

(ISSN 0022-409X)

JOURNAL OF RANGE MANAGEMENT



THE TRAIL BOSS

PUBLICATION OF THE
SOCIETY FOR RANGE MANAGEMENT

CALL FOR PAPERS

33rd Annual Meeting, February 11-14, 1980
San Diego, California

“People Impacts on Rangelands” will be the theme. Come to San Diego and join in the program—as a speaker, as a Town Hall panel member, or as part of an actively participating audience. The committee for the 1980 Annual Meeting has introduced two innovations aimed at stimulating interactions among all attendees at the meeting.

Town Hall Sessions will involve 4-way interaction among: (1) the Chairman, (2) two Invited Speakers who will present short papers, (3) a panel of at least six “Resource People” who will not present papers, and (4) the entire audience. For each session the Chairman will develop the approach to be followed, will invite the two speakers, and will select the persons to serve as resource people—volunteers’ for resource people are needed from those SRM members particularly interested in the Town Hall subjects. The Chairman, speakers, and resource people will prepare short summaries (less than two double-space pages) of their ideas and main points to be discussed. The printed summaries, along with abstracts of technical papers, will be available to the audience at the time of registration. We hope this kind of session will stimulate maximum SRM membership interest with minimum time devoted to formal presentations.

Subjects for the Town Hall Sessions will be: (1) *Role of people in rangeland ecosystems*; (2) *Use of fire on rangelands*; (3) *Animal relationships (Livestock/Wildlife/Fisheries) on rangelands*; and (4) *Communications within SRM*.

Technical Sessions will allot 20 minutes, instead of the usual 15, to each speaker’s subject. The Chairman for each session will make sure that at least 5 minutes will be used for discussion. Otherwise, the technical sessions will fit the pattern of previous meetings.

Volunteer papers accepted for the sessions will be placed into the following subject matter areas—others will be added if interest warrants: (1) Ecology [joint session(s) with Ecological Society of America]; (2) Roles of wild and domestic animals in resource management; (3) Modeling in range science and management; (4) Range management in practical application; (5) Grazing management systems; (6) Range resources and products; (7) Range economics; (8) Range improvements; (9) Range fertilization; (10) Physiology and morphology of range plants; (11) Range science education and extension; and (12) History of range management.

Deadlines and Procedures for Submitting Papers

1. *By June 15, 1979*, submit title of proposed paper(s). On a separate sheet for each paper include the title, intended subject matter area, name of the author(s), address of the one person to whom correspondence is to be sent, and a brief supporting statement on main points to be covered and their significance to the 1980 meeting.

Individuals volunteering to serve as resource people in Town Hall sessions must submit well-prepared statements.

Authors of volunteer technical papers will be sent instructions for preparing abstracts in a standard format. Similar instructions for preparing standardized summaries will be sent to persons selected as speakers or resource people in Town Hall sessions.

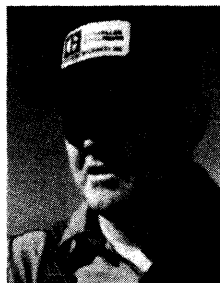
2. *By September 15, 1979*, submit abstracts, or summaries, complete with the title, names of author(s), and author affiliations. Authors of volunteer technical papers and persons selected as resource people in each Town Hall session will be notified by October 15, 1979, of their acceptance and assignment to specific sessions.

After acceptance of the abstracts of volunteer technical papers, the authors will be sent instructions for presentation of papers. Graphs and photos will be on 2×2 slides—each person will be expected to bring his or her personal carousel tray to avoid mixups or loss of slides.

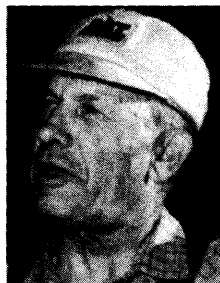
Program Committee Address—Send all proposed titles, abstracts, or summaries, and all correspondence concerning the 1980 SRM meeting program to: **Don Hedrick, Chairman, 1980 SRM Program Committee, School of Natural Resources, Humboldt State University, Arcata, California 95521.**

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

Contribution Policy

The Society for Range Management may accept donations of real and/or personal property, subject to limitations imposed by State and Federal Law. All donations shall be subject to control by the Board of Directors and their discretion in utilization and application of said donations. However, consideration may be given to the donor's wishes concerning which particular fund account and/or accounts the contribution would be applied.

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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 is a publication for the presentation and discussion of facts, ideas, and conclusions pertaining to the study, management, and use of rangelands and their several resources. Accepted for general publication herein is signed and reflects the individual views of the author 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 comments by an individual is also welcome and, subject to acceptance by the editor, will be published as a "Viewpoint."

JOURNAL OF RANGE MANAGEMENT

Published bimonthly—January, March, May,

July, September, November—by the
Society for Range Management

2760 West Fifth Avenue
Denver, Colorado 80204

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EDITORIAL CORRESPONDENCE, concerning manu-
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the Editor, Dep. Animal and Range Sciences, New Mexico
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INSTRUCTIONS FOR AUTHORS appear each year in the
March issue; copies of these instructions are available from
the editor.

SECOND CLASS POSTAGE paid at Denver, Colorado.

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President's Address

ROBERT M. WILLIAMSON



As I look back on the past year's activities in the Society, I have mixed reactions. Much has been accomplished, but had all of our efforts been channeled in a forward motion to achieve the Society's objectives, much more could have been achieved. However, I am firmly convinced that we can, as a Society, overcome the conflict we have dealt with. The challenge that faces all of us today is one of positiveness to keep moving our Society forward to achieve our goals and objectives. Let's now look at some of our major accomplishments of the past year. It will be quite a challenge to convey all of our activities in this brief statement, but let's give it a try. I hope I don't miss too many.

Our financial status has improved even in the face of inflation. It is our hope that the dues increase implemented in 1979 will help us hold our own in the face of inflation for a few years. Our new headquarters building is now paying its own way with a new 5-year lease on half of the building. Membership participation in the contribution program is strong and growing. Through this program we are beginning to see the foundation of a sound financial structure built. I urge you all to take advantage of this program. As our financial flexibility grows, our ability to increase our program activities grows. Financial integrity is the key to our future—we cannot expand our program without a good financial base. To keep these in balance, programs and finances become our challenge.

The development of an annual plan of work has been a big factor in our ability to have program continuity. It has allowed for continuity in our programs and committee functions. Our big need to accomplish long-range planning will allow for even more program continuity. Hopefully, we can get some of this type planning finalized in the near future.

