EACH USE CLASS	APPROXIMATE ACRES PER AUM IN EACH USE CLASS	APPROXIMATE AUM's IN EACH USE CLASS	APPROXIMATE % FORAGE SUPPLY IN PASTURE	APPARENT REASONS FOR USE-PATTERN PROBLEMS WITHIN THIS PASTURE.	MANAGEMENT ADJUSTMENTS PLANNED SO AS TO IMPROVE THE GRAZING EFFICIENCY
NONE	150	1	150	37%	No water No salt	Pipe water to area.
LIGHT	100 100 200	3 1	33 100 133	33%	No salt Area is sloping-cattle prefer Rolling Hills Too far from water	Salt in these areas
SAFE	300	3	100	25%	NO PROBLEMS	NONE NEEDED
HEAVY	250	15	17	4%	Close to water Only salt in pasture is here	Do not salt here Move stock to less-used areas by frequent riding.
SEVERE	100	20	5	1%	Only water in pasture is here.	Adopt grazing system to defer pasture 1 in 3 years and Change season of use.
TOTALS	1,000	XXX	405	100 %		

PRESENT GRAZING EFFICIENCY OF FORAGE SUPPLY WITHIN THIS PASTURE IS 25 %
Estimated potential grazing efficiency for this pasture is 85 %

GRAZING RECORD FOR THIS PASTURE: (includes game use if known and applicable)

No. and Class of Stock	An. Units	Dates Used	AUMs
216 cows w calves	216	May 15 – June 21	270
Approx 25-30 deer	6	Feb 15 – Mar 15 during first green feed	6
			276

GROWING SEASON CONDITIONS THIS YEAR: Above average ____ : Average X : Below average ____

REMARKS:

PASTURE RATING MADE BY: Pete + Roy Jones – B. Anderson-B. Currier DATE: 6/23/71 RANCH: JONES & SON PASTURE: Square

Record plants used in judging degree of range use on reverse side of this sheet.

Fig. 2. *Data sheet used in conjunction with use-zone map.*

used. This water development probably would also help increase the grazing in the LIGHT zone. With proper stocking, salting, and some riding, the grazing pressure probably could be decreased in HEAVY and SEVERE zones, which could eventually improve ecological condition, plant vigor, and watershed quality, as well as production. If 85% potential grazing efficiency were attainable through a combination of water development and other measures, based on the estimated existing available forage, there would be about 345 AUMs of grazing available, or about 25% more than is currently being used. Additional forage resulting from improved condition and vigor over a period of years would further enhance the long-time feasibility of investment.

Additional AUMs attained by increasing grazing efficiency within this pasture have an annual value to this cattle ranch that can be compared with annual costs of increasing the efficiency. A common way of arriving at this value is to assign a market value per AUM. A better way of assessing this value is by using a "multiple-effect" approach, analyzing the various impacts that a 25% increase in AUMs could have on the entire ranching operation (Anderson and Jernstedt, 1971). For example, additional AUMs and better grazing efficiency in this one grazing unit could contribute to an increased calf crop, increased weight of market animals, and reduced cow-cost for the entire ranch. This would be accomplished because additional AUMs provide the opportunity and flexibility needed for adjusting management and improving other areas of the ranching operation. As similar measures for improved grazing efficiency are applied progressively over the entire ranching operation, this could also result in a significant increase in cow numbers. The incentive to develop a total-resource program coordinating both public and private lands in the ranching operation appears to be great. The probability of achieving improved ecological condition, watershed quality, and wildlife habitat concurrent with benefits to the livestock enterprise is good.

Adjusting Livestock Numbers

The foregoing discussion of economic aspects assumes that something constructive will be done to improve grazing efficiency. There are occasions, however, when decisionmakers decide to do nothing in spite of seemingly obvious economic or resource benefits. In this setting, the management check provides a guideline to the public resource manager for adjusting livestock numbers or length of grazing period to be compatible with resource management objectives.

For example, assume that the sample pasture is on public land. The management check shows 150 AUMs of available forage not now being used. If current management continues, this forage should be considered as unavailable. The available forage for this grazing unit becomes 255 AUMs, not 405. The proportion of available forage now in each use class is: LIGHT, 52%; SAFE, 39%; HEAVY, 7%; SEVERE, 2%. If 85% grazing efficiency on the grazable portion of the pasture is an acceptable goal, there are about 217 AUMs of grazing available, or about 21% less than currently being taken. A reduction of livestock numbers or shorter grazing period is involved. Since the estimated initial stocking (217 AUMs) is merely a starting point from which to judge the effects of management on the resource, future additional reductions likely will be required in order to attain acceptable grazing on HEAVY and SEVERE zones. These two zones often represent areas of natural concentration that will continue to be grazed heavily under a continuation of the present kind of management even though livestock numbers are reduced. Obviously, a do-nothing approach is not prudent and only prolongs the eventual mandate to manage the public resource efficiently, which will be imposed with public insistence.

List the plants on which degree of use was judged for each different major range site within this pasture. For each plant, show the average degree of use (in percent) that occured within each applicable use-class. This information helps clarify how grazing may vary according to range site, season of use, class and kind of stock, weather, etc. It emphasizes the importance of KEY FORAGE PLANTS in range management.

AVERAGE % OF THIS YEARS GROWTH HARVESTED FROM KEY FORAGE PLANTS IN EACH USE CLASS

Forage plants used in rating each use class:	NONE	LIGHT	SAFE	HEAVY	SEVERE
SITE: Rolling Hills					
Squirreltail	%	%	5%	20%	80%
Bluebunch wheatgrass	%	%	60%	80%	— %
Idaho fescue	%	%	40%	— %	— %
	%	%	%	%	%
SITE: South Exposure					
Bluebunch wheatgrass	%	20 %	%	%	%
Thurber needlegrass	%	10%	%	%	%
	%	%	%	%	%
	%	%	%	%	%
SITE: North Exposure					
Idaho fescue	5 %	20%	%	%	%
Bluebunch wheatgrass	0 %	5%	%	%	%
	%	%	%	%	%
	%	%	%	%	%
SITE:					
	%	%	%	%	%
	%	%	%	%	%
	%	%	%	%	%

Fig. 3. *Reverse side of data sheet used for collecting information on utilization of forage species.*

Recording Species Utilization

Figure 3 illustrates the reverse side of the data sheet used in conjunction with the map. Observations on degree of utilization for major forage species in the plant community of each range site can be collected in this manner, usually by specialists. Such information is valuable for improving guidelines for judging grazing use on range sites.

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Recreation Potential of Texas Rangelands

MICHAEL E. BERGER

Highlight: *The uniqueness of the land ownership system in Texas is largely responsible for the development of recreation opportunities on private lands in that state. It appears that rangelands, in the traditional sense, are suited to a few specialized recreational uses, hunting probably being the most widely accepted and traditional. Any or a combination of hunting arrangements may be economically profitable for private landowners. The recreation potential of private rangelands awaits development.*

Perhaps the title of this paper should have been "Recreation Potential of *Private* Rangelands in Texas," since in fact a very large percentage of Texas rangelands are privately owned. The uniqueness of the land ownership system in Texas, which few landowners realize, is largely responsible for the development of recreation opportunities on private lands in Texas. The scarcity and overcrowding of federal and state owned lands available for outdoor recreation has created a demand for opportunities to be made available on private lands. This demand probably also exists in states other than Texas. The activities presently available are limited in availability and variety. The growing demand is presently unmet; there is room for expansion and improvement. Private landowners in Texas and elsewhere are failing to collect the extra income available through their lands. Landowners in many states are presently opening their private lands to public recreation use. While in theory this is commendable and should be encouraged, in fact many landowners incur an economic liability due to such activity. If the range resource is properly controlled and managed, it is possible to convert the present liability into economic asset. The Texas story may help to generate some ideas.

In pristine times, the rangelands of Texas were occupied only by native wildlife. The ecosystem was in balance: the range was not overpopulated and periodic natural fires kept brush from encroaching heavily. When man appeared on the scene, he probably set more fires to aid him in his hunting. The increased number of fires probably increased the extent of the rangeland and did little to detract from its quality. Early man had no domestic livestock and took relatively small numbers of native wildlife so that the system remained balanced.

The records of early Spanish missions indicate that an excellent grass cover existed: grass height varied from a foot to high enough to hide horses and sometimes even wagons (Leinweber, 1967). With the arrival of white men and their domestic animals, the bison, deer, antelope, and other wildlife were slowly replaced by cattle, sheep, and goats. The reintroduction of the horse greatly increased the efficiency of the hunting Indians and further reduced the numbers of wild herbivores. Although a few scattered Indian tribes cultivated the land on a small scale, organized agriculture was not prominent until the arrival of the Spaniards.

Following the Civil War, the use of barbed wire and windmills became more widespread, thus restricting the movements of wild animals and concentrating domestic livestock on certain areas. The result of all this was a general deterioration of the condition of the range. With the cessation of fire came the encroachment of brush, further deteriorating the quality of the rangelands. Where rangelands became too depleted for cattle, sheep and goats were introduced, bringing range condition to a new low in many areas.

Until the mid-1930's the range remained in pitifully poor condition. Improved understanding of range management principles began to bring about improvement in range conditions. Cattle, sheep and goats are now stocked side-by-side to bring about more efficient utilization of forage. However in an environment of rising taxes and land values, and decreasing and unstable prices paid for meat, wool and mohair, many ranchmen are looking for opportunities to earn additional income (Boykin and Forrest, 1971).

The first organized group of people to recognize the additional income potential of Texas rangelands was a group of about 60 individuals who organized, in 1941, the Edwards Plateau Game and Wildlife

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Management Association (Quinn, 1969). The first recreational leasing arrangements were probably made between a hunter or group of hunters and a landowner. The fee accepted for such a lease was probably a .30-30 carbine or some other equally desirable token (Teer and Forrest, 1968). From this small beginning the leasing of lands for recreational purposes has grown to the point where in Texas today net income realized from deer leases and other rangeland recreational uses exceeds net income from all other classes of livestock in many areas (Stribling, 1972).

Most public land management agencies now recognize recreation as a resource use equal to grazing, timber, water, and wildlife in importance. It is important that private landowners and managers realize the value and potential of their lands as recreational resources, especially in Texas where over 95% of lands are privately owned. Certainly hunting is not the only recreational use of Texas rangelands. Dude ranching, camping, and second or vacation home development are just a few of the more important alternative uses of rangelands. These uses are consumptive or competitive in nature and virtually remove rangeland from "more productive" uses. Hunting, fishing, and nature photography are highly productive recreational pursuits which may be conducted compatibly with grazing.

Rangeland recreational uses other than hunting may not be desirable or financially feasible at the present time according to the four postulates set forth by Gunn (1972). He states that:

1. Tourism-recreation flow and activity depend upon *attractions*;
2. Trends are toward *large complexes* of attraction clusters;
3. All attractions are related to and need the support of *transportation* and *cities*;
4. Mass recreation is heavily influenced by *distance* from origin.

If each of these postulates are examined separately, it becomes apparent that rangelands, in the traditional sense, are suited to a few specialized recreational uses. The attractions are usually based upon some type of development. Rangelands lacking large and costly developments have little attraction for most recreationists. Large complexes of recreational opportunities must be available in order to draw large numbers of participants. These large attraction complexes must be located reasonably close to large cities and accessible by modern means of transportation. Most rangeland resources in Texas do not meet these criteria at the present time. Thus the postulates appear to apply only to intensive tourism-recreation activities. And if, in fact, rangelands do not meet these criteria, it may well be that the criteria simply do not apply to rangeland recreational activities, which are usually extensive in nature.

Hunters appear to be a specific population who are little influenced by the postulates and criteria. To participate in their preferred form of outdoor recreation, they are willing to travel great distances, often on poorly maintained roads, to areas with no large recreation complexes and no apparent attraction at all for most people. In fact if job descriptions were written for most types of hunting, the applicants for these positions would be few indeed.

Hunting is probably rangeland's most widely accepted and traditional recreational use. It brings varying degrees of satisfaction to participants and varying levels of economic benefit to private landowners. Day hunting is probably the most flexible system used in the state and has the most potential for maximizing returns to the landowner, even though it demands more labor and investment than other arrangements (Forrest, 1968). With proper control and good judgment by the landowner, it provides the best harvest of game animals. It is easily adaptable to large and small game as well as game birds.

Season leases are better suited to ranches where labor, size, or investment potential is limited. In most instances it causes a low harvest rate, which in turn causes deer herds to increase to the point of serious competition with domestic livestock (Forrest, 1968). This usually results in depletion of forage and deterioration of the range.

Another hunting system which has become relatively popular and widespread in the last 20 years is the hunting of exotic animals for a specific fee per animal harvested. Since exotics are legally classified as livestock and because they have horns, which are not shed annually like antlers, they may be hunted on a year-round basis. This does not limit the rancher's hunting income to the traditional 45- or 50-day fall hunting season. The rearing of a trophy exotic animal may take 3 to 7 years or longer, thus the landowner must charge \$125-\$600 for the killing of a single mature ram or buck. Also, because exotics are classed as livestock, the females and non-trophy males may be sold as brood stock to other ranchers entering the commercial game harvest business.

Other leasing arrangements utilizing advantages of several systems may be incorporated to yield proper game harvests and maximum return per input investment while maintaining or improving range condition. The initiation of such game harvest systems may be a real source of income for landowners, even in states with relatively short hunting seasons such as South Dakota (Gartner and Severson, 1972).

While it is impossible to predict with 100% accuracy the recreation future of Texas rangelands, it is not so difficult to see that until the criteria set forth by Gunn are met, the nature of rangeland recreation will not change appreciably. More and more ranches will surely continue to develop and expand the hunting opportunity. This is true for other game animals as well as deer. "It does appear that more and more lands and developed facilities will be needed in the coming years" (Gunn, 1972). The degree of impact of this need cannot be predicted, but the impact will surely be great, especially in a state where 97% of the land is privately owned. The potential is there, awaiting development.

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Salt and Meal-Salt Help Distribute Cattle Use on Semidesert Range

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Highlight: *Cows on semidesert grass-shrub range ate less than ½ lb/day of 3:1 meal-salt mix when it was fed 1 to 2½ miles from water. No injury to cattle due to either inadequate or excessive salt intake was observed. Compared to feeding at water, placing salt or meal-salt 1 to 2½ miles from water increased average utilization of perennial grasses where use was usually light, but it did not materially decrease use near water.*

Forage is rarely used uniformly and properly because cattle usually go no farther than they must to get their fill, and they prefer flat, soft ground to steep, rocky terrain. They have definite preferences among forage species, and will regraze their favorite plants repeatedly rather than consume less palatable herbage that is more abundant.

Range managers have used fencing, water, and trail development, complex grazing rotations, and other tools to distribute cattle more evenly over the range. Placing salt where heavier use is desired is one of the easiest and cheapest methods of improving livestock distribution–if it works. The successes obtained by this method, however, have been mixed.

Chapline and Talbot (1926) reported that salt could be an economical aid in the local distribution of cattle. Ares (1936) found that feeding salt away from water reduced the length of time cattle hung around water, increased the area of the range receiving proper use, and decreased the percentages of heavy and light use on level rock-free range in southern New Mexico. Feeding meal-salt mix away from water only, likewise resulted in a larger properly used area and smaller areas of heavy and light use than did feeding meal-salt both at water and away (Ares, 1953). Skovlin (1965), in Oregon, found that cattle required little salt above that in forage to meet minimum nutritional needs, but that their appetite for salt compelled them to use it. Cattle took salt daily in the summer and every 2 to 3 days in cooler seasons. Cattle generally took salt during their grazing period and did not go directly from salt to water. Bentley (1941) placed salt 3/4 mile from water on California bunchgrass range and observed that cattle averaged more than 7 hr between salt and water. Ares (1936) observed that when salt was fed away from water, cattle licked salt then left to graze in a direction opposite from water. On the Santa Rita Experimental Range, with salt placed at water, Culley (1938) and Zemo and Klemmedson (1970) found that cattle usually visited the salt block after drinking, then went to graze. These results indicate that placing salt away from water does not hurt cattle either by depriving them of adequate salt or by making them thirsty.

It is common practice to limit consumption of protein supplements on the range by including one part salt to about three parts supplement. When fed at water on a free-use basis, meal-salt mixtures usually are consumed at a rate of about 2 lb./day per animal. A recommended precaution in use of meal-salt mixtures is that cattle should have adequate water (Cardon et. al., 1951). Cattlemen have been reluctant to place meal-salt mixtures away from water because cattle can get sick or die if they do not get water soon enough after eating large amounts of mixture. When 80% meal-salt mix was fed 1/2 to 3 miles from water in southern New Mexico, however, yearling cattle ate not more than 1/2 lb. of the mixture per day and exhibited no ill effects (Ares, 1953).

This study was undertaken to determine (1) whether salt or meal-salt mixtures were effective in improving distribution of grazing use, and (2) whether livestock were affected detrimentally by placing either salt or meal-salt at remote locations on semidesert range. Topography, rainfall, and vegetation at these remote locations were substantially different from those of earlier studies.

Study Area and Methods

The study was conducted in pasture 15 on the Santa Rita Experimental Range near Tucson, Ariz. The pasture is served by one permanent water; the greatest distance from water to forage is about 3 miles. Continuous year-long grazing since 1930 has reduced the stand of perennial grasses and increased the abundance of annuals near water (Fig. 1). The range is mostly flat to gently sloping, but a number of shallow, steepsided canyons and water courses interfere with livestock movements.

The bulk of the study area lies between 3,200 and 3,800 ft elevation. Average annual precipitation is from 13 to 15 inches, with 7 to 8 inches falling during the summer growing period. Effective rainfall from April to June is rare, and May and June are especially hot and

Table 1. Schedule for placement of salt and meal-salt.

Schedule	Station	Distance from water (miles)	Item fed	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1	S1	0	Salt	X	X	X	X	X	X	X	X	X	X	X	X
2	S2, S3	1 to 1½	Salt	X	X	X							X	X	X
	S4, S5	1½ to 2½	Salt	X	X	X	X	X	X	X	X	X	X	X	X
3	S1	0	Salt	X	X	X	X	X	X	X	X	X	X	X	X
		0	Meal-Salt				X	X	X	X	X		X		
4	S2, S3	1 to 1½	Salt	X	X	X							X	X	X
		1 to 1½	Meal-Salt										X	X	X
	S4, S5	1½ to 2½	Salt	X	X	X	X	X	X	X	X	X			
		1½ to 2½	Meal-Salt				X	X	X	X	X	X			

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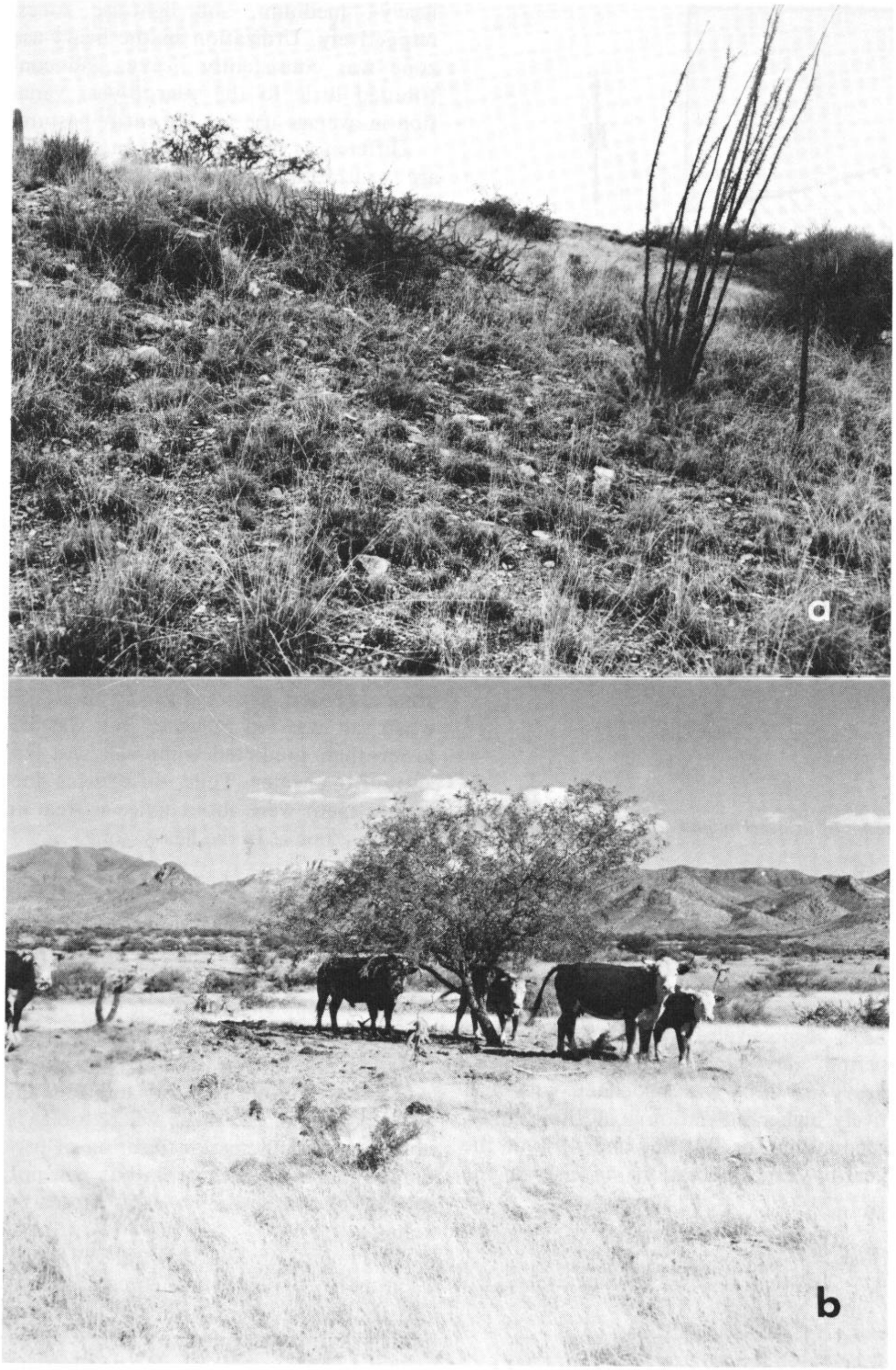

Fig. 1. *Past grazing has changed the vegetation. Long-lived perennial grasses dominate lightly used range far from water (a), but have been replaced by short-lived perennials and annuals near water where use is always heavy (b).*

dry.

Vegetation is a desert-shrub type dominated by a sparse stand of velvet mesquite (*Prosopis juliflora* var. *velutina*). Other important shrubs include catclaw acacia (*Acacia greggi*), white-thorn (*A. constricta*), burroweed (*Aplopappus tenuisectus*), blue palo-verde (*Cercidium floridum*), desert zinnia (*Zinnia pumila*), pricklypear (*Opuntia engelmannii*), and jumping cholla (*O. fulgida*).

Important perennial grasses include the tall threeawns (mainly *Aristida hamulosa* and *A. ternipes*), Santa Rita threeawn (*A. glabrata*), black grama (*Bouteloua eriopoda*), slender grama (*B. filiformis*), Rothrock grama (*B. rothrockii*), Arizona cottontop (*Trichachne californica*), tanglehead (*Heteropogon contortus*), and spike dropseed (*Sporobolus contractus*).

Major annual grasses are six-weeks threeawn (*A. adscensionis*) and needle grama (*B. aristidoides*).

Four schedules of feeding salt or salt in combination with 3:1 meal-salt mixture (3 parts cottonseed meal - 1 part salt) were used. These were: (1) block salt at water yearlong, (2) block salt away from water yearlong, (3) block salt at water yearlong with meal-salt added November–April, (4) block salt away from water year-long with meal-salt added October–June. The treatment year was July 1 through June 30. Each schedule was used for 1 year during the first 4 years of the study period, and again in the second 4-year period. Meal-salt troughs were refilled weekly. Block salt was always available where meal-salt was fed. Salt served as a standby attractant for cattle when the meal-salt mixture ran out between feeding dates.

Meal-salt was not fed July–September because supplemental feed is rarely needed or used during this period. Meal-salt feeding began 1 month earlier and ended 2 months later when placed away from water than when placed at water. This longer feeding period was used to maximize the effects of placing meal-salt away from water. Feeding meal-salt at water November–April conforms more nearly to common practice in which feeding rarely starts before December and is stopped as soon as spring growth of herbage or browse is available.

Five salt, meal-salt stations were established (Fig. 2). Station S1 was at the water. Intermediate stations (S2 and S3) were 1 to 1-1/2 miles from water. Far-out stations (S4 and S5) were 1-1/2 to 2-1/2 miles from water in areas used least frequently by cattle. These far-out stations were supplied, as scheduled, with salt or meal-salt October–March or with salt only July–September. Placement of salt and meal-salt under each schedule is indicated in Table 1.

Twenty-seven 1/4-mile-long paced transect courses were established. Transects were oriented at right angles to the direction to water. Utilization of each major perennial grass species was estimated by the ungrazed plant method (Roach, 1950); herbage production was estimated ocularly on ten, 1.0- by 9.6-ft plots equally spaced along the 1/4-mile transects. One or two herbage plots per transect were clipped to provide regression data for adjusting ocular estimates and to provide samples for dry-weight determinations. Utilization was measured three times a year around October 1, April 1, and June 1. Herbage production was estimated around October 1.

At the end of the 8-year period, the transects were ranked in order of average utilization in June. The area containing

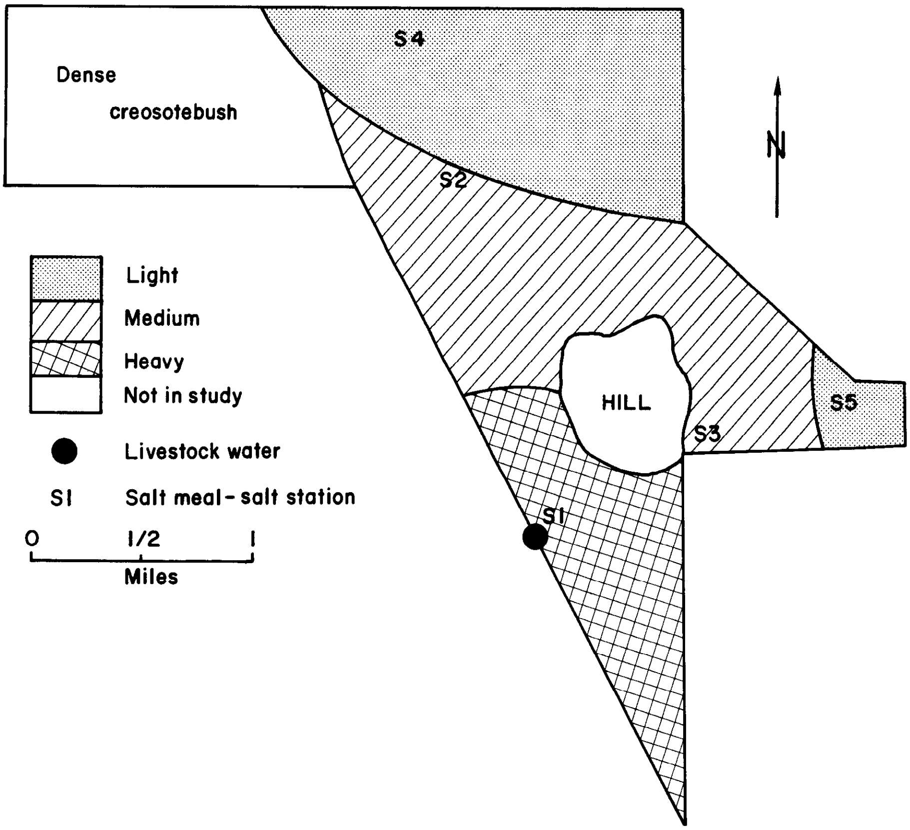

Fig. 2. *Locations of water, salt meal-salt stations, zones of utilization, and areas not sampled.*

the nine most heavily grazed transects was then designated as the heavy-use zone, that containing the nine intermediate transects as the medium-use zone, and the area with nine most lightly grazed transects as the light-use zone (Fig. 2). Replications were the first 4 and the last 4 years of the study. Analyses of variance and linear regressions were used to evaluate differences in utilization among zones and treatments.

Results

When the meal-salt mix was fed at water, cattle consumed about 2 lb./day per animal. When fed a mile or more from water, average consumption for all cattle in the pasture was less than 1/2 lb./day. We saw no evidence of salt sickness or toxicity. These results are similar to Ares' (1953) findings on black grama range in New Mexico. If green herbage was available, consumption of meal-salt was negligible. Apparently there is little danger of cattle gorging themselves on meal-salt when it is placed a mile or more from water in the presence of ample herbage. In some situations, however, low consumption itself could be a problem. If it is essential that animals take 2 lb. of supplement daily to meet minimum nutritional requirements, 3:1 meal-salt mixtures placed a mile or more from water will not supply it.

Average utilization for the pasture changed greatly from year to year and was related negatively to forage production. Utilization in the heavy-, medium-, and light-use zones averaged 69, 50, and 23%, respectively, for the 8-year study period. Low herbage production in the heavy-use zone was associated with relatively higher utilization in all three zones, accounting for 72, 85, and 49% of the year-to-year fluctuations in use in the heavy-, medium-, and light-use zones, respectively. Utilization in the heavy-use zone was consistently heavy, and contributed little to the year-to-year variation in average use for the entire pasture.

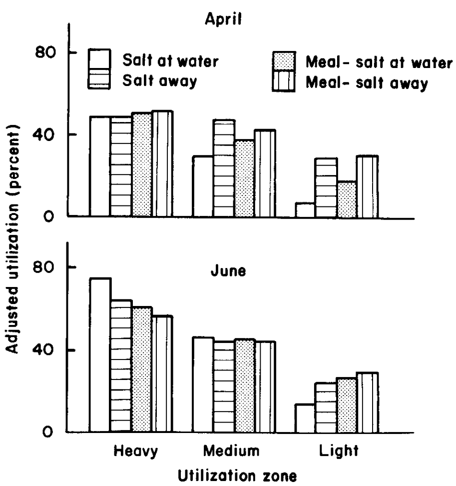

Fig. 3. *Average utilization at the end of April and June for each treatment and use zone (mean of 2 years).*

Differences between years in the average utilization for the pasture and in distribution of use were not affected significantly by placement of salt or meal-salt, but several trends were evident. The strongest treatment effect was increased utilization in the light-use zone when salt or meal-salt was fed away from water (Fig. 3). The effects of placement of meal-salt on distribution of use in the heavy- and medium-use zones were largely obscured by variations in forage production.

When the amount of perennial grass available per animal unit was used to predict utilization, actual use in the light-use zone was 10% lower than predicted when salt was fed at water and 12% higher when salt was fed away from water. Conversely, actual use in the heavy zone exceeded predicted use by about 6% when salt was fed at water, but was 5% lower than predicted when salt was fed away from water. Thus, differences due to treatment were about twice as great in the light zone as in the heavy zone.

Conclusions

Cattle are not apt to eat dangerous amounts of salt if meal-salt is fed free choice a mile or more from water. Low intake of supplement may be a problem, however, where mixtures containing as much as 25% salt are fed far from water.

Placing salt or meal-salt mixtures on remote parts of the range where forage is abundant will increase utilization of perennial grasses in such areas but will not greatly decrease use on areas closer to water.

Placement of salt or meal-salt alone cannot be expected to cure a serious distribution problem. In many cases, use on heavily grazed areas near water can be reduced materially only by appropriate periods of deferment or rest.

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Effect of Wildfires on Woody Species in the Monte Region of Argentina

E. EARL WILLARD

Highlight: *Woody vegetation was assessed on two adjacent areas 1 year after the occurrence of wildfires. One area was burned slowly by a backfire that moved mostly through the understory, while the other area was burned by a rapidly-moving headfire that reached into all crowns of trees and shrubs. The six woody species studied exhibited some degree of mortality after both fires, with the headfire causing significantly more mortality than the backfire. The tops of all woody plants were killed by both types of fire, except for caldén, which had considerable new crown growth following the backfire. Significantly greater percentages of plants of all six species were able to sprout following a backfire. Plant ignition and subsequent wood consumption were generally higher when subjected to a headfire than a backfire. The degree of ignition and wood consumption apparently had a direct effect on the ability of the plant to produce sprouts.*

The Monte region of central and western Argentina is a vast, almost continuous area of thorny shrublands encompassing nearly 60,000,000 hectares. This grazing region supports approximately 1,835,000 animal units of cattle, sheep, and goats, thus being one of the major livestock-producing regions of Argentina (Ragonese, 1967). Wildfires, set mostly by lightning during dry summers, are very common throughout the Monte. However, little is known about the effects of these fires on the vegetation.

Several large wildfires occurred in the Monte during the summer of 1971. One front burned for more than 100 kilometers from January 20 to 25, thus providing several thousand hectares for evaluation. A site was selected on the Biondini Estancia, approximately 150 kilometers west of Bahia Blanca, to assess the effects of wildfires on dominant woody species common throughout much of the Monte region.

Study Area and Methods

The area selected for study included a portion burned by a headfire and another by a backfire, thus affording an opportunity for evaluation of the effects of both types of fires within close proximity to each other, as both share a common boundary. No information is available concerning the amount of fuel in the form of grass that was on the area when it burned. However, samples clipped on a nearby unburned area within the same pasture yielded 1470 kg/ha. Thus, it is assumed that a comparable amount of fine fuel was present on the nearby burned areas to carry the fire. The headfire burned with the wind and advanced rapidly as a front often 4m high, while the backfire moved much slower into the wind and remained mostly in the herbaceous layer at an average height of 1m.

The plant community is a dense shrubland dominated by low-growing trees, mainly caldén (*Prosopis caldenia*)[1], algarrobo (*P. flexuosa*), and sombra de toro (*Jodinia rhombifolia*), and an abundance of shrub species, including piquillín (*Condalia microphylla*), molle (*Schinus fasciculatus*), chañar (*Geoffroea decorticans*), jarilla (*Larrea divaricata*), and alpataco (*Prosopis alpataco*). Grasses in the understory include mostly cool-season species such as flechilla (*Stipa tenuis*), paja (*S. tenuissima*), flechilla negra (*Piptochaetium napostaense*) unquillo (*Poa lanuginosa*), and cebadilla pampeana (*Bromus brevis*).

The topography is flat to rolling with slopes of 0 to 5%. Average annual rainfall is about 455mm with the major portion falling during the spring and summer. No precipitation records are available for the study area during the period

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[1]Common and scientific names of Argentine plants follow those of Ragonese (1967).

immediately before and after the occurrence of the wildfire. However, the general area was very dry at the time the fire occurred, while the remainder of the growing season following the fire was much wetter. The fire was terminated by heavy rains.

Soils range in texture from a fine sandy loam to a loamy fine sand with a thick layer of consolidated calcium carbonate at depths varying from 10 to 60 cm.

In January 1972, 1 year after the fire, 100 plants each of jarilla, piquillín, molle, caldén, chañar, and algarrobo were randomly selected for study under each of the two fire conditions. Wood samples were collected for each species present on the area for use in identification of dead plants and those having most of the top consumed by fire. Wood characteristics were sufficiently different among species to allow identification. Other characteristics such as growth form and leaves on live sprouts also were used in species determination.

Each plant was classified according to the following characteristics:

1. Dead or alive
2. Degree of wood consumption by the fire
   a. None—plants were only scorched with no charring
   b. Moderate—only certain portions of the plant were charred or consumed
   c. Heavy—plants severely charred or mostly consumed
3. Sprout production
   a. No sprouts
   b. One or more sprouts
4. Degree of canopy regrowth
   a. None
   b. Partial
   c. Total

Data were statistically analyzed where appropriate by use of a chi-square test (Steel and Torrie, 1960) at the 5% probability level to determine significant differences.

Results and Discussion

Plant Mortality

All six species of woody plants assessed in this study exhibited some degree of mortality 1 year after exposure to a headfire or a backfire. The conditions present during the headfire resulted in a significantly higher percentage of mortality in all species than occurred with the backfire. Fifty-eight percent of all woody plants were killed by the headfire, while 36.5% died in the area burned by the backfire. Mortality ranged from a high of 82% for molle plants to a low of 38% for chañar in the headfire area (Table 1). Molle again had the highest mortality of 55% in the area burned by the backfire, while calden and chanar had the lowest percentages, 18 and 19%, respectively.

These values represent plant mortality 1 year after the fire and may not express the final percentages of mortality attributed to the fire. However, these data indicate that a headfire is more damaging to woody plants than a backfire. Hare (1961) suggested that headfires develop considerably more heat than backfires because the flames are fanned by the wind to ignite new fuel ahead of the flame front. Thus, more fuel burns per unit of time, and more aerial fuels are consumed, resulting in greater crown damage.

Table 1. Percent of plants of six woody species killed by a backfire and a headfire.

Species	Type of fire		Difference
	Backfire	Headfire	
Algarrobo	35	58	23*
Chañar	19	38	19*
Jarilla	42	55	13*
Caldén	18	50	32*
Molle	55	82	27*
Piquillín	50	65	15*

*Significantly different at the 0.05 probability level.

Sprouting

One important variable which determines the relative fire resistance among species is the ability to sprout following a fire. Dormant buds were observed on the root crowns of all six species included in this study, indicating a source of buds for sprouting. These buds were apparently subject to apical dominance which was reduced or removed following fire injury to the aerial plant parts.

Wide variations in ability to sprout following exposure to fire were encountered with the species in this study. For example, the percent of plants sprouting ranged from a low of 18% for molle to a high of 62% for chañar on the headfire area (Table 2). Percentages were also quite variable on the backfire area, ranging from 45% for molle to 82% for chañar and caldén.

Table 2. Percent of plants of six species of shrubs sprouting after exposure to a backfire and a headfire.

Species	Type of fire		Difference
	Backfire	Headfire	
Algarrobo	65	42	23*
Chañar	81	62	19*
Jarilla	58	45	13*
Caldén	82	50	32*
Molle	45	18	27*
Piquillín	50	35	15*

*Significantly different at the 0.05 probability level.

A significantly greater percentage of plants of all six species sprouted following a backfire than after a headfire. Differences in sprouting on the two areas ranged from a low of 13% for jarilla to a high of 32% for caldén (Table 2). Twenty-one percent more of all woody plants sprouted in the area burned by the backfire than in that of the headfire. Thus, the damaging effects of the rapid-moving, hotter headfire were more restrictive to sprouting than those of the cooler-burning backfire, which moved at a slower speed.

Several of the new sprouts on chañar and jarilla plants were observed to be dead or in a weakened condition which would apparently lead to death. Very few herbaceous plants were present near the base of these two woody species 1 year after the fire. Thus, competition by herbaceous plants would not explain the observed sprout mortality. Apparently, more initial sprouts were produced than could be supported by the plant. Competition probably occurs between sprouts, with some having an advantage over others as evidenced by their continued growth. Willard and McKell (1973) reported the same phenomenon in snowberry (*Symphoricarpos vaccinioides*) and little rabbitbrush (*Chrysothamnus viscidiflorus*) in which various amounts of sprout mortality were observed on shrubs which had been clipped to simulate grazing and also on intact plants which had been protected from grazing or other forms of herbage removal. Sprouts on algarrobo, caldén, molle, and piquillín plants were all vigorously growing; thus it is assumed that little if any sprout mortality will occur in these species.