Perhaps, the most gratifying accomplishment has been to see our stature grow in the area of public affairs. We are being recognized and known by more and more individuals and groups that share common concerns and objectives. It has been extremely gratifying to receive requests for information and assistance from entities that we have developed strong rapport with. We are not always able to participate or take active roles as requested; however, in many cases we are able to participate with readily available material. By calling on members to represent us, we have been able to become involved in many issues throughout the world. As we become more widely recognized, we will become more involved. I am firmly convinced that our best role is to continue these efforts on a low profile, low intensity approach, taking advantage of opportunities, but being heard loud and clear when it is called for. We can be most effective by just knowing when and where to be available and being able to react when called upon. Creating of timely opportunities is a key. This approach does not take the resources that are required when we go at it in a direct approach trying to force the opportunities to become involved. Each of you must also take a part as an individual in the public affairs arena. Some of the major issues and special concerns that we have participated in are:

- **Use of Herbicides in Agriculture.** The Society for Range Management supported the continued production and currently registered use of 2,4,5-T and related products.

- **Predator Control.** We supported the need for direct control of predators rather than an indirect approach to dealing with predators or the management of predators.

- **The Range Improvement Act.** Commented and supported those portions of the Act that foster the improved management of rangelands.

- **Wild Horses and Burros.** We continue to stress that the management of these users of rangelands be in harmony with the carrying capacity of the rangelands they occupy. We fully support any amendments to the Act that result in a more efficient and economical means of controlling wild horses and burros.

- **Desertification.** The Society has adopted a tentative Benchmark Statement on Desertification. In addition, we are participating with the Department of Interior in the development of a domestic desertification policy for the administration.

- **Rangeland Policies for the Future—A Symposium.** I heard SRM mentioned more at this meeting than I have heard it mentioned at one of our Annual Meetings. An SRM statement of support and offer of help was entered in the Record. This statement was concurred in and supported by National Cattlemen's Association, Wool Growers, Public Lands Commission, and National Association of Conservation Districts. SRM was involved in putting the Symposium together.

In addition, we have many members appointed to represent the Society on numerous on-going task forces and steering committees. We are becoming involved. I ask you all to bear with us, as what we do in the arena of public affairs is to achieve the overall Society objectives.

Among the many new programs that we have undertaken is the Certification for Range Consultants. This program is now developed and operational with the first certifications issued for 1979. Our Certification Panel has done an outstanding job of getting the program moving. I look forward to this program developing at a fast rate the next few years and becoming an integral part of the growing range consultant industry.

The Accreditation Program is currently being implemented on a trial approach. Our intent is to learn as we go into this program. However, we are receiving considerable interest from universities who offer degrees in range management.

Our efforts to have the Civil Service Commission review the range conservationist standards continue to be a disappointment. However, I feel we are making some progress. We are obtaining a uniform commitment from agencies and some help from the Congress. It appears that we need time and patience on our side and we can accomplish this objective.

With the full implementation of the Certification for Range Consultants, College Accreditation, and update of the Civil Service Range Conservationist standards, we will have accomplished some major strides in the upgrading of basic educational requirements and establishment of "Professional" Range Management Standards. We must continue to be alert to the eroding of these standards.

This address was presented at the 32nd Annual Meeting of the Society for Range Management, held in Casper, Wyoming, February 12–15, 1979.

One of the newest standing committees of the Society is the Rangeland Research Committee. This committee, immediately upon establishment, undertook two very important and big projects. I am most pleased to report that tremendous headway has been made on both of these projects. They are:

- **Rangeland Research Legislation.** The Rangeland Research Act of 1978 was introduced by Congressman Poage into the last session of Congress. It has been introduced or will be into this session by Congressmen Foley and De La Garza. The Society Research Committee played a big role in the writing of this Bill. They are now getting organized to help push the Bill through Congress. We will have help in this endeavor for rangeland user groups.

- **Range Inventory—A Common Approach.** In this effort, it is our objective to serve as a catalyst in helping to establish more uniformity and standarization of methods and terminology presently used in identification, classification, inventory, and assessment of rangelands. Much progress has been made by the committee on this effort.

Both of these projects surfaced as needs at the recent Rangeland Symposium held in Tucson. The Research Committee stays active in promoting and encouraging the importance of strong programs to accomplish range research. To this end, we have a big challenge ahead of us. They will need all of us to help.

Our informal relations with the National Cattlemen's Association and Wool Growers are continuing to reflect a good mutual relationship. We have been able to work in a complementary way to support each other's objectives. One area where the NCA's support is beginning to pay off is in the joint interest of achieving a review of the Range Conservationist Standards by the Civil Service Commission. We have also been involved in co-sponsoring many programs where the program subject matter has been of mutual interest. It is hoped that we can continue. The recent Rangeland Symposium, once again, brought to the surface many areas where we can and should share mutual interests.

The Producer Affairs Committee has been active in working with the National Cattlemen's Association and Public Lands Committee. This effort is hoped to result in a strong bond between the two organizations.

The I&E Committee has been active through the year (1) providing Sections with five newsletters on current events and issues, and (2) assisting the Board with responses to requests for input from the Society. The I&E Student Talent Contest was initiated during the Annual Meeting at San Antonio. It was declared moderately successful. Hopefully, it will catch on and provide a means of developing working tools, displays, slide presentations, and brochures to help sell Society objectives to the public. The success of our I&E efforts is a very hard factor to measure and realize by any visible means.

The First International Rangeland Congress that was held in Denver, Colorado, in August was declared a big success. The registration was over 700, of which 286 were representatives from 39 countries outside the United States. At the Denver IRC, an organization was created to insure that a future IRC would be held. The second IRC is scheduled to be held in Venezuela in 4-6 years. The Society will participate in this effort as a supporting organization. The proceedings are just now off the press and will be mailed out in the near future.

Our membership at the end of 1978 was 5,882. This represents a steady growth rate over the past few years. Our need in membership recruitment is to interest those members that will be involved members, helping us to achieve our desired objectives. I don't feel we need members for numbers sake, but we do need members who will assist us with the achievement of our objectives. We cannot and should not measure our achievement levels by number of members.

The Old West Regional Range Program, through the effective production and use of movies, press releases, symposia, field tours, short courses, youth camps, and other methods has broadened the

understanding of the general public as well as rangeland users and workers toward range management and range problems. The positive effects of the program have aided in legislative endeavors on a national as well as a state level, and have fostered a better public attitude about range management. The program has also greatly increased the awareness of public agencies about range problems and opportunities. Youth education efforts have planted seeds of interest in the minds of future range managers and users. Technical knowledge has been increased and communicated, and special interest groups have gathered together in one program concentrated toward better range management. The two films, "An American Heritage" and the "Silent Resource" have been viewed by 3¼ million people these last 2 years. This is just one measure of the success of OWRC.

The continuation and expansion of this program and especially the cooperative efforts of the many special interest groups working together will, in the long run, provide additional visibility for the Society for Range Management as well as the art and science itself. Perhaps, this will some day be noted as the most important impact of the Old West Regional Range Program. A hardy thanks go out to the Old West Staff of Bob Gartner, John Shrader, Dan Bose, J.C. Shaver, Tom Sparks, Rod Baumberger and their constant pusher, Dave Smith. The Old West crew are now looking toward new challenges in a different environment. We wish each of them the best of luck.