Plant Combustion

Less plant combustion occurred during the backfire than the headfire, especially in the taller species, which include chañar, algarrobo, jarilla, and caldén (Fig. 1). The taller species and taller individuals had canopies well above the grass layer which carried the fire into the wind, thus escaping ignition of the upper branches and leaves to a greater extent than those plants subjected to the conditions of the headfire. The shorter molle and piquillín plants generally had canopies beginning in the grass layer, thus being more susceptible to ignition.

No chañar plants ignited when exposed to the conditions of the backfire. However, 44% received moderate combustion and 3% heavy combustion in the area burned by the headfire. Chañar plants have a particular type of cork cambium which produces layers or sheets of bark that peel away from the trunk after suberization is complete. This peeled bark appears to be highly susceptible to ignition, but in no instance were plants found with charred or burned bark. Combustion during the headfire occurred only in the canopy, mainly with leaves and smaller limbs.

Eighty percent of the jarilla plants failed to ignite in the backfire area, 15% received moderate fire damage, and only 5% were heavily burned. Conversely, 100% of the plants had heavy combustion when exposed to the conditions present during the headfire. Jarilla plants are several-stemmed, with the leaves and smaller twigs occurring above the grass layer. Thus, a taller flame such as was present during the headfire was necessary to ignite the canopy. Once the foliage caught fire, ignition was almost complete, with most plants being burned to the ground. Heat created by burning jarilla plants appears to have been more intense than for the other woody species, as evidenced by the almost complete mortality of plants in the understory beneath individual jarilla plants. This condition was observed to a much lesser degree under molle and piquillín plants. but not for the other species. Combustion of a dense stand of jarilla plants might be expected to greatly reduce the desirable grasses and forbs in the understory.

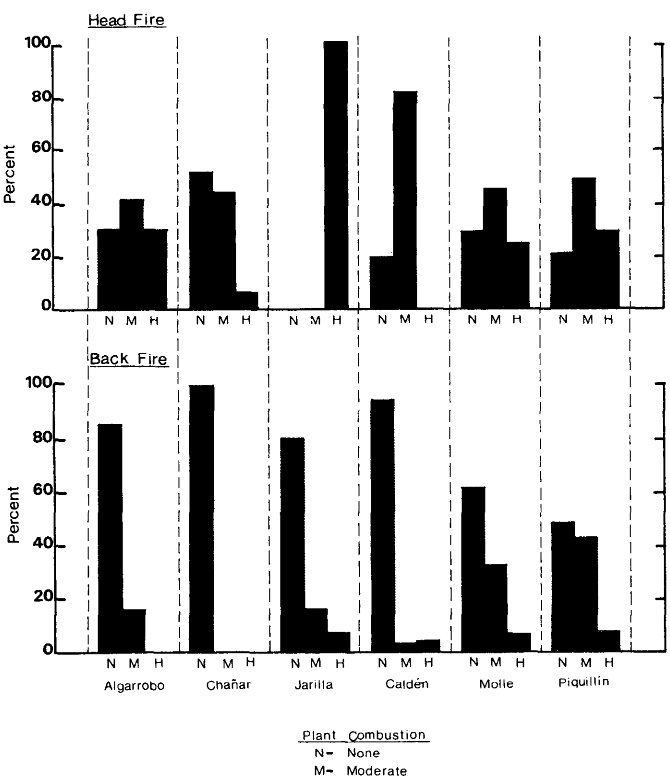

Fig. 1. *Percent of plants receiving various degrees of combustion in six woody species as related to the conditions present during a backfire and a headfire.*

Algarrobo and caldén are of the same genus and have the same general size and shape. Both were highly resistant to ignition from the backfire, as 85% of algarrobo and 94% of caldén plants failed to ignite. However, the degree of combustion during the headfire was quite different between the species. Only 16% of the caldén plants failed to ignite during the headfire, with the remaining 84% having only partial combustion. Almost twice as many algarrobo plants escaped ignition during the headfire, but 30% of those which ignited were heavily burned. Thus, algarrobo appears to be more resistant to ignition than caldén during a headfire, but, once ignited, burns to a greater degree.

The low-growing shrubs, piquillín and molle, exhibited similar degrees of resistance to ignition and combustion. Sixty-two percent of molle plants failed to ignite during the backfire, as compared with 47% of piquillín. Most combustion of plants that did ignite was moderate. Twenty percent of the piquillín plants and 30% of the molle plants failed to ignite during the headfire; approximately one-half of the plants burned only moderately; while 20% of piquillín plants and 25% of those of molle burned heavily, sufficiently to leave only charred stumps.

Fuel conditions on an unburned area in the same pasture as the burned areas were examined in an attempt to determine why certain plants ignited and others did not. As previously mentioned, the four taller species had canopies of mature individuals well above the level of the understory. The height and duration of the flames reaching into the canopy of a particular plant probably explains the variation encountered within a single species. The amount of fuel under a particular plant of the taller species probably had less influence than in the lower-growing species. The amount of grass fuel under piquillín and molle plants and also that reaching into the canopies was variable, and evidently influenced the degree of ignition and combustion of individual plants.

It appears, then, that the amount of fine fuel directly under low-growing shrubs is more important in regulation of ignition and combustion than under taller-growing species. The degree of ignition of plants with canopies above the fuel layer may be more influenced by the total amount of fine fuel in the general vicinity and the action of wind in whipping flames into the canopies.

White (1969) assessed the degree of combustion of six Arizona desert shrub species during a wildfire in relation to plant mortality. He reported that the percentage of survival of plants severely burned was significantly less than for those lightly or moderately damaged. Survival of lightly-burned plants was greater than for those moderately damaged in certain species. Thus, the degree of wood consumption by a fire may be an important variable influencing the plant's ability to sprout.

Britton and Wright (1971) found that 33.6 to 94.9% of individual stems of *Prosopis glandulosa* var. *glandulosa* ignited in areas experimentally burned under a wide range of weather and fuel conditions. However, these values relate to plants having tops previously killed by herbicide application; no information was available for ignition of live tops. Burndown was also reported to vary from 14.4 to 89.1% for the dead tops. I was unable to find any complete burndown of live tops of *Prosopis* plants following the wildfire in the Monte. The difference in burndown of live tops and dead tops of *Prosopis* is apparently at least partially related to the higher moisture content contributed by sap in live tops.

Sprouting as Related to Plant Combustion

The amount of crown material consumed by fire apparently had a direct effect on the ability of the woody plants to sprout later. Seventy percent of all woody plants which were exposed to fire but failed to ignite were able to produce sprouts the following year. Fifty-three percent of those moderately burned sprouted, while new sprouts appeared on only 14% of plants heavily consumed by fire.

A fire which fails to ignite the canopies of the six species studied will have a limited effect in controlling sprouting. Of those plants failing to ignite, algarrobo had the lowest percentage of plants sprouting (56%), while jarilla and caldén had the most sprouting with 77% and 78% respectively (Table 3). Sprouting of plants moderately burned was reduced below that of those escaping ignition, except for algarrobo, which had an 8% increase. Sprouting was greatly limited in plants heavily consumed by fire, ranging from none for chañar and caldén to a high of 24% for piquillin. The number of plants included in the heavy combustion class is quite low for certain species, especially caldén, but these appears to be a trend toward less sprouting with an increase in combustion.

Table 3. Percent of plants of six woody species sprouting following various degrees of plant combustion.

Species	Combustion class		
	None	Moderate	Heavy
Algarrobo	56	64	23
Chañar	73	72	0
Jarilla	77	58	15
Caldén	78	54	0
Molle	71	38	22
Piquillín	62	31	24

The relationship between sprouting ability and fuel consumption is probably that of increased temperatures at the bud zone when a plant ignites and burns for an extended period. The longer period of exposure to a high temperature may be important in heating the soil to a greater depth.

Canopy Regrowth

Canopies of all woody plants were killed by both the backfire and headfire with the exception of caldén, which had considerable new top growth after the backfire. However, caldén was also vulnerable to the backfire, since 38% of the tops were killed and 57% had partial regrowth (Table 4). Only 5% of the canopies of caldén plants in the backfire area were fully growing the year after the fire.

These data illustrate that heat alone without accompanying ignition can be effective in killing aerial parts of woody plants. Starker (1934) suggested that relative fire resistance includes such characteristics as bark thickness and composition. These variables may help explain the difference in top kill between caldén and the other woody species, as caldén was found to have a thicker bark than the other species. This thick bark apparently served as an insulating deterrent to the heat generated by the fire.

Table 4. Percentage of caldén plants with crown regrowth following a backfire and a headfire.

Degree of crown regrowth	Type of fire		Difference
	Backfire	Headfire	
None	38	100	62*
Partial	57	0	57*
Total	5	0	5

*Significantly different at the 0.05 probability level.

Conclusions

Wildfires are very common throughout the Monte region of Argentina and apparently have had an influence in controlling the density of woody vegetation, as was found in this study. However, uncontrolled fire is a hazard to livestock, wildlife, structures such as fences and houses, and even to man. Therefore, its natural occurrence must be discouraged and cannot be relied upon for controlling woody species. Controlled burning has been used in many parts of the world to suppress woody vegetation. West (1965) reviewed the literature related to the effect of fire on vegetation with special reference to Africa. He concluded that in savannah rangelands and in those types of grazing lands containing thick stands of shrubs, fire can effectively suppress brush and help to maintain open stands. The present study of an area of the Argentine Monte burned by wildfires suggests the feasibility of using prescribed burning in this region also.

Fire is an inexpensive method of controlling brush and reducing the actual numbers of woody plants. One problem encountered in the aerial application of herbicides to sprouting species is the high probability of sprouting following top kill. A second application of the herbicide is necessary to control sprout growth, as is the common practice with various species of *Prosopis* in the southwestern United States. A possibility exists for using controlled burning to kill the tops of woody species, reduce the number of live plants, and initiate growth of dormant buds on the root crowns of plants not killed by the fire. Control of the new sprouts might then be possible by use of a follow-up controlled burn, individual plant treatment by basal application of chemicals, or perhaps aerial application of herbicides. These control methods need to be tested, as no information exists for their use in controlling sprouting of the major woody species on the Monte region of Argentina.

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Small Mammals Increase on Recently Cleared and Seeded Juniper Rangeland

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Highlight: *Small mammal numbers were studied by snap trapping on six areas in Utah where juniper range had been cleared and seeded. On one area, which was trapped both before and for the first 3 years after treatment, numbers of deer mice (*Peromyscus maniculatus*) and pocket mice (*Perognathus parvus*) increased greatly in the first 2 years following treatment, then declined sharply to a level which was still above that before treatment. On two areas which were trapped only the first 2 years after treatment, many more small mammals were caught in the second year. Older seedings had about the same number of small mammals as did untreated juniper. Small mammals showed a clear preference for windrowed slash. This was especially true of deer mice and long-tailed voles (*Microtus longicaudus*).*

The invasion of sagebrush-grass rangelands by juniper and the ultimate domination of such sites by the pinyon-juniper type (Blackburn and Tueller, 1970) has led to the removal of trees in range rehabilitation programs. Although rodents are known to contribute to the failure of revegetation efforts in some plant types, little is known of small mammals in the pinyon-juniper type or of their reaction to the range renovation process. This paper reports preliminary findings of a study on small mammal-juniper range relationships in central Utah.

Trees usually are removed from deteriorated pinyon-juniper ranges by dragging a heavy anchor chain over them. The first chaining commonly is followed by aerial seeding and a second chaining in the opposite direction. An alternative is piling trees with a bulldozer after the first chaining to permit the use of a drill for seeding. Piles of trees are sometimes burned, usually after the new seeding is established. Areas that had been variously treated in these ways were sampled to evaluate the effects of tree removal and seeding and of different slash disposal methods on the numbers and kinds of small mammals.

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Methods

Six areas were studied in the foothills and lower slopes of the Tintic and Sheeprock Mountains west of Nephi and south of Vernon, Utah. The most intensive study was done at and near the Benmore Experimental Range, which has been described by Frischknecht and Harris (1968). At Benmore, a pretreatment survey was made in 1966 using one line of small snap traps having 30 stations and 90 traps for 3 nights. Other traplines were composed of 20 stations 50 feet apart, determined by pacing; each station had one rat trap and two museum special traps. Except in 1967, each line was run for 3 nights. Sets were made each evening, and all animals were removed the next morning.

The following four treatments of deteriorated pinyon-juniper range were sampled for small mammals: (1) untreated, usually old juniper stands with little understory; (2) chained two ways and seeded; (3) chained, windrowed, and seeded; and (4) chained, windrowed, seeded, and the windrows burned. Spacing of the windrows varied, but minimum distance between windrows was approximately 300 feet. Thus, where traplines were set along and between windrows, the traplines were 150 feet, or more, apart.

The clearing at Benmore was done for experimental purposes and was in 0.1-mile-wide treated and untreated strips.

Table 1. Numbers of small mammals caught at Benmore Experimental Range[1].

Time of trapping & type of treatment	Deer mice	Pocket mice	Long-tailed voles	Rabbits	Other small mammals
Traplines in experimental strips					
Aug. 24–26, 1966					
Untreated[2]	19	1	0	0	0
July 19–21, 1967					
Untreated	9	1	0	0	0
Chained-seeded-chained	8	1	0	0	0
Chained-windrowed-seeded[3]	9	1	0	1	0
Chained-windrowed-seeded[4]	2	1	0	0	0
Oct. 2–4, 1968					
Untreated	89	6	0	0	2
Chained-seeded-chained	118	19	1	0	0
Chained-windrowed-seeded[3]	107	5	1	0	1
Chained-windrowed-seeded[4]	112	10	0	0	0
Sept. 30–Oct. 2, 1969					
Untreated	30	0	0	2	0
Chained-seeded-chained	25	7	0	0	1
Chained-windrowed-seeded[3]	17	7	0	0	1
Chained-windrowed-seeded[4]	16	7	0	0	0
Sept. 30–Oct. 2, 1970					
Untreated	27	5	0	0	0
Chained-seeded-chained	27	2	0	0	0
Chained-windrowed-seeded[3]	37	1	0	0	1
Chained-windrowed-seeded[4]	21	4	0	0	1
Traplines in untreated juniper stands					
Nov. 19–21, 1968					
No. 1	15	0	0	0	0
No. 2	13	0	0	0	1
No. 3	22	0	1	0	4
No. 4	13	0	0	0	0

[1]Tree removal and seeding done in fall and winter of 1966–1967.
[2]270 trap nights, all others were 180.
[3]Traps along windrow.
[4]Traps between two windrows.

All other samples were taken from block treatments of 300 acres or more, which had been cleared for management purposes.

The chi-square test was used to test differences for significance. In instances where the number of trap nights was not the same on different areas, the data were reduced to the number of trap nights needed to catch one mouse before the chi-square test was applied. In the discussion, any statement that expresses a difference between or among results is based on statistical significance at the 95%, or higher, level of confidence.

Results and Discussion

General

During 7,350 trap nights, 1,321 small mammals of 13 species were taken. There were 1,097 deer mice (*Peromyscus maniculatus*), which comprised 83% of the total number caught and at least 50% of each catch, except one. Other species were represented by: 93 Great Basin pocket mice (*Perognathus parvus*), 37 long-tailed voles (*Microtus longicaudus*), 28 western harvest mice (*Reithrodontomys megalotis*), 27 chisel-toothed kangaroo rats (*Dipodomys microps*), 12 Nuttall's cottontails (*Sylvilagus nuttallii*), 7 sagebrush voles (*Lagurus curtatus*), 5 desert woodrats (*Neotoma lepida*), 5 pinyon mice (*Peromyscus truei*), 4 least chipmunks (*Eutamias minimus*), 2 cliff chipmunks (*Eutamias dorsalis*), 2 rock squirrels (*Spermophilus variegatus*) and 2 northern grasshopper mice (*Onychomys leucogaster*). The methods used were not well adapted to trapping rabbits and hares, and the results probably do not reflect their numbers or importance. Indeed, the biomass of the 12 cottontails caught might have approximated half that of all the deer mice caught and exceeded the biomass of all other small mammals caught.

Table 2. Number of small mammals caught in five study areas in central Utah.

Area, year of treatment, and sampling dates	Deer mice	Pocket mice	Long-tailed voles	Rabbits	Other small mammals
Beckstrom, 1966–1967					
Aug. 1, 1967					
Untreated	0	0	0	0	0
Chained-seeded-chained	6	0	0	0	2
Chained-windrowed-seeded[1]	0	0	0	0	2
Nov. 12–14, 1968					
Untreated	9	1	0	0	6
Chained-seeded-chained	40	2	0	1	5
Chained-windrowed-seeded[1]	18	4	0	0	2
Lofgreen No. 1, 1966–1967					
July 29, 1967					
Untreated	2	0	0	0	0
Chained-seeded-chained	6	0	0	0	0
Chained-windrowed-seeded[2]	12	0	1	1	2
Chained-windrowed-seeded[3]	6	0	0	0	0
Oct. 16–18, 1968					
Untreated	26	2	0	1	6
Chained-seeded-chained	39	1	0	1	10
Chained-windrowed-seeded[2]	35	2	4	1	7
Chained-windrowed-seeded[3]	7	1	1	2	14
Lofgreen No. 2, 1967–1968					
Oct. 30–Nov. 1, 1968					
Chained-windrowed-seeded[2]	39	0	14	1	3
Chained-windrowed-seeded[3]	24	0	0	0	4
Birch Canyon, 1965					
Oct. 23–25, 1968					
Chained-windrowed-seeded[2]	13	0	6	1	1
Chained-windrowed-seeded[3]	15	1	0	0	3
Oct. 22–24, 1969					
Chained-windrowed-seeded[2]	4	0	1	0	0
Chained-windrowed-seeded[3]	5	0	0	0	0
Boulter, 1956					
Oct. 23–25, 1968					
Chained-windrowed-seeded[2]	11	0	5	0	1
Chained-windrowed-seeded[3]	14	1	0	0	2
Oct. 22–24, 1969					
Chained-windrowed-seeded[2]	17	0	2	0	0
Chained-windrowed-seeded[3]	13	0	0	0	0

[1]Windrows burned.
[2]Traps along windrow.
[3]Traps between two windrows.

Effects of Tree Removal and Reseeding

At Benmore the average catch on all treatments was less in 1967 than before treatment in 1966 (Table 1), but trapping success on the untreated strip in 1967 was not different from the pretreatment sample. Because the 1967 sample was taken earlier in the summer and nearby samples in sagebrush-grass range (Black, 1968) showed an even greater decline in 1967 than occurred on the treated strips, the 1967 data from the strips could be interpreted as no change or even a slight increase. In the 2nd year after treatment (1968), there was a dramatic increase in the catch of deer mice and pocket mice on the Benmore strips, but similar high numbers were not indicated by the catch from four traplines in untreated juniper in the same vicinity. In the 3rd and 4th year after treatment, the catch at Benmore dropped to a much lower level, but remained higher than before treatment.

Results from the Beckstrom and Lofgreen No. 1 areas in the first 2 years after treatment (Table 2) showed the same trend as those from Benmore; there was a sharp increase in the 2nd year after treatment. However, 2nd year catches on these large block treatments did not increase as much as at Benmore. Apparently the high degree of edge afforded by the narrow strips of different treatments at Benmore created a generally favorable habitat for small mammals. The greater number of "other small mammals" caught at Lofgreen No. 1 is probably related to the sandier soil of the area. Kangaroo rats and harvest mice accounted for most of this difference.

The data from Birch Canyon, 3–4 years after treatment, and Boulter, 12–13 years after treatment (Table 2), suggest that numbers of mice may continue to decline into the 4th year after treatment but may become stabilized at a relatively low level soon thereafter. Trapping success on old seedings with windrowed slash did not differ from that on large units of untreated juniper in 1968.

Effects of Slash Disposal

On the Benmore strips, in the 4 years following treatment, the summed data for all small mammals revealed no differences due to treatment. Data from individual years indicated a preference for heavier cover in some, but not all, situations. In the larger clearings of other areas that had been treated as recently as 2 years before sampling, a preference was shown for slash cover—especially that of windrows

(Table 2). At Beckstrom, more mice were caught on the chained area than either the untreated or burned areas. At Lofgreen No. 1, deer mice indicated a preference for windrows, but not scattered slash, or they avoided open areas between windrows. At Lofgreen No. 2 in the 1st year after treatment and at Boulter and Birch Canyon, where treatments had occurred 3 or more years before sampling, no effect of windrows was apparent.

The few pocket mice caught showed no preference for treatment except on the Benmore strips in 1968, when more were caught in the scattered slash of the chained-two-ways strip.

Voles showed a strong preference for heavy cover. Thirty-four of 37 long-tailed voles caught in all areas were caught adjacent to windrows, and one was caught in a chained area having heavy cover. These microtines are characteristically found in heavy brush-grass cover but not in typical "bare ground and juniper" sites. It seems quite clear that piling trees creates vole habitat.

A study of rodent response to juniper removal and range seeding was reported by Turkowski and Reynolds (1970). They found from 1.2 to 4.0 times as many rodents on treated areas as on untreated plots, but trapping did not start until 3 years after treatment. Thus, a peak population such as we found in the 2nd year would have been missed in their study.

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Discerned Fragments in Feces Indicates Diet Overlap

R. M. HANSEN, D. G. PEDEN, AND R. W. RICE

Highlight: *A mean dissimilarity index was used to measure the degree of dietary overlap of appropriately paired diet and fecal samples of cows, bison, and sheep. When botanical composition is determined by the microscope technique for plant fragments identified in the feces of different kinds of herbivores (cattle, sheep, and bison), the estimated degree of dietary overlap is approximately the same as if diet samples had been used to estimate dietary overlap.*

The occurrence of recognizable plant fragments in the feces of livestock and wild herbivores has been used in the scientific literature (Dusi, 1949; Storr, 1968) for the determination of botanical composition of diets. Normally the relative discernability of plant fragments in the feces decreases as the digestibility of plant species increases (Casebeer and Koss, 1970; Free et al., 1970; Grenet, 1966; Regal, 1960; Stewart, 1967). The difference in thickness of the plant cell walls before and after digestion in steers can be used to estimate the plant's digestibility (Regal, 1960).

Use of a polarizing microscope and new slide preparation techniques permits recognition of most epidermal fragments (Storr, 1961 and 1968; Williams, 1969). The purpose of this paper is to examine the potential use of identifying plant fragments in fecal samples to quantitatively describe dietary overlap. The purpose of this approach is the desire to overcome the difficulties both in observing feeding behavior and in the fistulation of herbivores in order to estimate dietary overlap. The results obtained from fecal samples are compared to those obtained from esophageal samples by use of an index of dissimilarity.

Methods and Materials

Dietary overlap was evaluated for different herbivores, sites, stocking levels, and seasons. Control samples (esophageal) were collected from three bison and two cows on light and heavily stocked pastures in northcentral Colorado during May of 1970. Two independent sets of mean botanical compositions were obtained for each sample. For each sample an index was derived in order to observe how much dissimilarity could be expected from laboratory error alone.

Corresponding diet and fecal samples were obtained from esophageally fistulated cattle and bison from two blue grama (*Bouteloua gracilis*) dominated ranges. One site was in northeastern Colorado (N.E.) and the other was in northcentral Colorado (N.C.).

The sheep feces were collected from metabolism cages. The sheep were fed the four composited esophageal fistula samples each taken from steers grazing during each of the four seasons on a pasture lightly grazed by cattle at the northeastern Colorado site (Wallace and Denham, 1970). In the data analysis it was assumed that the diets of the N.E. steers and the sheep were identical. The cattle and bison samples from the northcentral Colorado site were each from spring and autumn and each from pastures grazed by cattle at light, moderate, and heavy stocking rates.

Dissimilarity indices were developed for each individual animal's diet-fecal pair. For each species-site combination, mean index (I) values were obtained. These were then compared to the control by paired t tests in order to see whether the dissimilarity between diet and fecal samples could be explained in terms of sampling error. On the basis of these comparisons, dissimilarity indices were derived for different herbivores, different sites and different seasons, and cross-comparisons.

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Dissimilarity index used in this study is a modification of Ivlev's standard deviation of food densities (Watt, 1968).

Denote the dissimilarity index as I. Let the subscripts *e* and *f* designate the nature of the compared diets where *e* indicates ingesta and *f* indicates feces. Thus I_{ee}, I_{ef}, and I_{ff} imply comparisons of two ingesta samples, one ingesta and one fecal sample, and two fecal samples respectively. Then

$$I_{ee} = \sqrt{\sum_{i=1}^{N} \frac{(d_{i1} - d_{i2})^2}{N - 1}}$$

where d_{i1} and d_{i2} are the relative densities of recognized fragments of the ith plant in ingesta samples 1 and 2 respectively. N denotes the total number of plants encountered in both samples. Similarily

$$I_{ef} = \sqrt{\sum_{i=1}^{N} \frac{(d_{i1} - d_{i2})^2}{N - 1}}$$

is the dissimilarity index when one ingesta and one fecal sample are being compared and

$$I_{ff} = \sqrt{\sum_{i=1}^{N} \frac{(d_{i1} - d_{i2})^2}{N - 1}}$$

is the dissimilarity index when two fecal samples are being compared for overlap.

The index, I, will approach zero as the number of plant components in sample 1 become more similar to their counterparts in sample 2. Conversely, the index, I, will increase in value and thus denote greater dissimilarity when each of the number of plant components in sample 1 are less similar to their counterparts in sample 2.

Use of the index, I, necessitates certain assumptions when applied to fecal samples. First, the digestion of a specific plant leafy material in one herbivore is a linear function of that in another herbivore. This has been suggested by Peden (1972). Secondly, the subdividing of large particles from both esophageal and fecal samples by grinding results in plant particles that represent a similar weight value and thereby removes the effect of differential leaf fragmentation. This last assumption has been suggested by Cavender and Hansen (1970).

The microscope technique used to quantify the discerned plant fragments in the samples was described by Sparks and Malechek (1968). The relative percent density (RD) of identified fragments of plants in each of the diet and fecal samples was estimated by observing 20 systematically located fields on each of 20 slides with a microscope at about 100 power magnification. The occurrence of each recognized species of plant in each field was recorded. Average percent frequency was computed for all plant species identified in the samples. The RD, calculated as the number of recognized fragments of a species and expressed as a percentage of the total number of fragments of all species (Curtis and McIntosh, 1950), was calculated for each species of plant.

The identification procedures used in this study were described by Baumgartner and Martin (1939) and by Dusi (1949).

Results and Discussion

There are no statistically significant differences between the control and any one diet-fecal comparison (Table 1). Therefore, we can assume that dissimilarity in the diet-fecal comparison was not a technique error. However, the diet-fecal comparisons showed that the northcentral Colorado cattle were significantly different from the other three diet-fecal mean indexes.

Similar *t* tests were used to compare the dissimilarity between sites, season, and grazing intensity. In these comparisons there were no significant differences.

There was a significant difference within cattle from northcentral Colorado even though there was no significant difference between the comparable diets of cattle and bison at this site.

In this study, the "best" fistula-fecal pairs were those of the sheep, because they were fed four whole samples. The samples were studied for plant species composition by taking from each 20 or more sub-samples for determining the percent relative densities (RD's) of recognized fragments. Since all the feces of the sheep for each season were pooled and then subsampled for RD's of recognized fragments the fistula-fecal pairs of sheep seem to have been "near-perfectly" matched. By pooling the fistula and fecal subsamples of the whole samples, a homogeneous mixture was obtained so that the variance between microscope slides was not influenced by the sequence of ingestion or the sequence of digestion, and there was no way in which the solid excreta could not have been the residue of the known diets. The mean I_{ef} index within sheep was 2.18 ± .56 and within the steers the index was 2.73 ± .83 and although the difference is not significant we believe the higher index for steers resulted because the steer fistula samples did not as perfectly match the "true diets" of the steers as well as the steer fecal samples did represent the "true diets." Even though the rumen contents are being well mixed during digestion it is common knowledge that the solid excreta defecated within any given hour or two roughly represents a sequence of ingestion.

The assumption that there is differential digestibility of fragments between different plants is valid, which results in lower relative discernability of fragments in the feces than in the forage, more so for highly digestible plants than for others. However, discernible fragments in feces, apart from being fragmented and stained differently from comparable fragments in fistula material, have the same epidermal cell patterns. The observed differences between easily discernible (resistant plants) plant species and those that are not (fragile plants) appear to be associated with the distribution of cutin (Storr, 1961). The cuticle extends down between cells and completely surrounds them for the epidermal cells of "resistant plants," but only the outer wall of the epidermis is covered with cutin of "fragile plants". Thus, the observed RD's of fragments in feces owes its discernibility to the degree to which cells are encased in cutin and lignin; both generally appear to be undigested.

The process whereby leaf fragments are broken down into fine particles facilitates digestion because this renders soluble plant protoplasm more available through leaching into the rumen fluids. That there is a gradual erosion of cell walls of resistant plants in rumen digestion has been shown by Regal (1960). The problem of dissolving the resistant leaf fragments that have already leached their soluble products is accom-

Table 1. Comparison of mean dissimilarity index values, I, with control.

Sample types[1]	Mean (%) index (I)	± S.D. of (I)	No. of data sets	t for test with control[2]	Significant difference from control
Control (N.E.)	5.58	2.75	10	–	–
Cattle					
N.E.	2.73	.83	5	0.92	No
N.C.	8.50	0.93	5	0.96	No
Sheep (N.E.)	2.18	.56	5	1.16	No
Bison (N.C.)	2.67	1.76	5	0.86	No

[1]Diets and feces from northeastern Colorado (N.E.) and northcentral Colorado (N.C.).
[2]Degrees of freedom = 13.

plished with enzymes found in the rumen fluids. However, if the observed differences in discernibility of plant fragments before and after digestion are similar among different species of herbivores, it seems logical that diet overlap can be measured even when small, significant differences in mean ability to digest exist among the herbivores.

There are three potential explanations for a higher mean index for cattle at northcentral Colorado in contrast to other similar paired samples used in this study. The fragments of blue grama and other plants known to decompose slowly were relatively more abundant in the N.C. cattle feces than in the N.C. fistula samples. One explanation is that the N.C. cattle fistula samples did not closely represent the cattle diets. The second is that cattle can digest the forage much more completely than can bison. Both seem to be unlikely since the diets were collected twice a day and composited in similar ways to that of other samples, and cattle do not digest forage from the area any better than do bison (Peden, 1972). The third, and most likely, explanation for the large differential in RD's of fistula and fecal samples is that the feces was collected in fecal bags and there was a significant amount of microbial decomposition that occurred after the solid excreta had been voided. The fragments of plants suspected to be "fragile" were relatively less discernible in the cattle feces than we would expect if the erosion of cell walls by digestion had been normal. Total collections in fecal bags and storage of feces in plastic bags awaiting processing probably permitted enzymatic activity to continue after "cow" digestion of fragments had ended. To insure that the differences in fecal overlap indexes do represent diet overlap, the excreta collecting techniques must be the same for each species of herbivore.

We believe that a microscopic analysis of feces can be used to estimate the approximate amount of diet overlap between different herbivores as long as comparable samples are obtained by a standard technique. Correction factors are not required to account for either differences between the digestibility of different plants or for differences between species of herbivores in the extent to which they digest any single plant. Even though the establishment of such regressions might be desirable and scientifically valuable, a great deal of practical use can be obtained from fecal indexes.

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Foods Eaten by the Rocky Mountain Elk

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Highlight: *Forty-eight food habits studies were combined to determine what plants are normally eaten by Rocky Mountain elk (*Cervus canadensis nelsoni*), and the relative value of these plants from a manager's viewpoint based on the response elk have exhibited toward them. Plant species are classified as* highly valuable, valuable, *or* least valuable *on the basis of their contribution to the diet in food habits studies where they were recorded. A total of 159 forbs, 59 grasses, and 95 shrubs are listed as elk forage and categorized according to relative value.*

Knowledge of the relative forage value of plants eaten by elk is basic to elk range surveys, and to planning and evaluation of habitat improvement programs. Numerous elk food habits studies have been conducted; however, individual studies are limited to a specific area, and relatively few plant species are found in the diet compared to the number of plants eaten by elk throughout their range. The amount of a particular species consumed in one study may or may not be indicative of its true value as elk forage. The purpose of this inquiry is to combine all food habits work to determine which plants are eaten by elk, and their relative value as reflected by the degree to which they are normally sought.

Methods

With one exception only studies which pertain to food habits of the Rocky Mountain elk (*Cervus canadensis nelsoni*) in the western U. S. and Canada were included. The exception study involving *C. canadensis manitobensis* (Blood, 1966) was incorporated because of its quality and because the plants eaten closely paralleled those consumed on elk ranges in Montana and Idaho. Studies of Rocky Mountain elk transplanted to areas outside their normal range were excluded.

An extensive literature review was made to assemble references concerning elk food habits, and studies meeting the following criteria were incorporated: (1) Data must be original and derived from a specific effort to collect food habits information. References containing statements of what elk eat based on general knowledge, or those which summarized previous food habits studies were excluded. (2) Data must be listed by species eaten, and relative quantity consumed must be expressed in terms which would allow degree of use to be categorized. (3) Season of use must be shown. (4) Data must be listed separately for elk. Studies which referred to combined deer and elk use or "game use" were excluded. (5) Studies with a very limited sample (for example, only two or three stomachs) were excluded. (6) Elk must have had free choice of available forage. This excluded some pen feeding studies. (7) Study animals must not be starving. Forty-eight studies were incorporated in this summary.

Methods of data collection were assigned four categories: stomach analysis, feeding observations on wild animals, apparent use of plants, and pen feeding studies designed to determine preference.

Studies of food habits differ widely in method of data collection and presentation; in number, relative abundance, availability, and relative palatability of plant species encountered; and in number of animals using the study area. Thus, firm guidelines cannot be established for comparing relative forage preference among several food habits studies. In every study, however, some plants were consumed more extensively than others. The procedure used herein involved categorizing plants encountered in each study according to whether they were used (1) lightly (2) moderately or (3) heavily in relation to all species consumed in the particular reference. Plants which contributed less than 1% of the diet or which were reported as trace amounts were excluded. Factors such as relative plant abundance in relation to consumption were considered in assigning plants to use categories when such information was available. An average ranking for each species was then determined on the basis of all studies where it was found to contribute at least 1% of the diet.

The following terminology is used throughout this report. *Highly valuable plant*—One avidly sought by elk and which made up a major part of the diet in food habits studies where encountered, or which was consumed far in excess of its vegetative composition. These had an average ranking of 2.25 to 3.00. *Valuable plants*—One sought and readily eaten but to a lesser extent than highly valuable plants. Such plants made up a moderate part of the diet in food habits studies where encountered. Valuable plants had an average ranking of 1.50 to 2.24. *Least valuable plant*—One eaten by elk but which usually made up a minor part of the diet in studies where encountered, or which was consumed in a much smaller proportion than it occurred on the range. Least valuable plants had an average ranking of 1.00 to 1.49. These terms are used to reflect the relative value of a plant's presence on elk range from a manager's viewpoint because of the response elk have exhibited toward it. Value as used here does not consider nutrient quality or the importance of a species in maintaining a certain desired stage of ecological succession.

Data were separated by the following seasons of use: *Winter*—December, January, February; *Spring*—March, April, May; *Summer*—June, July, August; *Fall*—September, October, November.

Results

Seasonal Use of Major Forage Groups

Winter—Winter use is concentrated on either grasses or shrubs, depending on forage availability. The following authors reported winter grass consumption on Montana's predominately grass ranges as varying from 63 to 100%, and averaging 84%: Casagranda and Janson (1957); Constan (1967); Gordon (1968); Greer (1959); Greer et al. (1970); and Morris and Schwartz (1957). Winter shrub use averaged 9% and forb use 8% in these studies.

DeNio (1938) reported 65% winter use of grasses, 15% shrubs, 2% forbs, and 5% mosses and lichens in Montana, northern Idaho, and northeastern Washington. Winter grass consumption was as high as 97% in Jasper Park, Alta. (Cowan, 1947). Shrubs comprised 95% of the winter diet in New Mexico (Lang, 1958), 62% in Manitoba (Blood, 1966), and 82% in

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Idaho of which 22% were conifers (Trout and Leege, 1971). Boyd (1970) recorded 57% shrub use in Colorado from December through April. In these studies grass consumption averaged 22% and forbs were eaten in only two studies where maximum consumption was 10%.

Spring—Spring grass use on eight Montana studies remained high, averaging 87% (Eustace, 1967; Greer et al., 1970; Gordon, 1968; Kirsch, 1963; Mackie, 1970; Morris and Schwartz, 1957; Rouse, 1957; and Stevens, 1966). Little information outside Montana was available on spring use of major forage classes except for Manitoba, where use of grasses, shrubs, and forbs was 54, 37 and 9%, respectively.

Summer—Forbs became important forage during summer. The summer diet in Montana averaged 64% forbs, 30% grasses, and 6% shrubs (Eustace, 1967; Greer et al., 1970; Kirsch, 1963; Mackie, 1970; Morris and Schwartz, 1957; Rouse, 1958; Stevens, 1966). Rouse (1958) recorded 100% forbs in the summer diet. Summer forage consumption in Colorado, as reported by Nichols (1957), was 58% grasses, 41% forbs, and 1% shrubs. Boyd (1970), also in Colorado, recorded 78% summer use of grasses, 12% forbs, and 10% shrubs. Studies where high summer shrub use were recorded were made by Young and Robinette (1939) in Idaho, where use was 55% shrubs, 25% grasses, and 20% forbs; and by Blood (1966), in Manitoba, who noted 52% use of shrubs, 22% grasses, and 26% forbs.

Fall—Primary use reverts to grasses in the fall in Montana where grass use averaged 73% in nine studies (Greer, 1959; Greer, 1960; Greer et al., 1970; Kirsch, 1963; Mackie, 1970; Morris and Schwartz, 1957; Peek 1963; Rouse, 1957, Rush, 1932). High grass use in fall was also found in Colorado by Boyd (1970), who recorded 92% grass consumed. In New Mexico, Burt and Gates (1959) found that grass comprised 84% of the fall diet; however, Lang (1958), also in New Mexico, recorded 77% use of shrubs, 21% grasses, and 2% forbs. Shrub use was high in Manitoba and Idaho, where Blood (1955) and Young and Robinette (1939) found 55 and 40% use of shrubs, 37 and 40% use of grasses and 8 and 20% forb use, respectively.

Plant Species Value

Plant species eaten by elk and their relative value rankings for each season are listed by forbs in Table 1, grasses in Table 2, and shrubs in Table 3. Validity of these rankings increases with the number of references on which a ranking is based.

Table 1. Relative value of forb species eaten by Rocky Mountain elk.

Plant name	Forage value[1] Winter	Spring	Summer	Fall	References[2]
Achillea				1.00 – 2	29, 36
Achillea millefolium	1.33 – 3		1.00 – 4	1.00 – 2	9, 14, 17, 18, 30, 31, 37, 44
Actaea spicata			1.00 – 1	2.00 + 1	48
Agastache urticifolia			1.50 + 2		37, 48
Agoseris glauca		1.50 + 4	2.33 * 6		7, 17, 29, 30, 39, 44
Alectoria fremontii	1.00 – 1				13
Allium textile		2.00 + 1			32
Angelica lyallii			1.00 – 1	1.00 – 1	48
Antennaria	1.00 – 3	1.00 – 2	1.00 – 1	1.00 – 2	18, 25, 36, 39
Antennaria parvifolia		1.00 – 1			44
Antennaria rosea	1.00 – 1				18
Aquilegia flavesens		1.00 – 1	1.00 – 1		7
Arenaria			1.00 – 1		10
Arnica		1.50 + 2	2.00 + 1	1.00 – 1	25, 30, 44
Arnica cordifolia			2.00 + 2		17, 29
Arnica latifolia			2.00 + 1	3.00 * 1	48
Arnica sororia		2.00 + 1			32
Artemisia dracunculus	2.00 + 1				42
Artemisia frigida	1.33 – 6	1.00 – 4			14, 20, 24, 25, 29, 30, 42, 44
Artemisia longifolia	1.00 – 1			1.00 – 1	32
Artemisia ludoviciana	1.00 – 1			2.00 + 1	30, 32
Asplenium felix-femina			3.00 * 1	2.00 + 1	48
Aster	2.00 + 2	2.00 + 2	1.75 + 4	1.50 + 8	18, 21, 23, 24, 25, 29, 30, 33, 36, 39, 42, 43
Aster canescens			2.00 + 1	3.00 * 1	48
Aster commutatus				2.00 + 1	32
Aster eatoni			2.00 + 1	3.00 * 1	48
Astragalus	1.50 + 2		3.00 * 1	2.00 + 1	30, 42, 48
Astragalus miser			1.00 – 1		30
Balsamorhiza saggittata	1.75 + 4	2.00 + 2	1.00 – 1		3, 7, 11, 18, 38, 42
Boykinia heucheriformis			3.00 * 1	2.00 + 1	48
Caltha leptosepala			2.50 * 2		6, 35
Castilleja			1.00 – 1		37
Castilleja miniata			1.00 – 1		48
Cerastium arvense		1.00 – 1			44
Chalachortus elegans			1.00 – 1		48
Chamaenerion angustifolium	3.00 * 1		3.00 * 1	2.00 + 1	18, 48
Cirsium	1.00 – 1	1.00 – 2		2.00 + 3	20, 21, 25, 36, 42
Cirsium foliosum		1.00 – 1	1.00 – 1	3.00 * 1	30
Claytonia asarifolia			3.00 * 1	3.00 * 1	48
Claytonia sibirica			3.00 * 1	3.00 * 1	48
Clintonia uniflora			1.00 – 1	1.00 – 1	48
Commandra sp				1.00 – 1	25
Commandra pallida			2.00 + 1		33

Coptis occidentalis			1.00 – 1	2.00 + 1	48
Corydalis scouleri			2.00 + 1		48
Delphinium sp			2.00 + 1		3
Delphinium bicolor		1.00 – 1	2.00 + 1		17, 20
Delphinium scopulorum		2.00 + 1	2.00 + 2		7, 48
Dodecatheon conjugens			3.00 * 1	3.00 * 1	48
Dodechatheon pauciflorum		1.00 – 1			20
Dodocathelon conjugens			3.00 * 1	3.00 * 1	48
Epilobium angustifolium			2.00 + 2		4, 29
Equisetum	1.00 – 1		1.00 – 1	1.00 – 1	23, 25
Erigeron		2.00 + 1	1.50 + 2	2.00 + 1	17, 30
Eriogonum	2.00 + 1			1.50 + 2	18, 24, 25
Eriogonum heracleoides				1.00 – 1	37
Eriogonum umbellatum				1.00 – 1	44
Fragaria	1.50 + 2	2.00 + 1	1.00 – 3	1.00 – 2	18, 25, 30, 48
Fragaria virginiana			1.00 – 1		44
Fraseria sp.			2.00 + 1		3
Gaillardia sp.			1.00 – 1		48
Galium boreale	1.00 – 1				42
Geranium		2.00 + 1	1.50 + 2	1.00 – 1	3, 25, 29, 30
Geranium richardsonii		3.00 * 1			30
Geranium viscossissimum		2.00 + 2	2.43 * 7	2.00 + 2	17, 29, 30, 39, 40, 44, 48
Geum			2.00 + 1		6
Geum triflorum		1.00 – 1	2.00 + 1		17, 20
Geum turbinatum		1.00 – 1			10
Glycyrrhiza lepidota			3.00 * 1	3.00 * 1	32
Hedysarum sulphurescens			2.00 * 1		29
Helianthus maximilliana				2.00 + 1	32
Heracleum lanatum		1.00 – 1	1.00 – 2		7, 48
Hieracium sp.			2.00 + 1		3
Hieracium albiflorum			2.00 + 1	1.00 – 1	48
Hieracium chapacanum			2.00 + 1		37
Hieracium cynoglossoides		1.00 – 1	1.00 – 1		44
Hieracium scouleri			1.00 – 1		48
Heuchera glabella			2.00 + 1	2.00 + 1	48
Hydrophyllum capitatum			3.00 * 1		48
I ris missouriensis				1.00 – 1	9
Lactuca pulchella		2.00 + 1			32
Lactuca serriola			2.00 + 1		32
Lathyrus	1.00 – 1	2.00 + 2	2.00 + 1		4, 6
Lathyrus laetivirens			2.00 + 1		5
Ledum groenlandicum	2.00 + 1				4
Liatris punctata	1.00 – 1			3.00 * 1	30, 42
Ligusticum grayi			1.00 – 1		37
Ligusticum scopulorum			2.00 + 1	1.00 – 1	48
Ligisticum tenufolium			2.00 + 1	1.00 – 1	48
Lithospermum ruderale	1.00 – 2				18, 42
Lupinus	1.50 + 2	2.00 + 1	1.00 – 7	2.40 * 5	14, 17, 23, 24, 25, 29, 36, 37, 39, 42, 44, 48
Lupinus leucophyllus			3.00 * 1		33
Lupinus ornatus	2.00 + 1				18
Lupinus sericeus	2.67 * 3	2.00 * 2	2.00 + 1		7, 20, 30, 42
Medicago sativa			3.00 * 1	3.00 * 1	2, 33
Melilotus officinalis	1.00 – 1	1.00 – 1	2.50 * 2	3.00 * 1	32, 33
Mertensia ciliata			3.00 * 1	3.00 * 1	48
Microseris		1.00 – 1	1.00 – 2		30, 44
Mitella stauropetala			1.00 – 1	2.00 + 1	48
Myosotis alpestris			3.00 * 1	3.00 * 1	39
Oenothera flava				2.00 + 1	39
Opuntia sp.		3.00 * 1			46
Oreoxis alpina			3.00 * 1		10
Osmorhiza occidentalis			3.00 * 2		37, 48
Oxytropis			1.00 – 1		25
Oxytropis splendens		1.00 – 1			29
Oxytropis viscida		3.00 * 1			30
Pedicularis cystopteridifolia			2.00 + 1		17
Pedicularis groenlandica			2.00 + 1		48
Pedicularis racemosa			2.00 + 1	1.00 – 1	48
Penstemon	1.00 – 1				18
Penstemon confertus				1.00 – 1	48
Penstemon pinetorum			3.00 * 1	3.00 * 1	48
Penstemon procerus			1.00 – 1		37
Petasites saggittatus		2.00 + 1			4
Phacelia heterophylla			1.00 – 1	2.00 + 1	48
Phlox	1.00 – 1			1.00 – 1	25, 36
Phlox hoodii	1.00 – 1				39
Polemonium delicatum			2.00 + 1	1.00 – 1	48
Polygonum phytolaccaefolium			2.50 * 2		37, 48

Potentilla		1.00 – 2	1.29 – 7	1.50 + 2	10, 17, 25, 29, 30, 39, 44
Potentilla glandulosa			1.50 + 2	2.00 + 1	37, 48
Potentilla gracilis			1.00 – 1		29
Pteris aquilina			1.00 – 1		48
Ranunculus			2.00 + 1		30
Ranunculus glaberrimus		1.00 – 1	1.00 – 1		7
Rumex paucifolius		2.00 + 1	2.00 + 1		7
Sanguisorba sitchensis			2.00 + 1		37
Selaginella densa		1.00 – 1			44
Senecio	1.50 + 2		1.00 – 2		4, 18, 35, 39
Senecio columbianum			3.00 * 1		48
Senecio triangularis			2.50 * 2	3.00 * 1	37, 48
Smilacina racemosa				2.00 + 1	48
Smilacina stellata				2.00 + 1	48
Solidago	1.00 – 1				18
Sonchus arvensis			2.00 + 1		4
Sphaeralcea rivularis			3.00 * 1	3.00 * 1	48
Stellaria	1.00 – 1				30
Taraxacum		1.00 – 2	3.00 * 3		17, 29, 44
Taraxacum officinale		1.00 – 2	2.00 + 3	3.00 * 1	4, 7, 30
Thermopsis montana			1.00 – 1		39
Thermopsis pinetorum				1.00 – 1	9
Tragopogon				1.00 – 1	21
Tragopogon dubius	2.00 + 1	2.00 + 1	2.00 + 1		20, 32, 42
Trifolium		1.00 – 1	2.00 + 3		17, 30, 40
Trifolium dasyphyllum			3.00 * 1		10
Trifolium haydeni		2.00 + 1	2.00 + 1		7
Trifolium repens			3.00 * 1		44
Trifolium rydbergi		2.00 + 1	2.00 + 1		7
Typha				1.00 – 1	25
Valeriana sitchensis			3.00 * 1	3.00 * 1	48
Veratrum eschscholtzii			1.00 – 1		48
Vicia americana		2.00 + 1	2.00 + 1		4, 32
Viola nuttallii		1.00 – 1	1.00 – 1		7
Wyethia			2.50 * 2	2.50 * 2	36, 39, 40
Xanthium strumarium	3.00 * 1				32
Xerophyllum tenax	1.00 – 1		2.00 + 1		18, 48
Zizia aptera		3.00 * 1	3.00 * 1		30

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[2]Numbers indicate references in literature cited section on which value rankings were based.

Table 2. Relative value of grass species eaten by Rocky Mountain elk.

Plant name	Forage value[1] Winter	Spring	Summer	Fall	References[2]
Agropyron cristatum		2.00 + 1			29
Agropyron dasystachyum		1.00 – 1			29
Agropyron pauciflorum	3.00 * 1				18
Agropyron scribneri			2.00 + 1		10
Agropyron smithii	3.00 * 1	3.00 * 1	2.00 + 1	3.00 * 1	32
Agropyron spicatum	3.00 * 8	2.00 + 8	1.50 + 2	2.00 + 1	8, 11, 14, 17, 18, 20, 29, 30, 33, 38, 42, 43, 44
Agropyron subsecundum			1.00 – 1	3.00 * 1	17, 39
Agropyron trachycaulum			1.00 – 1	2.00 + 1	39
Agrostis exarata			3.00 * 1	2.00 + 1	48
Agrostis idahoensis			1.00 – 1		35
Bromus	1.00 – 1		1.67 + 3		17, 30, 44
Bromus carinatus			3.00 * 1	3.00 1	48
Bromus inermis			2.00 + 2	2.00 + 1	29, 33
Bromus marginatus	3.00 * 1				18
Bromus tectorum	2.00 + 2				8, 13
Calamagrostis canadensis	2.50 * 2				18, 30
Calamagrostis rubescens	2.00 + 2	3.00 * 1	3.00 * 1	1.50 + 2	18, 30, 48
Camassia quamash		2.00 + 1	1.00 – 1		30
Carex	2.00 + 3	1.00 – 1	1.67 + 6	2.33 * 3	2, 17, 18, 25, 30, 35, 37, 38, 39, 44
Carex filifolia	3.00 * 1				18
Carex geyeri	2.33 * 3	3.00 * 1	2.33 * 3	2.50 * 2	13, 18, 29, 30, 37, 48
Carex nubicola		2.00 + 1	2.00 + 1		7
Carex raynoldsii		2.00 + 1	2.00 + 1		7
Danthonia	2.00 + 1	1.00 – 1	2.00 + 1		30
Danthonia intermedia	3.00 * 1				18
Danthonia parryi	2.00 + 1				30
Danthonia unispicata	2.00 + 1				11
Deschampsia caespitosa			3.00 * 1		35
Distichlis stricta	2.00 + 1				32

Elymus flavescens	3.00 * 1	3.00 * 1			46
Elymus glaucus	2.00 + 1	2.00 + 1	3.00 * 1	3.00 * 1	39, 48
Elymus innovatus				1.00 – 1	39
Festuca idahoensis	2.56 * 9	2.83 * 6	1.50 + 2	3.00 * 2	7, 8, 11, 14, 17, 18, 20, 29, 30, 38, 39, 42, 43,44
Festuca ovina		2.00 + 1	2.00 + 1		7
Festuca scabrella	2.40 * 5	2.75 * 4	1.00 – 2	2.00 + 1	11, 17, 18, 20, 29, 30, 42, 44
Juncoides parviflorum			3.00 * 1	3.00 * 1	48
Juncus balticus			3.00 * 1		35
Juncus parryi			3.00 * 1		37
Koeleria cristata	1.60 + 5	1.50 + 4	2.00 + 1	2.00 + 2	11, 17, 18, 20, 32, 38, 44
Melica spectabilis			1.00 – 1		39
Muhlenbergia	1.50 + 2				11, 38
Muhlenbergia cuspidata	1.00 – 1			2.00 + 1	32
Orzyopsis hymenoides				3.00 * 1	46
Phleum		2.00 + 1	1.50 + 2		7, 44
Phleum alpinum		2.00 + 1	2.00 + 2		7, 35
Phleum pratense	2.50 * 2	2.00 + 1	1.00 – 1	3.00 * 1	18, 30
Poa	2.00 + 5	2.67 * 6	2.00 + 5	2.50 * 2	13, 14, 17, 20, 29, 30, 33, 42, 44
Poa alpina			2.00 + 1		30
Poa canadensis	3.00 * 1				18
Poa compressa	3.00 * 1	2.00 + 1		2.00 + 1	18, 32
Poa epilis		2.00 + 1	2.00 + 2		7, 35
Poa secunda	2.00 + 1	2.50 * 2	1.50 + 2	3.00 * 1	7, 32
Sitanion hystrix			1.00 – 1		37
Stipa	2.33 * 3	2.00 + 1	2.00 + 1	3.00 * 1	11, 30 38
Stipa columbiana	3.00 * 1		1.00 – 1		18, 37
Stipa comata				3.00 * 1	46
Stipa viridula	1.00 – 1	2.00 + 1			32
Trisetum spicatum			2.00 + 1	2.00 + 1	17, 29
Trisetum wolfii			2.00 + 1		35

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[2]Numbers indicate references in literature cited section on which value rankings were based.

Table 3. Relative value of shrub species eaten by Rocky Mountain elk.

	Forage value[1]				
Plant name	Winter	Spring	Summer	Fall	References[2]
Abies grandis	1.00 – 2				18, 45
Acer glabrum	2.25 * 4	1.00 – 1	3.00 * 1	3.00 * 1	18, 19, 27, 30, 48
Acer spicatum			2.00 + 1		4
Alnus tenuifolia	1.00 – 1		1.50 + 2	2.00 + 1	5, 18, 48
Amelanchier alnifolia	2.50 * 6	2.00 + 2	2.50 * 2	2.33 * 3	1, 4, 5, 18, 19, 26, 27, 30, 42, 48
Arctostaphylos uva-ursi	1.00 – 2	1.00 – 1		1.50 + 2	4, 29, 42
Artemisia cana	2.00 + 1				32
Artemisia tridentata	1.50 + 8	1.25 – 4	1.00 – 2	1.67 + 3	5, 6, 13, 19, 21, 22, 25, 27, 32, 37, 39, 43, 46
Artemisia tripartita	3.00 * 1	2.00 + 1			39
Berberis repens	2.00 + 2	1.25 – 4	1.00 – 1	1.80 + 10	1, 2, 6, 21, 23, 24, 25, 28, 29, 30, 36, 39, 45
Betula glandulosa	2.00 + 2		3.00 * 1		18, 30
Betula fontinalis	1.00 – 1				18
Ceanothus velutinus	2.40 * 5		3.00 * 1	2.00 + 2	13, 18, 19, 30, 33, 47, 48
Ceanothus sanguineus	3.00 * 3		3.00 * 1	3.00 * 1	18, 45, 47, 48
Cercocarpusmontanus	3.00 * 2				27, 31
Cercocarpus ledifolius	2.00 + 1			3.00 * 1	1, 13
Chrysothamus nauseosus	2.00 + 3	1.00 – 1			12, 13, 43, 46
Chrysothamus viscidiflorus	1.25 – 4	3.00 * 1		2.00 + 2	12, 20, 32, 43, 46
Cornus stolonifera	2.20 + 5		3.00 * 1	2.00 + 1	4, 18, 19, 27, 45, 48
Dasiphora fruticosa	1.00 – 1				18
Elaeagnus commutata	2.50 * 2				18, 30
Fraxinus	2.00 + 1				26
Garrya wrightii	3.00 * 1				31
Juniperus	1.50 + 2			1.00 – 1	24, 31
Juniperus communis	1.00 – 3			1.00 – 1	18, 29, 42
Juniperus horizontalis	1.00 – 3				11, 30, 42
Juniperus occidentalis	2.00 + 1				13
Juniperus scopulorum	1.50 + 2	1.00 – 1		1.00 – 1	18, 32
Ledum groenlandicum	2.00 + 1				4
Linnaea		1.00 1		1.00 1	29
Linnaea borealis	1.00 – 1				18
Lonicera involucrata	2.00 + 1		2.00 + 1		18, 48
Lonicera utahensis			3.00 * 1	1.00 – 1	48
Menziesia ferruginea			3.00 * 1		48
Odostemon sp.	1.00 – 1				13
Odostemon aquifolium	1.00 – 1				18

Opulaster malvaceus	1.00 – 1		2.00 + 1	1.00 – 1	48
Pachistima myrsinites	1.50 + 2			2.33 * 3	2, 13, 18, 28, 31
Philadelphus lewisii	3.00 * 1				18
Pinus	1.00 – 3			1.00 – 1	6, 24, 39, 45
Pinus conterta	1.33 – 3			1.50 + 2	18, 21, 25, 30, 42
Pinus flexis				1.00 – 1	36
Pinus ponderosa	1.00 2				13, 18
Populus balsamifera	2.00 + 1				4
Populus tremuloides	2.50 * 8	2.25 * 4	1.74 + 4	2.50 * 8	2, 4, 5, 6, 9, 18, 25, 27, 30, 31, 36, 42, 48
Populus trichocarpa	3.00 * 1				18
Potentilla sp.				1.00 – 1	9
Potentilla fruticosa	1.00 – 1				30
Prunus virginiana	2.38 * 8	2.00 + 3	2.00 + 2	1.50 + 2	4, 12, 18, 21, 26, 27, 30, 32, 39, 42, 46, 48
Prunus emarginata			3.00 * 1	3.00 * 1	48
Prunus pensylvanica	2.00 + 1				4
Pseudotsuga menziesii var.*glauca*	1.27 – 11	1.00 – 3		2.00 + 1	5, 6, 13, 15, 18, 21, 24, 25, 29, 32, 42, 45
Purshia tridentata	3.00 * 4			3.00 * 1	2, 12, 13, 27, 46
Quercus gambellii	3.00 * 3	2.00 + 1			5, 26, 27
Rhamnus purshiana			1.00 – 1		48
Ribes	1.00 – 1				18
Ribes cereum			1.00 – 1		5
Ribes cognatum			3.00 * 1	2.00 + 1	48
Ribes montigenum			3.00 * 1		37
Ribes petiolare			1.00 – 1	1.00 – 1	48
Ribes viscosissimum			3.00 * 1	2.00 + 1	48
Rosa	1.50 + 2		3.00 * 1	2.00 * 1	18, 42, 48
Rosa acicularis	1.00 – 2		3.00 * 1	3.00 * 1	4, 38
Rubus				1.00 – 1	25
Rubus idaeus			2.00 + 1		4
Rubus parviflorus			3.00 * 1	2.00 + 1	48
Salix	2.11 + 9	2.00 + 1	1.71 + 7	2.29 * 7	4,6,13,19,21,22,25,29,30,33,36 39,42,44,47,48
Salix bebbiana	3.00 * 1				18
Salix exigua	2.00 + 1				18
Salix geyeriana	2.00 + 1				18
Salix lutea	3.00 * 1				18
Salix melanopsis	2.00 + 1				18
Salix scouleriana	1.50 + 2				18, 45
Salix subcoerulea	3.00 * 1				18
Sambucus sp.			3.00 * 1		3
Sambucus caerulea			3.00 * 1	3.00 * 1	48
Sambucus melanocarpa	3.00 * 1		3.00 * 1	3.00 * 1	18, 48
Sericotheca discolor	1.00 – 1		2.00 + 1	1.00 – 1	47, 48
Shepherdia canadensis	2.00 + 1		1.00 – 1	2.00 + 1	25, 33, 42
Sorbus americana			3.00 * 1	3.00 * 1	48
Sorbus occidentalis	2.00 + 1				18
Spirea	1.00 – 1		1.00 – 1	1.00 – 1	18, 29
Spirea betulifolia	2.00 + 1				42
Spirea lucida			2.00 + 1	2.00 + 1	48
Spirea menziesii			2.00 + 1	2.00 + 1	48
Symphoricarpos	1.40 – 5		1.50 + 2	1.83 + 6	13, 23, 25, 27, 29, 32, 33, 36, 42, 47
Symphoricarpos albus	3.00 * 1		3.00 * 1	2.00 + 2	4, 18, 48
Symphoricarpos occidentalis	1.00 – 1				39
Symphoricarpos utahensis		1.00 – 1	1.00 – 1		5
Tetradymia canescens	1.50 + 2			1.50 + 2	46, 39
Thuja plicata	2.00 + 1				45
Vaccinium	2.00 + 2		1.00 – 3	1.00 – 2	6, 13, 25, 30, 36, 44
Vaccinium membranaceum	1.00 – 1		3.00 * 1	1.33 – 3	18, 29, 33, 48
Vaccinium scoparium	1.00 – 1		1.00 – 1	1.00 – 3	9, 18, 29, 31, 48

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[2]Numbers indicate references in literature cited section on which value rankings were based.

Forbs having the best documented highly valuable rankings as summer forage were *Agoseris glauca* and *Geranium viscossimum. Lupinus* spp. was rated as highly valuable fall forage on the basis of five studies. *Aster* spp. was frequently mentioned and was considered a valuable plant throughout the year.

Highly valuable grasses or grasslikes having the best documented rankings were *Agropyron spicatum, Carex* sp., *Carex geyeri, Festuca idahoensis, Festuca scabrella,* and *Poa* sp. Highly valuable ratings were seasonal for most of these species. Only *Carex geyeri* was rated highly valuable throughout the year. *Koeleria cristata* was well documented as a valuable species on an annual basis.

Among shrubs, the highly valuable species with rankings based on a relatively large number of references were *Amelanchier alnifolia, Ceanothus sanguineus, Ceanothus velutinus, Populus tremuloides, Prunus virginiana, Purshia tridentata, Quercus gambellii* and *Salix* spp. Like forbs and grasses, these shrubs were highly valuable during only certain portions of the year. Most were highly valuable during the fall or winter.

Discussion

The validity of some value rankings could be influenced by the fact that various strains of the same species can differ in palatability. Palatability may also vary with differences in climate, soil conditions, and topography. However, the impact of these factors on rankings cannot be assessed until their effects on palatability of all elk forage species have been researched extensively.

Relative abundance and availability are two other factors which may have influenced value rankings. Some species may have received least valuable rankings because they were not abundant or because they were relatively unavailable due to some factor such as snow cover. Thus, they were only minor contributors to the diet. They may be highly valuable when they are more abundant or available. However, unless the normal abundance or availability of such species can be increased through management, their assigned rankings must stand as indications of their value as elk forage under natural conditions.

It must be remembered that rankings contained herein are averages for all studies where the species were eaten. Thus, some elk managers working where food habits have been studied extensively may feel that certain ratings are too high or low for their particular area. In such instances, questionable rankings may be adjusted up or down to fit the circumstances. However, the real benefits from these rankings should be realized by managers who lack sufficient data to determine the relative forage value of plants in their area and by managers who want to revegetate their ranges with plant species known to be good elk forage.

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Seasonal Changes in *Trans*-Aconitate and Mineral Composition of Crested Wheatgrass in Relation to Grass Tetany

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Highlight: *Grass tetany (hypomagnesemia) frequently occurs from March through June in cattle grazing crested wheatgrass in western United States. High levels of* trans-*aconitate and/or citrate, K, K/(Ca + Mg) ratios and low Mg in the grass are implicated in the etiology of the disease. In the moist 1967 season, during periods of "flush" growth following warming trends,* trans-*aconitate and K increased while Ca and Mg decreased in crested wheatgrass. These characteristics may explain the incidence of grass tetany during periods of "flush" growth. During the dry 1968 season, these trends were not observed. Growth chamber studies confirmed some of the reasons for changes in crested wheatgrass composition observed in 1967 and 1968.*

Grass tetany (hypomagnesemia), a metabolic disorder of ruminants, frequently occurs from March through June on pastures of crested wheatgrass (*Agropyron desertorum*) and other grasses in the western United States (Grunes et al., 1970). In the last 10 years at least 470 known cases of tetany and many suspected cases were noted in northern Nevada, mainly in the extreme northeastern part of the state (unpublished Nevada State Office, BLM Report). Most reported cases were on crested wheatgrass, but losses also happened on native grasses. Tetany occurs in northeastern Nevada in early spring or late winter when cows are fed grass hay. Hjerpe (1964) reports tetany to be a major problem in California, with losses estimated at 4,000 to 6,000 head during the winter of 1963-64 and sporadic losses reported annually. Losses also occur in Idaho and Utah. Tetany may be prevalent during the autumn months, especially on regrowth after late summer showers.

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Induction of the disorder involves many factors. Among factors that promote tetany are low temperatures or a change from low to high temperatures with rapid growth when moisture is adequate (Kemp and 't Hart, 1957). During dry years incidence of tetany is much lower. High rates of K and N fertilization and low forage Mg are also involved (Kemp, 1958, 1960). The Mg content of grass tetany-prone pastures is between 0.07% and 0.20% dry weight basis, with averages of 0.17% for the Netherlands (Kemp and 't Hart, 1957) and 0.145% for Scotland (Butler, 1963). The critical level is controlled by the relative availability of Mg to the animal. Ratios of K/Ca + Mg) (expressed as meq/kg) greater than 2.2 have been related to the occurrence of tetany (Kemp and 't Hart, 1957).

More recently, *trans*-aconitate of 1% or more in grass has been associated with tetany (Burau and Stout, 1965; Stout et al., 1967). Also, the dietary intake of 1% citric acid, as sodium citrate, reduced the Mg concentration in the blood serum of ruminants (Burt and Thomas, 1961). Bohman et al. (1969) induced tetany in cows by giving citric or *trans*-aconitic acid and KC1 as an oral drench. For a comprehensive review of grass tetany, the reader is referred to the article by Grunes et al. (1970). The objective of this study was to evaluate the effect of environmental temperatures on changes in *trans*-aconitate, Mg, Ca, and K in crested wheatgrass and relate such changes to the incidence of grass tetany on spring ranges in northern Nevada.

Methods

During April and May of 1967 and 1968, crested wheatgrass samples were collected from a well established, non-grazed seeding at Orovada in Northwestern Nevada. Losses from grass tetany had occurred in this area in previous years. Sampling began when the blades were about 5 cm long and continued until the soft dough stage. About 100 g of fresh plant material were collected weekly by taking a few blades from randomly selected plants. The grass was cut from 2.5 to 5 cm above the ground. Samples were frozen with solid CO_2 or liquid N_2, subsequently freeze-dried and ground to pass a 40-mesh screen.

Sodium, K, Ca and Mg were determined on nitric-perchloric acid digests of dried plant material by atomic absorption spectroscopy. Chlorides were extracted with 0.1N nitric acid and determined potentiometrically (Brown and Jackson, 1955). Total aconitate was determined by a modification of a polarographic procedure (Burau, 1969). Fifty ml of extracting solution (0.1 M Na_2HPO_4–0.1 M NH_4Cl, pH 9.5) was added to 0.5 g of plant material and shaken for 1 hour in the presence of approximately 1 g of gas-produced carbon black. After filtering, a 10-ml aliquot of the extract was combined with 10 ml of 0.5 N HCl and made to a volume of 50 ml with water. A 25-ml aliquot was then placed in a polarographic electrolysis vessel, "H" form, and de-aerated with nitrogen. The diffusion current at −0.9 volt was measured and compared with a standard curve to give the concentration of total aconitate in the unknown.

Air temperatures were recorded on a thermograph in a standard U. S. Weather Bureau shelter 15 cm above the ground surface. The temperatures are shown as 5-day means. Rainfall data were taken from the U. S. Weather Bureau Station at Orovada approximately 2 km from the plots.

Soil samples were taken at 15-cm increments to a depth of 45 cm, dried and ground to pass a 2-mm sieve. Each sample was extracted with neutral 1 M ammonium acetate (Richards, 1954); the concentration of Na, K, Ca and Mg was determined by atomic absorption spectrophotometry. The pH of the saturated soil paste was measured with a glass electrode; soluble salts were estimated by electrical conductivity of extracts of saturated soil pastes (Richards, 1954).

In order to investigate the relationships among temperature, "flush" growth, and changes in elemental and *trans*-aconitate contents of crested wheatgrass, a growth chamber study was undertaken.

For growth chamber studies, eight crested wheatgrass seeds were planted in each of 42 black plastic pots, 12.7 cm diameter and 15 cm high. Each pot was filled with a potting mix consisting of six parts loam, one part expanded vermiculite, and one part peat moss. The soil was kept moist and left in the greenhouse about 12 weeks until the grass was 18 to 23 cm tall. These pots were then transferred to a temperature and light controlled growth chamber. Plants were left in the chamber with a light intensity of 21,500 lux and a 10-hour dark and 14-hour light period for 15 days. Temperature was programed for a minimum of 6° C about an hour before the light period started and for a peak of 27° C midway through the light period. Temperatures were programed to follow the regimen of a typical warm spring day at Orovada.

After the first 15-day period was over, the photoperiod was left the same, but light intensity was lowered to 10,750 lux. The temperature was programed to follow a typical cool, cloudy spring day at Orovada with a low of −1° C and a high of 7° C. This regimen continued for 18 days. On the 18th day the grass was returned to the high light, high temperature regimen. Sufficient water was added to maintain good plant growth. Samples were taken periodically during the cool and warm periods by removing a few blades of grass from each pot. The grass was analyzed as previously described.

When the sampling period was over, the grass was clipped to a height of 2.5 cm and sprayed for aphids. Regrowth was not good because the grass appeared deficient in P and N. Each pot was fertilized with 3 g of diammonium phosphate, equivalent to 502 kg/ha of N and 556 kg/ha of P. The fertilized grass was grown under the high light, cool temperature regimen until the plants were 18 to 23 cm tall. The regimen was then changed to reduced light and cool temperatures for 17 days and then to high light and warm temperatures for the rest of the sampling period (30 days). Periodic samples were taken during both the cool and warm periods and analyzed.

Results

1967 and 1968 Field Study

Mean annual rainfall at Orovada is 29.15 cm with a mean of 10.1 cm in March, April, and May. However, rainfall during the spring of 1967 was 2.9 greater than normal for March, April, and May. Soil moisture was adequate, and plants showed no water stress during the 1967 sampling season. The spring of 1968 was much drier than normal, following a dry winter. Precipitation totaled only 5.4 cm during March, April, and May. The majority of the precipitation, 2.6 cm, occurred during the first 2 weeks of April. Grass showed water stress by the May 11, 1968, sampling.

Soils were derived from well-drained mixed alluvium, silty loam in texture, and were not strongly developed morphologically, although the 30- to 45-cm depth was calcareous. The pH was approximately neutral (6.8 to 7.4). Soluble salts were low in the surface 15 cm but increased slightly with depth. Considerable volcanic ash was also present. Cations in the 1 M ammonium acetate extracts and the cation exchange capacity are shown in Table 1. The 1968 samples were from a site adjacent to the 1967 site and illustrate some of the natural variability. Soil K and Mg appeared adequate for plant growth.

During the moist 1967 season the *trans*-aconitate and K levels of crested wheatgrass paralleled each other (Fig. 1). Changes in K correlated significantly with maximum temperature changes. *Trans*-aconitate almost correlated with temperature changes. When air temperatures increased in early May, K and *trans*-aconitate increased while Ca and Mg decreased. Using the *t*-distribution test (Snedecor, 1956) and ignoring the first two sampling dates when the blades were less than 5 cm, K and T. A. were significantly (1%) higher and Ca and Mg were significantly lower (1%). At the beginning of the season, Mg values were above the 0.14% to 0.17% Mg levels of the tetany-

Table 1. Ammonium acetate (1-molar) extractable cations, and cation changeable capacity (meq/100 g) Orovada, Nevada, 1967 and 1968.

Location	Depth (cm)	Na	K	Ca	Mg	Exc. cap.
Orovada, 1967	0–15	0.5	1.8	7.2	3.7	12.9
	15–30	2.7	1.3	8.9	3.3	14.5
	30–45	6.3	0.9	26.0	4.0	14.8
Orovada, 1968	0–15	1.8	1.8	9.3	3.0	14.8
	15–30	5.1	1.2	10.3	2.9	15.1
	30–45	12.5	0.6	22.8	2.5	14.7

prone pastures of the Netherlands and Scotland. Magnesium reached tetany-prone levels (0.09 to 0.12%) following the increase in temperature.

The ratio of K/(Ca + Mg) was low until the temperature increased and then rapidly increased to tetany-prone levels. Following the increase in temperature, K/(Ca + Mg) was significantly higher (1%) than before the temperature increase. Chloride levels were 0.75% at the beginning of the season, fell to 0.5%, and rose to 0.64% at the end of the season. Sodium was low, less than 0.09%, throughout the season.

The rapid increase in blade length is indicative of the period of "flush" growth following the general rise in air temperature about May 5.

The dry 1968 season produced plant composition patterns that were different from those of the moist 1967 season (Fig. 2). Excluding the first sampling date, K and *trans*-aconitate values tended to parallel each other until soil moisture was depleted during the first week in May. When the temperature increased, K and *trans*-aconitate increased; but when moisture stress developed, *trans*-aconitate decreased. About a week later K also decreased. No significant difference was found in K or *trans*-aconitate between the cool and warm periods. There was no significant difference in *trans*-aconitate between the dry and wet years, but K was significantly (1%) lower in the dry year.

Magnesium and Ca were significantly

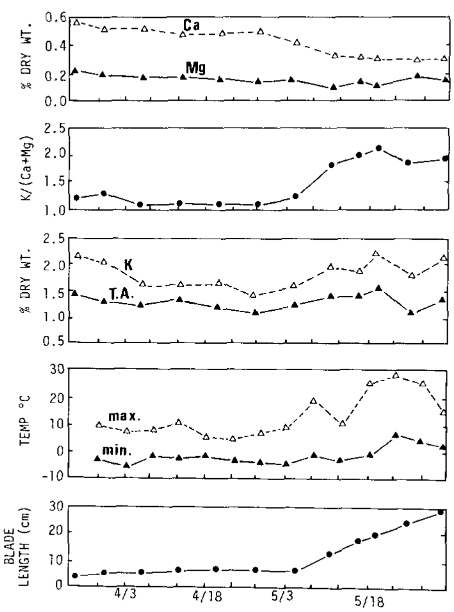

Fig. 1. *Relation between air temperature (15 cm above soil surface), Ca, Mg, K, trans-aconitate (T. A.), K/(Ca + Mg) (meq/kg) and blade length in crested wheatgrass at Orovada, Nev. Spring 1967.*

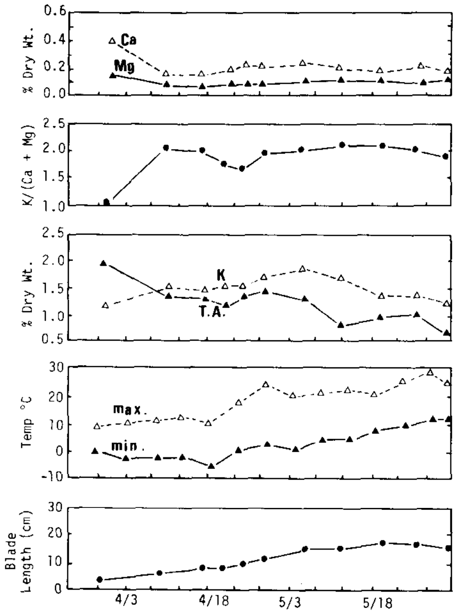

Fig. 2. *Relation between air temperature (15 cm above soil surface), Ca, Mg, K, trans-aconitate (T. A.), K/(Ca + Mg) (meq/kg) and blade length in crested wheatgrass at Orovada, Nev. Spring 1968.*

(1%) lower during the dry 1968 season, but no difference was found between the cool and warm periods. The K/(Ca + Mg) ratios reached a peak at the beginning of the season and declined slightly when the grass showed moisture stress. The ratios never reached more than 2.0, and there was no significant difference between the cool and warm period in the dry year. There was also no significant difference in maximum K/(Ca + Mg) ratios in the wet (1967) and dry year (1968). Chlorides were slightly lower (approx. 0.5%) than in the wet year and remained essentially unchanged throughout the season. Sodium was also lower than in the previous season (less than 0.04%) and remained essentially constant.

Blade length did not increase as rapidly and was not as great following the temperature increase in 1968 as in 1967 because moisture stress symptoms had begun to develop. Crested wheatgrass did not show any sustained period of "flush" growth in 1968.

In the growth chamber experiments, Ca and Mg in both the fertilized and nonfertilized crested wheatgrass decreased about 6 to 10 days after temperature and light had been increased (Fig. 3). The difference in Ca and Mg between the cool and warm periods were significant (1%) for the nonfertilized crested wheatgrass. The differences were also significant at the 1% level for Ca and significant at the 5% level for Mg in the fertilized crested wheatgrass. The Ca concentration of the fertilized grass dropped about 3 days sooner than in the nonfertilized grass. The change in Mg was not as great as in Ca, but Mg concentration of both the fertilized and nonfertilized grass was lowest about 14 days after temperature was increased.

As the cool period continued, K became progressively lower in both the fertilized and nonfertilized grass. About 6 days after temperature and light were increased, K increased rapidly in the fertilized grass and remained about the same in the unfertilized. In the fertilized grass, K was significantly higher (5%) in the warm period; in the nonfertilized grass, the reverse was found. *Trans*-aconitate concentration also increased about 6 days after temperature and light were increased. The differences in *trans*-aconitate between the cool and the warm periods were significant in the unfertilized grass but not in the fertilized grass. Potassium and *trans*-aconitate concentrations tended to parallel each other in fertilized grass.

The ratio of K/(Ca + Mg) also increased between 6 to 10 days after temperature and light were increased in the fertilized and nonfertilized grass. The K/(Ca + Mg) was significantly higher (nonfertilized 5% level, fertilized 1% level) in the warm period. In the fertilized grass, the ratio increased more rapidly and reached a high point of 4.0 in about 15 days. After the peak was reached, the ratio dropped to about 3.5 and stayed there for the remainder of the experiment.