During the past 2 years, the Society has been a member of CAST (Council for Agricultural Science and Technology). Our experience in this endeavor to date has been far less than satisfactory. In fact, it has been very disappointing overall. During the next two days, the Board will be facing the decision to retain this membership or to withdraw.

Beginning with the February issue of *Rangeman's Journal*, there will be a new look. This new look includes the name change to *Rangelands* coupled with a photograph on the cover. It is the hope of the Board that these changes will further the popularization of the periodical. Our hard working editor, Danny Freeman, continues to accomplish his outstanding job as editor. It seems he and his Board come up with a new endeavor to improve quality with each issue. The new "In Brief" section in the October issue is a good example. We encourage students, ranchers, and all other members to contribute to this section. I look forward to articles of varying perspectives in *Rangelands*—let's have them all. Let's begin to present both sides of issues to our membership.

During the past few months, I have received numerous compliments on the quality of the *Journal of Range Management*. I agree with these comments; however, Rex Pieper and his Editorial Board are the ones to whom the compliments should be given. The minor changes that continue to improve this publication are the results of a special study and recommendations by the Publications Committee.

I am sure that both Rex Pieper and Danny Freeman join me in giving a big thanks to Dave, Pat Smith, and the rest of the Denver Office staff for their contributions to the high quality of these periodicals. As is often the case, the workers in the background make the success of any effort.

The Society is built on its individual members. It is not the Chapters, Sections, or the Denver Office that makes our Society what it is. Rather, through the work of individuals in a coordinated effort, we are able to accomplish the Society's objectives. We grow when more members become involved in the "Doing" elements of the Society. Diversity of membership is another one of our strengths.

The many facets of the Art and Science of Range Management provide the opportunity to retain our diversity. To retain and enhance the opportunities for a diverse membership, the Society will further its role as a leader in fostering the Art and Science of Range Management.

I am sure I have missed many minor points and some major ones in this State of the Union Address. However, I hope that I have hit the key and/or critical spots. I have had a wonderful crew to work with. They have all done everything I asked and then some. The Denver Office has especially been a big help.

Let me close by saying it has been a pleasure to serve as President of the Society for Range Management. I only hope that the Society has gained as much from me as I have gained from the Society.

Grazing Management of Mediterranean Foothill Range in the Upper Jordan River Valley

MARIO GUTMAN AND NO'AM G. SELIGMAN

Abstract

A grazing trial with dry beef cows was conducted on an herbaceous Mediterranean range for 10 consecutive years. It included comparisons of continuous heavy (1.2 head per ha); continuous moderate (0.7 head per ha); and rotational moderate (0.8 head per ha) grazing during the first 7 years and rotational heavy (1.3 head per ha) grazing during the last 3 years. Under continuous grazing the liveweight gain per head was higher at the moderate stocking rate, especially during the dry season. Even though the cattle received protein supplement, they began to lose weight towards the end of the summer when the pasture biomass dropped below 700-800 kg dry matter per ha. The liveweight gain per unit area was almost proportional to the grazing pressure and no diminution of the pasture production was recorded as a result of 10 consecutive years of heavy grazing. This result is attributed to the fact that less than 45% of the plant biomass was consumed during the growing season and that the amount of dead standing vegetation had little effect on the growth during the following season. The cattle in the rotationally grazed paddocks gained slightly less weight per head than those in the continuously grazed paddocks. However, on an area basis this difference was not significant. At the end of the grazing season there was more litter in the rotationally grazed paddocks than in the continuously grazed ones. Continuous and/or heavy grazing decreased the relative cover of the grasses. These were replaced by forbs (annual dicotyledons). Under equal grazing pressures the relative cover of grasses was higher in rotational than in continuous grazing. The grazing treatments had no influence on the occurrence of annual legumes, or on *Psoralea bituminosa* (a common perennial legume) and *Echinops viscosus* (a widespread perennial thistle).

Now Abram was very rich in cattle . . . and Lot . . . also had flocks and herds and tents, so that the land could not support both of them dwelling together, and there was strife between the herdsmen of Abram's cattle and the herdsmen of Lot's cattle.—Genesis 13:2-7

The state of Israel is unique in that four major ecological regions are represented in a relatively small area (Zohary 1973). As a result, there is great botanical diversity in the rangeland, with many species that have become common pasture plants in other parts of the world. For the range specialist the country is also of interest because of the fact that three types of society use the rangelands with entirely different methods of management:

Authors are research scientist and director, Division of Range and Forage Crops, Agricultural Research Organization, Bet Dagan, Israel.

This report is a contribution of the Agricultural Research Organization, Israel, 1977, series no. 268-E.

Manuscript received January 26, 1978.

a modern agricultural society, with range allocated to individual herds; nomadic herding, which has not changed much since the days of Abram and Lot; and, in between these two, the traditional village society of the Fallahs where range is grazed as common land.

The range types include the open oak park forest (Naveh 1967, 1970); the shrubby maqui range of the Mediterranean zone; the Mediterranean steppes; the 150–300 mm belt which constitutes the border between the desert and the sown (Tadmor et al. 1974); and the shrubby desert range (Seligman et al. 1962). The Mediterranean steppes, which are the subject of this paper, are located in the north east of the country and extend across the Upper Jordan River Valley onto the Golan plateau. These are rocky ranges in which small patches of soil have been cultivated in the past, mostly for wheat and barely crops. Agriculture with modern machinery is not feasible, except after costly land reclamation. In the last few centuries the local population grazed the range intensively with camels, horses, donkeys, cattle, goats, and sheep. All this, together with tree cutting and selective gathering of plant species for food and fuel, strongly influenced the vegetation (Sonnen 1952). The area has been inhabited since the Bronze Age. To this day early dolmens, terraces, and ruins of ancient habitations testify to the ancient history of the area. The area was noted in the Bible for the good wheat produced there (Vilnay 1953). During the period of the Ottoman Empire, the region was inhabited by Bedouin, who also extracted passage tolls from the people who travelled the main road from Galilee to Damascus.

At the end of the War of Independence in 1948, very few livestock remained, most having been removed to neighbouring countries. Slowly the range came into use again—first for sheep and cattle of dairy herds, and later mainly for beef cattle. New methods of range management were introduced, mainly with the help of the U.S. Operations Mission (USOM) to Israel, which was active from the early 1950's. It soon became apparent that more information on the carrying capacity of the range and its response to grazing was urgently needed. In 1960, the Karei Deshe experimental range was established 10 km north of Lake Kinneret, close to the Jordan River. The first trials were planned with Mr. Larry Short of the USOM. The objective of these trials was to determine the response of animals and pasture vegetation to grazing pressure and to rotational grazing in the context of the rocky, herbaceous, foothill range, typical of large areas in Israel and other parts of the Mediterranean region.

Climate

Karei Deshe is in a winter rainfall area, with all precipitation falling between October and April and 50% in December-January. Rainfall and growing seasons are thus designated by two calendar years; e.g. 1966/67 refers to the year from October 1966 to September 1977. The extreme rainfall fluctuations during the trial years were 394 mm in 1972/73 and 911 mm in 1968/69. Rainfall distribution within a season greatly influences vegetation growth. Mean values are given in Table 1.

Table 1. Mean monthly precipitation for Karei Deshe, 1960–1970.

Month	Precipitation (mm)	SD (mm)	CV (%)
October	16	18	114
November	17	16	90
December	134	91	68
January	171	77	45
February	96	66	69
March	81	47	58
April	21	15	71
May	5	6	120

The coldest month is January, with mean minimum and maximum temperatures 7° and 14°C, respectively; only very seldom does the absolute minimum descend below 0°C. The hottest month is August, with mean minimum and maximum temperatures of 19° and 32°C, respectively.

Soils and topography

The soil is a basaltic protogrumosol (Dan and Raz 1970). Field capacity is about 33% (gravimetric) and wilting point is about 23%. Bulk density is 1.35. The outstanding features of the landscape are the hilly topography overlain with basaltic rocks which cover about 30% of the surface. Most of the area is inaccessible to vehicles. The slopes are gentle and the cattle can graze most of the range. There is very little erosion from the basaltic protogrumosol (Morin et al. 1976).

Vegetation

The vegetation is classified as Mediterranean transitional batha (Zohary 1973), composed principally of hemicryptophytes (*Psoralea bituminosa*, *Echinops viscosus*, *Hordeum bulbosum*). These species form 40–60% of the cover. The other botanical components include over 250 species, mostly therophytes, among which the following are prominent: Annual grasses: *Avena sterilis*, *Hordeum ithaburensis*, *Bromus* spp.; Perennial grasses (traces): *Phalaris tuberosa*, *Dactylis glomerata*; Legumes: *Medicago polymorpha*, *Medicago rotata*, *Trifolium subterraneum*, *Trifolium pilulare*; Forbs: *Scabiosa prolifera*, *Scolymus maculatus*, *Carthamus glauca*, *Hirschfeldia incana*, *Anthemis* spp., *Linum strictum*.

Seasonal development of this vegetation depends almost wholly on the rains. Only *Psoralea bituminosa* and *Echinops viscosus* begin to grow in October, before the rainy season starts. After the onset of the first effective rains, usually between mid-October and late November, the annuals germinate and the perennials emerge. The growing period extends until the end of April (or, rarely, the beginning of May), when most of the herbaceous vegetation dries up. *Psoralea bituminosa* stays green till the end of May. During the summer the only green species are *Cynodon dactylon* and *Prosopis farcata*. The latter is a thorny dwarf shrub occasionally eaten by the cattle. Some of the similarities and differences between this type of vegetation and the grasslands of California have been discussed by Naveh (1967).

Experimental Animals and Herd Management

The Cattle Herd

In each year, 150 to 200 head of cattle made up the experimental

herd, which was composed of dry cows that were served during the green season (from December to May). The composition of the experimental herd followed the changes in breed composition of the beef cattle of Israel. At the beginning of the trial most of the cows were Baladi (local), Turkish, and Yugoslavian land races. The bulls were Brahman and Hereford initially, and later Simmental and Charolais. All the off-spring of the Charolais breed were sent to the feed lots, because cows with Charolais blood perform poorly on the rough, rocky range. The average liveweight of the cows at the beginning of the grazing season (January) was 260–280 kg. In 1970 the trial was conducted with heifers that weighed about 200 kg at the beginning of the grazing season.

The Grazing Season

After the first heavy rains, the residual dry vegetation decomposes quickly. The newly germinated vegetation is generally insufficient to maintain the cattle until 40 to 60 days after emergence or regrowth of perennial species. This period (from November to January) is a difficult transitional season, when supplementary feeding is generally practiced. Grazing started with range readiness in the experimental paddocks when the herbaceous vegetation was about 10 cm tall, usually between January 15 and 25. The grazing season lasted approximately 200 days and ended when the cattle in the heavily grazed paddocks began to lose weight at two consecutive weighings. The protein content of the vegetation from June to December is low, less than 4%. Protein supplements are necessary and poultry litter has commonly been used for this purpose in recent years. From 1964 to 1969 the protein supplement was 0.8 kg oil cake (cotton seed or soya) mixed with 0.2 Kg salt per head per day. In 1970 no supplement was given and from 1971 to 1973 chicken litter was supplied *ad lib*. The cattle usually consumed from 1.8 to 3.3 kg per head per day.

Treatments and Experimental Layout

The trial was conducted during 14 consecutive years (1960–1973) and can be divided into phases with the following grazing treatments:

Paddock number	Establishment and calibration phase 1960–1963 (4 years)	Grazing treatment period	
		Phase I 1964–1970 (7 years)	Phase II 1971–1973 (3 years)
1 & 4	Continuous moderate grazing in all the paddocks	Rotational moderate	Rotational heavy
2 & 5		Continuous moderate	Continuous moderate
3 & 6		Continuous heavy	Continuous heavy

In the center of the farm, six experimental paddocks were fenced and divided into two blocks of three. The paddocks varied in size from 25.5 ha to 33.8 ha and were planned so as to have a similar mix of habitat types (Fig. 1). This was done to ensure the similarity of the carrying capacities of the range in the individual paddocks. During the calibration phase, which lasted 4 years, the grazing pressure was planned to be uniform in all six paddocks. This period was regarded as necessary to disclose differences in the productivity of the pasture between the paddocks, which could complicate the analysis of the results. This was one of the methodological conclusions that could be drawn from other, similar, trials (Wagnon et al. 1959).

During the first treatment phase (1967–1970) three grazing treatments were compared: rotational moderate, continuous moderate and continuous heavy. No range improvement methods were applied besides the management of the range inherent in the grazing treatments. The stocking density was 1.2 head·ha⁻¹ for the heavy continuous and 0.8 head·ha⁻¹ for the moderate treatments (continuous and