Discussion

During 1967, outbreaks of grass tetany occurred the week of May 16 in northern Nevada (about 25 km north of the plots) and southern Idaho. This was the first week with minimum temperatures above 0° C. A few cases of tetany are normally reported each year on seedings adjacent to the sample plots. In 1967, ranchers in this area delayed turn-out until the tetany season had passed and thus avoided the possibility of high death losses. No cases of tetany were reported during the dry spring of 1968 in the Orovada area. However, in the wetter parts of northern Nevada and southern Idaho, outbreaks of tetany were reported shortly after May 1, when temperatures started to rise.

In the moist spring of 1967, the tetany-prone period began about a week after the temperature changed from cool to warm. At this time some of the factors

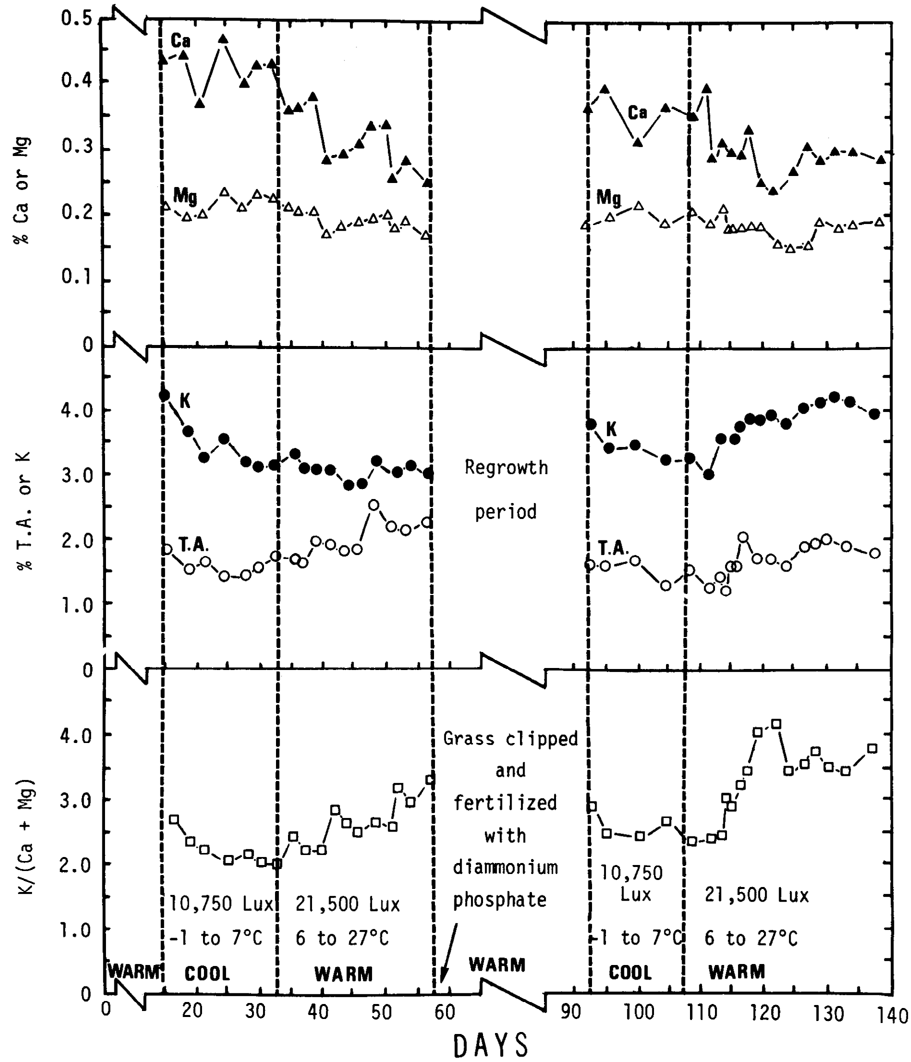

Fig. 3. *Changes in Ca, Mg, K,* trans-*aconitate (T. A.), and K/(Ca + Mg) (meq/kg) in crested wheatgrass grown in a growth chamber, when changed from a cool (-1 C to 7 C) low light (10,750 lux) regimen to a warm (6 C to 27 C), high light (21,500 lux) regimen. After the first cycle, grass was clipped and fertilized with diamonium phosphate.*

involved in the induction of grass tetany were optimal: high K and *trans*-aconitate levels, low Ca and Mg, and a rapid increase in the ratio of K/(Ca + Mg). This occurred at the same time as a period of "flush" growth induced by ample moisture and rising temperatures.

In the dry spring of 1968, no period of "flush" growth was observed and no tetany was reported in the Orovada area. Potassium and *trans*-aconitate declined as moisture became limiting, and Ca and Mg were low. The ratio of K/(Ca + Mg) was consistently rather high as a result of low Ca and Mg values.

Soil contained ample Mg, but crested wheatgrass from the Orovada site was low in Mg. Similar results were obtained for samples collected throughout northern Nevada (unpublished data of the authors). Apparently, crested wheatgrass and other grasses (unpublished data of the authors) are unable to accumulate concentrations of Mg required for good animal nutrition, even though the soils appear to contain adequate Mg. In the greenhouse study, the potting mixture did not contain soil from the Orovada area, and the Mg concentrations in the plants were appreciably higher.

The rapid increase in K/(Ca + Mg) observed during 1967 when temperature was increased may be similar to the rapid increase in the ratio observed in fertilized growth chamber herbage upon warming (Fig. 3). Experience has shown that tetany proneness in the field is of several weeks duration, and this period may coincide with a period of rapid increase in the K/(Ca + Mg) values. The initiation of tetany may result from this rapid change in elemental concentration, rather than a particular level. We hypothesized that tetany did not occur in 1968 because there was no rapid change in the ratio even though the ratio was high throughout the entire period. The prevalence of grass tetany in cattle grazing rapidly growing crested wheatgrass following a change from cool to warm temperatures probably results from optimization of tetany inciting factors, in addition to those explained by the changes in elemental content (Grunes et al., 1970).

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Production and Nutrient Status of Whitetop

ALAN L. SMITH

Highlight: *Post-flowering production of whitetop (*Scolochloa festucacea *[Willd.] Link.) was greater from burned and mowed sites than from undisturbed sites. Production from grazed stands was equal to that from undisturbed sites. Whitetop growth was initiated earlier on burned sites resulting in an earlier flowering time. Phenological differences in N content of the plant could be detected relative to water depth in the pothole. Nitrogen content decreased through flowering then increased. Potassium content decreased through the growing season. No concentration patterns were noted for other basic cations in the plant tissue relative to growth stage, site condition, or land-use practice. No relationship was ascertained between nutrient status of whitetop and land-use practice of the supporting site.*

Whitetop (*Scolochloa festucacea* [Willd.] Link.) is an emergent hydrophytic grass (Fig. 1) of wetland communities in glaciated regions of the Central Lowlands and Great Plains physiographic provinces of northcentral United States and southcentral Canada (Martin and Uhler, 1939; Stewart and Kantrud, 1969). Wetland habitats of this area are mostly small, ephmeral to permanently inundated, ponds commonly called potholes (Smith et al., 1964). They are located within a youthful glacial landscape of poor drainage. These potholes were formed by iceblock basins and irregularly deposited till of Pleistocene glaciers (Flint, 1957).

Whitetop may be hayed in late July to early August when water levels drop in the potholes. The species is highly palatable to livestock but does not tolerate continued grazing pressure (Clarke and Tisdale, 1945; Smeins, 1967).

Whitetop production varies with soil types, depth, and duration of submergence and salinity (Cosby, 1964). Crude protein content of the herbage is high during early stages of flowering (Zagrabaev and Zenchenko, 1970) but both protein and Ca content decrease considerably after flowering (Clarke and Tisdale, 1945).

Estimates of whitetop productivity or nutrient status are not well documented. The objectives of this study were to (a) estimate production and nutrient status of whitetop herbage in stands which were undisturbed, burned, mowed, or grazed, and (b) evaluate seasonal changes in N, Ca^{++}, Mg^{++} Na^{+} and K^{+} content of the herbage.

Methods and Materials

Production

Post-flowering herbage production of whitetop was obtained during 1969 and 1970 from 26, randomly-selected stands. Treatments evaluated were undisturbed, burned, mowed, and grazed by livestock. Burning treatments were applied the previous fall after senescence. Mow treatments were applied in August prior to sampling the following growing season. Samples were collected between July 25 and August 15 both years. Plants were clipped at ground level in four 0.25 m^2 quadrats and air-dried 1 week. Samples were then oven-dried 72 hr at 105° to 110° C and weights recorded.

Oven-dry whitetop herbage weight was

Fig. 1. *Whitetop (A) growing in a North Dakota pothole which is fall burned annually. The grass commonly grows with other emergent hydrophytes such as bulrushes (B) and tall manna grass (C) in potholes which are inundated in early spring.*

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estimated in relation to water depth in a stand near Buxton and another near Petersburg, N. Dak. The Buxton site was burned in the fall of 1968 and 1969. Plots were arranged in a randomized block design and stratified across a water-depth gradient. Four blocks of 3.3 x 3.3 m plots were established for sampling June through August, with four 0.25 m^2 subsamples clipped each sampling date at each of four water levels. The experiment was expanded in 1970 to estimate production from April through August. The Petersburg site was burned the fall of 1968 but not in 1969. Plots were delineated similar to those at Buxton and were sampled from June through August in 1969. The study was expanded in 1970 to include monthly sampling from May through August.

Water levels were measured in the potholes at both sites when monthly herbage production samples were collected to determine hydrological changes. Due to the unpredictable nature of the hydrology of these potholes, water levels are referred to as those measured in the study plots at the time they were delineated. Water levels at the Buxton site included no standing water at the first block, 8 cm at the second block, 15 cm at the third block, and 24 cm at the fourth block. No standing water was recorded in the first and second tiers of plots when the study was initiated at the Petersburg site. Five cm of water was standing in the third block and 8 cm of water in the fourth. Soil and water temperatures were recorded at the time of sampling during 1970.

Chemical Analyses

Plant—Total N by micro-Kjeldahl (Jackson, 1958) was determined on 26 post-flowering, production samples of whitetop. The 1970 seasonal herbage samples from the two permanent sites also were analyzed.

Concentrations of Ca, Mg, Na and K ions were estimated with an atomic absorption spectrophotometer. Leaf tissue was prepared for analysis utilizing a modification of the wet-ash method outlined by Jackson (1958). One g of tissue was digested with a ternary acid mixture at 350°C in a 100 ml volumetric flask. After digestion the flask was brought to volume with double distilled water.

Soil—Soil salinity by electrical conductivity (Jackson, 1958) and total carbonate (Bower and Wilcox, 1965) was determined on saturation extracts. Organic carbon was determined using the Walkley-Black method (Jackson, 1958).

The atomic absorption spectrophotometer was utilized for Ca, Mg, Na and K ion determinations of soil extracts. Extracts were prepared by a modification of Chapman's (1965) ammonium acetate (NH_4OAc) extraction technique. Ten g of soil were saturated with 50 ml of 1 N NH_4OAc and placed on a shaker for 12 hr. Samples were filtered with an excess of solution and brought to 100 ml.

Soil texture was determined by the hydrometer method (Bouyoucos, 1962); available (1/3-15 atm) using matrix suction (Richards, 1965); and bulk density by weight to volume ratio (Blake, 1965).

Table 2. Comparison of seasonal productivity (kg/ha) of whitetop from four water levels in a pothole near Buxton, North Dakota, for two seasons following fall burns.[1]

Treatment and month	Water level[2] 1	2	3	4	Mean
Burned fall, 1968, and sampled 1969					
June	5,760 a	7,200 a-d	6,920 abc	7,560 a-d	6,840 a
July	7,800 a-d	6,160 abc	9,440 de	8,680 cde	8,000 ab
August	8,320 b-e	8,360 b-e	10,160 e	8,880 cde	8,920 b
Mean	7,320 a	7,240 a	8,840 a	8,400 a	
Burned fall, 1969, and sampled 1970					
April	240 a	320 a	440 a	600 abc	400 a
May	1,720 abc	2,160 bc	1,680 abc	2,240 bc	1,960 b
June	4,200 d	7,000 fgh	6,040 f	6,640 fg	5,960 c
July	8,480 hi	10,880 jk	10,320 jk	9,680 ij	9,840 d
August	8,320 gh	11,600 k	11,720 k	11,200 jk	10,720 e
Mean	4,600 a	5,600 ab	6,040 b	6,080 b	

[1]Means followed by the same letter within a time of burning or within a group of overall means are not significantly different at the 5% level using Duncan's multiple range test.

[2]Water levels represent the hydrological status at the time the study site was delineated in June, 1969. Level 1 = no standing water, 2 = 8 cm, 3 = 15 cm, 4 = 24 cm above the soil surface.

Results and Discussion

Herbage Production and Nutrient Status

Whitetop is utilized as forage in the Northern Great Plains. In many areas, water levels drop sufficiently by late July and early August to permit haying. Herbage production during the study period varied from 3,080 to 15,080 kg/ha. Burning and mowing increased yield, while grazed stands produced herbage equal to protected stands.

Water level had little influence on whitetop production unless the pothole was dry the year round. Cosby (1964) reported high yields, 8,900 kg/ha, on soils where ponding occurred; production decreased 2,600 kg/ha without ponding.

Production on burned stands averaged more than 11,500 kg/ha and 10,090 kg/ha on mowed stands (Table 1). Undisturbed stands produced only an average of 7,480 kg/ha. Production was not correlated with stem density (Smith, 1971). Burning and mowing resulted in more uniform distribution of whitetop stems, while undisturbed stands contained heavy litter accummulation. Litter accummulations often resulted in aggregations of stems in openings in the litter. Consequently, samples of high stem density but of low production were obtained.

Whitetop herbage production from grazed stands was equal to production from stands with no disturbance (Table 1). No estimates of acres/animal unit month were obtained relative to grazed potholes. Comparison of two potholes, one-half mile apart, indicated duration of grazing was an important factor. One stand was grazed continuously throughout the growing season (personal communication with local residents). A mean density of 51 stems/m^2 and a high density of slough sedge (*Carex atherodes* Spreng.) suggested that whitetop was grazed selectively. Continuous grazing would tend to deplete food reserves in the rhizomes and eventually eliminate the species from the stand. Smeins (1967) also reported whitetop decreases under intense, continuous grazing. The other stand was normally grazed at a high

Table 1. Average oven-dry herbage production (kg/ha), nitrogen (%) and basic cations (%) by weight in whitetop tissue collected from 26 post-flowering stands in North Dakota during the 1969 and 1970 growing seasons.

Treatments	Number of stands	Production	Element in tissue N	Ca	Mg	K	Na ($x10^{-2}$)
No disturbance	8	7,480	1.02	.12	.08	1.2	.54
Burned	10	11,580	1.05	.15	.10	1.2	.84
Mowed	5	10,090	1.19	.17	.11	1.1	.53
Grazed	3	7,450	1.11	.15	.07	1.2	.29

intensity for 4 to 6 weeks starting in mid-June, terminating with almost complete removal of aerial shoots. This stand was not grazed in 1970, the year it was sampled. Density of whitetop was 580 stems/m². This grazing system prevented litter accumulation and plants had sufficient time during the remainder of the growing season to develop rhizomes for the next season's growth.

Herbage N (% oven-dry weight) ranged from 0.5 to 1.92% with a mean of 1.08% in late July and early August for all land use categories. No trends were noted in the relation of herbage N content to land use practice. Calcium was the most consistent basic cation with a range of 0.09 to 0.23% and a mean of 0.15%. Magnesium ranged from 0.02 to 0.32% with a mean of 0.10%. Potassium occurred in higher amounts than any other cation. It ranged from 0.8 to 2.3% with a mean of 1.18%. Sodium occurred in least amounts with a range of 0.02 to 2 x 10^{-2}% and a mean of 0.62 x 10^{-2}%.

No significant correlation was derived between edaphic factors and production. However, negative trends were noted for organic carbon, Mg and K ion content, and conductivity of soil extracts. The latter value was closer to significance than other variables. All other variables were positively correlated within the limits of this study. Since these potholes are depressions in the glacial till, they usually represent the lowest point of the local topography. Fluctuation of the water table, rate of siltation, and deposition of fertilizer from the surrounding agricultural lands could influence the factors estimated in this study.

Production and Nutritional Changes

Whitetop herbage production on the burned site (Buxton) (Table 2) indicated little influence of water depth on production during 1969. A significant difference ($p<.05$) was noted between the mean June and August production. This site was damaged by hail 3 days prior to the August clipping date. Significant production differences occurred among the first, third and fourth water levels from April through August, 1970. Significant differences were noted among the overall monthly mean production values in any given year. June production was 6,840 kg/ha in 1969 but only 5,960 kg/ha in 1970. July production increased 1,200 kg/ha over June production in 1969, while production increased about 3,000 kg/ha for the same period in 1970. These data indicate earlier and more rapid growth of whitetop occurred in 1969.

Table 3. Comparison of seasonal productivity (kg/ha) of whitetop from four water levels in a pothole near Petersburg, North Dakota, following a fall burn and a season with no fall burn.[1]

Treatment and month	Water level[2] 1	2	3	4	Mean
Burned fall, 1968, and sampled 1969					
June	5,320 a	6,800 ab	7,440 abc	5,440 a	6,240 a
July	8,200 abc	7,560 abc	8,960 bc	9,080 bcd	8,440 b
August	5,400 a	9,880 cd	8,920 bc	11,880 d	9,040 b
Mean	6,320 a	8,080 b	8,440 b	8,880 b	
No fall burned and sampled 1970					
May	440 a	240 a	40 a	0 a	200 a
June	3,320 bc	3,320 bc	1,680 ab	3,080 b	2,840 b
July	7,880 f	7,520 f	8,800 f	8,720 f	8,240 c
August	6,040 de	8,960 f	11,800 g	5,200 cd	8,000 c
Mean	4,440 a	5,000 a	5,600 a	4,240 a	

[1]Means followed by the same letter within a time of burning or within a group of overall means are not significantly different at the 5% level using Duncan's multiple range test.
[2]Water levels represent the hydrological status at the time the study was delineated in June, 1969. Level 1 = no standing water, 2 = no standing water, 3 = 5 cm, 4 = 8 cm of water above the soil surface.

Water level had little influence on 1969 production at Petersburg, N. Dak., following a fall burn in 1968. A seasonal difference was noted for the first level (Table 3). Significant increases occurred in production among water levels for 1970. August production was greater in 1969 than in 1970 at the same site. These data support the hypothesis that burning tends to increase whitetop production.

May whitetop herbage production from the unburned site was 200 kg/ha or half the production on the burned site for 1970 (Tables 2 and 3). Lack of April production on the unburned site in 1970 was attributed to accumulation of litter which reduced light penetration to the substrate. An average of 3,140 kg/ha of accumulated oven-dry litter was obtained at the first level while 11,430 kg/ha was collected at the deepest level in June 1970.

Water levels in the pothole at the onset of whitetop culm elongation were lower for the burned site than the unburned site in 1970 (Fig. 2). However, the water level increased approximately 15 cm between April and May harvests on the burned site. Water levels were approxmately the same in April for 1969 and 1970 on the unburned site. This indicates that water levels were not entirely responsible for the decreased production.

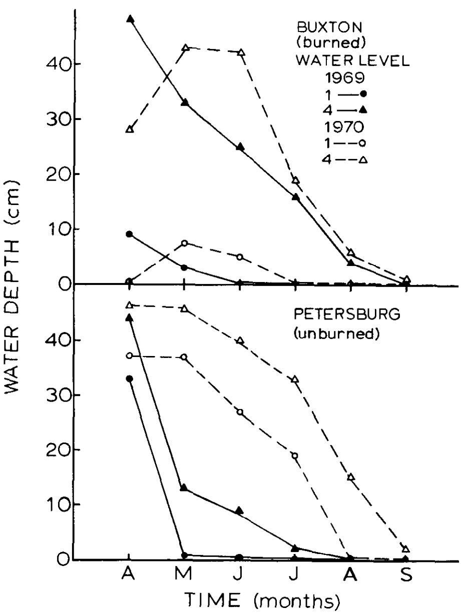

Fig. 2. *Seasonal water level patterns for the study period on two whitetop dominated potholes in North Dakota.*

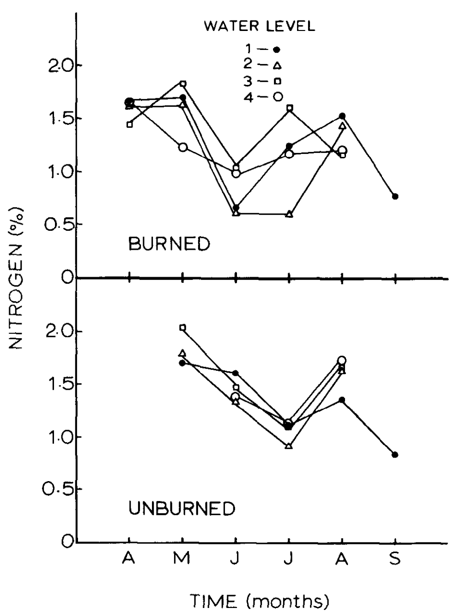

Fig. 3. *Seasonal changes in nitrogen content in whitetop tissue in relation to water depth on burned and unburned sites in North Dakota in 1970.*

Table 4. Nitrogen and basic cation content (%) by weight in whitetop tissue from the seasonal productivity study sites near Petersburg (unburned) and Buxton (burned), North Dakota, during 1970.

Treatment and month	N	Ca	Mg	K	Na $(x10^{-2})$
Unburned					
May	2.03	.15	.12	2.9	.24
June	1.47	.14	.07	1.9	.50
July	1.20	.15	.08	1.4	.20
August	1.65	.18	.11	1.0	.50
September	0.84	.29	.13	0.5	.40
Burned					
April	1.44	.12	.20	2.5	.70
May	1.84	.08	.23	2.3	.50
June	1.03	.09	.16	1.7	.50
July	1.61	.18	.31	1.2	.30
August	1.26	.31	.35	0.7	.70
September	0.77	.22	.35	0.3	.40

A comparison of N values of plants growing at various water levels indicated phenological differences (Fig. 3). Herbage N content was about 0.5% higher from plant tissue growing at the third and fourth levels than for plants growing at the first and second levels in June on the burned site. Plant tissue tested from both locations decreased in N content at the onset of flowering (Table 4). This occurred in mid-June at the burned sites and early July at the unburned site. Delayed flowering was probably due to the later initiation of spring growth. Nitrogen content in whitetop tissue increased after flowering at both sites. A decrease was noted during senescence.

Calcium content of whitetop tissue varied little through the growing season, but increased at senescence (Table 4). Magnesium content declined from 0.12% in May to 0.08% in July on the unburned site, then increased to 0.13% by September. The Mg concentration dropped in June on tissue sampled from the burned site, followed by an increase through August. These fluctuations could have been responses to phenological changes. Differences in Mg concentrations of the burned and unburned sites (Table 4) were probably edaphic rather than due to burning. Variability of Mg concentrations within treatments (Table 1) substantiate this idea. Plant tissue from both sites declined in K content during the growing season. The highest K level occurred in the earliest growth stages and lowest prior to senescence. Nitrogen and K are two elements which show greater concentrations in young shoots and a dilution in concentration as plant volume increases. Calcium and Mg are considered to enter plants at rates that prevent dilution (Smith, 1962). No pattern of Na concentration could be ascertained at either site relative to growth condition.

Whitetop is an excellent forage producer following burning and mowing. Forage protein content approach preflowering levels in late August, early September. Inundation of monodominant whitetop stands through flowering followed by drainage prior to mowing would provide maximum production. Proper management of whitetop would establish the species as an important forage grass of the Northern Great Plains.

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Plant Induced Soil Salinity Patterns in Two Saltbush (*Atriplex* spp.) Communities

M. L. SHARMA AND D. J. TONGWAY

Highlight: *A detailed examination was made into the soil salinity distribution of two* Atriplex *communities,* A. vesicaria *and* A. nummularia, *established at regular spacings on two soil types. The results based on total soluble salts and chlorides suggested that both saltbush species induced significantly higher salinity in the 0–15 cm soil horizon beneath the bush canopies compared to between the bushes, although* A. nummularia *induced significantly higher salinity than* A. vesicaria *on both the soils. The pH was also significantly increased under the bushes, but only for the 0–7.5 cm layer.*

A mechanism for plant-induced soil salinity is proposed by which distinct zones of salt depletion, accumulation and compensation are established. It is suggested that the accumulation of significantly large quantities of salt in the surface layer under the bushes occurred as a result of decomposition of large quantities of salt-rich leaves and fruits. This salt is mainly derived from the soil profile under the plant. Implications of the spatial variability in soil salinity are discussed.

In understanding drylands, interest in soil-site relationships centers on the soil as one of the environmental factors important in determining species composition and plant growth. Soils and vegetation do not exist as independent components of the ecosystem, but rather each plays an important role in determining the character of the other. Some plants exert a pronounced influence on soil properties, and this influence must be appreicated and evaluated if a better understanding of the dryland ecosystem is to be accomplished.

Various species of *Atriplex* occupy a considerable area in the arid and semi-arid regions of Australia (Leigh and Noble, 1969) and other parts of the arid world. They are tolerant to drought and salinity and have high salt content in their leaves (Wood, 1925; Beadle et al., 1957). Our own studies (Sharma et al. unpublished) on oldman saltbush (*A. nummularia*) and bladder saltbush (*A. vesicaria*) have indicated the extremely high salt concentration in their leaves and its fluctuation with the season. The leaves of these and similar plants, after falling to the ground, are likely to increase the salinity of soil beneath the plant (Jessup, 1969). Other arid plants, such as greasewood (*Sarcobatum vermiculatum*), shadscale (*Atriplex confertifolia*), and sagebrush (*Artemisia tridentata*), have also been reported to be directly responsible for changing the chemical properties of soil beneath the plant (Roberts, 1950; Fireman and Hayward, 1952). However, these studies have been of an observational type in naturally occurring, irregularly distributed plant communities; and for this reason, critical interpretation of salt distribution has not been possible. The purpose of the present study was to investigate such plant induced soil variability in terms of soil salinity and related properties in two regularly spaced, semi-arid saltbush communities.

Methods and Material

Climate, vegetation and soils

The experimental site is located at the Falkiner Memorial Field Station, about 24 km north of Deniliquin (35° 30′S altitude 100 m) in southwest New South Wales. The climate of the area is semi-arid with an average annual precipitation of 380 mm and potential evaporation of 1,550 mm. Most of the effective rain is received during winter, with few summer storms. Table 1 summarizes some of the climatological data at the site for the experimental period.

In the present study, established plantations of *A. nummularia* and *A. vesicaria* growing side by side on two types of soils

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Table 1. Monthly rainfall (mm), evaporation (mm) (U. S. Class A pan), and minimum and maximum temperatures (°C) at the experimental site.

Date		Rainfall	Evaporation	Temperature Minimum	Temperature Maximum
1969	June	9.6	41.4	2.1	12.2
	July	34.3	42.2	3.9	14.7
	August	29.2	74.2	2.2	16.7
	September	22.1	90.2	3.9	16.1
	October	20.6	181.1	8.4	23.9
	November	23.4	231.6	10.5	21.6
	December	8.9	315.2	11.4	27.8
1970	January	73.9	271.5	15.6	29.2
	February	15.0	283.5	16.4	33.1
	March	43.4	184.4	12.6	26.3
	April	75.7	118.6	10.5	23.1
	May	12.7	62.2	6.5	17.4
	June	35.3	33.3	3.9	12.6

were used. The *Atriplex* had been planted at regular spacings on soils which had not previously, at least in recent years (>100), carried these plants. Therefore, the observed salinity patterns in these communities can be attributed to the presence of these plants. The important plant factors which might affect salt distribution appear to be age and size of plants, distance between plants, intervening vegetation type, etc. These features for the plants of the experimental communities are summarized in Table 2.

On the Riverine Plain, saltbush communities occur naturally on a group of soils known as grey, brown, and red clays. Two important members of this group, Billabong and Riverina clay, supported the plant communities of the present study. The landscape of both soils is flat with an average grade of 1:1500. Some features of the soils are given below:

Billabong clay—An A horizon of loam to clay loam about 5 cm deep, diffusing into a light clay and then to dark brown heavy clay. Traces of calcium carbonate occur at about 30 cm and a mixture of calcium carbonate and crystalline gypsum at about 45–50 cm.

Riverina Clay—An A horizon of brownish silty clay loam, about 1–2 cm deep, abruptly changing into dark grey heavy clay. Traces of calcium carbonate and crystalline gypsum occur at about 45 cm. This soil exhibits more shrinking and swelling properties and micro-gilgai surface patterns than Billabong clay.

Experimental procedure

On each of five occasions during the year 1969–1970, seven paired soil core samples were collected from two positions: under the bush canopies (U), and between bushes (B) from each community on both soils. These samples were separated into profile depths, 0–7.5–15–30–45–60–75–90 cm. After air drying, the samples were crushed and passed through a 1 mm sieve and then analyzed for pH and electrical conductivity (EC_5) in 1:5 soil-water suspensions and chloride content determined by the titration method using silver nitrate (U.S. Salinity Laboratory Staff, 1954).

In order to examine the distribution of salts in the profile with respect to distance from plant and profile depth, in March 1970 seven transects were sampled in the *A. nummularia* community on Billabong clay. Seven profile samples were collected along each transect between two plants, spaced 3 m apart. The sample nearest to each plant was 0.3 m from the plant, while subsequent samples were 0.4 m apart from each other. These samples were analyzed for chloride.

Results

Spatial Pattern of Variation in Salinity

Average EC_5 data based on soil samples (seven samples from each U and B position) collected in March 1970 are presented in Table 3. These results indicate that (1) there was a significantly higher salt concentration down to 15 cm depth at U compared with B position for both species on both soils; (2) invariable the soil salinity of the surface layer under *A. nummularia* was significantly higher than under *A. vesicaria*; (3) there were no significant differences at position B for the two communities in both soils, although there was slightly higher salinity at this position in *A. nummularia*; (4) at depths below 45 cm, generally there was higher salinity at B compared to U positions, particularly in *A. vesicaria.* These differences were not always statistically significant. (5) Salinity associated with each plant species were similar on both soils.

The chloride contents of soils, in general, followed the EC_5 trends. This is illustrated by Figure 1 showing the average chloride concentration in the Billabong clay profile. These determinations were made on the same samples as were used for EC_5 measurements of Table 3. Again, similar conclusions can be drawn. This indicates that the salts are predominantly chlorides of various cations.

The spatial variability among replicates was higher in EC_5 than in chloride, particularly at depths below 30 cm where gypsum and calcium carbonate start appearing. Therefore, it is felt that chloride content would be a better indicator of salinity level than EC_5.

The pH was significantly higher at U compared with B positions in both communities and on both soils, but only for the surface (0–7.5 cm) layer; otherwise it remained relatively unchanged. For example, in March the pH values of 0–7.5 cm Billabong clay at B and U positions in *A. nummularia* were 6.56 and 7.12, and in *A. vesicaria* 6.68 and 7.10 respectively. The corresponding pH values of Riverina clay in *A. nummularia* were 6.56 and 6.85 and in *A. vesicaria*, 6.32 and 6.62.

Seasonal Changes in Soil Salinity

Although soil samples were collected and analyzed on five occasions during the year, results are presented in Table 4 for only two occasions which serve to illustrate the extremes. As is

Table 2. Characteristics of plant communities used in the experiment.

Community	Average distance between plants (m)	Average height of plants (m)	Average diameter of plants (m)	Age of plants	Predominant vegetation in the intervening area
A. nummularia	3	1.26 ± 0.19	1.16 ± 0.45	10 years	*Danthonia caespitosa, Stipa variabilis*
A. vesicaria	2	0.46 ± 0.12	0.94 ± 0.41	10 years	*Danthonia caespitosa, Stipa variabilis, A. vesicaria*

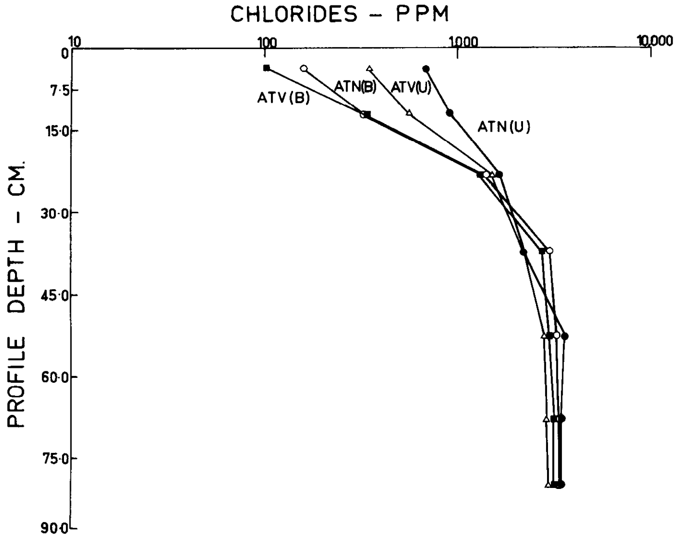

Fig. 1. *Chloride as a function of profile depth of Billabong clay from under (U) and between (B) the plants of* A. nummularia *(ATN) and* A. vesicaria *(ATV).*

clear from the table, the salinity level of only surface layers (0–7.5–15 cm) fluctuated with the season; the salinity was highest during and after summer when the evaporative demands were high, and lowest during winter after rains (Table 1).

Salinity Distribution

The distribution of chloride in the profile with respect to distance from the *A. nummularia* plant and profile depth is presented in a generalized diagram (Fig. 2) which was constructed mainly from the chloride results of seven transects. The diagram shows that chloride content under the plant, compared to that between the plants, was higher in the 0–7.5 cm layer, but was lower in the 30–45 cm layer. The differences in chloride between U and B positions at both depths were significant ($P < 0.05$). The chloride content of the 15–30 cm layer was almost the same as U, B, and intervening positions. Based on the net gain or loss of chloride with respect to position, three distinct zones are proposed; accumulation zone, compensation zone, and depletion zone.

Contribution from Water Table

The possible contribution of salinity from the water table was examined by obtaining a salinity profile down to the water table (about 15 m). From such a deep water table, it can be suggested that transport of salts by capillarity is extremely doubtful.

Discussion

It is hypothesized that accumulation of a significantly higher quantity of soluble salts in the surface layers ("accumulation zone") has occurred as a result of the large turnover of salts derived from leaves and fruits, which are shed in large quantities. It is suggested that this salt is derived mainly from the soil profile under the plant, thus creating a "depletion zone." It is further suggested that in the "compensation zone," the depletion of salts by plant uptake is compensated by salt leachates from surface layers. Thus, salt accumulation, depletion, and compensation are a net result of processes which accumulate salts at one position and those which deplete them from the other. In order to discuss these results, several processes need to be considered: plant litter fall and its decomposition; leaching of salts from plants with rain, also leaching in the soil profile; evaporation of water from soil surface and deposition of salts at the soil surface; water movement to plant roots and convectional transport of salts, and salt transport by ionic diffusion.

The old leaves of both *A. nummularia* and *A. vesicaria* are shed steadily during autumn and winter, but heavy shedding occurs particularly after a prolonged dry season. The litter is compounded from separate growth flushes. In *A. vesicaria* the annual litter fall is much greater than the amount of vegetative material on the plant when it is in its period of maximum production, the fruit fall contributing to about 50 to 60 per cent of total litter fall (Charley, 1959). The sodium chloride content of leaves of both *Atriplex* sp. varied with the age and was much higher compared to other plant parts (Table 5). The fruits contain about half the amount contained by leaves (Charley, 1959). It is proposed that these falling leaves and fruits on rapid decomposition (Charley and Cowling, 1968) release a considerable amount of salt, which raises the salinity level of the soil under plants.

Table 3 shows that surface soil under *A. nummularia* contains significantly higher salt than soil under *A. vesicaria*, although the salt concentration of leaves of both plants is about the same (Table 5). However, the amount of litter fall per unit area under the canopy of *A. nummularia* is likely to be much higher than under *A. vesicaria*, because the former plants are taller and bear larger leaves.

The salt turned over in the form of litter is apparently

Table 3. Average electrical conductivity (EC_5 – mmhos/cm) of soil samples determined in 1:5 soil: water suspensions under the bush canopies (U) and between bushes (B).

Depth (cm)	Billabong clay						Riverina clay					
	A. nummularia		*A. vesicaria*				*A. nummularia*		*A. vesicaria*			
	B	U	B	U	Ø	†	B	U	B	U	Ø	†
0 – 7.5	0.301**	0.677**	0.229*	0.388*	NS	**	0.218**	0.605**	0.185**	0.331**	NS	*
7.5 – 15	0.658*	1.051*	0.443*	0.727*	NS	NS	0.258**	0.608**	0.206*	0.339*	NS	**
15 – 30	1.609	1.807	1.578	0.912	NS	**	0.564	0.837	0.360	0.545	NS	NS
30 – 45	2.271	2.394	1.974	1.811	NS	*	0.898	1.425	0.873	1.002	NS	*
45 – 60	3.207	3.758	4.693*	2.804*	*	NS	1.872	2.120	1.507	1.457	NS	*
60 – 75	4.791	5.150	5.671	5.363	NS	NS	3.790	4.350	3.857	2.094	NS	**
75 – 90	4.350	3.552	3.580	2.684	NS	NS	4.120	5.130	5.708	4.782	*	NS

Ø Statistical significance between *A. nummularia* and *A. vesicaria* at position B.
† Statistical significance between *A. nummularia* and *A. vesicaria* at position U.
* Difference between means significant at specified depths $P < 0.05$.
** Difference between means significant at specified depths $P < 0.01$.
NS Difference between means non-significant.

derived from the soil beneath the bush, thus causing a depletion of salts in the 39–45 cm layer (Fig. 2). Part of this salt may also be derived from the area between bushes (Jessup, 1969). Since at B position salt content in the two communities was similar to that in an adjacent non-saltbush area, it is suggested that the amount of salt taken by roots from the intervening areas may be of minor consequence.

Direct leaching of salts from intact leaves on the plants contributes very little to salt turnover, although fruits are more easily leached by rains (Charley, 1959; Sharma et al., unpublished). The leaching of salts from the surface soil to lower horizons explains the seasonal decrease in salt content of surface layers after rainy seasons (Table 3) and the formation of a "compensation zone." Continuous uptake of salt from lower depths, its deposition at the surface under the canopy, and its subsequent leaching seem to be an endless cycle. Because of this, salt depletion from the 15–30 cm layer (Fig. 2) seems to be compensated by salt leachate. This was confirmed by our supporting studies, which indicated that water penetration in these soils did not exceed 30–40 cm depth.

Evaporation of soil water from the surface soil and deposition of salts on the surface is the usual process of salinity build-up. During and after summer, increased salinity under the plants may be a consequence of a combination of large litter fall and evaporation, but increased salinity in the intervening area is certainly caused by the evaporation mechanism (Table 4). Movement of water carrying salts from B to U position is unlikely since there is extensive non-saltbush vegetation in the intervening area. Even in summer when intervening vegetation is dormant, direct upward loss of water is more likely during wet periods because of high evaporative demands.

Figure 2 indicates that there is a large chloride accumulation directly under the canopy, with a gradual decline towards the B position. There are two explanations offered for this. Firstly, it is likely that some litter is carried beyond the canopy by wind and deposited. Secondly, during dry seasons, when chances of having convective flow of salts to the plants are slight, ionic diffusion under concentration gradients might still cause some salt movement away from the plants.