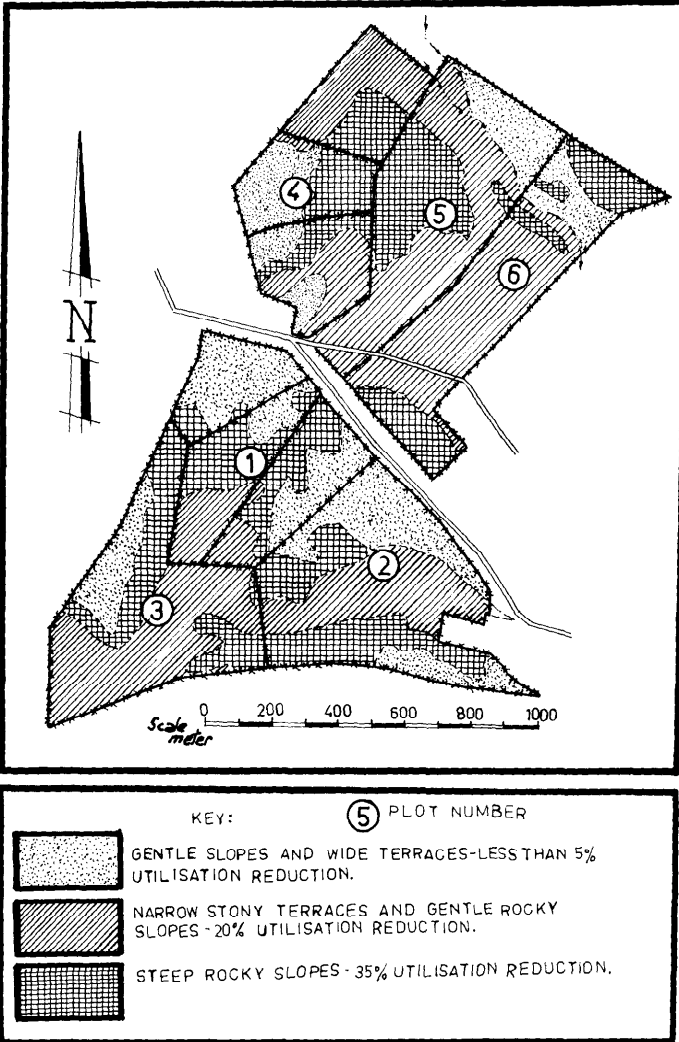


Fig. 1. Habitat map of grazing trial paddocks, Kare Deshe Experimental Range, Israel.

rotational). The paddocks allocated to the rotational treatment were divided into three fenced sub-units. Only one sub-unit was grazed at a time and each sub-unit was grazed at least once during the growing season, for a period of 15-50 days. All the sub-units were grazed (also one at a time) during the dry season. The order in which the sub-units were grazed was changed each year. Each treatment was replicated twice, once in each block.

During the second treatment phase (1971-1973), the grazing pressure in the rotational treatment was increased from moderate (0.8 head-ha⁻¹) to heavy (1.3 head-ha⁻¹). The other treatments were continued without change.

Methods

Climate

Rainfall was measured daily with a standard rain gauge; temperature was recorded by a clockwork thermohygrograph; potential evaporation was measured with a Class A pan.

Vegetation

At the beginning of each grazing season, the vegetation cover and botanical composition of each paddock were recorded. The observations were conducted along permanent transects, with a total length of 1,500 m in each plot. At 10-m intervals an iron quadrat, 0.25 × 0.25 m, was placed. The samples were taken only from herbaceous vegetation (annuals and *Hordeum bulbosum*). In the event of the quadrat falling on boulders or on concentrations of *Psoralea bituminosa* or *Echyniops viscosus*, the quadrat was moved 1 m forward. For

each quadrat, the observations included vegetation cover in relation to bare soil, and relative cover of grasses, legumes, and forbs. The plant biomass of each quadrat was determined by a double sampling method. A visual estimate was calibrated by harvesting, drying, and weighing a subsample of 10-20% of the quadrats (Campbell and Arnold 1973; Pechanec and Pickford 1973; Tadmor et al. 1975). A survey of the amount and cover of litter left in each paddock was conducted at the end of the grazing season. This survey was also carried out along the permanent transects and based on double sampling. Detailed botanical composition was determined by the step-point method (Evans and Love 1957) in 1969 and 1974.

Cattle

The dry-cows were taken from a commercial herd grazing the area adjacent to the trial paddocks. Each year about 120 head were divided into six herds between 16-24 each, depending on the treatment grazing pressure and size of paddock. The mean herd-weight and weight distribution were kept as uniform as possible. Number of animals in each paddock sometimes changed between grazing periods because of cattle jumping fences or removal due to illness or death.

All the animals were weighed at the beginning of *i*-th grazing periods, which were one-month during the green season, and 15-20 days long during the dry season. Before each weighing, the animals were held in the corrals overnight (12 to 16 hours), without food or water (Baker and Guilbert 1942). The number of days the herd spent in each paddock (*d_i*) was recorded for each grazing period.

Daily metabolisable energy requirements for each *j*-th cow (*ED_{ij}*) for each grazing period were calculated from A.R.C. tables based on body weight and on changes in the body weight during the grazing period (A.R.C. 1965; Levy and Holzer 1971). The total ME consumed per hectare (*EH*) in each paddock was calculated as follows:

$$EH = \frac{1}{a} \cdot \sum_{i=1}^p \left[d_i \cdot \sum_{j=1}^n ED_{ij} \right]$$

where,

- p* = number of grazing periods per season
- n* = number of cows in paddock
- a* = area of paddock in hectares
- d_i* = number of days in *i*-th grazing period.

EH is probably a low estimate of ME consumed as A.R.C. *ED* tables are based on hand-fed and not on grazing animals.

Calibration of Trial Paddocks

During 4 years, the treatment in all six paddocks was supposed to be continuous moderate grazing, but because of initial technical difficulties, the grazing was truly continuous over the whole grazing season only during the latter 2 years. The total apparent productivity of the pasture was calculated as the sum of the cattle intake (calculated as above) and the ME value of the ungrazed biomass at the end of the grazing season. The relative pasture productivity of each paddock (*RPP*) was calculated as a percentage of productivity of the best paddock. The analysis of the calibration period data gave the following results (Seligman and Gutman 1977).

	Block A		Block B
	<i>RPP</i>		<i>RPP</i>
Paddock 1=	100	Paddock 4=	90
Paddock 2=	96	Paddock 5=	90
Paddock 3=	94	Paddock 6=	90

The results show that there was little measured difference in productivity between the paddocks within Block A, and none in Block B. The differences between the blocks appear to be due more to differences in the management of the individual trial paddocks rather than to differences in the inherent productivity of the blocks. This interaction between management and productivity makes it difficult to

Table 2. Animal performance and pasture production during the two phases of the trial.

Year	Precip. mm		Liveweight gain						Pasture product ⁴			Residual litter		
			kg. head ⁻¹			kg. ha ⁻¹			10 ³ .MCal ha ⁻¹			tonne. ha ⁻¹ (D.M.)		
Phase 1 ¹			CH	CM	RM	CH	CM	RM	CH	CM	RM	CH	CM	RM
1964	672	(g) ²	81	81	76	73	45	50	3.75	2.32	2.45	0.65	0.96	1.60
1965	786	(p)	77	93	91	72	52	59	3.14	2.31	2.33	0.70	1.00	1.24
1966	488	(g)	83	88	82	80	61	55	3.51	1.89	2.41	0.78	1.24	1.32
1967	684	(p)	70	85	76	85	62	54	2.68	(1.76)	(1.59)	0.67	5	5
1968	568	(g)	69	80	80	82	61	63	3.73	2.35	2.36	0.79	1.17	1.41
1969	911	(p)	84	108	100	109	85	77	3.51	2.36	2.22	0.49	1.19	1.51
1970	602	(g)	50	67	61	77	55	48	2.82	1.61	1.51	0.72	1.33	1.60
Average														
Phase 1	673		74	86	81	83	60	58	3.30	2.09	2.12	0.69	1.15	1.45
Signif. (6)			a	a	a	a	ab	b	a	b	b	b	a	a
Phase 2 ³			CH	CM	RH	CH	CM	RH	CH	CM	RH	CH	CM	RH
1971	657	(g)	84	79	80	107	59	96	3.26	1.87	2.95	0.66	1.28	1.00
1972	450	(p)	80	87	73	102	68	101	3.48	2.17	3.53	0.65	1.22	0.98
1973	394	(g)	60	79	61	72	65	78	2.82	2.00	2.94	0.61	1.27	0.99
Average														
Phase 2	500		75	82	71	94	64	92	3.19	2.02	3.14	0.64	1.26	0.99
Signif. ⁶			ab	a	b	a	b	a	a	b	a	c	a	b

¹ Phase 1 treatments: CH-continuous heavy; CM—continuous moderate; RM-rotational moderate.

² Letters in brackets denote rainfall distribution; g-good; p-poor.

³ Phase 2 treatments; as above except RH-rotational heavy.

⁴ Pasture productivity as utilized metabolizable energy.

⁵ Dry pasture burnt as a result of Syrian shelling in 1967 war. Pasture productivity of CM and RM up to June only.

⁶ Significance $p=0.05$ by the Duncan multiple range test; analysis as split plot with treatment as mainplots and years as subplots. Significance much improved with factorial analysis, treatment \times years, which is only partially valid as herds were changed each year but paddocks were not.

determine an absolute value for potential productivity. The average relative productivity of the two paddocks assigned to each treatment (1-4, 2-5, and 3-6) was 95, 93 and 92, respectively. For practical purposes it was decided to consider the pasture in all the treatments as uniform on a total paddock basis.

Results

Animal performance and pasture production during the trial years are shown in Tables 2 and 3.

Cattle Responses to Stocking Density

The influence of stocking density can be analysed by comparing the continuous moderate and the continuous heavy grazing treatments.

Liveweight Gain per Head. Phase I (1964-1970)

The liveweight gain per head was higher in the pastures under moderate stocking density. The difference was not large during the green season (Table 3): 0.69 kg.head⁻¹.day⁻¹ in the heavy stocking treatment compared with 0.76 kg.head⁻¹.day⁻¹ in the moderate treatment. During the dry season the difference was greater, because the daily average increase per head in the moderate stocking density was 0.04 kg, whereas in the heavy intensity treatment the animals lost weight, especially during the last month of the grazing season. The cattle began to lose weight when the amount of pasture biomass dropped below 700 kg dry matter.ha⁻¹. In spite of these low pasture biomass values, the body condition of the cattle in the heavily grazed plots was satisfactory. There were no clear differences between treatments in the percentage of cows that came into calf.

Phase II (1971-1973):

The same treatments were compared and the results were similar to those of Phase I. Two of the three years in Phase II were "drought" years (1972 with 450 mm poorly distributed

and 1973 with 394 mm). In the heavy stocking treatment, the liveweight gain per head was the same in both phases (Table 2). On the other hand, in the moderate treatment the liveweight gain per head (which was higher than in the heavy stocking treatment) was lower in Phase II—apparently due to the shorter green seasons in the drought years of Phase II. In the heavily

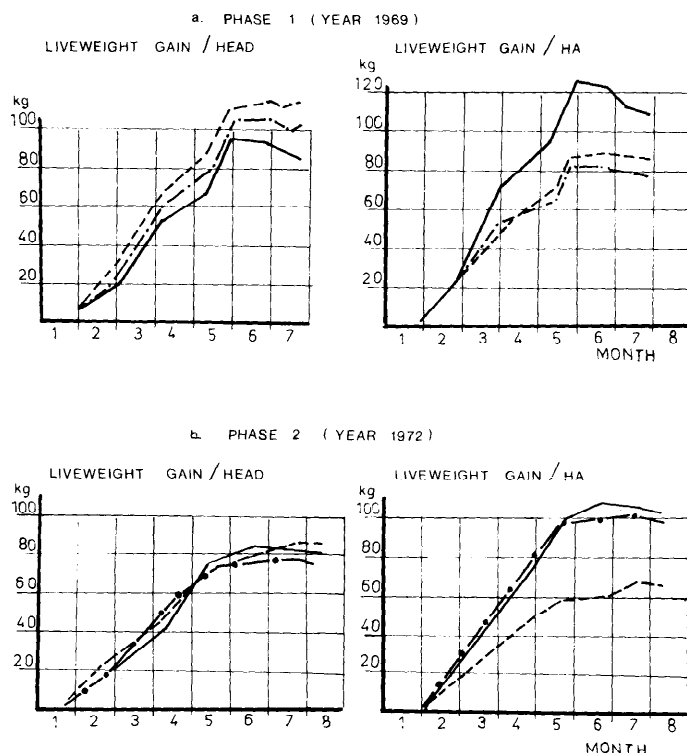


Fig. 2. Average liveweight gain of dry beef cows in two seasons, representative of each phase of the experiment. Grazing treatments:

—○—○—○ rotational moderate; —○—○—○ rotational heavy;
 — continuous moderate; — continuous heavy.

Table 3. Animal density and production parameters in the green and dry season.

Grazing treatment	Stocking rate (head.ha ⁻¹)	Grazing pressure (grazing days.ha ⁻¹)	Daily liveweight gain (kg head ⁻¹)		Daily metabolizable energy requirement (Mcal.head ⁻¹)	
			Green season	Dry season	Green season	Dry season
a. Treatment Phase 1 (1964-1970)						
Rotational moderate	0.8	150	0.72	0.04	17.0	11.6
Continuous moderate	0.7	140	0.76	0.04	17.5	12.0
Continuous heavy	1.2	236	0.69	-0.03	16.7	11.3
b. Treatment Phase 2 (1971-1973)						
Rotational heavy	1.3	253	0.52	-0.05	13.7	10.8
Continuous moderate	0.8	153	0.56	0.17	14.2	11.4
Continuous heavy	1.3	245	0.59	-0.06	14.5	10.8

stocked paddocks, the smaller amount of pasture biomass which was available per head for grazing, rather than the length of the green season seemed to limit the total seasonal liveweight increase per head in both phases.

Liveweight Gain per Unit Area:

The liveweight gain per unit area was higher in the heavily stocked paddocks. The results of Phases I and II are similar: 61 and 64 kg·ha⁻¹ in the moderate stocking densities and 83 and 94 kg·ha⁻¹ in the heavy stocking density. Within the range of stocking densities applied in this trial, the liveweight increase per unit area was in almost direct relationship to the grazing pressure.