An increase in soil salinity can affect plant growth directly, by lowering the soil water potential and by its toxic effects, and indirectly, by changing the hydrologic properties of soil and thus affecting the water balance. Our approximate calculations show that the osmotic potential values attained at −0.1, −1.0, and −15 bars matric potential of surface layer (0–7.5 cm) of Billabong clay in an *A. nummularia* community

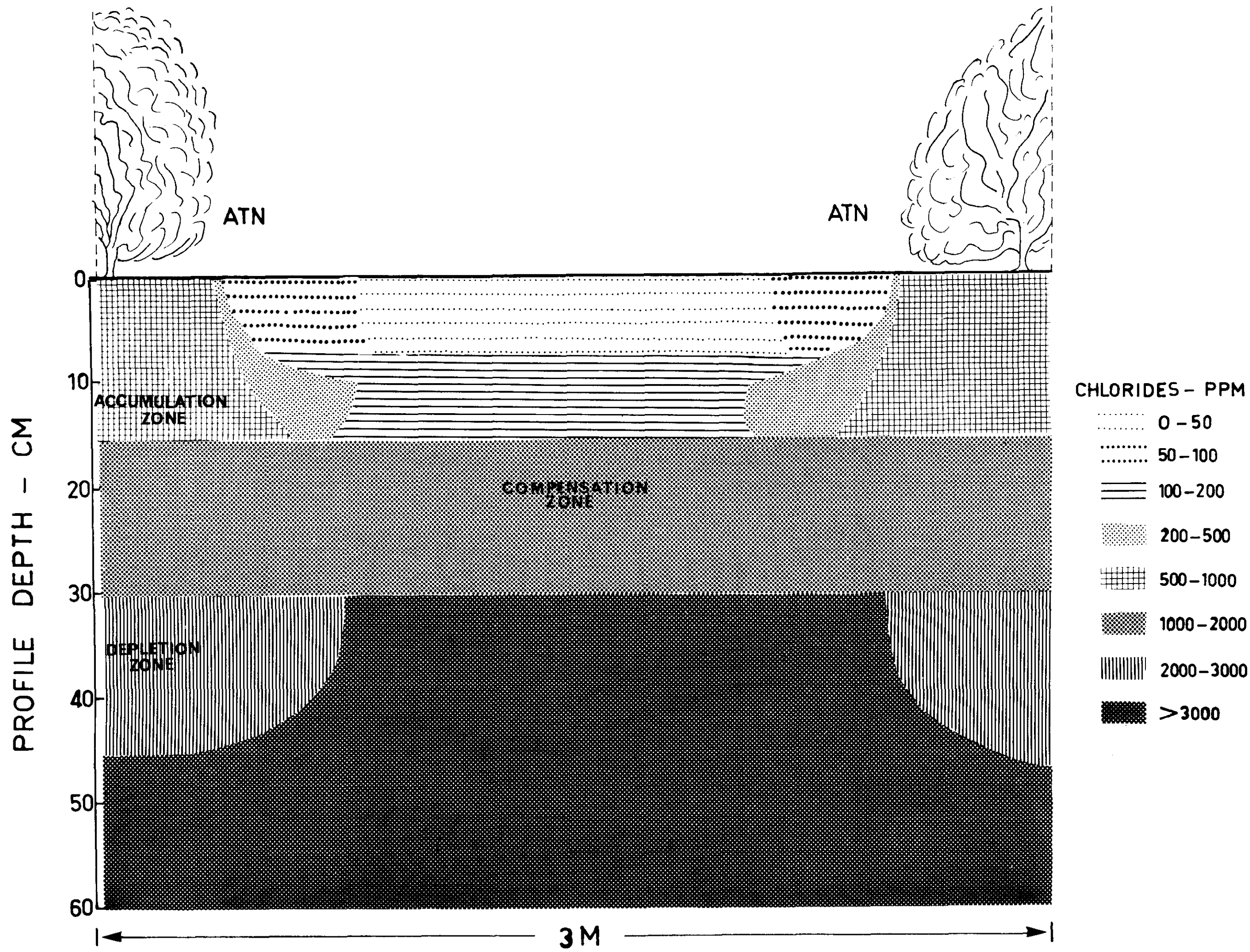

Fig. 2. *Pictorial diagram showing distribution of chloride as a function of profile depth between two plants of* A. nummularia *(ATN) on Billabong clay.*

Table 4. Seasonal changes in electrical conductivity (EC_5 – mmhos/cm) of a Billabong clay in *A. nummularia* community under the bushes (U) and between bushes (B).

Soil depth	August 1969		December 1969			
(cm)	B	U	B	U	Ø	†
0 – 7.5	0.23*	0.39*	0.34**	0.69**	*	*
7.5 – 15	0.48*	0.69*	0.58*	1.07*	NS	*
15 – 30	1.29	1.66	1.31	1.67	NS	NS
30 – 45	2.29	2.61	2.11	2.28	NS	NS
45 – 60	2.66	3.30	3.55	2.80	NS	NS
60 – 75	5.16	6.37	6.32	7.01	NS	NS
75 – 90	4.85	5.05	5.18	4.55	NS	NS

* Difference between means significant at specified depth $P < 0.05$.
** Difference between means significant at specified depth $P < 0.01$.
Ø Statistical significance between August and December sampling at position B.
† Statistical significance between August and December sampling at position U.

would be −3.1, −5.2, −7.8 bars under the bush compared to −1.4, −2.4, −3.6 bars between the bushes respectively. These values indicate that germination, seedling survival, early establishment, and plant growth of non-halophytes are likely to be affected by the spatial distribution of salinity (U. S. Salinity Laboratory Staff, 1954). This might cause spatial variability in vegetation density and composition.

Table 5. Sodium chloride* content of various plant parts of two *Atriplex* species, determined January 18, 1971.

	Percent sodium chloride	
Plant parts	*A. nummularia*	*A. vesicaria*
Leaves		
Medium	18.52	15.05
Senescing	15.58	12.01
Young	23.68	21.46
Stems		
Fine	0.58	0.59
Main	0.28	0.22
Roots		
Fine	0.69	0.58
Main	0.41	0.33

*Chlorides are expressed as sodium chloride assuming that all the chlorides are associated with sodium.

Our observations indicated that the vegetation under *A. vesicaria* plants was denser than between the bushes, whereas in most cases, the soil surface under *A. nummularia* plants was devoid of vegetation (Fig. 3). However, these differences cannot be solely attributed to salinity buildup under the latter species since other features such as light, temperature, water withdrawal, nutrient status of soil, etc., are also affected by the presence of bushes.

Our preliminary studies indicated that salinity buildup and increase in pH under the bushes were also associated with an increase in exchangeable sodium, which significantly affected soil physical properties such as structure, water retention, etc.

Fig. 3. *Comparative vegetative growth under and between* A. nummularia *plants on Billabong clay.*

However, whether this alteration in physical properties of soils would affect plant growth to a significant extent is not known. Although the pH of the surface soil was significantly increased by the presence of plants, it appears unlikely that such small increases in pH near neutral range would affect plant processes to any considerable degree.

It should be emphasized that our results distinctly imply that extreme care must be exercised while collecting representative soil samples from *Atriplex* plant communities. Large differences in the chemical and physical properties of soil can be encountered in samples collected only a few metres apart.

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Infiltration Rates: Three Soils with Three Grazing Levels in Northeastern Colorado

FRANK RAUZI AND FREEMAN M. SMITH

Highlight: *The influence of soil type, grazing level, and vegetation on infiltration rates were evaluated at the Central Plains Experimental Range near Nunn, Colorado. Total plant material was significantly correlated with infiltration rates on two of the three soil types tested. Heavy grazing significantly decreased infiltration rates on two of the soil types. Grazing influences did not reduce infiltration rates until after 20 minutes of simulated rainfall.*

Physical properties of the soil mass and physical conditions of the soil surface control the infiltration process. In terms of the properties of the soil mass, Allis and Kuhlman (1962) found that runoff from native rangelands in South Dakota was three times greater from fine-textured soils than from medium-textured soils.

Hanks (1965) states that the physical condition of soil surface can indeed control the amount and rate of water entering the soil during a rain, but when the soil surface is well covered with plant material, surface sealing is quite small. However, for rangelands, it is surface conditions that are affected by grazing levels, both through removal of plant material and through compaction.

Physical changes in surface soil (i.e., compaction) resulting from grazing occur more slowly than changes in vegetation. Compaction often disappears after seasonal wetting and drying or freezing and thawing. Nevertheless, Rauzi et al. (1968) have shown that changes in both soil and vegetation can be evaluated by infiltration experiments.

Plant material, both standing crop and litter, have a pronounced effect on infiltration. In northern Utah, Meeuwig (1970) found that the weight of live plants and litter accounted for 73% of the variance in amount of water infiltrated by soil. At Mandan, N.D., Rauzi (1963) found that changes in weight of total plant material accounted for 88% of the variations in amount of water infiltrated on a silty upland range site. Dee et al, (1966) showed that the amount of water entering a Pullman silty clay loam was positively correlated with the amount of standing crop and litter on the soil.

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Study Area and Procedure

This study was conducted at the Central Plains Experimental Range near Nunn, Colo. The purpose was to evaluate infiltration rates on three predominant soil types as affected by three grazing levels.

Average annual precipitation for the Central Plains Experimental Range is 12 inches. An average of 8.3 inches falls from May 1 through September 30, with a peak usually occurring in May or June.

The three major soils are Ascalon sandy loam, Shingle sandy loam, and Nunn loam. Ascalon sandy loam is a member of the fine loamy, mixed, mesic family of Aridic Argiustolls formed by fluvial outwash materials. The outwash materials consist primarily of granitic sediments (Franklin, 1969). These soils occupy the slopes.

Shingle sandy loam is a noncalcareous solum variant of the fine loamy, mixed mesic shallow family of Ustollic Camborthids formed on shale and siltstone outcrops of the Pierre sedimentary formation. Shingle sandy loam occupies the hills and knolls. These soils are shallow and moderately drained with a moderately light-textured surface and a moderately heavy-textured subsoil. The surface of these soils has iron-stained shale and siltstone fragments.

Nunn loam is a noncalcareous variant, fine montmorillonitic mesic family of Aridic Argiustolls. The soils are deep, moderately well-drained with a medium texture, and a moderately textured subsoil. These soils occupy swales and lower portion of the slopes. Table 1 describes the experimental sites used in the study.

Vegetation is characterized by blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*), the dominant forage grasses. Red Threeawn (*Aristida longiseta*) is scattered throughout the lightly and moderately grazed pastures. Annual and perennial forbs are scattered throughout the pastures, but

Table 1. Soil, grazing level, and slope (%) characteristics where infiltration experiments were conducted on the heavy, moderate, and light use pastures. Central Plains Experimental Range, 1970.

Soil series	Grazing level	Slope of the site	Slope exposure
Ascalon sandy loam (slopes)	Heavy	1–2	Southwest
	Moderate	1–2	East
	Light	1–2	North
Shingle sandy loam (knolls)	Heavy	2–3	South
	Moderate	5–6	South
	Light	5–6	North
Nunn loam Swales	Heavy	0–1	North
	Moderate	0–1	East
	Light	0–1	East

are considered a minor part of the overall composition of the vegetation. Numerous annual forbs may become conspicuous in wet years.

Cattle stocking rates have averaged 4.14, 3.13, and 1.79 acres per yearling heifer per month for the lightly, moderately, and heavily grazed pastures, respectively. Vegetation changes obtained from differentially grazed pastures have been reported by Klipple and Costello (1960) and Bement (1968, 1969). Grazing for 23 years at the different stocking rates given above has not affected the species' frequency to a great extent, but heavy grazing has reduced herbage yields (Hyder et al., 1966).

Infiltration studies were conducted in June, 1970, on pastures grazed lightly, moderately, and heavily since 1940. Simulated rainfall was applied with a mobile infiltrometer (Rauzi et al., 1968) to a circular area of approximately 13 ft^2. The test plot was 2 ft sq and located in the center of the circular area receiving the simulated rainfall. Simulated rainfall was applied to the test plots for 1 hr. The simulated rain rate was constant for each plot, but varied between 2.5 and 3.5 inches/hr among all plots.

Infiltration rates were measured as the difference between application rate and measured runoff rates. Runoff was measured volumetrically for each 5 min interval during the 1-hr test. Runoff rates were calculated by dividing the volume by the time increment.

Three tests were made on each soil type for each grazing level for a total of 27 test plots. All standing vegetation (standing crop) including growth of the previous year was clipped at ground level a few days after simulated rainfall was applied. All litter on test plots was also collected. The standing crop was separated by species and, together with the litter, was oven-dried and weighed. Yield values in pounds per acre for standing crop, litter, and total plant material (standing crop + litter) were calculated for each plot.

Data were analyzed by analysis of variance and simple correlations. Difference among means was tested for significance by Duncan's Multiple Range Test at the 5% probability level.

Results and Discussion

At the time of the infiltration experiments, the soils were uniformly dry because precipitation was considerably below the long-time average. Precipitation from January 1 through June 30 was only 4.7 inches. The lack of May-June precipitation was reflected in the limited growth made by the native species.

Infiltration rates, standing crop, litter, and total plant material varied with the soil type and grazing level. The results obtained from the three grazing levels on three soils will be discussed separately by soil type.

Ascalon Sandy Loam Site

Blue grama and buffalograss were the dominant species (Fig. 1). Scattered plants of red threeawn were present on the lightly and moderately grazed pastures. Annual and perennial forbs were present on all grazing treatments. Sun sedge (*Carex heliophila*) was found scattered throughout the composition. Average weights of standing crop, litter, and total plant material on test plots are shown in Table 2. Blue grama and buffalograss accounted for nearly all herbage on the heavily grazed pasture, whereas they made up slightly over 50% of the total herbage on the lightly and moderately grazed pastures.

Because of variations in amount of standing vegetation on

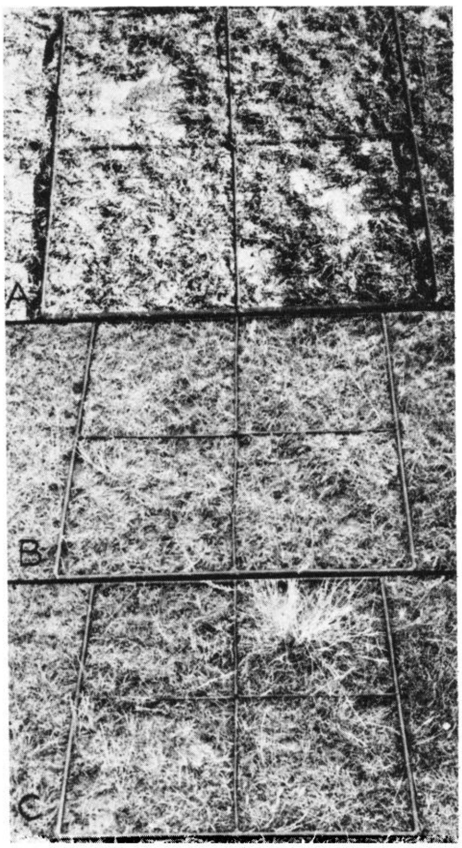

Fig. 1. *Vegetative cover on the pastures on Ascalon fine sandy loam grazed: A–heavily, B–moderately, and C–lightly since 1940.*

Fig. 3. *Vegetative cover on the pastures on the Shingle sandy loam grazed: A–heavily, B–moderately, and C–lightly since 1940.*

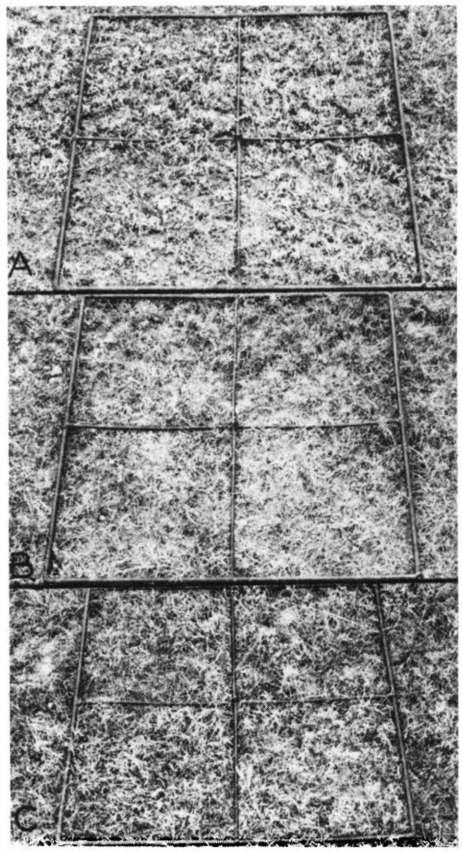

Fig. 4. *Vegetative cover on the pastures on the Nunn loam grazed: A–heavily, B–moderately, and C–lightly since 1940.*

Table 2. Weights (lb/acre) of standing crop, litter, and total plant material/acre and percent of shortgrasses making up the total herbage on three soils and three levels of grazing. Central Plains Experimental Range, 1970.

Soil type	Grazing level	Standing crop	Litter	Total plant material	Percent shortgrasses
Ascalon sandy loam	Heavy	482[a]	339[de]	821[e]	97.5
	Moderate	926[a]	1062[a]	1988[a]	57.2
	Light	1015[a]	448[d]	1463[c]	55.8
Shingle sandy loam	Heavy	622[a]	420[d]	1042[d]	88.4
	Moderate	346[a]	252[e]	598[f]	90.3
	Light	607[a]	97[f]	704[ef]	90.7
Nunn loam	Heavy	801[a]	277[e]	1078[d]	87.9
	Moderate	714[a]	864[b]	1578[bc]	84.6
	Light	1088[a]	697[c]	1785[ab]	80.1

[1]Means within columns followed by the same letter do not differ significantly at the 5% level of significance according to Duncan's multiple range test.

the test plots, there were no significant differences among the three grazing levels for the three soil types (Table 2). There were significant differences in amounts of litter and total plant material among treatments and soils.

Infiltration rates after the first 15-min period were significantly higher for the lightly and moderately grazed pastures than for the heavily grazed pasture (Fig. 2). During the first 15 min the infiltration rate for the lightly and moderately grazed pastures was 2.20 and 2.32 inches/hr, respectively, which accounted for 30% of the total water infiltrated during the 1-hr test. Infiltration rate during the first 15 min for the heavily grazed pasture was 1.88 inches/hr and accounted for 44% of the total water infiltrated during the 1-hr test.

Infiltration rates for lightly and moderately grazed pastures were significantly greater (P>0.05) than for the heavily grazed pasture.

Infiltration rates for lightly and moderately grazed pastures began to increase slightly, whereas that for the heavily grazed pasture continued to decrease after 25 min of simulated rainfall (Fig. 2). Rhoades et al. (1964) reported a similar increase in infiltration rates. They suggested that perhaps during the early part of infiltration, some degree of hydrophobic behavior was occurring and that as wetting gradually occurred, infiltration rates increased.

We have no completely acceptable explanation, but it is most likely that the increase in infiltration rates is due to border effects. Briefly, it is known that infiltration is truly a three dimensional process. However, for the early part of the experiments, borders of the plot essentially confined infiltration to the vertical direction. Once the wetted front penetrated deeper than the plot borders, infiltration could have proceeded in all directions at a total rate greater than in the vertical only. Further experiments must be carried out to arrive at a more satisfactory accounting for our observations.

Simple correlation values between infiltration rates for each 5-min period of the 1-hr test and total plant material were determined. All 5-min periods during the 1-hr test except the first two showed a correlation (P>0.05) between infiltration rates and total plant material. The 45-min period showed a correlation (P>0.01) between infiltration rate and total plant material. Except for the 5-, 10-, and 45-min periods, 53% to 63% of the variation in rate of infiltration was accounted for

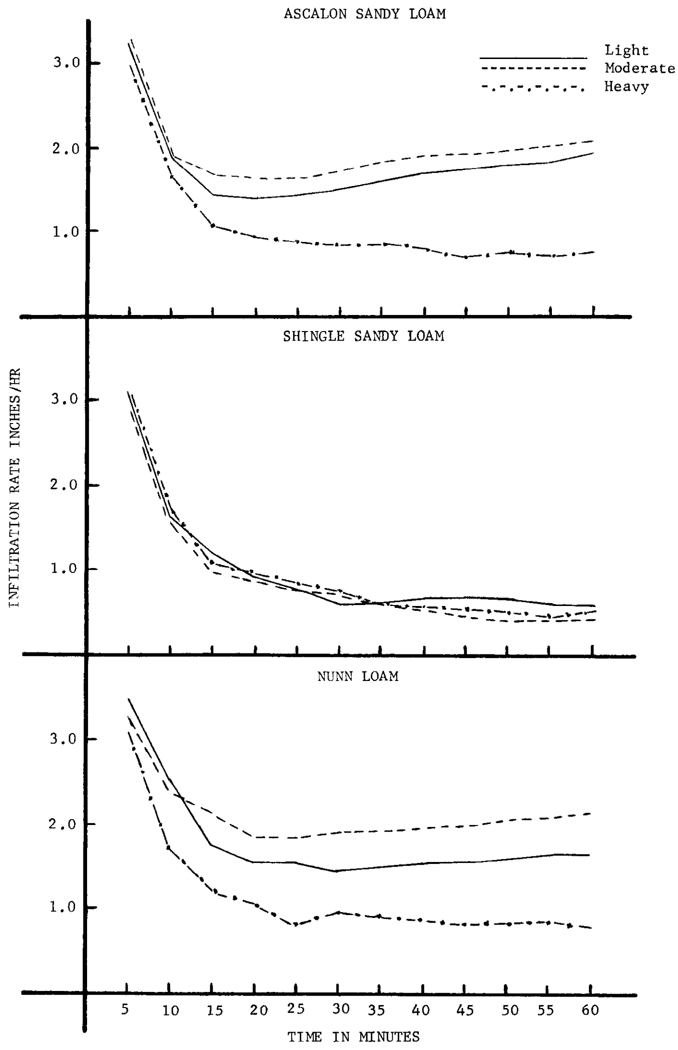

Fig. 2. *Comparison of infiltration rates on three soil types and three grazing levels.*

by the amount of total plant material.

The infiltration rate during the first 30-min period of the 1 hr test was not significantly correlated with total plant material, whereas the infiltration rate during the second 30-min period and for the hr was correlated with total plant material (Table 3).

Shingle Sandy Loam Site

Blue grama and buffalograss accounted for 90% of total herbage at all levels of grazing (Table 2). There were significant differences in amount of litter and total plant material between grazing levels (Fig. 3).

There were no significant differences in infiltration rates between the grazing levels for any time interval, indicating that

Table 3. Simple correlation values of total plant material and infiltration rates in inches/hr for the first and second 30-min period and 1-hr period for the Ascalon and Shingle sandy loams and Nunn loam sites.

Minute intervals	Ascalon sandy loam	Shingle sandy loam	Nunn loam
First 30-min	.664	−.088	.749*
Second 30-min	.788*	−.203	.706*
Total 60-min	.799*	−.146	.724*

*Significant at 5% level.

soil characteristics were more important than level of grazing (Fig. 2).

There was a high percentage of bare ground on plots as may be seen in Fig. 3. The beating action of the raindrops on the bare soil resulted in puddling and sealing of the soil surface. Between 48% and 51% of the total water infiltrated (light 1.01 inches, moderate 0.90 inch, and heavy 0.97 inch) during the 1-hr test occurred during the first 15 min. These results indicate that runoff would be rapidly generated from a storm with high rainfall rates.

Infiltration rates for each 5-min period of the 1-hr test and total plant material were not significantly correlated during any of the 5-min periods or the 1-hr period. In all but two of the 5-min periods, the correlations were negative. Infiltration rates and total plant material were not significantly correlated during the first and second 30-min period or the 1-hr period (Table 3).

Nunn Loam Site

Blue grama and buffalograss accounted for 80% to 85% of total herbage (Table 2). Sun sedge, 6-weeks-fescue (*Festuca octoflora*), and a scattering of annual and perennial forbs made up the rest of the composition. There were significant differences in amount of litter and total plant material between grazing levels. Total plant material was significantly greater on pastures lightly and moderately grazed than on heavily grazed pastures (Fig. 4 and Table 2).

During the first 15 min the infiltration rate for lightly and moderately grazed pastures was 2.56 and 2.72 inches/hr, respectively, and accounted for 30% of the total water infiltrated during the 1-hr test. The infiltration rate during the first 15 min for the heavily grazed pastures was 2.04 inches/hr and accounted for 44% of the total water infiltrated during the 1-hr test. Infiltration rates for the first and second 30-min periods and the 1-hr period were significantly higher for lightly and moderately grazed pastures than for heavily grazed pastures. There was no significant difference in infiltration rates between lightly and moderately grazed pastures.

Simple correlations between infiltration rates for each 5-min period of the 1-hr test and total plant material showed no significant correlation ($P>0.05$) until the 25-min period of the test. After 30 min of the 1-hr test, infiltration rates and total plant material were significantly correlated ($P>0.05$).

Significant correlations during the 5-min period showed that from 46% to 60% of the variation in infiltration rate was accounted for by total plant material. Soil structure in the first horizon was nut-like and conducive to water movement. This was an important factor for this site.

Infiltration rates for the first and second 30-min periods and the 60-min period were significantly ($P>0.05$) correlated with total plant material (Table 3).

Conclusions

For Ascalon sandy loam, infiltration rates after 15 min for light and moderate grazing levels were significantly higher than for the heavy grazing level, but not different from each other. Similarly, for Nunn loam soil, infiltration rates for the first and second 30-min periods and for the total 60-min period for light and moderate grazing levels were significantly higher than for the heavy grazing level, but again, were not different from each other. Finally, for Shingle sandy loam, there was no difference in infiltration rates among light, moderate, and heavy grazing levels.

If the significance of soils, grazing, and soils x grazing is inspected in terms of infiltration rates for given time intervals, an interesting pattern emerges. During the first 10 min of the infiltration process, only the effect of soils is significant. After 15 min, grazing influences are detectable; after 20 min, soil and grazing effects are equally important. By 30 min, interaction appears important. This interaction most probably arises from the Shingle sandy loam, for which there was no significant difference in infiltration rates for any time period for any grazing level.

Infiltration data obtained from this study indicate that moderate grazing of vegetation on the Ascalon sandy loam and Nunn loam soils would be recommended. Even though differences in infiltration rates were not significant between grazing levels on Shingle sandy loam soils, moderate grazing would be recommended.

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Influence of Chaining Pinyon-Juniper on Net Radiation, Solar Radiation, and Wind

GERALD F. GIFFORD

Highlight: *Net and solar radiation, and wind were measured during parts of 1968 and 1969 on a pinyon-juniper site in southwestern Utah. Treatments were chaining-with-debris windrowed, chaining-with-debris-in-place, and undisturbed woodland. Net radiation on the chain-windrow treatment and chain-debris treatment averaged 71 and 91%, respectively, of that measured on undisturbed woodland. Albedo values averaged 13 and 12% for the 2 years on woodland plots, 21 and 19% on the chain-windrow treatment, and 13 and 14% on the chain-debris treatment. Roughly 3 miles of wind (as measured at approximately mid-canopy height) occurred on the chained treatments for every 1 mile measured in the woodland.*

The pinyon-juniper (*Pinus* sp.-*Juniperus* sp.) type extends over approximately 60 million acres in the western United States (Dortignac, 1960). The trees have been removed over several hundred thousand acres by chaining, burning, bulldozing, or spraying. Grass was artifically seeded on some sites, but native species (shrubs and grasses) were allowed to naturally seed other sites.

The study was designed to provide some preliminary data on microclimatic changes that occur when trees are removed from pinyon-juniper sites about 40 miles southwest of Milford in southwestern Utah.

Methods and Site Description

The study site was chained (using a large anchor chain between two tractors) in the fall of 1967. The three chaining treatments were chaining with all debris windrowed (crested wheatgrass [*Agropyron cristatum*] drilled at 8 lbs./acre); double chaining with debris-in-place (crested wheatgrass broadcast seeded at 8 lbs./acre); and no chaining. Approximately 30 to 40 acres were involved in each treatment. All treatments were fenced to exclude livestock.

The woodland plots (control) had a 20 to 45% canopy coverage of pinyon and juniper trees. Shrub cover consisted of big sagebrush (*Artemisia tridentata*), black sagebrush (*Artemisia nova*), and small rabbitbrush (*Chrysothamnus* sp.). Scattered plants of *Eriogonum* sp., *Aster* sp., and *Salsola kali* were also present. Vegetation on the chain-with-windrowing treatment was limited during the duration of this study; crested wheatgrass seedlings were the dominant species present. Seedling canopy coverage was less than 20% during 1968 and from 10 to 20% during 1969. On the chain-with debris-in-place plot, the crested wheatgrass seedling canopy coverage was less than 10% during both 1968 and 1969; shrub canopy coverage (all species) was 15% or less during both years.

Soils are sandy loam in texture and were derived from basaltic parent materials.

During the summer of 1968 climatic stations were established in each of the three treatments. Net radiation was measured at 20 ft above the ground surface in the undisturbed and chained-with-debris-in-place treatments and at 8 ft above the ground surface in the chained-with-windrowing treatment. The difference in measurement heights was a reflection of the amount of spatial variability necessary for viewing by each radiometer to insure a single measure as representative as possible. For radiometers mounted 20 ft above the soil surface, nine-tenths of the field of view is within a diameter of 115 ft (Reifsnyder and Lull, 1965). A Fritschen (1963) type miniature net radiometer, as modified by Campbell et al. (1964), was used to make net radiation measurements. Measurements were recorded on a Rustrak Model 88 12 v dc MA recorder with an unregulated motor. The radiometers (and all other instruments) were not moved about but remained at or very near the same position for the duration of the study (Fig. 1). The net radiation measured is the difference between the downward flux, consisting of direct and diffuse solar radiation and atmospheric thermal radiation, and the upward flux, consisting of reflected solar and thermal radiation and emitted thermal radiation.

Incoming and reflected solar radiation was measured with a Sol-A-Meter (silicon cell) from the Yellot Solar Energy Laboratory. Dirmhirm (1968) has discussed the use of this instrument in radiation studies. A single Sol-A-Meter measured incoming solar radiation in the open at a height of approximately 6 ft. All measures of reflected shortwave radiation were made at the same height above the soil surface as the net radiation measures. Measurements were recorded on a Rustrak Model 88 12v dc MV recorder with an unregulated motor.

Wind was measured at a height of 11 feet (roughly mid-canopy height) with Belford Model 9924A totalizing anemometers.

Results and Discussion

Net Radiation

Net radiation values for each chaining treatment are shown in Figure 2 for the period August 24 to September 22, 1968. Data for the woodland were available only for the period September 7 to September 22, 1968.

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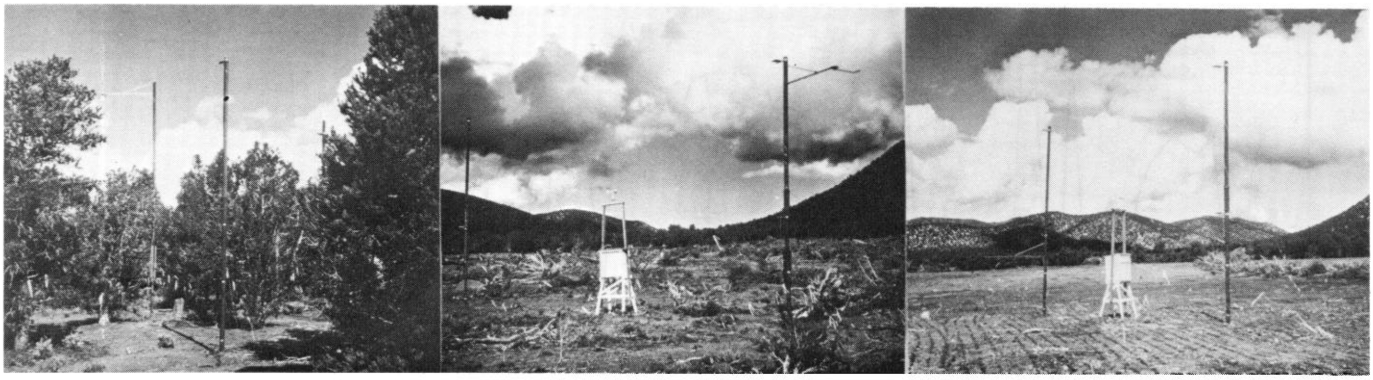

Fig. 1. *Instrumentation of plots used in the study: (*left*) control plot, (*middle*) chain-with-debris-in-place treatment and (*right*) chain-with-windrow treatment.*

Highest net radiation values were measured over the control treatment, followed by the chain-with-debris-in-place treatment. The chain-with-windrow treatment gave the lowest net radiation values. Net radiation in the chain-with-windrow treatment averaged 71% (range was 48 to 85%) of that measured on the woodland plot. Net radiation on the chain-with-debris-in-place treatment averaged 91% (range was 80 to 105%) of that measured on the woodland plot.

The above results are somewhat expected. The net radiation (R_n) of a surface is the algebraic sum of the downward flux of solar radiation (R_{sd}) from sun and sky, the downward infrared or thermal radiation flux (R_{id}) from the atmosphere, and the upward flux of reflected solar radiation (R_{su}), and the upward infrared radiation flux (R_{iu}) from the surface. Thus:

$$R_n = R_{sd} + R_{id} - R_{su} - R_{iu}. \qquad (1)$$

The downward fluxes R_{sd} and R_{id} are controlled by atmospheric conditions and are usually rather constant except under partly cloudy skies. The magnitude of R_{su} is dependent on the reflective properties of the surface, the ratio of outgoing (reflected) solar radiation to incoming being referred to as the albedo (a). Thus:

$$R_{su} = aR_{sd}. \qquad (2)$$

The flux of R_{iu} is dependent primarily on radiation emitted by the surface, but the reflected part of the downward infrared radiation is also included. Using the absorptivity or emissivity ϵ, the Stefan-Boltzmann constant σ and the fact that surface temperature (T_o) governs radiation emitted by the surface, then

$$R_{iu} = \epsilon \sigma T_o^4 + (1 - \epsilon) R_{id}. \qquad (3)$$

If we can assume that $\epsilon = 1$ (usual range 0.95 to 0.98 for natural surfaces), then combining and rearranging (1), (2), and (3) gives

$$R_n = (1 - a) R_{sd} + R_{id} - \sigma T_o^4. \qquad (4)$$

Examination of (4) will show that net radiation is dependent on the albedo and surface temperature if downward components (R_{sd}, R_{id}) are somewhat constant. These conditions were closely approximated in this study. It will be seen later that albedo of the chain-with-windrow treatment was considerably higher than that measured on the other two treatments. Presence of debris scattered about on the debris-in-place treatment would tend to reduce albedo, as would the presence of standing trees.

Influence of surface temperature differences on net radiation in this study is not known at this time, but Federer (1968) has found in the Northeastern states that variations in surface temperature and albedo were about equally important in affecting net radiation. Baumgartner (1965) and Tromble and Simanton (1969) have found that net radiation values over open areas may be only about 60% of that measured over a forest canopy. Tajchman (1971) found that total net radiation over a spruce forest in Germany was 20% greater than that over alfalfa and 16% greater than that over potatoes.

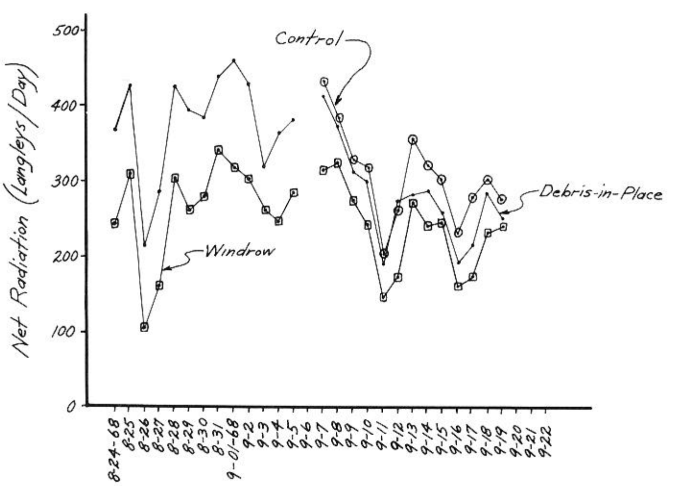

Fig. 2. *Net radiation as measured on various dates over each treatment.*

Solar Radiation

An example of values for incoming and reflected shortwave for two periods is shown in Figure 3. Data were also available for the periods August 10 to September 5 and October 1 to October 31, 1968. During the 1968 measurement period, the albedo (ratio of reflected to incoming shortwave) of the chain-with-windrow treatment averaged 21% (range of 16 to 26%), or not quite twice the albedo of the chain-with-debris-in-place treatment (average 13%, range 7 to 20%) and the woodland (average 13%, range 9 to 21%).

The above relationship held for the 1969 measurements also. Albedo of the chain-with-windrow treatment averaged 19% (range of 12 to 25%), as compared with 14% for the chain-with-debris-in-place treatment (range of 9 to 23%) and 12% for the control treatment (range of 4 to 22%). Some slight changes are to be expected, as vegetation increased

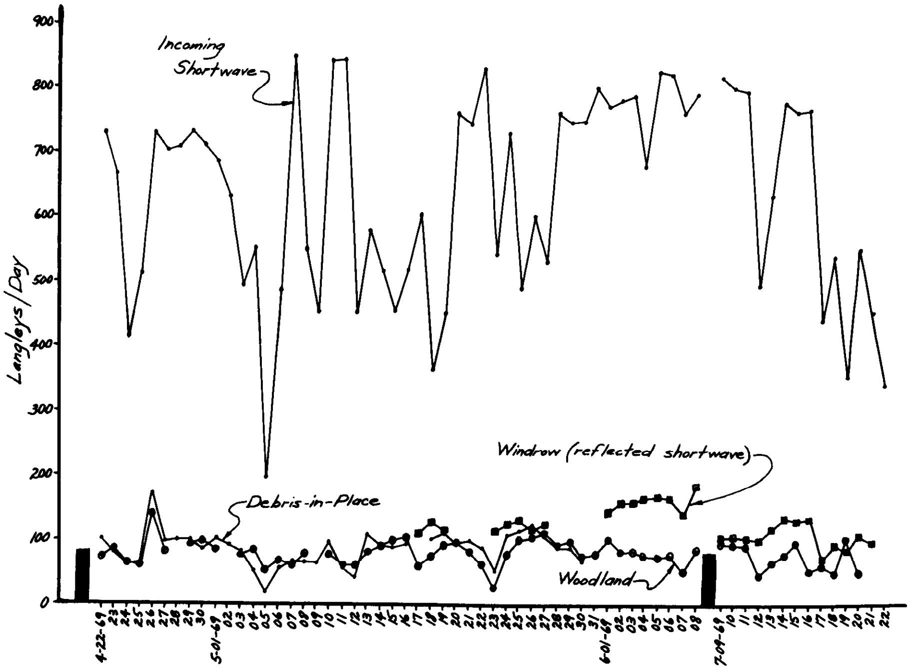

Fig. 3. *Incoming and reflected solar radiation for two select periods.*

somewhat on both chaining treatments.

Figure 4 gives some idea of the magnitude of change in reflected solar radiation which may be expected following a snow storm. No data are available for incoming solar radiation. The increased reflectivity in response to snow is greatest in the chain-with-window treatment, intermediate in the chain-with-debris-in-place treatment, and least in the control treatment.