Pasture productivity in terms of utilized metabolizable energy (ME) is calculated as total requirements of the cattle for maintenance and liveweight gain during the grazing season. The results (Table 2) showed that the pasture productivity was higher in the heavy stocking density. At the heavy stock density, the productivity of range relative to moderate stock density did not decline after 10 consecutive years (Table 2).

If one adds the 10-year mean ME value of the residual litter at the end of the grazing season (assuming 1.5 Mcal·kg⁻¹ dry-matter, A.R.C. 1965) to the ME utilized, the difference between heavy and moderate grazing becomes very much reduced: 4300 Mcal·ha⁻¹ in the heavy treatment and 3900 Mcal·ha⁻¹ in the moderate. These results differ from those of many grazing trials conducted with similar vegetation in the western U.S.A. (Beetle et al. 1961; Klipple and Costello 1960; Launchbaugh 1957; Lewis et al 1956). The range productivity was relatively stable in spite of wide seasonal fluctuations in rainfall. The average ME utilised by the cattle during the grazing season in the heavy stocking density, was 3,350 Mcal·ha⁻¹ (S.D. ±340), with minimum and maximum values being 84.7% (1973) and 112% (1964) of the mean.

Cattle Responses to Rotational Grazing

The effect of grazing rotation on cattle and vegetation was studied under moderate and heavy stocking densities (Phase I and II, respectively). In both phases the liveweight increase per head was lower in the rotational than in the continuous treat-

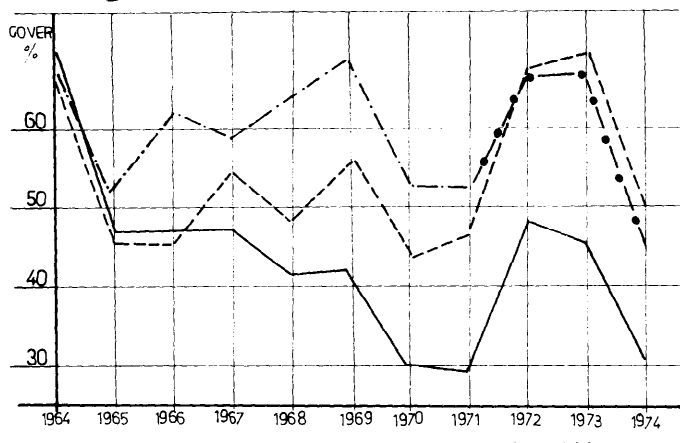
ments (Table 2). The results are similar to those obtained in grazing trials in the western U.S.A. (Heady 1961; Murray and Klemmedson 1968).

During the green season the cattle in the rotational grazing treatment gained slightly less per head than those in the continuous grazing treatment; the difference was not significant but fairly consistent (Table 3). It appears that toward the end of each grazing period, in each rotational sub-unit, the feed available during the green season was insufficient for the livestock to maintain their potential liveweight increase. During the same period, feed was abundant in the continuous treatment. As the animal density was the same in the two systems (rotational moderate compared with continuous moderate in Phase I, and rotational heavy compared with continuous heavy in Phase II) and the differences in liveweight increase per head were very small, there were no significant differences in the liveweight gain per unit area or in range production measured as metabolizable energy per unit area.

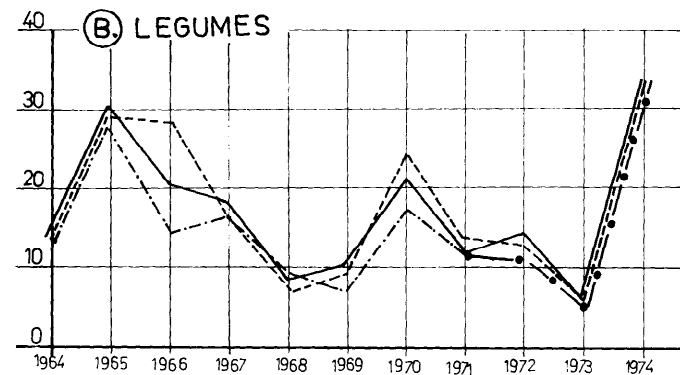
Vegetation Responses to Stocking Density

The botanical composition in all the paddocks at the beginning of the grazing treatment was similar (Fig. 3). During the first 2 years of the trial, no significant changes occurred, but after the third year the forbs began to increase in the continuous heavy treatment. As the relative cover of the forbs increased, the cover of the grasses decreased. After 5 years an equilibrium was reached and subsequently only small yearly fluctuations were observed. The relative cover of the legumes was not affected by the grazing treatments, but marked yearly variations occurred (Fig. 3), apparently due to the climatic conditions during seed set and germination (Quinlivan 1968). The amount of ungrazed vegetation at the end of the grazing season was greater in the moderate grazing treatment than in the heavy one (Table 2), but the amount of dead vegetation had no measurable influence on the growth in the subsequent season. Similar results were obtained by Weaver and Rowland (1952). At the beginning of the grazing season (January) the total cover of the herbaceous vegetation was similar in all the paddocks. No discernible influence of the grazing treatments was observed on the cover of

A. GRASSES



B. LEGUMES



C. FORBS

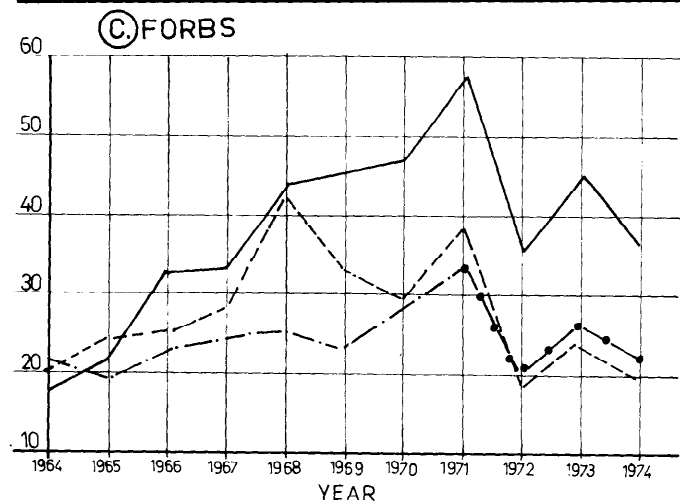


Fig. 3. Effect of grazing treatments on botanical composition of the herbaceous sward. (Key to grazing treatments as in Fig. 2).

the hemicryptophytic dicotyledons—*Psoralea bituminosa* and *Echinops viscosus*.

Vegetation Responses to Rotational Grazing

At the moderate stocking density, the relative cover of grasses was higher in the rotationally grazed paddocks than in the continuously grazed ones. At the beginning of Phase II (1971), the botanical composition in the paddocks with the heavy stocking treatments (rotational and continuous) was different, due to the different treatments in the preceding Phase I. Consequently, it is possible to compare the trend in botanical composition of the paddocks due to the change in treatments.