Results of both net radiation and albedo measurements agree closely with those of Hornbeck (1970), who compared the radiant energy of clearcut and forested sites in West Virginia.

Wind

Average miles of wind per day at mid-canopy height on each treatment as averaged over approximately 2-week periods were analyzed for July 14 to November 30, 1968 and for April 4 to July 11, 1969. Relationships were similar for both 1968 and 1969. In general, for each mile of wind recorded in woodland plots at mid-canopy height, approximately 3 miles was recorded on each of the two chaining treatments. Slightly more wind was recorded during all time intervals on the chain-with-windrow treatment than on the chain-with-debris-in-place treatment.

Summary

The objective of this study was to provide some preliminary information regarding microclimatic changes that may occur when a pinyon-juniper site is significantly altered by removal of trees. This paper has provided some insight regarding net radiation differences, albedo differences, and wind relationships.

Net radiation measurements were greatest over the natural pinyon-juniper woodland. Net radiation on the chain-with-windrow treatment and chain-with-debris-in-place treatment averaged 71 and 91%, respectively, of that measured on the woodland plot. Part of the difference is due to a higher albedo on the chain-with-windrow treatment.

Average albedo values varied only slightly during measurement periods in 1968 and 1969. Albedo values averaged 13 and 12%, respectively, for the 2 years on woodland plots, 21 and 19% on the chain-with-windrow treatment, and 13 and 14% on the chain-with-debris-in-place treatment. Presence of debris on the ground in the debris-in-place treatment tended to bring albedo values close to those measured on woodland plots, at least during snow-free periods. Following a snow storm, the amount of reflected solar radiation increased most of the chain-with-windrow treatment and least on the woodland treatment.

As might be expected, wind (as measured at approximately mid-canopy height) was greatest where standing trees were absent. Roughly 3 miles of wind occurred on chained treatments for every 1 mile measured in the woodland.

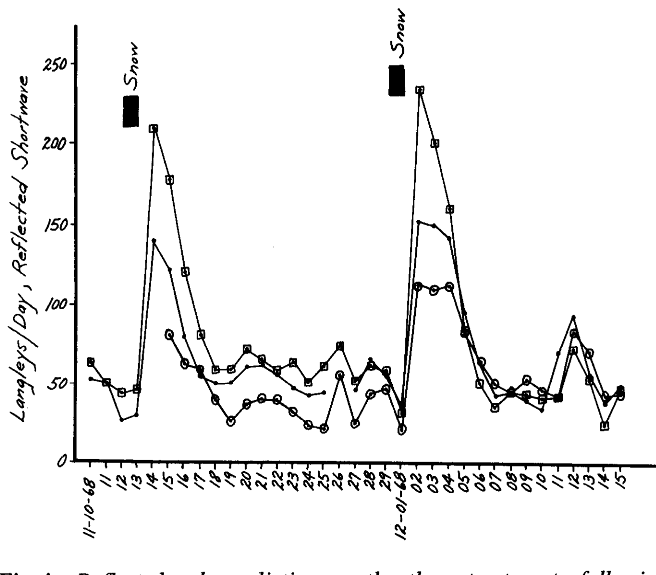

Fig. 4. *Reflected solar radiation on the three treatments following two periods of snow. Squares represent the chain-with-windrow treatment, circles the natural woodland, and dots the chain-with-debris-in-place treatment.*

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Duration of Seeded Stands on Terraced Mountain Lands, Davis County, Utah

A. C. HULL, JR.

Highlight: *Thirty-seven species were seeded experimentally in northern Utah on 14 areas on depleted and terraced mountainous rangelands from 1936 to 1939. Seventeen species had fair to excellent 3-year-old stands. Most stands decreased; and in 1971 only smooth brome, tall oatgrass, intermediate wheatgrass, and red fescue have fair to excellent stands. Smooth brome spread slowly by rhizomes and usually formed a dense sod. Tall oatgrass spread by seed with a poor to good stand on ten times the original seeded area. Intermediate wheatgrass has spread by rhizomes and forms a good stand on the large plot where it was seeded in 1941. Red fescue did well on favorable sites but was not tested under typical conditions. Native grasses, forbs, shrubs, and trees have reinvaded the seeded areas.*

Davis County, in northern Utah, was much in the news from 1923 to 1930 because of floods which took six lives and caused more than $1 million damage (Marston, 1958). The 1930 Flood Commission concluded that depletion of plant cover by grazing and fire was the primary cause of flooding (Cannon et al., 1931; Bailey et al., 1934.)

From 1933 to 1939, about 1,300 acres of high-elevation flood-source lands in Davis County were contour-trenched and seeded. The earliest seedings were in 1934, when all terraces constructed during 1933 and 1934 were fall-seeded to a mixture of four cultivated grasses and to some native species gathered in the area. Beginning in 1935, terraces constructed each year were seeded to mixtures of perennial grasses and rye[1] in the fall of each year. Seeds were broadcast at 30 lb./acre, and the ground surface was brushed or raked to cover the seed.

All seedings produced good initial stands, but early records are lacking. Observations in 1936 and 1937 showed poor to fair stands of smooth brome, slender wheatgrass, rye, and horsemint on these early seedings.

To determine species for seeding these depleted and terraced mountain lands, experimental seedings were made from 1936 to 1939. This is a report on the 32- to 35-year-old stands that resulted from these seedings.

Procedures

Seeded areas were depleted and usually supported only sparse, weedy vegetation such as tarweed (*Madia glomerata*), knotweed (*Polygonum* sp.), and coneflower (*Rudbeckia occidentalis*). Surrounding vegetation was mainly alpine fir (*Abies lasiocarpa*), aspen (*Populus tremuloides*), big sagebrush (*Artemisia tridentata*), snowberry (*Symphoricarpos oreophilus*), slender wheatgrass, columbia and letterman needlegrasses, geranium (*Geranium viscossissimum*), and other plants of minor importance.

Seeded areas ranged from 7,400 to over 9,000 ft elevation, with most being about 8,000 ft. Most areas sloped south, west, or east with some slopes over 70%. Annual precipitation is about 30 inches at the lowest seeded area and over 45 inches at the highest.

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Seeding studies were initiated and conducted until 1954 by the Forest Service. At that time, responsibility for seeding research for domestic livestock on rangelands was transferred to Agr. Res. Serv. The author was formerly with the Forest Service and did much of the early work.

The author thanks personnel of the Forest Service and Agr. Res. Serv. who assisted with these studies. Special thanks to Grant Harris, Richard Hurd, W. M. Johnson, G. J. Klomp, C. K. Pearse, Henry E. Peterson, and R. H. Walker, who participated in the early work.

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[1] Scientific names of most species mentioned are listed in Table 1.

We made 14 experimental seedings from 1936 to 1939. Seedings were mostly in the Parrish, Ford, Davis, Steed, and Farmington Creek drainages. Seeded areas had been terraced as described by Bailey and Croft (1937). Plots are irregularly shaped along the contour terraces. They extend up and down the slope from the crest of one terrace to the crest of the next. This width varies from 12 to 50 ft and averages about 25 ft. Along the slope, plots occupy part of or all the length of a single terrace. Plot length varies from 20 to 280 ft and averages about 100 ft. The amount of seed sown was adjusted to the size of the plot.

Thirty-seven species were tested, with 4 to 20 species in each of 14 studies. Seeding rate was at 12 to 20 lb./acre for species such as smooth brome and tall oatgrass. Rates for smaller seeded species were reduced about 25%. Mountain brome was seeded at 15 to 25 and rye at 20 to 40 lb./acre. There were from one to three replications of each species within each study. Table 1 lists species used with the number of plots of each.

We seeded some study areas in the spring and some in early or late fall. Spring seedings were made in May or June, just as snow melted from the area. This often necessitated using horses to get to areas when roads were still covered with snowdrifts. Early fall seedings were made in late August or early September; late fall seedings occurred in October. In three areas we seeded in early fall, late fall, and in the spring; in one area we seeded in early fall and in the spring. As stands for each season of seeding were similar, they are averaged for each of the four studies.

Seeds were broadcast by hand on the loose soil of the newly-constructed terraces or, in the case of spring seeding, on terraces constructed the previous summer. Seed was covered by raking with garden rakes. On hard soil or on undisturbed soil between the terraces, rake-like hand diggers were used to loosen the soil and cover the seeds.

For 3 to 5 years following seeding, notes were made on seeding success, and the stands were rated. Ratings were again made in 1966 and 1971. Ratings range from 10 to 0, with 10 being a full stand of seeded grass. In 1938 we obtained yields by clipping the grass mixture on 36 1-ft^2 samples per area. In 1971 we clipped ten 4.8-ft^2 samples of each seeded or native grass sampled on each area. In both years the samples were from areas judged to have a good stand of grass.

Table 1. Species seeded, number of areas and plots, and ratings of 37 species about 3 years after seeding and in 1971. Davis County. Ratings are 10 to 0 with 10 being a full stand of grass.

Species	Areas seeded	Number of plots	Average ratings 1938-43	Average ratings 1971
GRASSES				
Bluegrass, Canada (*Poa compressa*)	4	10	1.2	.2
Bluegrass, bulbous (*Poa bulbosa*)	4	10	.3	0
Bluegrass, Kentucky (*Poa pratensis*)	4	10	3.2	.3
Brome, mountain (*Bromus carinatus*)	11	31	4.7	.1[a]
Brome, smooth (*Bromus inermis*)	13	37	5.0	5.2
Canarygrass, reed (*Phalaris arundinacea*)	7	16	4.1	.6
Fescue, meadow (*Festuca elatior*)	7	16	4.0	0
Fescue, red (*Festuca rubra*)	2	3	3.7	8.3
Fescue, sheep (*Festuca ovina*)	8	19	4.0	.2
Fescue, spike (*Hesperochloa kingii*)	2	4	4.3	1.3
Needlegrass, Columbia (*Stipa columbiana*)	3	10	5.3	1.0[a]
Needlegrass, letterman (*Stipa lettermanni*)	2	4	6.5	1.0[a]
Oatgrass, tall (*Arrhenatherum elatius*)	12	32	4.2	4.4
Orchardgrass (*Dactylis glomerata*)	5	15	3.1	.7
Redtop (*Agrostis alba*)	4	10	6.7	.2
Rye (*Secale cereale*)	6	14	4.0	0
Ryegrass, perennial (*Lolium perenne*)	7	16	2.3	0
Timothy (*Phleum pratense*)	5	13	5.2	.5
Wheatgrass, bearded (*Agropyron subsecundum*)	3	10	2.4	0
Wheatgrass, bluebunch and beardless (*Agropyron spicatum* and *A. inerme*)	2	8	1.4	.1
Wheatgrass, crested (*Agropyron desertorum*)	8	24	3.6	.7
Wheatgrass, slender (*Agropyron trachycaulum*)	12	34	5.6	1.0[a]
Wheatgrass, western (*Agropyron smithii*)	7	17	2.6	.1
Wildrye, blue (*Elymus glaucus*)	3	10	5.0	0
Wildrye, Canada (*Elymus canadensis*)	2	8	3.9	0
LEGUMES				
Alfalfa (*Medicago sativa*)	6	14	1.7	0
Clover, white (*Trifolium repens*)	3	9	0	0
Lupine, ornate (*Lupinus ornatus*)	1	2	.5	0
Lupine, tailcup (*L. caudatus*)	1	2	2.5	0
Sweetclover, white (*Melilotus alba*)	1	2	0	0
Sweetclover, yellow (*M. officinalis*)	3	10	3.3	.3
FORBS				
Goldeneye, showy (*Viguiera multiflora*)	2	4	3.8	0
Groundsel, butterweed (*Senecio serra*)	1	2	0	0
Horsemint (*Agastache urticifolia*)	2	4	6.8	.1
Ligusticum, Porter (*Ligusticum porteri*)	1	2	4.0	0
Sunflower, little (*Helianthella uniflora*)	1	2	2.5	0
Yarrow, western (*Achillea, lanulosa*)	2	4	7.0	.8

[a]Probably native.

Results

The loose soil provided seed covering, and good seedling stands followed most seedings. Seventeen of the 37 species had stands which rated 4 (fair) or better 3 years after seeding (Table 1). Stands of most species deteriorated over the 32 to 35-year period, and by 1971 only three species (smooth brome, tall oatgrass, and red fescue) had stands which exceeded 4. From 1939 to 1971, stands of smooth brome on 37 plots increased on 16, decreased on 12, and remained the same on nine plots. On 32 plots, tall oatgrass increased on 11, decreased on 15, and remained the same on six. Red fescue increased on all three plots. However, fescue plots were on partially-shaded, moist, favorable sites and were not typical of the seeded areas.

Intermediate wheatgrass (*Agropyron intermedium*) was seeded in 1941 in a larger planting adjacent to experimental seedings in Farmington Canyon. This species has spread rapidly by rhizomes and has a good stand of vigorous plants over the seeded area. Seedings in other areas show that this grass is well adapted to many mountainous ranges. Reed canarygrass failed on dry sites, but it produced dense stands and spread in gullies and moist places wherever it was seeded. This species should be considered for seeding such sites.

The growth habits and spread of smooth brome and tall oatgrass are different. Smooth brome has spread slowly, mainly by rhizomes, and has formed a good sod to the exclusion of most other species. On harsh sites, the sod is often interrupted. Seldom has brome spread to double the original seeded area. The low brome ratings resulted when brome occupied only part of the plot but was averaged over the entire plot.

Tall oatgrass has spread widely by seed. Adjacent plots often have heavier stands than the seeded plots. In two studies on the Davis Creek watershed, tall oatgrass was seeded on six of 120 plots. It now occupies 60 plots with an average rating of 5.6. It also occurs in smaller amounts on 30 additional plots. Its spread is most rapid on disturbed areas; however, it is growing well on some areas with good stands of big sagebrush and other native vegetation.

In general, the best seedling stands were in the bottom of the terrace trenches. Next best were stands on the loose soil of the fill, followed by stands on the cut. If melting snows or spring rains filled the trenches for extended periods, the young seedlings in the bottom of the furrow were killed, and spotty stands resulted. As plants matured, they were able to withstand flooding. After 32 years the best seeded and naturally revegetated stands are in the furrow, the fill, and the cut in the order named. However, species have spread and there are often good stands on the undisturbed area between terraces.

In 1938 the 1-, 2-, 3-, and 4-year-old stands of seeded grass mixtures yielded 77, 294, 840, and 2,644 lb./acre, air-dry, respectively. Yields of the three most successful seeded species and the two most abundant native grasses in 1971 are shown in Table 2.

Based on these studies, smooth brome, tall oatgrass, and intermediate wheatgrass are the best species for long-time stands and have out-yielded native species. These three grasses are recommended for high elevations in Utah and Idaho by Plummer et al. (1955), Hull et al. (1962), and Hull and Holmgren (1964). The tests were not fair for slender wheatgrass because the plains strain was used. This is shortlived and does not reseed itself on these areas. Other possible adapted species, such as meadow foxtail (*Alopecurus pratensis*), were not readily available for testing when these seedings were made.

Native species have increased on all areas. Where terraces were close to aspen, the formerly closely-cropped aspen sprouts were released and aspen trees up to five inches in diameter are growing in the trenches. Dense stands of big sagebrush account for 70% of the vegetation on some areas (Fig. 1). Sagebrush does especially well on the outer terrace bank. Two needlegrasses, columbia and letter-

Table 2. Production (lb./acre air-dry) of seeded and native grasses at 4 locations on the Davis County watershed, 1971.

Species	Davis Creek	Ford Creek	Parrish Creek	Farmington Creek
Seeded				
Smooth brome	1625	2436	2170	3780
Tall oatgrass	1267	1380	1625	2132
Intermediate wheatgrass[a]	–	–	–	3720
Native				
Slender wheatgrass	1524	1484	1628	2179
Columbia and letterman needlegrasses	1204	924	921	1297

[a]Seeded in 1941 adjacent to experimental studies.

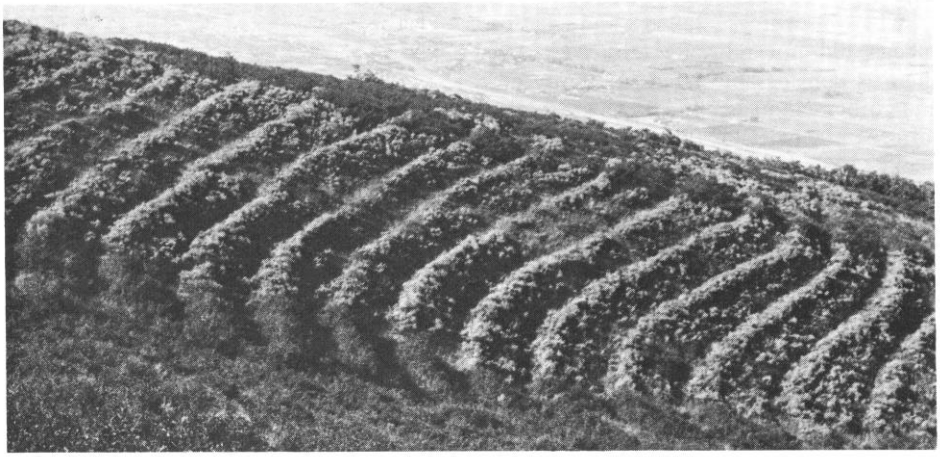

Fig. 1. *General view of experimental seeding on the Davis Creek watershed. When terraced and seeded in the fall of 1936 and the spring of 1937, this area supported a sparse stand of perennial and annual weeds. Big sagebrush is now the dominant species. Smooth brome has an average rating of 8.7 and tall oatgrass 8.3 on three plots of each. Tall oatgrass has spread to 37 of the 60 plots on this site. The town of Bountiful is left center.*

Fig. 2. *This site had only scattered annual weeds when it was terraced and seeded in the fall of 1936. Native and seeded species, especially columbia needlegrass, are growing so well that it is difficult to see the terrace trench in the center of the photo.*

man, are present on all areas and sometimes comprise 50% of the vegetation (Fig. 2). Native slender wheatgrass and a great variety of perennial forbs are abundant on most areas. The estimated average percent cover of all native species on seeded areas follows:

Species	% Cover
Forbes, including sedges and rushes	30
Sagebrush	22
Other shrubs, mainly snowberry	4
Needlegrasses	21
Other grasses, mainly slender wheatgrass	20
Trees, aspen, and chokecherry	3

Where seedings failed and native species did not reinvade terraced areas, there is considerable tarweed, knotweed, and other annuals. In such areas the terraces are partially filled and the outer banks are reduced in height by soil sloughing. Good stands of seeded and native vegetation have helped hold the soil and prevent filling of trenches or breakdown of the outer banks. With good stands, the gullies are healing, and there has been no disastrous runoff from these areas since they were terraced and seeded over 30 year ago (Fig 3). Some larger gullies which could not be treated now have good stands of reed canarygrass and smooth brome. These two rhizomatous seeded species along with native species are helping to stabilize these gullies.

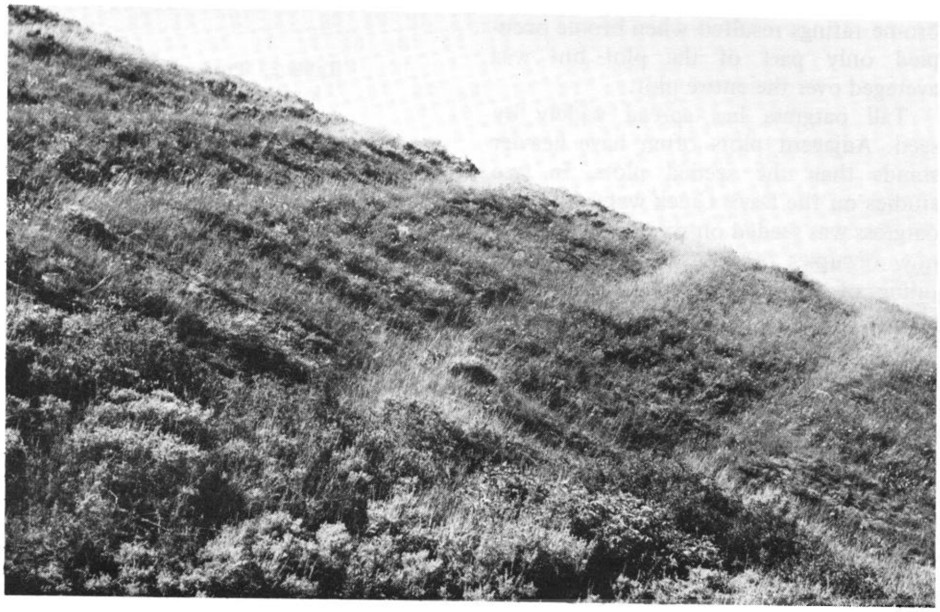

Fig. 3. *Gullies from the 1923–30 floods may still be seen in this experimental seeding on the Davis Creek drainage. This site was raw and bare with no vegetation when it was terraced and seeded in fall, 1936, and spring, 1937. A good stand of smooth brome and tall oatgrass with some native species are holding the soil, and there has been no appreciable soil erosion since 1936. Photographed in 1971.*

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Wheatgrass Response to Seasonal Applications of Two Nitrogen Sources

FORREST A. SNEVA

Highlight: *Fall, winter, and spring applications of 20 lb. N/acre as urea or as ammonium nitrate were applied in each of 3 years to two introduced grasses, crested and Siberian wheatgrasses, on Oregon's high desert range. Mature herbage yield increased with fertilizers, but there were no significant interactions with application date. Urea increased mean yield 3% more than did ammonium nitrate, but the increase may not be of practical significance. Crude protein concentration of mature yields, evaluated in 1 year only, was not influenced by either fertilizer or application time. Fall- and winter-applied N fertilizer increased available soil nitrate concentration in mid-April, but differences due to date and source of N were nil.*

Returns from nitrogen (N) fertilizers applied to seeded grass stands on semi-arid lands of the Great Basin and bordering areas have been marginal to sub-marginal (Sneva et al., 1958; Patterson and Youngman, 1960; Eckert, et al., 1961; Kay and Evans, 1965; and Sneva, 1970).

These returns, for the most part, have been based upon the vegetal response from fall applied ammonium nitrate. There is virtually no research information as to the efficiency of N as influenced by source of N or by its time of application for introduced grasses on semi-arid soils of the northern Great Basin. Monetary values to the rancher may also be influenced by time of application as it relates to (1) time of fertilizer purchase, (2) storage costs, and (3) seasonal work-load (Lavin, 1967).

Response to N fertilizer in arid regions has been greatest in years receiving greater than normal amounts of precipitation (Sneva, 1965). Thus, selective fertilization for response in above normal years could enhance the economic picture. Unfortunately, with fall fertilization the judgement of the favorableness of the coming season is not feasible. Decision making for applying fertilizer in the spring could be much more effective. The greater part of the precipitation would have been received, and only that remaining to be received in the subsequent 2-3 months need be estimated by predictions.

Because of technological advances in the past decade, urea is a strong competitor as the cheapest source of N. Comparisons of urea with ammonium nitrate are lacking for the semi-arid range area.

This paper compares mature yields in 3 years, available soil nitrogen in 2 years, and herbage concentrations of crude protein in 1 year as influenced by urea and ammonium nitrogen fertilizer applied in fall, winter, and spring.

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Procedure

The study site is located within the Squaw Butte Experiment Station, 42 miles west of Burns, Ore. Annual precipitation at this 4,300 ft elevation station is approximately 12 inches. Big sagebrush-bunchgrass types dominated the areas now seeded to introduced species. The sandy-loam soils supporting these stands have been described by Eckert (1957).

The study was conducted with the 3 years (1969, 1970, and 1971) and seven application dates (Sept. 15, Nov. 15, Jan. 15, Feb. 15, March 15, Apr. 15, and May 15) randomly allocated to main plots in factorial combinations. Main plots consisted of 6, 10-ft rows spaced 1 ft apart. The two sources of N and a control were allocated to subplots, a single row each with a buffer row between each treatment row. Treatments were replicated four times in standard crested wheatgrass (*Agropyron desertorum* [Fisch,] Schult). and four times in Siberian wheatgrass (*Agropyron sibiricum* [Beauv.]) stands. The replications were 30 x 60-ft blocks seeded in 1957 and comprising a portion of a larger study (Hyder and Sneva, 1963). Fertilizer at the rate of 20 lb N/acre was weighed, packaged, and, on the given date, applied by hand. The fertilizer was applied directly to the row; rarely did pellet dispersion exceed 3 inches on either side of the row center. Row ends were marked with 18-inch wire flags for determining row location when snow covered. When rows were snow covered, foot tracks directly above the row were made and fertilizer distributed within the track.

Herbage was clipped at ground level from the center 8 ft of the treatment row on or about August 1 of 1969, 1970, and 1971. Following harvesting, the herbage was oven dried at 160 F. Yield samples in 1969 were subsequently ground through a Wiley mill and a subsample retained for determining Kjeldahl-N. Yield and crude protein (N x 6.25) values were statistically analyzed and differences between means tested with Duncan's multiple range test.

General observations of surface and subsurface soil conditions (0-6 inches) at the time of fertilizer applications were recorded. Precipitation, air, and soil temperature during the study years were recorded daily at the Station's headquarters 1/2 mile away.

Soil samples for determining available soil nitrate were taken on April 10, 1969, and April 15, 1970. In 1969, soils were sampled at 0-3, 3-6, and 6-9 inches below the soil surface. Samples in 1970 were from the 0-3 inch depth. Each sample consisted of two, 1/2 inch diameter cores obtained directly from the row center of each plot between plants, from the first five application dates on four replications. The samples were air dried, thoroughly mixed, and two determinations per sample conducted with a LaMotte Available Soil Nitrate Kit[1].

Results

Surface and subsurface soil moisture characteristics at the time of fertilizer application in each year, average maximum and minimum soil temperature at 2 inches, and mean air temperature in the week following are shown in Table 1. Total crop-year precipitation (Sept. 1-June 30) was 10.7, 9.9, and 11.4 inches for the years 1969, 1970, and 1971, respectively.

Significant differences due to species interaction did not occur. Thus, the data were analyzed as that of one species with eight replications. The herbage will here-

[1]The mention of a proprietary product does not constitute a guarantee of the product by U. S. Dep. Agr., and does not imply its approval to the exclusion of other products that may also be suitable.

Table 1. Soil moisture characteristics, soil temperature (F), and air temperature (F) at the time of fertilizer application.

Date of application	Moisture characteristics		Soil temperature[1]		Air temperature
	Surface	Subsurface	Max.	Min.	Mean[2]
Sept. 24, 1968	Dry	Dry	75	55	58
Nov. 15, 1968	½ in. snow	Moist	41	41	33
Jan. 15, 1969	½ in. snow, frozen	Moist	39	39	25
Feb. 17, 1969	8 in. snow	Moist	39	36	26
Mar. 14, 1969	10 in. snow	Moist	39	37	–
April 16, 1969	Dry	Moist	61	47	33
May 15, 1969	Dry	Moist	71	54	53
Sept. 16, 1969	Dry	Dry	78	55	53
Oct. 19, 1969	Moist	Moist	58	44	49
Jan. 15, 1970	4 in. snow	Moist	38	38	38
Feb. 1970	Dry, unfrozen	Moist	39	39	32
Mar. 17, 1970	Moist	Moist	52	41	35
April 15, 1970	Dry	Moist	58	41	36
May 17, 1970	Dry	Moist	81	56	58
Sept. 25, 1970	Dry	Dry	80	51	51
Nov. 20, 1970	Moist	Dry	41	40	31
Jan. 18, 1971	Snow, free water	Moist	39	39	33
Feb. 15, 1971	Damp	Moist	39	39	33
Mar. 9, 1971	Dry	Moist	–	–	31
April 14, 1971	Damp	Moist	58	45	40
May 17, 1971	Dry	Moist	76	50	40

[1]Mean values at 2 inches below soil surface for the week following application.
[2]Mean air temperature for the week following application.

after be referred to as crested wheatgrass.

Study yields differed significantly ($P < 0.01$) by years and averaged 100.2, 73.4, and 90.0 g/sample for 1969, 1970, and 1971, respectively. Date of application was also a significant source of variation ($P < 0.05$); but in the absence of any significant interaction, its importance relates to study variability.

Mean sample yields were 76.5, 92.8, and 95.4 g, respectively, for no fertilizer, ammonium nitrate, and urea. These yields differed significantly ($P < 0.01$) from each other.

Crude protein concentrations in mature herbage harvested in 1969 did not differ from each other regardless of treatment or application date. The mean crude protein concentration was 4.2%.

Average available soil nitrate, at three soil levels in the spring of 1969 and at one soil level in the spring of 1970, is tabulated in Table 2. In 1969, there was no available soil nitrate at any depth of sampling of any unfertilized plots. Fertilizers applied in the fall of 1958 and winter, 1969, increased concentrations of available soil nitrate at all sampled depths; but concentrations in the surface 3 inches were influenced the most.

Available soil nitrate in the surface 3 inches was in greater supply on both fertilized and unfertilized plots in spring, 1970, than on the similar sampling date in 1969. Urea and ammonium nitrate both caused a significant increase ($P < 0.05$) in available soil nitrate above that of controls, but differences between the two fertilizers were not significant ($P > 0.05$).

Discussion

Herbage yield and N response in 1969 were probably influenced by carryover effects of 1968. A record drought in 1968 probably resulted in a more favorable soil N status in 1969 and consequently reduced response to applied N. The drought was broken by abnormally high precipitation (2.75 inches) in August, which quite likely enhanced the effectiveness of the 1969 crop-year precipitation.

Mean N response by years was 28, 12, and 38% for 1969, 1970, and 1971, respectively, and was in direct relation with total crop-year precipitation received. Mature yields were increased 23% with ammonium nitrate and 26% with urea fertilizer. The small response to N in this study is believed to have resulted from the manner in which the study was conducted. Although individual rows at 1-ft spacings are quite discrete, it is unlikely that their root systems are. I believe that the adjacent buffer rows were obtaining some of the applied fertilizer through their root system; subsequently, less applied N was available for grasses in fertilized rows. This dilution effect may have reduced the opportunity to detect differences due to treatments.

The small differences between response to ammonium nitrate and urea, though significant, may not be of practical significance. The lack of strong differences between these two fertilizers in this study agrees with results on wild-flood meadows (Rumburg, 1961).

Bleak (1961) and Hull (1963) found spring applications of N no better than fall applications on grasses growing at high elevations. Equality of response to application in the fall, winter, and spring months in this study are in accord with their findings.

Nitrogen fertilization has often increased crude protein concentrations in herbage grown on semi-arid lands (Duncan and Hylton, 1970). However, in the majority of studies they reviewed, the rates of N used were substantially higher than in this study. Previous research at this Station suggests that 20 or 30 lb N/acre would increase crude protein concentrations in dry years but not in normal or above-normal years (Sneva et

Table 2. Available soil nitrate (ppm) under crested wheatgrass at 0-3, 3-6, and 6-9 inches on April 10, 1969 and at 0-3 inches on April 15, 1970, as influenced by fertilizer treatment.

Date applied	Soil depth 0-3			3-6			6-9		
	No Fert	NH_4NO_3	Urea	No Fert.	NH_4NO_3	Urea	No Fert.	NH_4NO_3	Urea
1968									
Sept. 24[1]	0	2	4	0	1	1	0	0	0
Nov. 15[1]	0	4	2	0	1	0	0	1	1
1969									
Jan. 15[1]	0	3	2	0	1	1	0	1	1
Feb. 17[1]	0	3	2	0	1	2	0	1	1
Mar. 14[1]	0	1	1	0	0	1	0	0	0
Sept. 16[2]	4	8	8	–	–	–	–	–	–
Oct. 19[2]	3	8	9	–	–	–	–	–	–
1970									
Jan. 15[2]	4	9	14	–	–	–	–	–	–
Feb. 16[2]	3	16	12	–	–	–	–	–	–
Mar. 17[2]	4	14	5	–	–	–	–	–	–

[1]Observations were made on April 10, 1969.
[2]Observations were made on April 15, 1970.

al., 1958; and Sneva, 1965).

Fertilizers applied in the fall and winter months in 2 years increased available soil nitrate at all sampled levels; largest increases were in the surface 3 inches. The greatest increase occurred in 1970. Differences in growth activity of the grass, and hence the rapidity of removal of available N, probably accounted for differences between the 2 years. Mean maximum temperature for the 5-day period prior to sampling was 52 F in 1969, approximately 8F warmer than that for a similar period in 1970. Thus, growth in 1969, particularily on unfertilized plots on or about April 10, may have been utilizing all soil N available. This total use of mobilized soil N by growing grasses is not uncommon in grassland soils (Walker, 1956). Except for available soil nitrate data of March 14, 1969, the levels of available nitrate as influenced by the date of application also indicate agreement with the harvested yield data.

Fertilizers applied in early fall of 1970 were exposed to dry soil conditions as long as 4 weeks. In February and March, 1969, application of N was on deep snow. Losses of N may occur through gaseous processes under these circumstances. Wullstein and Gilmour (1964) suggest that gaseous losses of N from surface-applied N fertilizers on rangelands may be of economic significance. If such losses took place in this trial and differed because of date of application, those differences were masked by other factors more dominant or similar for all dates.

Conclusions

Urea fertilizer was slightly more effective (3%) than ammonium nitrate in increasing mature yield of crested wheatgrass. No difference in mature yield increase was found among fertilizer applications made in the fall, winter, or spring. Thus, fertilizer purchase time relative to market prices, storage opportunity and cost, and application time relative to seasonal workload can be important considerations when figuring the economics of N fertilization of crested wheatgrass on eastern Oregon rangelands.

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Vegetative Response to Chemical Control of Broom Snakeweed on a Blue Grama Range

R. W. GESINK, H. P. ALLEY, AND G. A. LEE

Highlight: *All rates of picloram, either alone or in combination with low rates of 2,4-D, effectively controlled broom snakeweed on a blue grama range in southeastern Wyoming. Picloram also eliminated the low amounts of plains pricklypear present among the dense stands of snakeweed. Blue grama was initially injured by the 0.5 and 1 lb/acre rates of picloram, but needle-and-thread was damaged only by the 1 lb/acre rate. This initial injury to the grasses had a renovating effect upon the range, and, in combination with the elimination of undesirable plants, resulted in notable range improvement as measured 5 years after treatment. The study illustrates how herbicides may be a useful tool for selective manipulation of rangeland vegetation.*

Numerous studies concerning chemical control of undesirable plants on native rangeland have been reported over the years. Relatively little information, however, is available regarding the long-term effects of herbicides, particularly as they influence non-target components of the plant community. Laycock and Phillips (1968) have pointed out that the long-term ecological effects must be known if a herbicide is to be adequately evaluated as a method of range improvement. Because of time consuming methods, herbicide treatments are often evaluated in terms of the response of a single species (Hyder, 1971); and usually, only the short-term effects are reported.

The study presented here is an evaluation of the vegetative changes on a blue grama (*Bouteloua gracilis* [H.B.K.] Lag. ex Steud.) range in southeastern Wyoming, 5 years after the area had been subjected to treatment with herbicides. The treatments were made initially to investigate their effectiveness in the con-

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The authors express their appreciation to Richard Strom, rancher, Laramie, Wyo., for providing a research area, and gratefully acknowledge the valued assistance of T. E. Bedell and R. L. Lang, Plant Science Division, Univ. of Wyoming, Laramie.

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trol of broom snakeweek (*Gutierrezia sarothrae* [Pursh.] Britt. & Rusby), a species which occurred in abundance on the study site. Also included in the trials were evaluations on plains prickly-pear (*Opuntia polyacantha* Haw.), a species found in relatively low amounts among the dense stands of snakeweed.

Broom snakeweed is a relatively unpalatable, competitive range week widely distributed over the western states (Forest Service, 1937). For the most part, studies on the control of this plant have been limited to the Southwest (Schmutz and Little, 1970), and only a small amount of research has been conducted in Wyoming (Alley and Lee, 1967). Stoddart and Smith (1955) state that thousands of acres of the short-grass plains have been invaded by snakeweed due to over-grazing. Recently, however, Jameson (1970) reported a study on Southwestern pinyon-juniper ranges in which changes in snakeweed over a 13-year period appeared to be the result of oscillating populations rather than of range condition.

Snakeweed is not particularly abundant in Wyoming; but it presents a range problem in certain local areas, usually those that have been subjected to heavy grazing. Herbicides used to control snakeweek have been limited largely to picloram and the chlorophenoxys (Alley and Lee, 1967; Johnsen, 1966; Schmutz and Little, 1970). Chemical control of snakeweek in Arizona has increased blue grama yields substantially (Jameson, 1966).

Plains pricklypear has received considerable attention because of the extensive acreages of rangeland it inhabits throughout the central and northern Great Plains. Thatcher et al. (1964) reported that the invasion and increased abundance of plains pricklypear has become an acute problem in many range areas of Wyoming. This abundance of pricklypear in the short-grass region has been attributed to over-grazing (Stoddart and Smith, 1955). However, 25 years of light, moderate, and heavy grazing by cattle in northeastern Colorado induced no outstanding changes in cactus population (Bement, 1968).

Bement (1968) hand-removed pricklypear from a blue grama range in northeastern Colorado and found no increase in blue grama production, but more forage was available for grazing. Alley and Lee (1969) stated that the increase in available forage from removing cactus would be in direct proportion to the density of the infestation and the ground area opened up by its removal. Although no forage production figures have been obtained from chemically treated cactus areas, Hyde et al. (1965) reported forage production was doubled where pricklypear had been controlled by mechanical beaters.

Responses of desirable species to picloram in rangeland ecosystems have not been extensively studied (Scifres and Halifax, 1972). In pricklypear control studies in western Nebraska, picloram eliminated about 50% of the native grass with May and July applications of 2 and 4 lb/acre (Wicks et al., 1969). Hyde et al. (1965) reported similar results in northeastern Wyoming. Picloram at less than 1 lb./acre injured smooth bromegrass (*Bromus inermis* Leyss.), especially with fall applications (McCarty and Scifres, 1968). Gesink et al. (1972) showed that smooth brome was greatly injured with picloram treatments of 1 and 1.5 lb/acre, western wheatgrass (*Agropyron smithii* Rydb.) was only slightly injured, and Kentucky bluegrass (*Poa pratensis* L.) was not injured by these rates. In Oklahoma picloram applied to established warm-season native grass species did not reduce forage production or desirable plant frequency; however, certain perennial grasses were injured when treated during the two- and four-leaf stages. At the six-leaf stage, only blue grama and sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.) stands were reduced at the high treatment level of 4 lb/acre (Arnold and Santelmann, 1966).

Materials and Methods

This study was established in 1966 on a blue grama range near Laramie, Wyo. The area had been heavily grazed by sheep and in 1966 supported dense, uniform stands of snakeweed. Pricklypear was also present on the site, but in considerably less abundance than snakeweed. Blue grama comprised most of the perennial grass cover but was present in relatively small amounts because of the competition from snakeweed and pricklypear. Other perennial grasses that occurred as scattered plants were needle-and-thread (*Stipa comata* Trin. and Rupr.), western wheatgrass, and Indian ricegrass (*Oryzopsis hymenoides* [R. and S.] Ricker).

Herbicide treatments were made on a site with less than 1% slope and nearly uniform vegetation and soils. The soils of this area are deep, well-drained, loamy sands.

The herbicides were applied on June 26, 1966, as individual trials on unreplicated, 1/5 acre (43 x 200 ft) plots (Fig. 1). A truck-mounted sprayer was used to apply the herbicides in water at a spray volume of 25 gal/acre.

Herbicides[1] and rates applied were as follows:

Herbicide	*Rate*
1. Untreated check	
2. Silvex	2.00 lb./acre
3. Silvex	4.00 lb./acre
4. Picloram	0.50 lb./acre
5. Picloram	1.00 lb./acre
6. Picloram	0.25 lb./acre
+ 2,4-D	+1.00 lb./acre
7. Picloram	0.50 lb./acre
+ 2,4-D	+2.00 lb./acre

Visual evaluations concerning the vegetative response to the treatments were recorded each year. Percent control of undesirable plants was determined by averaging separate ocular estimates made by three individuals. In 1971, an intensive vegetation survey of the study area was made by utilizing the line intercept method (Canfield, 1941) to sample each 1/5 acre plot with ten randomly located 30 ft transects. Herbage was clipped by species from 15 circular (2.5 ft dia.) plots randomly located in each of the 1/5 acre herbicide treatments. Samples were oven-dried at 80 C for 24 hr and weighed. Cover and production estimates were tested by analysis of variance and Duncan's multiple range test at the 5% level of significance.

Results and Discussion

Snakeweed Response

All treatments that included picloram effectively controlled snakeweed (Table 1). These four treatments provided 95 to 100% control for 3 years after application date. After 5 years this level of control was still apparent for both picloram at 0.5 lb./acre (Fig. 1), and one combination of picloram + 2,4-D (0.5 + 2 lb./acre). Snakeweed control with picloram at 1 lb./acre and the other combination of picloram + 2,4-D (p.25 + 1 lb./acre) declined after 5 years with values of 85 and 80%, respectively, for each treatment.

Silvex treatments did not control snakeweed (Fig. 1). Recent field observations suggest that this occurred because treatments were applied too late into the growing season after the plants had developed beyond more susceptible growth stages.

Schmutz and Little (1970) also found picloram to be a very effective treatment for snakeweed in Arizona. Picloram was two to four times more toxic to snake-

[1]Chemical names of herbicides used were: 2-(2,4,5-trichlorophenoxy) propionic acid (Silvex), 4-amino-3,5,6-trichloropicolinic acid (Picloram), 2,4-dichlorophenoxy) acedic acid (2,4-D).

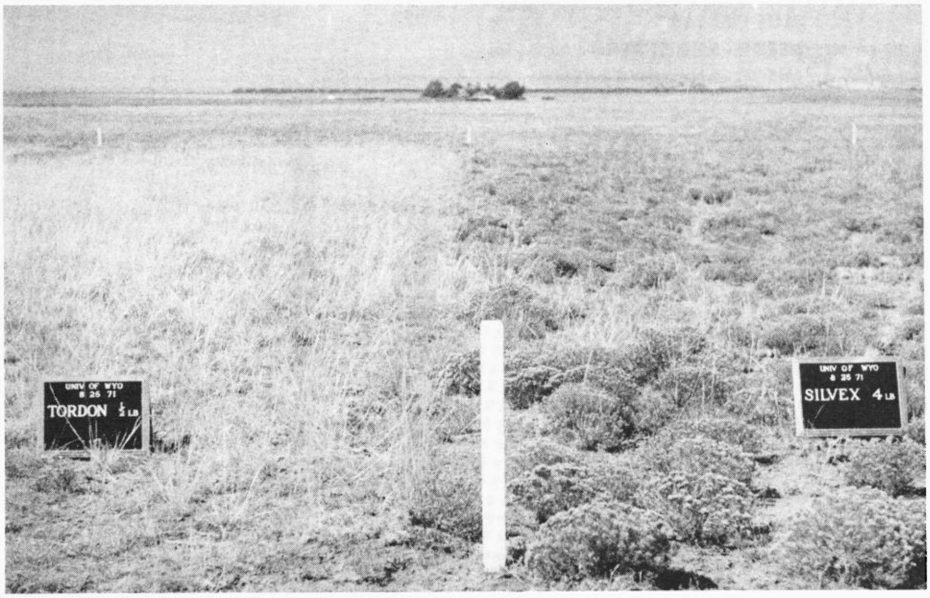

Fig. 1. *View of picloram (*Tordon*) treatment at 0.5 lb/acre and silvex treatment at 4 lb/acre as they appeared in August of 1971, 5 years after treatment. The silvex plot is similar to the untreated check.*

weed than 2,4-D or 2,4,5-T, and the period of susceptibility was longer. They suggested the longer period of susceptibility may result from greater picloram translocation under moisture stress, as reported by Merkle and Davis (1967).

Pricklypear Response

All rates of picloram and picloram + 2,4-D completely controlled pricklypear for the entire 5 year period, a response consistent with previously reported studies. The silvex treatments, however, were much less effective. At 4 lb./acre, silvex gave 80% control the first year after treatment, but this dropped to 50% when control was evaluated after 5 years. The 2 lb./acre rate was even less effective, with only 20–25% control for the entire study period. The effectiveness of silvex in the control of pricklypear has been demonstrated (Alley and Lee, 1969; Thatcher et al., 1964; Wicks et al., 1969), but no explanation can be provided for the unusual results obtained in this study.

Perennial Grass Response

Certain perennial grasses were injured during the first and second years after the herbicides were applied. Blue grama cover was greatly reduced on the areas treated with picloram at 0.5 and 1 lb./acre, and one combination of picloram + 2,4-D (0.5 + 2 lb./acre). Picloram at 1 lb./acre not only injured blue grama but also greatly reduced the abundance of needle-and-thread, a species not adversely affected by the lower rates. Neither silvex treatments nor the other combination of picloram + 2,4-D (0.25 + 1 lb./acre) injured any perennial grass species.

A comparison of the grass cover estimates obtained from the 1971 survey showed the silvex treatments were essentially similar to the untreated check (Fig. 1 and 2). The highest cover of blue grama (14.3%), occurred with the lowest rate of the combination of picloram + 2,4-D (0.25 + 1 lb./acre). Blue grama cover estimates from the other three picloram treatments were significantly lower, ranging from 6.8% to 8.9%; but these values were still significantly high when compared to the silvex treatments and the untreated check.

All areas treated with picloram alone or in combination with 2,4-D had a higher cover of needle-and-thread than either the untreated or silvex-treated area. The highest cover for this grass, 4.6 and 4.3%, occurred on areas that received picloram at 0.5 lb/acre and the combination of picloram + 2,4-D (0.5 + 2 lb./acre), respectively.

The miscellaneous grasses occurring on the study plots were Indian ricegrass, western wheatgrass, Junegrass (*Koeleria cristata* [L.] Pers.), Sandburg bluegrass (*Poa secunda* Presl.), and sand dropseed (*Sporobolus cryptandrus* [Torr.] Gray). Cover values for these species did not differ significantly among treatments. All miscellaneous grasses, with one exception, were found to occur on all treated plots. Sand dropseed was found only on areas that received picloram at 0.5 lb./acre and the combination of picloram + 2,4-D (0.5 + 2 lb./acre).

By 1971, perennial grass production had increased substantially with all treatments which included picloram (Fig. 3). Needle-and-thread produced 500 and 444 lb./acre, respectively, on the areas treated with picloram at 0.5 lb./acre and the combination of picloram + 2,4-D (0.5 + 2 lb./acre). Production of needle-and-thread was significantly lower on areas treated with picloram at 1 lb./acre and the combination of picloram + 2,4-D (0.25 + 1 lb./acre), but was greater than on either the untreated or silvex treated areas.

Blue grama production on all picloram-treated plots was significantly

Table 1. Control (%) of snakeweed and pricklypear as recorded for 5 years following treatments.

Treatment[1] and Species	Percent control				
	1967	1968	1969	1970	1971
Silvex 2.0 lb/A					
Snakeweed	00	00	00	00	00
Pricklypear	25	25	25	20	20
Silvex 4.0 lb/A					
Snakeweed	00	00	00	00	00
Pricklypear	80	65	65	60	50
Picloram 0.5 lb/A					
Snakeweed	100	100	100	95	95
Pricklypear	90	100	100	100	100
Picloram 1.0 lb/A					
Snakeweed	100	100	100	90	85
Pricklypear	95	100	100	100	100
Picloram 0.25 lb/A +2,4-D 1.0 lb/A					
Snakeweed	98	100	95	85	80
Pricklypear	95	99	100	100	100
Picloram 0.5 lb/A + 2,4-D 2.0 lb/A					
Snakeweed	100	100	99	95	95
Pricklypear	95	100	100	100	100

[1]Treatments were applied June 26, 1966.

greater than on silvex treated plots or the untreated check (Fig. 3). The treatment on which the highest cover of blue grama occurred, picloram + 2,4-D (0.25 + 1 lb./acre), resulted in the lowest production for this species of all picloram treatments. The blue grama stand on this plot was not initially reduced by the herbicide treatment; 5 years after application the blue grama plants still exhibited their characteristic low growth habit. In contrast, blue grama plants were more sparse on areas treated with the higher rates of picloram, either alone or in combination with 2,4-D; plants were vigorous and robust with a great deal of foliage and many seed heads. These higher rates of picloram appeared to have a renovation effect on the blue grama stands. The results are similar to those obtained from range pitting investigations in this region, where blue grama stands were thinned. In years subsequent to treatment, the thinned stands outproduced the original (Rauzi and Lang, 1956).

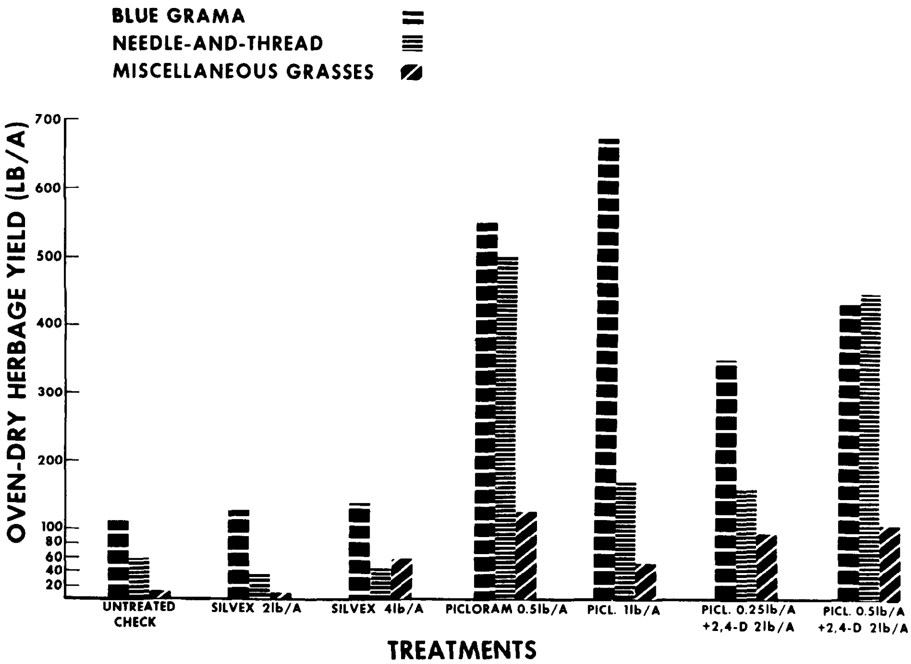

Fig. 3. *Herbage yields (lb/acre) oven-dried, 5 years after treatment.*

Plant Community Response

Essentially no vegetative changes occurred as measured 5 years after treatment with silvex. Some pricklypear was eliminated; however, this did not appear to affect perennial grass and forb production and cover, primarily because pricklypear was not originally a particularly abundant species.

One combination of picloram + 2,4-D (0.25 + 1 lb./acre) completely removed pricklypear and gave high level control of snakeweed. This treatment did not injure perennial grasses present; therefore, upon the elimination of cactus and snakeweed, there were large increases in blue grama. Needle-and-thread did not increase greatly with this treatment, probably because of competition provided by the rather dense stands of blue grama that developed on the treated area.

Picloram at 1 lb./acre eliminated both snakeweed and pricklypear and for 2 years after treatment caused injury to both blue grama and needle-and-thread. Blue grama recovered after the second year and with the removal of snakeweed and pricklypear competition, greatly increased in abundance. This high rate of picloram appeared to have a renovation effect upon the blue grama, resulting in vigorous growth as evidenced by exceptionally high herbage production for this species. Needle-and-thread grass recovered after the second year but did not significantly increase under this treatment.

Picloram at 0.5 lb./acre and the other combination of picloram + 2,4-D (0.5 + 2 lb./acre) affected the plant community similarly. These two treatments eliminated snakeweed and pricklypear and injured blue grama but did not damage needle-and-thread. With a reduction of blue grama during the first 2 years and with the elimination of snakeweed and pricklypear, an excellent opportunity was provided for an increase in needle-and-thread, a species that precedes blue grama in natural succession in this region. By 1971, blue grama had greatly increased, but needle-and-thread was still abundant on these areas. These two treatments caused a shift towards earlier stages of succession. This deduction was made on the basis of the large amounts of needle-and-thread and the presence of sand dropseed which occurred as a result of these two treatments. That needle-and-thread and sand dropseed characterize early successional stages is borne out by Lang (1945) in a study of the revegetation of abandoned farm land on the short-grass plains of southeastern

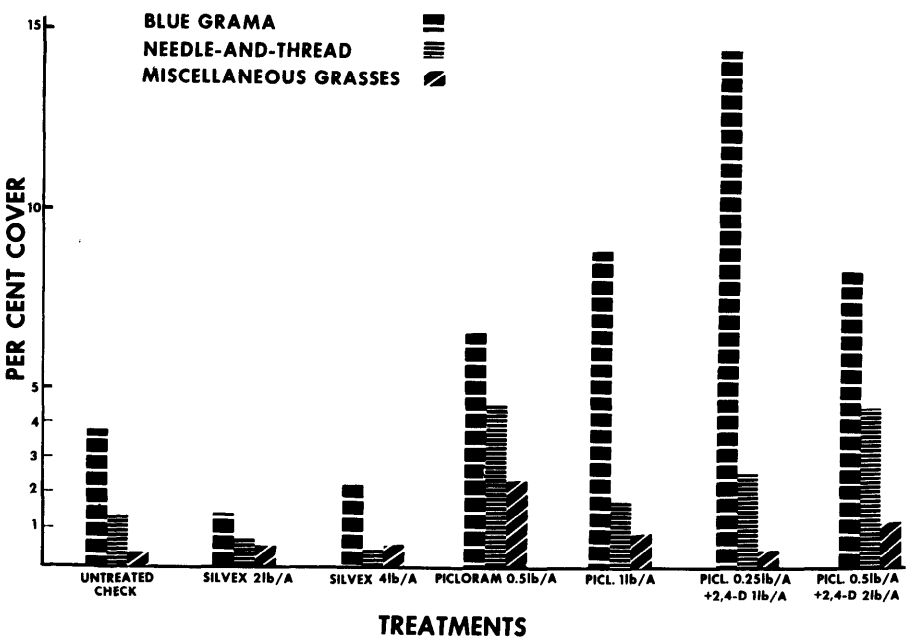

Fig. 2. *Basal cover of grasses 5 years after treatment.*

Wyoming.

This study shows how a portion of a snakeweek infested, blue grama range was improved greatly by manipulation of the vegetation with the use of various picloram treatments. Although picloram has been used in the past primarily as a means to eliminate undesirable plants, it may also have potential as a tool for the selective manipulation of rangeland vegetation.

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Effects of Cultural and Management Practices on Seed Production of 'Plains' Bluestem

R. M. AHRING, C. M. TALIAFERRO, AND L. G. MORRILL

Highlight: *Seed production of 'Plains' bluestem (*Bothriochloa ischaemum *[L.] Keng.) is difficult to assess because of its indeterminate flowering habit and its vegetative canopy which, when excessive, interferes with seed harvests. The variety will produce two seed crops annually. The first matures in July and the second, if managed properly, in October. The effects of three management treatments on the amount of forage associated with each seed crop were highly significant in 2 out of 3 years. The study suggests that a delay of about 21 days in removing the residual forage remaining after the summer seed harvest will favorably influence fall seed yields. Where nitrogen was applied, the decline in vegetation associated with the seed crop was directly related to the previous year's forage cropping practice. Burning residual litter in early March, fertilizing with a 60-45-0 (N, P, K) pound rate of N and P was best for the production of a summer seed crop. The removal of residual forage by mowing and baling about July 29, cultivation, fertilization, and irrigations as needed, favorably influenced fall seed yields. The combined yield of the two crops in 1969 was in excess of 200 lb/acre pure seed.*

Bothriochloa ischaemum var. *ischaemum* belongs to the tribe *Andropogoneae* and is composed of warm season, perennial, bunchgrasses locally termed "Old World bluestems." Numerous accessions of these grasses were acquired by the Oklahoma Agricultural Experiment Station and investigated by Harlan and Associates (1958, 1961) in basic biosystematic studies of the genus. Attributes of Old World bluestems include aggressiveness, persistence, and good forage yield potential. Generally, they reproduce by facultative apomixis, have an indeterminate flowering habit, and bear chaffy seeds which are difficult to harvest, process, and plant.

'Plains' bluestem (*B. ischaemum* var. *ischaemum*) is a recent varietal release developed from the Old World bluestem collection. The forage production of the variety is at its maximum and of greatest value to livestock in Oklahoma during the summer, i.e., July, August, and September. The cultivar spreads aggressively by volunteer seedlings and will produce seed

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The paper is a contribution of Plant Science Res. Div., Agr. Res. Serv., U. S. Dep. Agr., and Oklahoma Agricultural Experiment Station at Stillwater.

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stalks continuously from June until frost. Under proper management, two seed crops are harvestable each year: the first matures seed in late June and the second in October. Preliminary observations suggested the major problems involved in seed production of the variety:

1. Continuous seed stalk production, indeterminate flowering habit, thus, lack of uniform seed maturity;
2. Lack of knowledge concerning proper fertility and moisture levels for maximum seed stalk production and seed set;
3. Vegetative canopies which, when excessive, interfere with seed harvests; and
4. The presence of seed-feeding insects (Ahring and Howell, 1968).

Although a number of seed production studies on grasses have been conducted, none to our knowledge have involved any Old World bluestems, i.e., 'King Ranch' (*B. ischaemum* var. *songarica* [Rupr.] Celarier); 'El Kan' (*B. ischaemum* var. *ischaemum* Keng.); 'Caucasian' (*B. caucasia* C.E. Hubb); or 'Medio, (*Dicanthium papillosum* [Hochst.] Stapf.) Generally, seed yields of these Old World bluestem varieties have been low and have been a factor limiting widespread use. Since the success of a seed-propagated forage cultivar is highly dependent on the quantity and quality of seed produced, we undertook to assess the seed production potential of 'Plains' bluestem and to determine what cultural and management practices would enhance seed production.

Published reports of research on grass seed production usually deal with species that produce only one seed harvest per year. Information on practices required for species that mature more than one crop per year is totally lacking for many important forage grass species. Mechanical removal or burning of stubble after harvesting seed is a common management practice of most grass seed growers. Fall burning of cool-season grasses: red fescue (*Festuca rubra* L.) (Musser, 1947; Pumphrey, 1965); 'Kentucky 31' tall fescue (*Festuca elatior* var. *arundinacea*) (Spencer et al., 1950); intermediate wheatgrass (*Agropyron intermedium* [Host] Beauv.) (Canode, 1965); perennial ryegrass (*Lolium perenne* L.) (Hardison, 1948); and orchardgrass (*Dactylis glomerata* L.) (Rampton and Warren, 1963) has been shown to benefit seed production and to aid in the control of several diseases (Hardison, 1960). Spring burning or mechanical removal of plant residue on warm-season grasses is documented for forage production, but no literature was found on comparative seed production practices other than Burton's (1944) work on several southern grasses. Although fertilization of burned areas gave the greatest seed yields, the percentage increase due to fertilization was greater on unburned plots.

The production of seed on most cool-season grasses is related to nitrogen fertilization. Optimum rates range from 30 to 120 lb. N/acre, depending on the kind of grass involved, age of stand, and whether production is under irrigated or dryland conditions. Dates of application vary from spring or fall to split spring and fall in different parts of the country. Similarly, warm season grasses grown for seed respond differently to fertilizer rates and dates of application. A split application of 40 to 30 lb. N in early spring and at boot stage, respectively, on switchgrass (*Panicum virgatum* L.) (Harlan and Kneebone, 1953) significantly increased seed yields. However, comparisons made on the number of panicles per plot were not significantly different between 100 lb. N applied as one application in early spring or split rates of 40-30 and 70-30 pounds. A mid-August application of 50 lb. N on blue grama (*Bouteloua gracilis* (H. B. K.) Lag. ex Steud.) under irrigated conditions significantly increased fall seed yields (Kneebone, 1953). The need for fertilization (Smith, 1948) becomes apparent in grasses producing a summer seed crop about the third year under dryland and the second year under irrigated conditions. Although seed-yield data on little bluestem (*Andropogon scoparius* Michx.) was not recorded (Murphy, et al., 1947), nitrogen in combination with phosphorus produced the greatest number of seed stalks. Light applications of nitrogen were not sufficient for maximum seed production, and phosphate alone actually decreased seed stalk production. In addition, Murphy, et al. (1947) reported 45 to 48 lb. N produced .91 to 4.2 lb. of weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees.) seed per pound of applied nitrogen.

Methods

Studies were initiated in 1968 at the Oklahoma State University Agronomy Research Station, El Reno, Okla. The soil at this location is predominantly a Brewer clay loam with a pH of approximately 7.3. Soil analyses of the test location showed that it contained 190 to 260 pounds available phosphorus, 645 to 915 pounds available potasssium, and less than 10 pounds nitrate-nitrogen per acre. One acre of 'Plains' bluestem was established in rows 39 inches apart in 1964.

The field layout for the first crop in 1968 consisted of plots in three columns across three blocks and assigning fertility treatments once to each column and to each block in a three-by-three latin square design. In the second and all succeeding crops, the design was modified into a split plot design with randomized forage cropping frequencies (clippings) within each fertility treatment as sub-plot treatments. Three nitrogen fertilizer levels (0, 60, and 180 lb./acre) were used. Fertilizer was

Table 1. Mean yields (lb pure seed/acre) of 'Plains' bluestem for summer (H_1) and fall crops (H_2) at three management levels and nitrogen (lb/acre) treatments over a 3-year period.[1]

Year and management treatment	H_1				H_2				H_T
	0N	60N	180N	Avg.	0N	60N	180N	Avg.	Total
1968[3]									
A[2]	15.9	26.5	18.1	20.2	104.7	106.7	106.5	195.9	126.1
B	–	–	–	–	8.5	16.4	16.2	13.7	13.7
C	–	–	–	–	2.0	2.0	3.1	2.3	2.3
Mean	15.9	26.5	18.1	20.2	38.4	41.7	41.3	40.6	47.4
1969[3]									
A	29.9	81.4	98.4	69.9	118.4	166.0	70.1	118.2	188.0
B	55.4	111.0	97.0	87.8	123.0	238.2	133.7	164.9	252.8
C	37.9	62.6	74.8	58.4	89.3	105.8	96.9	97.3	155.7
Mean	41.1	85.0	90.1	72.0	110.2	170.0	100.2	126.8	198.8
1970[3]									
A	24.3	39.0	103.0	55.4	96.3	100.3	82.4	93.3	148.7
B	64.1	66.9	66.7	65.9	–	–	–	–	65.9
C	45.2	124.8	62.9	77.6	86.4	106.1	95.9	96.1	173.7
Mean	44.5	76.9	77.5	66.3	91.3	103.3	89.1	94.7	129.4

[1]Mean of three replications/harvest.
[2]H_1 yields in 1968 were harvested before application of treatments A, B, and C.
[3]$LSD_{(.05)}$ Main plots (N-level); Sub-plots (Manage.)

	H_1	H_2	H_T	H_1	H_2	H_T
Means 1968,	–	8.2	– ;	–	5.6	–
Means 1969,	64.5	66.7	43.4;	37.0	49.8	58.9
Means 1970,	58.5	33.7	53.3;	53.1	23.6	63.1

applied to the plots twice a year, once in April and immediately after residue removal following the first seed and forage harvest in July. Blanket applications of 45 lb. of phosphorus were applied in April of each year. Irrigation was applied as required to supplement rainfall. Generally, plots were cultivated two or three times per crop each year.

Forage and seed were harvested from all treatments in July (H_1). Forage cropping frequencies designated as management practices A, B, and C were used only on the second or fall seed crop each year (H_2). Management A consisted of mowing and baling the forage after harvesting the first or summer seed crop in July (H_1) and allowing regrowth to mature a fall crop. Management B consisted of A plus one additional cropping of the regrowth 21 days after H_1. Management C consisted of A plus two additional forage cropping dates at 21 and 42 days after H_1. The residue remaining after harvesting seed and forage yield from the above plots was burned the following March.

The H_1 yields (after the initial year) are measures of the management effects as applied the previous year. With this in mind the data collected were evaluated for:

1. The amount and quality of seed produced as affected by nitrogen fertilization and forage cropping frequencies;
2. The effects management practices A, B, and C had on the amount of forage associated with each seed crop; and
3. Stand longevity and spring recovery as affected by treatment.

Seed was harvested by hand, air dried, hammer-milled, and scalped with a small seed cleaner. The scalped seed was weighed, recorded by plot and treatment, and percent pure seed determinations were made following the method proposed for chaffy seeded grasses by Harlan and Ahring (1960). Yields are reported in pounds of pure seed and forage in tons of plant dry matter per acre.

Results and Discussion

Both management practices B and C significantly reduced the vegetative canopies associated with the summer and fall seed crops. However, the amount of pure seed produced (Table 1) at the fall seed harvest (H_2) in 1968 was not directly attributable to the forage cropping frequencies of either management B or C. The seed crops of all management treatments were harvested on the same day in 1968. Seed harvested from the plots of management B and C were immature, had a low percent pure-seed content, and thus had low yields. The continuous seed stalk production requires close observation of the pattern of head and field maturity to judge the optimum time for seed harvest. In the remaining two years, plots were harvested by management practice according to stage of maturity (i.e., when 50% or more of the seed heads, at several locations in the plot, could be stripped easily by pulling the head gently between the fingers).

Seed yield differences were highly significant in the fall crop of 1969. Management practice B at all levels of nitrogen produced the greatest amount of pure seed. The quantity of seed produced under C was not significantly different from A at any levels of nitrogen used. Management B appeared to reduce the vegetative cover at the harvest of the fall (H_2) seed crop and resulted in more erect, uniform seed stalk production. The advantage of B over C was due to the lack of sufficient plant recovery under C with fewer seed stalks and obviously weakened plants. The forage cropping practice of management B removed the excess forage that interfered with the fall (H_2) seed harvests of management A, without a loss in seed yields.

The analysis of variance of dry matter produced (forage yield) in conjunction with the summer seed harvests (H_1) in 1969 showed significant response to management levels (Table 2). Management practices B and C significantly reduced the forage yield associated with seed production the following year. Where nitrogen was applied, the decline in dry matter produced at H_1 compared to the control, management A, was directly related to the previous year's forage cropping practice. Summer (H_1) yields were consistent within years for management A over the 3-year study.

Nitrogen applications did not significantly increase yields at H_1 in 2 of the 3 years. Plant dry matter associated with the H_1 seed harvest of each of the 3 years reflects the effects of management practices B and C on vigor. Dry matter production on control or non-fertilized (N) plots progressively declined each year. Reduced yields were the result of lowering fertility levels in the soil and, in the case of managements B and C, the combined effects of increased numbers of harvests and reduced soil fertility.

Additional nitrogen improved forage yields at H_2B and H_2C. Table 2 presents the plant dry matter associated with each seed harvest but excludes the yield of the additional cropping dates of management practices B and C. The combined harvests of management B, excluding H_1, averaged over fertility rates of the initial year of study, were considerably greater, 5.63 as compared to 4.41 tons for management A. The amount of plant dry matter produced by management B was reduced at H_1 in 1969. This effect was masked in 1970 at H_1 because supplemental irrigations were limited during a major part of

Table 2. Mean yields (tons/acre) of 'Plains' bluestem associated with each seed harvest at three management levels and nitrogen treatments (lb/acre) over 3 years.[1]

Year and management treatment	H_1				H_2			
	0N	60N	180N	Avg.	0N	60N	180N	Avg.
1968[3]								
A[2]	4.03	4.05	4.30	4.13	3.89	4.42	4.93	4.41
B	3.92	4.11	4.32	4.11	3.39	4.42	4.52	4.11
C	4.10	4.21	4.42	4.24	1.32	1.58	3.30	2.06
Mean	4.10	4.12	4.34	4.16	2.86	3.47	4.25	3.52
1969[3]								
A	3.42	4.39	4.61	4.14	1.90	2.99	3.12	2.67
B	2.49	3.64	3.35	3.16	0.69	1.63	2.41	1.57
C	1.99	2.43	2.60	2.34	0.23	0.59	0.96	0.59
Mean	2.63	3.49	3.52	3.21	0.94	1.74	2.16	1.61
1970[3]								
A	1.86	2.38	2.29	2.18	2.37	3.24	3.46	3.02
B	1.60	2.94	2.44	2.32	0.44	0.56	1.26	0.75
C	1.32	2.29	2.34	1.98	2.14	2.90	3.42	2.82
Mean	1.59	2.53	2.36	2.16	1.65	2.23	2.71	2.20

[1]Means of three replication/treatment by harvest.
[2]H_1 yields in 1968 were harvested before application of treatments A, B, and C.
[3]$LSD_{(.05)}$ Main plots (N-level); Sub-plots (Manage.)

	H_1	H_2		H_1	H_2
Means 1968,	–	0.61	;	–	0.46
Means 1969,	1.05	0.58	;	0.69	0.33
Means 1970,	0.69	0.44	;	0.35	0.50

Table 3. Mean dry plant matter (tons/acre) over all harvests by management treatments and nitrogen levels (lb/acre).

Year and management treatment	Nitrogen Levels 0	60	180	Mean
1968				
A	7.92	8.47	9.23	8.54
B	8.67	10.09	10.56	9.77
C	7.23	7.79	9.85	8.29
Mean	7.94	8.78	9.88	8.86
1969[1]				
A	5.34	7.38	7.73	6.82
B	3.48	5.82	6.26	5.18
C	2.76	4.13	4.73	3.87
Mean	3.86	5.77	6.24	5.29
1970[1]				
A	4.23	5.62	5.75	5.21
B	3.62	5.30	6.14	5.02
C	3.46	5.19	5.76	4.80
Mean	3.77	5.37	5.89	5.01

[1] $LSD_{(05)}$ Main plots (N-level); Sub-plots (Manage.)
Means 1969 - 2.07 Tons ; 1.07
Means 1970 - 1.02 Tons ; 1.07 Tons

the growing season (May and June). Significant differences in the amount of dry matter produced in 1970 existed among the three nitrogen levels.

Forage yields produced by management practices A and B were significantly higher than C at the H_1 and H_2 seed harvest dates in 1969. In 1970, a delay in removing H_1 forage in preparation for the fall seed crop was such that the one additional cropping of the forage regrowth of management B was comparable to the second cropping date of the previous year of H_2C. Due to the slow recovery of the C plots after H_1, additional forage croppings were not taken in that year. The recovery in 1970 of management C as depicted by the H_2 dry matter production was surprising. The species evidently can be heavily abused for 2 years and then rapidly regain its vigor the 3rd year if managed normally, i.e., management A.

The response to nitrogen fertilization was significant at the last harvest (H_2) throughout the 3 years of study. The tonnage of dry matter produced each year was generally greater with application rates of 180 lb. N/acre, but this was not significantly different from the 60 lb. rate. As one moves to a higher fertility level, regardless of management, a higher combined yield was obtained, (Table 3). Also, as the management practice was changed from A to B to C, there was a reduction in quantity of dry matter produced. The more frequently cropped management C produced less dry matter than did management A or B at all levels of nitrogen fertilization. Regrowth following the cropping practices of management B and C was more rapid with nitrogen applications. Thus residual effects of the different management practices as reflected in tons of dry matter per acre from uniform harvests (H_1) indicated that nitrogen level and cropping management practices influence yield or amount of vegetative cover present.

The significant responses to nitrogen (main effects) and management practices A, B, and C (sub-plot effects) indicated: 1. The quantity of vegetative material associated with seed production was altered by cropping management in both summer (H_1) and fall seed (H_2) crops; 2. Nitrogen applications of approximately 60 lb. N/crop/acre were essential for production of maximum yields; and 3. The normal procedure, management A, or removing the residual forage immediately following the summer seed harvest, was not the best practice.

The study suggests that a delay of about 21 days in removing the forage after the summer (H_1) seed harvest will probably influence seed yields favorably in the fall. A small but favorable reduction in forage present in the summer harvest the following year, as shown by management practice B, is sufficient to promote and increase harvestable seed. However, reduction in vegetative canopies associated with both seed crops can be attained by narrow row spacing. Although data are not presented, a 12- to 24-inch row spacing may be better than 39-inch rows for seed production of this species under irrigated conditions.

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A Simple Stereophotographic Technique for Analyzing Small Plots

Fig. 1. *Camera with stereo adapter attached.*

RAYMOND D. RATLIFF AND STANLEY E. WESTFALL

Highlight: *An inexpensive stereo adapter for a camera provided stereo pairs on a single color print. At a camera height of 48 inches, we obtained good resolution of a square-foot area and a scale of 1:7. The stereo prints are used with a dot grid overlay and a pocket stereoscope to estimate foliar cover and composition.*

During a study of back country meadows in the central Sierra Nevada Mountains of California, we needed information on foliar cover and composition. Travel in this high country was by helicopter and on foot and, therefore, expensive. We had much ground to cover and a limited budget. Hence, we needed a method of gathering these data which would reduce field time—even at the expense of increasing office time.

Review of the literature had indicated that stereophotographs would do the job. However, equipment similar to that described by Pierce and Eddleman (1970) or Wells (1971) appeared too cumbersome for packing up and down steep mountain trails.

Instead, we used a Honeywell Pentax[1] 35 mm single-lens reflex camera with a stereo adapter of the same make (Fig. 1). The adapter splits the 24-mm by 36-mm format into a stereo pair of single-frame images. If Kodacolor X film is used, the stereo pairs come from the processor on one print (Fig. 2) and can be easily viewed with a pocket stereoscope. Hence, we decided to use prints rather than slides.

Because a standard format and scale were required for later assessment of foliar cover and composition, we devised a simple "photo frame" (Fig. 3). The upright portion, bent out of 1/2-inch electrical conduit, was made to set up a camera height of 48 inches. We had found that this height produced good resolution of the vegetation on a square-foot area, and that standard 3-1/2-inch by 5-inch prints gave a scale of about 1:7.

The base of the photo frame was made to slip over a square-foot sampling frame. The photographer could thus leave a sampling frame in place for clipping and move to the next location. This arrangement permitted herbage yield as well as foliar cover and composition to be determined for each plot. In addition, a slate with a plot code was photographed with each plot, providing positive identification of each print.

We are using the stereo prints with a dot grid overlay and a pocket stereoscope to estimate foliar cover and composition. Generally, individual species can be identified, but a familiarity with the species comprising the vegetation type is a necessity.

Using a single camera with a stereo adapter has several advantages over techniques now in common use. The stereo adapter ends off-setting for a second picture and only costs about $30—much less than a second camera. As with two

Fig. 2. *Color prints 3½- by 5-inch provide good resolution and can be viewed in stereo with a pocket stereoscope.*

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[1]Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U. S. Dep. Agr. is implied.

Fig. 3. *A photo frame is used to obtain a stereo photo of a square foot plot.*

cameras triggered simultaneously, problems with wind or clouds or both producing somewhat different images are avoided. But if only one camera must be focused, equal depth of field on the stereo pair is assured. Because the stereo pair is produced on one print or slide rather than two, total costs for film, developing, and printing are reduced. Furthermore, problems of matching up stereo pairs, as is necessary with separate print methods, are eliminated.

We have not yet tested this stereophotographic technique for quadrates larger than a square foot. We do know that a greater camera height would be required. The scale would therefore be smaller and species identification perhaps more difficult. However, the technique is a valuable tool where small plots will suffice and in situations in which use of more sophisticated equipment is impractical.

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A Test of Stereophotographic Sampling in Grasslands

W. R. PIERCE AND L. E. EDDLEMAN

Highlight: *Color stereophotography was used to sample a grassland vegetation typ for species presence and for cover. Square foot estimate plots were used as a check Three-Pee sample selection was also tested. Species identification proved difficult i dry, weathered vegetation. Cover estimates were lower for single stemmed and linea leaved weathered plants in the stereophotographic sample than in the square foot fiel estimate. Three-Pee sampling gave similar results to complete estimates.*

In 1970 the authors reported on a stereo photographic technique for recording rangeland vegetation and forest understory on film for later analysis (Pierce and Eddleman, 1970). Subsequent testing of this inventory tool under demanding conditions has been completed and is the subject of this report.

A native bunchgrass range in fair condition near Missoula, Mont., was selected to provide a diversity of growth form. The vegetation aspect was dominated by a mixture of bluebunch wheatgrass (*Agropyron spicatum*), one-spike oatgrass (*Danthonia unispicata*), cheatgrass (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), and Pennsylvania cinquefoil (*Potentilla pennsylvanica*).

Methods and Results

Sampling was carried out in mid-August, and as a consequence, grasses and most forbs were mature and dry. Since the color stereo photographic technique relies heavily on color as a means of identification, conditions were most difficult. An area 200 x 200 ft, located on a 10% south slope, was used for the test sampling. Forty-two photographic plots one meter square were established on a uniform spacing throughout the test unit (Fig. 1).

To provide a check on the accuracy of the photographs used for estimating certain range vegetation parameters, a second and more conventional sampling technique was applied with considerable intensity. Four hundred one-square-foot plots on a uniform spacing throughout the test area were used to determine the percent of ground cover by estimation in the field for each species of grass, forb, and shrub detected. None of these 400 plots were located on the same ground as a photographic plot.

The one-square-meter photographic plots were recorded with two types of cameras. A Hasselblad 500 C with a 50 mm, 75 degree lens was the principa piece of equipment being tested. At th same time, some of the plots wer recorded with a Nikkon-Nikkorma camera with a 28 mm, wide-angle len Both cameras were suspended about 5 f above the ground and offset 18 cr between the two exposures. A full ring strobe light (4400 ECPS) was used wit both cameras. Kodacolor X film with a ASA rating of 80 was used in bot cameras.

The day was partly cloudy with a ligh southwest wind. During periods of sur shine the plots were shaded. The focu was set at just under 5 ft, and th exposure was at *f*16 with a shutter spee of 1/60 of a second. A commercial colo film processing laboratory processed filr and prints.

Two exposures were made with th camera placed over the center of eac plot for vertical exposures; then th camera was moved to a position over th south edge of the plot for two obliqu exposures. The focus for these latte photographs was adjusted for the plo center. The entire field operation wa completed in one day.

The finished prints of each plot wer dry mounted on light cardboard with th centers of the stereo pairs 2.4 inche apart. The vertical photographs wer mounted directly under their obliqu counterpart.

A year later the mounted photograph were used to make quick estimates of th total ground cover in each of the twent 400 cm^2 subunits of the 1-m plots. Afte these values were recorded, the plots wer examined in detail and the percent o ground covered by each species in eac sub-plot listed. The results of this worl are shown by location charts beside th corresponding values resulting from th one-square-foot plots recorded in th field the year before. The distribution o two species are shown (Fig. 2 and 3) Photographic plots resulted in a considerably lower percent ground cover fo certain species (Fig. 3) than was esti mated on the one-square-foot plots. Th distribution pattern of each species a shown by comparison of the tw methods was essentially the same, sc

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presence detection and identification is not a problem; however, mature weathered leaves and stems of certain grasses and forbs were difficult to detect in the photograph.

Photographs underestimated bluebunch wheatgrass, cheatgrass, Japanese brome, and ballhead sandwort. Tufted grasses and broadleaf forbs yielded much the same cover estimates from both photographic and square-foot plot techniques. On the basis of the observed limitations, photographs are not recommended as an inventory technique where percent of ground cover is important, unless the photographs can be taken while the plants are green.

Three-Pee Sampling

A second study utilizing photographic plots was conducted to determine the feasibility of using Three-Pee sample selection (probability proportional to prediction) for range vegetation sampling (Grosenbaugh, 1967). The total cover estimate made for each sub-plot of each square-meter plot was applied to a random number table built expressly for this experiment using the THRRP program of Grosenbaugh (1965). Those sub-plots that had estimated values greater than or equal to the random number selected from the table in systematic order were examined in detail to correct the average of the estimated ground cover.

The corrected percent ground cover for each square-meter plot was computed by using the following formula:

Percent ground cover = $(\Sigma KPI/M) \times (\Sigma(YI/KPI)/N)$ where KPI = the estimated percent ground cover for each sub-plot and M = the number of sub-plots per plot. YI is the more accurately determined percent ground cover; N is the number of these plots selected by application of the random number table.

The percent total ground cover for each photographic plot was computed by applying this formula as well as the percent ground cover on each plot of several individual species. The accuracy of the percent ground cover obtained for species found in scattered locations was not comparable to the values obtained by using all sub-plots of photographic sample locations. Minor species in the one-meter plots will frequently be missed if all sub-plots are not used for detailed examination. It is possible with Three-Pee sampling to make an estimate of the percent ground cover of individual species in each sub-plot, instead of all species, and so obtain acceptable levels of accuracy; however, this does not save

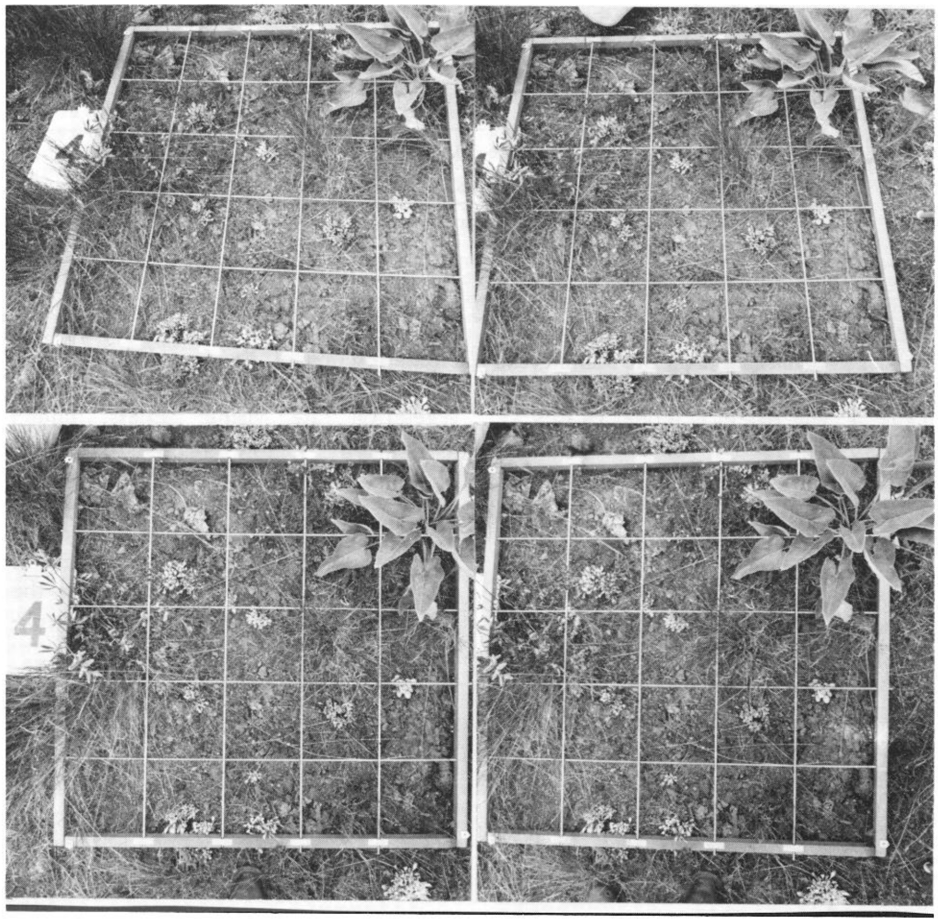

Fig. 1. *A stereophotographic plot recorded when the vegetation was green (*upper *oblique pair and* lower *vertical pair).*

time. The over-all averages of the Three-Pee sampling as described above are shown in Table 1 along with results obtained by a detailed examination for each photographic plot. The results as tabulated for each square-meter plot are available on request from the authors. The numerical differences of percent ground cover in the square-meter plots estimated by examination of all the sub-plots and by the examination of only those sub-plots selected by the Three-Pee system showed no significant differences.

Essentially, the same equipment described by Pierce and Eddleman (1970) was used in this study. Since that writing,

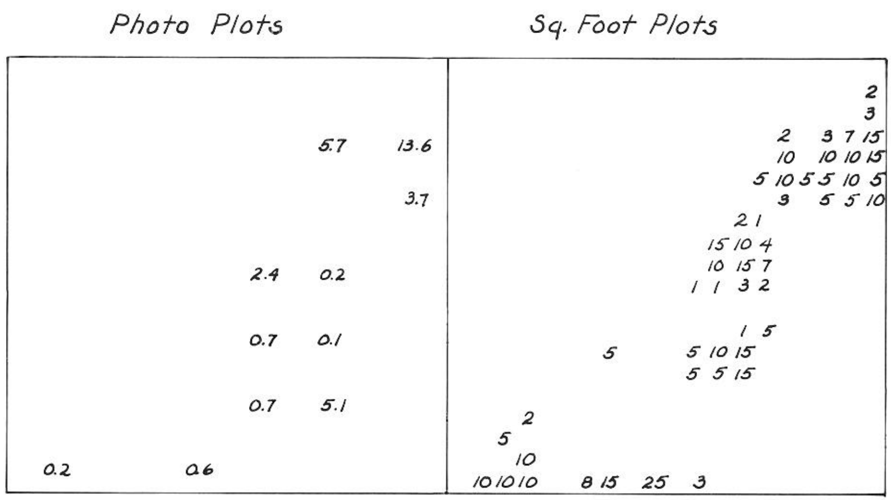

Fig. 2. *Percent ground cover for* Potentilla pennsylvanica. *Average for all photo plots was 0.8%. Average for square foot plots was 0.9%.*

Table 1. A comparison of the ground cover (%) estimates by square-meter plots using all sub-plots and using only those plots required for a Three-Pee sample.

Cover measurement	All species		Daun[1]		Pose[1]		Agsp[1]		Pope[1]	
	All S-plots	3-P	All S-plots	3-P	All S-plots	3-P	All S-plots	3-P	All S-plots	3-P
Average	16.52	16.30	2.38	2.40	2.40	2.48	1.88	1.83	0.79	0.72
S. E.[2]		0.182		0.211				0.244		

[1]Daun = *Danthonia unispicata;* Pose = *Poa secunda;* Agsp = *Agropyron spicatum;* Pope = *Potentilla pennsylvanica.*
[2]Standard error of the difference.

however, an improved plot frame has been designed and a more convenient tripod has been found on the commercial market. The camera and tripod is shown in Fig. 4. The tripod is model Hi-Boy IV made by Quick-set, Skokie, Ill. Not shown is a black plastic shield for shading the plot.

Conclusions

The 35mm photographs did not prove as functional as those recorded on 70 mm film by the Hasselblad; they were inferior in the following respects:

1. The resolution was not as good, and minor plants were missed freqently or could not be identified.
2. The entire one-meter plot could not be included in the field of view from five feet. This distance could be increased, but this would make adjustments of the camera awkward and the resolution would be reduced. A 60 x 80 centimeter aluminum frame has been used with the 35 mm camera with acceptable results.
3. The depth of field was less, which could cause difficulty in working with taller plants.

Standardized camera settings make the field work very simple and fast and result in uniform negatives which can be processed commercially. The permanent record provided by the photographs permits a highly trained technician to devote his time to this work whenever it is convenient, and questionable results can be checked at any time. The authors believe, however, that the greatest value of this technique lies in the ability to identify vegetative trends on permanently marked sampling stations. Recent work done in England by Grimes and Hybbard (1969) has recognized this value of photographic sampling. Wells (1971) has also noted the value of stereo photographs for retrieving information on species composition, cover, and herbage weight.

The effectiveness of this system of recording vegetation on stereographic photographs depends on the use of the ring-strobe light. This light around the circumference of the lens eliminates all shadows, so that both large and small vegetation are visible unless hidden behind other plants. The use of two sets of photographs, vertical and oblique, uncovers most hidden plants. If a sun shield of translucent material is used, an adjustment in exposure may be required. A camera with automatic adjustment of the exposure would cause additional problems unless the sun shield was effective for the entire field of view. The use of two cameras providing simultaneous exposures would result in improved photographic resolution if there was any wind-caused motion in the vegetation and the strobe light was not required; however, shadows are recorded when artificial light is used. Since we find shadows to be an important restriction in species identification, any technique that does not eliminate them should not be used.

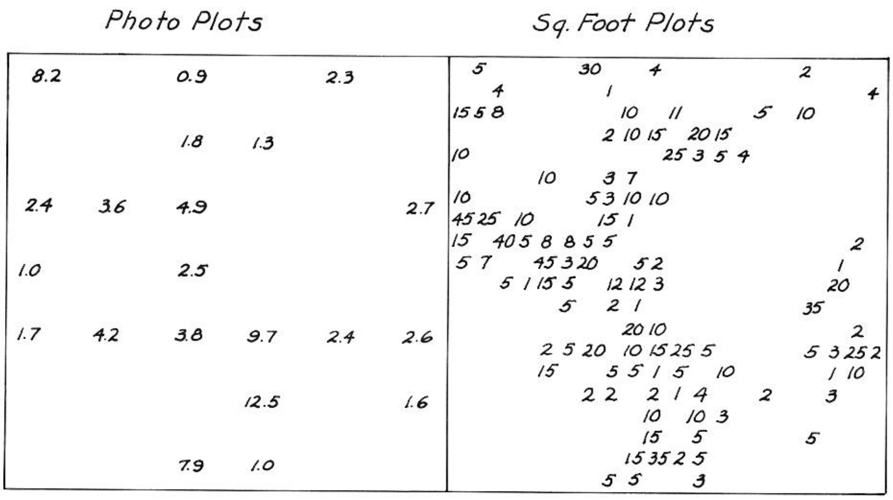

Fig. 3. *Percent ground cover for* Agropyron spicatum. *Average for the photo plots was 1.9%. Average for the square foot plots was 2.5%.*

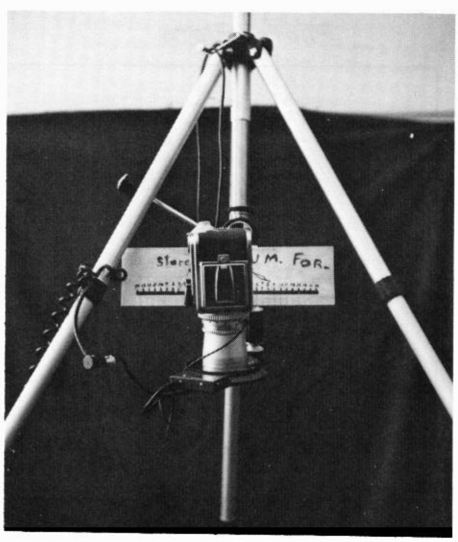

Fig. 4. *Tripod and camera suspension detail.*

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TECHNICAL NOTES

Effect of Woody Stems on Estimating Herbage Weights with a Capacitance Meter

L. H. CARPENTER, O. C. WALLMO, AND M. J. MORRIS

Highlight: *Ignoring woody stems significantly improved capacitance-meter estimates of herbage weight.*

Electronic capacitance meters have proven useful in estimating weights of herbaceous vegetation (Back et al., 1969). Equally good results have recently been obtained in shrub-dominated stands (Morris et al., 1970). The effect of woody stems on the relationship of capacitance measurements to herbage weight has not been well defined, however. Since it is a major task to cut large woody stems into pieces small enough to sack for subsequent weighing, the procedure could be greatly simplified if the effect of such stems on capacitance readings and weight estimates of herbage could be ignored. This study was conducted to determine the significance of such effects.

Study Area and Methods

The work was done in central Colorado in big sagebrush (*Artemisia tridentata* Nutt.) communities with Douglas rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.), Saskatoon serviceberry (*Amelanchier alnifolia* Nutt.), antelope bitterbrush (*Purshia tridentata* [Pursh] DC.), and mountain snowberry (*Symphoricarpos oreophilus* Gray) as commonly associated shrubs. Grasses and forbs also occurred on most plots. The instrument used was Model 18-1000 of Neal Electronics, Burbank, Calif.[1]

For herbage estimates, the clipped material was air dried and stored about 4 weeks, then oven dried 24 hours at 100 C before weighing. Capacitance values customarily are used in a double-sampling technique, wherein a small sample of the total plots metered is subsequently clipped for a meter:weight relationship. The linear regression of herbage weight on meter readings from the small sample permits estimating weights from meter readings in the large sample.

Data from 450 metered and clipped plots were evaluated, with three different meter estimates being made on each plot (Fig. 1-3). The meter sensed vegetation in a 3-dimensional plot 12 by 24 inches horizontally and 18 inches high. When the meter was first placed on the plot, the

Fig. 1. *Herbage meter on plot prior to any clipping.*

Fig. 2. *Herbage meter on plot after leaves and current annual growth of shrub stems were removed.*

Fig. 3. *Final clipped plot after all vegetation, including large woody stems, was removed.*

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[1]Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Dep. Agr., or Colo. Div. of Wildlife.

Table 1. Statistics from the six computed regressions of weight on meter values.

Independent variable (meter values)	Dependent variable (weights)		r	Conf. Lim. .95 for r	r^2
A	Shrub leaves and current stems, grasses, and forbs	with wood	0.663a*	0.594–.732	0.440
A	" " " "	without wood	.799a	.744–.854	.638
A	Shrub leaves and current stems	with wood	.646	.575–.717	.417
A	" " " "	without wood	.771	.712–.830	.594
C	Shrub leaves and current stems	with wood	.671b	.611–.731	.450
C	" " " "	without wood	.849b	.800–.898	.721

*Pairs followed by same letter are significantly different at $\alpha = .05$.

location of the corner probes was marked with golf tees and meter value A was taken before any vegetation was clipped (Fig. 1). Then the corners of the plot were marked with steel pins to define the area sensed by the meter, and the meter was removed for the first clipping. In the first clipping, only leaves and current annual growth of shrub stems were removed and sacked.

For meter value B, the instrument was replaced on the golf tees and a second reading was taken (Fig. 2). It was again removed, and forbs, grasses, and the remaining large woody stems were clipped (Fig. 3). The effect of large stems was included in both A and B meter values. The A value indicated capacitance of total vegetation including wood; the B value, forbs and grasses plus remaining wood.

The difference between the A and B values (meter value C) indicated the capacitance of shrub leaves and current stem growth. Six regressions were computed for the meter values as shown in Table 1.

Results and Conclusions

As shown by the first and second regressions in Table 1, a single meter reading of the plot estimated weight of total herbaceous material more accurately than it estimated total herbaceous material plus woody stems. The difference between the correlation coefficients was significant at the 95% level. Twenty percent more variation in estimated weight (Y) was accounted for by excluding wood.

The third and fourth regressions reveal that a single meter reading estimated the weight of shrub leaves and current stems (despite the inclusion of forbs and grasses) more accurately than it estimated the same plus wood. Eighteen percent more variation in Y was accounted for by excluding wood, although the correlation coefficients were not significantly different at the 95% level.

The fifth and sixth regressions show that the difference (C) between a first reading of total vegetation and a second reading of forbs and grasses plus wood estimated the weight of shrub leaves and current stems alone more accurately than it estimated shrub leaves and stems plus wood. The correlation coefficients were significantly different. Twenty-seven percent more variation in Y was accounted for by the exclusion of wood. Our experience reveals that higher r^2 values can be obtained from more homogeneous sample units than from the lumped data we present here.

Excluding wood probably improved the regressions because (1) wood has little capacitance relative to herbaceous material, so that we were combining regressions with grossly different slopes, and (2) the amount of wood on plots varied so greatly (0 to 869 g) relative to herbaceous material (3 to 99 g).

The weight of shrub leaves and current stem growth can be estimated more accurately with a capacitance meter if the effect of forbs and grasses is removed (the sixth regression contrasted with the second in Table 1). If forbs and grasses are sparse and cannot be estimated accurately, however, the effort to take a second meter reading may not be justified.

Our records indicate that clipping and sacking woody stems requires nearly one-third more time spent at each plot; about 10% more time is added to the sorting, drying, and weighing operations. Since herbage weight can be estimated more accurately by ignoring the contribution of woody stems to capacitance readings, these stems should be clipped and measured only if an estimate of total biomass is desired.

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Prescribed Burning Rotations on Pine-Bluestem Range

H. E. GRELEN AND L. B. WHITAKER

Highlight: *Burning one-seventh of a range each year in winter, one-seventh in spring, and one-seventh in summer produced no more gain on Brahman crossbred heifers than did burning one-third of the unit in winter. Average gains during the 4-year study ranged from 120 to 271 lb./head for a 168-day period, or 0.7 to 1.6 lb./head/day.*

Burning one-third of grazing units in late winter or early spring adequately distributes grazing and maintains forage quality on southern pine cattle ranges (Duvall and Whitaker, 1964). Recent investigations on ungrazed range indicated, however, that forage quality might be further enhanced by burning smaller patches in winter, spring, and summer. Forage regrowth following a July burn was higher in protein than that on plots burned in March or May and clipped monthly (Grelen and Epps, 1967). If this high-quality forage was made available to cattle in midsummer when protein content of forage on winter burns is often deficient, it appeared that animal gains would improve. We report here the results of seasonal and winter burning for 4 years on grazed range in central Louisiana.

Procedures

Two adjacent 80-acre grazing units of the Palustris Experimental Forest near Alexandria, La., were selected for the study. Both sites are typical of the flatwoods of south-central Louisiana. All commercial-sized pines were removed several years before the study began, and large hardwoods were killed by herbicide injections. Fire and livestock were excluded for 5 years preceding the study. Consequently, many seedlings and saplings of longleaf pine *(Pinus palustris* Mill.) and loblolly pine (*P. taeda* L.) were present, and scrub hardwoods and shrubs, primarily blackjack oak *(Quercus marilandica* Muenchh.) and southern waxmyrtle (*Myrica cerifera* L.), had grown too large for effective control by fire. In open areas, dense grass, principally pinehill bluestem (*Andropogon divergens* [Hack.] Anderss. ex Hitchc.) and slender bluestem (*A. tener* [Nees] Kunth), was interlaced with blackberry briers (*Rubus* sp.). Exclusion of fire and grazing had allowed an increase of cutover muhly *(Muhlenbergia expansa*

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Table 1. Cumulative heifer gains (lb.) on winter and seasonally burned range during 168-day grazing periods. Yearlings grazed in 1967 and 1969, 2-year-olds in 1968 and 1970.

Year and burning treatment	Stocking rate (acres/AU[1])	Average initial weight	Average seasonal gain	Average daily gain	Average gain/acre
1967					
Winter	6.3	343	138[2]	0.8	31.0
Seasonal	6.3	359	103	0.6	23.2
1968					
Winter	11.1	454	154	0.9	15.4
Seasonal	11.1	454	164	1.0	16.4
1969					
Winter	11.4	438	174	1.0	21.8
Seasonal	11.4	446	186	1.1	23.2
1970					
Winter	17.7	558	259	1.5	16.2
Seasonal	17.7	555	282	1.7	17.6

[1]Based on conversion factors of 0.7 animal units (AU) for yearlings and 0.9 for 2-year-olds (Range Term Glossary Committee, 1964).
[2]Only in 1967 did seasonal gains differ significantly by treatment.

[DC.] Trin.), an early-maturing grass that is unpalatable to cattle in the full-leaf stage.

A different third of one unit was burned each March 1 (winter). Approximately three-sevenths of the other unit was burned each year—one-seventh in winter (March 1), one-seventh in spring (May 1), and one-seventh in summer (July 1). The first treatment was designated winter burning and the second, seasonal burning.

Brahman crossbred heifers grazed the study units from mid-April through October. Yearlings grazed both units during the 1967 and 1969 seasons, and 2-year-olds during 1968 and 1970. Stocking rates, which were equal for both study units, varied from 6 to 18 acres/animal-unit during the study. Animals were randomly assigned to study herds and weighed individually at 28-day intervals. Loose salt and steamed bonemeal (10% phosphorus) were provided free-choice, and cottonseed cake was fed occasionally to facilitate handling.

Herd gains were compared by the "t" test for unpaired replicates, with significance tested at the 5% level.

Results and Discussion

In 1967 the herd on winter-burned range significantly outgained the one on seasonally burned range, but in other years neither significantly outgained the other (Table 1). Spring gains tended to be highest on the winter-burned range, whereas total gains tended to be highest on the seasonally burned.

Gains per animal were inversely related to stocking rate—they were greatest in years of lightest stocking (Table 1). Gains per acre were directly related to stocking rate; gains were highest with heaviest use. With similar stocking rates, yearlings outgained 2-year-olds.

Animal gains reported here were higher than those on longleaf pine range in Mississippi (Smith et al., 1958), where yearling and 3-year-old steers gained about 0.5 lb./head daily during a comparable grazing period.

Seasonal burning offered no apparent advantage over winter burning in beef production. The lack of a statistically significant difference probably reflects the benefits of proper grazing on winter-burned range, rather than a failure of seasonal burning to improve forage quality. With proper stocking, the one-third of the range burned in winter of the current year was grazed almost continuously by the entire herd. Close grazing maintained a supply of new forage growth, which was apparently as palatable and nutritious as that on seasonally burned range. Because different thirds are burned in the 2 years following heavy use, the plants had 2 years of light grazing in which to regain vigor. Thus, close grazing accomplished on the winter-burned range what the delayed burns did on seasonally burned range. Both provided high-quality forage through much of the grazing season. The winter burning rotation, because of its simpler and less expensive application, is recommended for forage management on forested or clearcut native range in the longleaf-slash pine timber type.

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Larger Seeds of Winterfat Germinate Better

H. W. SPRINGFIELD

Highlight: *Seeds of winterfat (*Eurotia lanata*) were separated into three size classes and germinated under four temperature regimes. Large- and medium-size seeds germinated better and faster than small-size seeds.*

Larger seeds of a plant species usually produce more vigorous seedlings than smaller seeds (Kittock and Patterson, 1962). With some species—wheat, for example—seedling emergence also has been reported to be higher from larger seeds (Kittock and Law, 1968). Similar results were found with alkali sacaton (Knipe, 1970).

Germination, however, is not always greater from larger seeds. For example, little relationship was found between seed size and viability for mature seed of Hardinggrass (Whalley, et al., 1966). Likewise, size of fourwing saltbush seeds had no significant effect on germination provided the seeds contained embryos (Springfield, 1970).

The objective of this study was to determine the effects of size of winterfat (*Eurotia lanata* (Pursh) Moq.) seeds on their germination under four temperature regimes.

Ripe fruits of winterfat were collected in November from a group of plants near Corona, N. Mex. Four months later (when after-ripening was complete[1]), seeds were threshed from the fruits by hand, then separated into three size classes (Table 1).

Treatments consisted of six replications of 50 seeds each under constant temperatures of 45, 51, and 56 F in darkness and under an alternating regime of 76 F (12 hrs light) -60 F (12 hrs dark). Seeds were germinated in petri dishes filled with 100 ml vermiculite and 60 ml distilled water. Two layers of germination blotter were put on the vermiculite. The seeds, dusted with fungicide, were placed on the blotters, which remained moist throughout the experiment.

Germinated seeds were counted daily. A seed was considered germinated if the cotyledons and radicle together measured

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[1]Unpublished results of another experiment showed after-ripening of this collection of seeds was complete in 9 weeks.

Table 1. Characteristics of seeds.

	Large	Medium	Small
Number of seeds per lb.	150,000	199,000	310,000
Length of seed (mm)			
Average	3.3	2.8	2.4
(Range)	(2.9–3.6)	(2.5–3.1)	(2.0–2.6)
Width of seed (mm)			
Average	2.0	1.7	1.4
(Range)	(1.7–2.3)	(1.5–2.0)	(1.1–1.7)

Table 2. Germination of large, medium, and small seeds of winterfat at four temperatures.

Germination temperature (°F)	Percent germination (by seed size)			
	Large	Medium	Small	Mean[1]
45	98.0	96.0	76.0	90.0b
51	98.7	96.7	92.0	95.8a
56	99.3	99.3	94.0	97.5a
76–60	100.0	99.3	86.7	95.3a
Mean	99.0a	97.8a	87.2b	

[1]Means with the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

1/2 inch and both were detached from the seed coat. Germination percentages were transformed to arc sin for analysis of variance.

Germination was complete within 7 days for all seed sizes and temperatures, except for a few small seeds that germinated the 8th and 9th day under the 45 F temperature.

Total germination was higher for large and medium seeds than for small seeds under all four temperature regimes (Table 2). The greatest difference between germination of small and large seeds came under the lowest temperature. Subtle biochemical differences related to size and influenced by temperature may explain why large seeds germinated 98% but small seeds only 76% under a temperature of 45 F.

The relatively low germination of small seeds under 76–60 F, compared with large and medium seeds, is not easily explained. Apparently the small seeds are more sensitive to external conditions and therefore are less likely to produce seedlings in a field environment.

The larger seeds germinated more rapidly than the small seeds under all four temperatures (Fig. 1). Differences in speed of germination between large and small seeds were greatest under temperatures of 45 and 51; for example, at 51, 93% of the large seed had germinated by the 4th day, as against only 41% of the small seed. The faster germination of the larger seeds may be attributed to greater amounts of essential constituents available to the developing seedling (Mayer and Poljakoff-Mayber, 1963). This is further implied through results with germinating wheat; significant relationships were found between seed size and tetrazolium reduction, a biochemical index of vigor (Kittock and Law, 1968).

Maximum germination of the smaller seeds may be possible only when external factors, like moisture and temperature, are nearly optimum. Results of other studies (Springfield, 1972) suggest that 45 F is below the optimum temperature range for germination of winterfat.

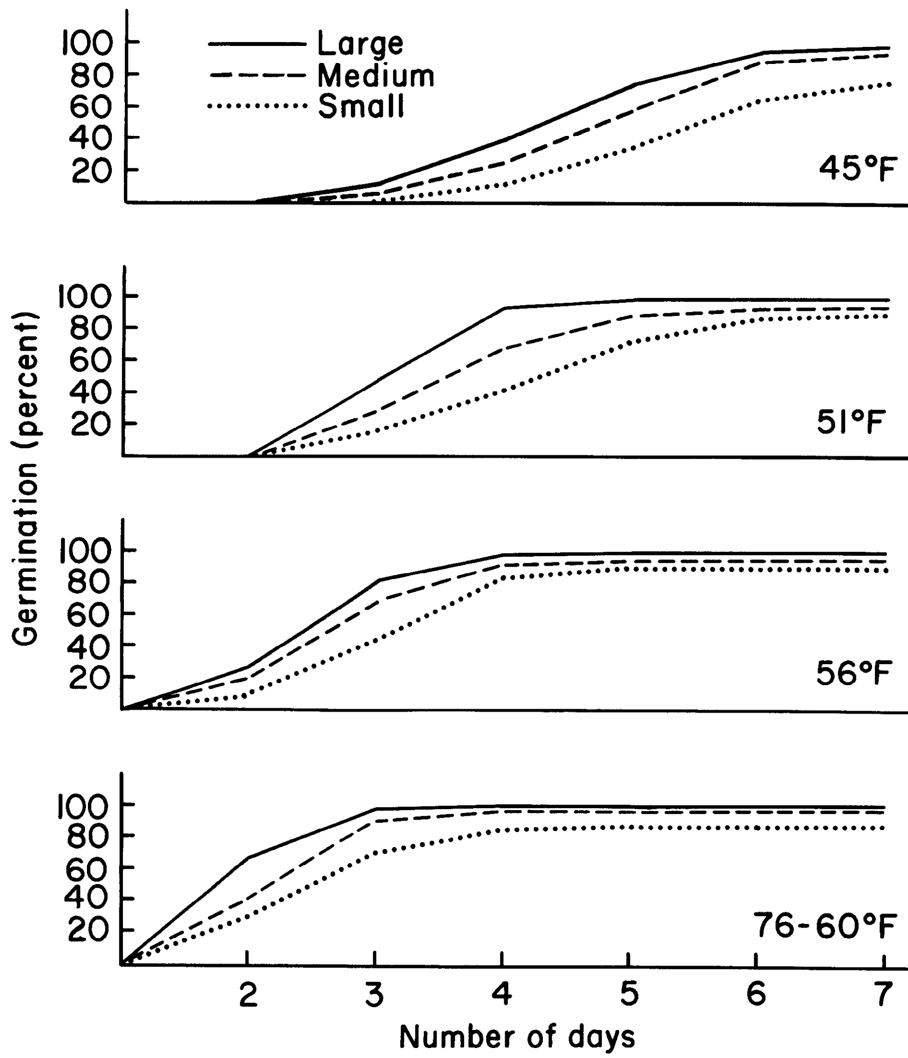

Fig. 1. *Speed of germination of large, medium, and small seeds under four temperature regimes.*

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BOOK REVIEWS

The Biology and Utilization of Grasses. Ed. by V. B. Youngner and C. M. McKell. Academic Press Inc., 111 Fifth Avenue, New York, N. Y. 10003. 452 p. 1972, $22.50.

The 28 papers originally presented as a symposium by the same title offer a diverse but good assemblage of information by grass biologists with worldwide distribution and authority. Such a symposium was greatly needed. While the biology of the dicotyledons and even the cereal grasses of the monocotyledons are generally well understood and documented, the biology of turf, forage, and, especially, rangeland grasses has been greatly neglected.

As a logical introduction, the first five chapters are oriented toward the evolution and genetic configuration of grasses. An insight to the early forms of grasses and the importance of polyploidy are stressed. Of specific interest to range scientists is the discussion on sterile intergeneric hybrids and the philosophy of grass breeding research, including current limitations and thoughts on improvement.

The second and fifth sections, totaling 13 chapters, are probably the most interesting to range scientists and should possibly have been located together in the text. These sections provide excellent coverage on grass growth and development and effects of defoliation on regrowth. Composited into one source is excellent coverage of environmental problems and techniques to improve seedling establishment. For once a person can also find in one text reliable information on morphology of leaf growth and tiller dynamics including adequate basic physiological discussion of growth and the role of grass plant hormones. The fifth section applies to many of the concepts presented in terms of grazing management and techniques to increase grazing resistance. Never before has any biology text covered so completely the basic and applied function of grass growth.

The five chapters covering the ecology of grasses present good information on energy transfer, competition, and community structure. Several excellent texts have been prepared recently on these topics, and one feels the writers are trying to present new concepts and thoughts rather than covering old ground. In general this is true, and the information presented is stimulating supplemental reading. The lone chapter on facultative parasites does seem out of place when isolated with chapters on energy transfer and community structure.

While the fourth section on soil nutrition doesn't talk directly to rangeland grasses, it does present useful information on aeration problems, efficiency of water use, infiltration, evaportranspiration, and nutrient uptake and assimilation.

Like any symposium proceedings, the book has some discontinuity, a few chapters that seem out of place, and considerable variation in depth and type of coverage. However, material is presented in this book that is not found in any other source. The data presented and literature reviewed are outstanding. Information presented on turf and forage grasses only enhance the book value to the range scientist, as they present insight to many common problems. This is not necessarily a book to be read from cover to cover in one reading, but it is a book that will not collect dust on one's shelf. The considerable amount of integrated information and the collected references will be used often by anyone desiring to learn more about the biology and utilization of grasses.—*Gary B. Donart,* Las Cruces, N. Mex.

Pastos naturales del Altiplano de Peru y Bolivia. By Mario E. Tapia. Publicacion miscelanea no. 85. Instituto Interamericano de Ciencias Agricolas (I. I. C.A.). Programa de Investigacion Zona Andina. Quito. Ecuador. 200 p. 1971.

Knowledge about the botanical composition of the grasslands of the South American Andes and their use by livestock is rather scarce. This booklet provides some first-hand information about the natural grasslands of the high plains (3000 to over 5000 m altitude) of Peru and Bolivia, where grazing is mainly by sheep and different types of llamas. The author is from Puno, located on the Peruvian shore of Lake Titicaca. For several years he has taught range management at the Universidad Nacional Tecnica del Altiplano; this publication summarizes material and topics covered in the course.

The first chapter describes the area in terms of geography and topography, climate, soils, and related vegetation types. The second chapter (p. 39-131), preceded by an historical review of plant explorations undertaken in the region, gives botanical descriptions of the principal forage species found in the region. Drawings of most species accompany the text. The last two chapters discuss basic and somewhat traditional concepts and techniques used in range research and utilization.

The booklet contains good and interesting information. However, a reviewer can find some inconsistencies and inaccuracies. The somewhat surprising statement on page 15 that temperature and rainfall patterns are expressions of a typical tropical climate is refuted by the phenomenons of snow and hail storms (p. 17), frosts (p. 21), and native vegetation composed of cool-season grasses. The chapter on "Criteria for Pasture Evaluation" (Chapter 3) does not mention the "ultimate" measure of pasture productivity, namely animal performance.

The quality of printing and of the illustrations unfortunately is very poor. Furthermore, the reader should note that the scale of the drawn illustrations is about four times smaller than indicated. Unfortunately, the author did not have an opportunity to proofread the final type, which has resulted in many spelling errors. *Dirk H. van der Sluijs,* Fort Collins, Colo.

Accumulation of Nitrate. National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, D. C. 20418. 106 p. 1972. $4.25.

This report of accumulation and distribution of nitrogenous compounds in the environment and the potential hazards of these compounds was prepared by a special committee of the Agricultural Board in the Division of Biology and Agriculture of the National Research Council, N.A.S. The study was supported by the Environmental Protection Agency and the U. S. Department of Agriculture.

The increasing use of nitrogen in fertilizers, industrial compounds, and food preservatives; the increasing production and consumption of high protein foods; and the consequent increasing accumulation of nitrogenous compounds in water supplies have already created several nitrogen problems in the environment – and they may become worse. Only recently have the hazards of nitrate, nitrite, and other additives in human food and water been studied. The nitrosamines (complex forms of amino acids) are potentially hazardous because of their possible carcinogenic, teratogenic, and mutagenic properties. Yet present analytical methods are inadequate for determining their presence and concentration.

The objectives of this paper-back report were to examine problems associated with the accumulation of nitrogen in the environment, to assess the hazards of nitrogenous compounds in food and feed, to recommend courses of action to reduce these problems, and to point out areas where further information and research are needed.

The report is divided into five sections: Nitrogen compartments in the biosphere; Sources of nitrogen accumulation; Fertilizer and soil nitrogen; Hazards of nitrate, nitrite, and nitrosamines to man and livestock; and Eutrophication. Each section includes a set of conclusions drawn from the available literature as well as recommended courses of action. In addition, a concise summary and a 12-page list of references are provided.

The report considers all aspects of nitrogen accumulation, movement, storage, and hazards to man and livestock in surprising breadth and depth, considering the briefness of the report.

Of interest to agriculturists is that municipal waste and refuse dumps probably contribute as much nitrogen to waterways as all agricultural sources. The contribution of industrial and food-processing wastes as well as urban runoff to nitrogen levels in waterways is largely unknown. Unfortunately, no governmental unit at present requires information on behaviour and effects of many industrial nitrogenous chemicals before they are admitted to waterways—sometimes in large quantities.

The low cost of nitrogen fertilizers and favorable returns tend to encourage use up to the point of diminishing economic returns. The consequent high rates of application then result in decreasing efficiency of use and a greater potential for loss of nitrogen to water ways. Conceivably, this could bring about a future limitation on use of nitrogen fertilizers based on pollution potential rather than on traditional economic benefits.

This report is a useful and convenient source of information on nitrogen in the environment. Every investigator, rancher, and farmer working with nitrogen fertilizers and compounds should be familiar with it.—*Walter R. Houston,* Fort Collins, Colo.

Grasses and Legumes in British Agriculture. Ed. by C. R. W. Spedding and E. C. Diekmahns. Commonwealth Agricultural Bureaux. Farnham Royal Bucks, England. 511 p. illus. 1972. $18.20.

This book, a concerted effort by 43 contributors to relate research results to practical grassland agriculture, is an excellent reference for scientists, teachers, and students. Although the material presented is drawn largely from research in Great Britain and is restricted to grasses and legumes grown there, many of the principles set forth are applicable to grassland in general.

The book is divided into four parts. Part I discusses grasses and legumes as crops, their nutritive value, and their growth in relation to soil, climatic, and light environments. Part II discusses grasses, and Part III discusses legumes in relation to origin, morphological development, establishment, growth and reproduction, pests and diseases, and chemical composition. These two parts contain individual chapters on grasses and legume species commonly grown in Great Britain. Part IV is a comparative assessment of species in terms of yield, nutritive value, suitability for utilization as hay or for grazing, and value for milk, beef and sheep production. While the book is valuable as a reference it would not be suitable as a classroom text in the United States because of its restriction to British grasslands and literature concerning them.—*Clee S. Cooper,* Bozeman, Mont.

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3. The title of the paper and the name, position, and complete address of the author should be typed as distinct, well-spaced entries on a separate page.

4. A "Highlight," typed on a separate page, should accompany each manuscript. The "HIghlight" should succinctly state the purpose, major findings or conclusions, and their application.

5. Names of plants and animals must be shown in both common and scientific form the first time they are mentioned in the text; further mention should be by common name only. Authorities for scientific names may be included at the discretion of the author.

6. Footnotes should be used very sparingly and numbered consecutively throughout the text. All text footnotes should be typed together (double spaced) on a separate sheet.

7. Good illustrations are desirable but should be held to a minimum. Photographs should be black-and-white glossy unmounted prints (remember that poor photographs will result in poor reproductions), and graphs should be prepared on white or blue-lined cross section paper with neat lettering of a size suitable for reduction. Illustrations should be no larger than 8½x11 inches, and should carry an identification number. *Illustrations should be adequately protected against possible damage in transit.*

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9. The "Literature Cited" section (when used) should begin on a new page and citations should be listed alphabetically. References to citations in the text are to be by author and date, i.e., Jones (1949) or (Jones, 1949). The "Literature Cited" section should be typed in the style of the following examples:

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Sperry, Omer E. 1949. The control of bitterweed (*Actinea odorata*) on Texas ranges. J. Range Manage. 2:122-127.

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