The relative cover of the grasses dropped when the stocking

density in the rotational treatment was increased from moderate to heavy. After 3 years the relative cover of grasses was almost the same in the heavy rotational treatment (originally moderate rotational with high grass cover) as in the moderate continuous one. It appears that grasses persist better and even increase under rotational grazing compared with continuous grazing, but increasing stock density—even under rotational grazing—causes a reduction in the cover of grasses (Driscoll 1967; Rossiter 1952; Smith et al. 1967).

At the end of the grazing season there was consistently and significantly more litter in the rotationally grazed paddocks than in those grazed continuously. This appears to be due not only to more vegetative growth under the rotational treatment but also to the fact that the cattle apparently grazed less, as evidenced by the lower weight gains in these treatments.

Discussion and Conclusions

The heavy stocking density in this experiment was 1.2 dry cows ha^{-1} or 1.0 cow-calf units ha^{-1} (Paulsen and Area 1962). Corrected for yearlong grazing, this is equivalent to about 0.7 cow-calf units a^{-1} , compared to 0.3–0.4 cow-calf units ha^{-1} previously proposed for the region by the local extension service. Production under heavy grazing was maintained for 10 consecutive years. This result must be viewed in the light of the fact that the native vegetation has been grazed continuously since Biblical times (Seligman and Tadmor 1972). The species that have evolved and survived under these conditions can clearly withstand heavy grazing pressure. A very diverse flora—over 250 common species at Kare Deshe alone (Seligman and Gutman 1976)—must also contribute to the viability and flexibility of the vegetation under grazing.

The stability of the pasture productivity from year to year was due partly to deferring grazing for about 6 weeks after germination and partly to the length of the grazing season, which extended almost to the end of the dry period, when the plants are dead or dormant. As a result, the consumption rate of pasture during the green season (about 11 kg $\text{ha}^{-1} \cdot \text{day}^{-1}$) was much less than the growth rate throughout the period when it was grazed (20–100 kg $\text{ha}^{-1} \cdot \text{day}^{-1}$). The amount of dead vegetation had no measurable influence on the new growth in the subsequent season, so that heavy utilisation of the dry standing biomass increased rather than reduced secondary production. It should, however, be pointed out that the basaltic protogrumosol, with additional protection from the rock cover, is very resistant to erosion, and litter cover plays a small role in this regard.

The calves in the region are weaned during May–June. Most of the differences in live-weight increase per head between the continuous heavy and continuous moderate treatments occurred during July and August. It is thus likely that production would have been higher with suckling cows, even after correction for stocking density for the greater requirements of the cow-calf unit.

No important differences in cattle production per unit area between the rotational and continuous grazing systems were observed. The principal possible advantage of the rotational grazing was the higher amount of ungrazed vegetation at the end of the grazing season that could have been utilised. At heavy stocking densities, it is thus possible to extend the dry grazing seasons in the rotationally grazed paddocks for a longer period than in the continuously grazed ones.

In some years the residual vegetation was grazed to obtain an estimate of its value. Daily intake of dry pasture was calculated

by dividing the reduction in the amount of litter during the residual grazing period, (i.e. the difference in the amount of litter on the ground at the beginning and end of the period) by the number of grazing days in the same period. It was found that the cattle intake during the dry season was approximately 4–5 kg dry matter per head per day, about half that consumed per day in the green season. The amount of grazable vegetation left in the rotational heavy treatment, over and above what was left in the continuous heavy treatment, was 350 kg·ha⁻¹ (Table 2). Accordingly, with 1.2 head·ha⁻¹ it was possible to graze another 5 days in the rotational treatment. Thus, when the animals are to be kept all the year long on the pasture, there is a possible advantage to rotational grazing that was not covered by this trial. However, for systems where seasonal use—especially green season use—is made of the pasture, there appears to be no obvious benefit from rotational grazing.

In the rotationally grazed paddocks, there were more grasses and fewer forbs than in the continuously grazed paddocks. Nevertheless, the production in the continuously grazed paddocks did not drop in spite of the high proportion of forbs. Thus, in the Mediterranean steppe range, botanical composition alone is a poor indicator of the productivity of a pasture.

An important advantage of rotational grazing is that where fire is a hazard—as in our region—those paddocks most exposed can be grazed down early in the dry season. Thus, the choice of grazing system will depend on many factors: type of cattle, grazing season, fire hazard, herd management, etc.; but production from a given area seems to depend more on the animal density than on the grazing system.

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Influence of Brush Control on White-tailed Deer Diets in North-Central Texas

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Abstract

Botanical composition of white-tailed deer fecal pellets from untreated and brush-controlled areas of the Texas Rolling Plains was studied by microscopic analysis. Deer showed a marked preference for 11 of 54 plant species selected as food from a total of 250 identified on the study area. The bulk of the diet was comprised of mistletoe on non-brush control areas and of prickly-pear on brush-controlled areas. Similarity indices relating habitat across diets as well as diets across a habitat indicated that several habitats had preferred foods removed. These habitats also had low populations of deer. Brush control involving limited removal of noxious species affected dietary selection of deer but did not appear to affect overall deer usage of the habitats studied.

Ever-increasing costs and low returns to the ranching industry in Texas has made the noxious brush problem an item of major concern. With more than 50% of Texas rangeland covered with brush too dense for optimal livestock production and an additional 23% moderately infested (Smith and Rechenbach 1964), brush control has become a common practice. This control has been used mainly for increasing grass and livestock production, with little effort expended to document the effects of brush control on wildlife populations.

The value of wildlife resources becomes increasingly important to land managers when leased trespass rights for hunting compare favorably with economic returns from livestock production (Ramsey 1965). Since habitat management is of paramount importance for sustained optimal production of game animals, land managers should carefully scrutinize brush control practices that will affect wildlife populations. The objectives of this research were to determine the importance of brush species in the diet of white-tailed deer (*Odocoileus virginianus*), to ascertain deer diets in various brush control habitats of north-central Texas, and to compare the similarity of deer diets to available forage in deer habitats.

Study Area

The study was conducted on 17,000 ha of native grassland located near the juncture of Haskell, Shackleford, and Throckmorton counties in the Rolling Plains of north-central Texas. The area, traversed by the Clear Fork of the Brazos River, is typified by varying topography, ranging from nearly flat plains to rough broken terrain along the river. Differences in elevation (152 m) between valley bottom areas and adjacent ridges limit mechanical brush control practices to the more

level areas. Soils are deep on level areas and shallow with limestone outcroppings along drainage channels. Precipitation averages 69 cm per year (Korschgen 1967).

Vegetational communities in the area included 250 different species of plants. Valley bottom habitat had large honey mesquite (*Prosopis glandulosa*), pecan (*Carya illinoensis*), and soapberry (*Sapindus saponaria*) as the most prevalent trees. Pricklypear cactus (*Opuntia macrorhiza*) and tasajillo (*Opuntia leptocaulis*) were prevalent in the midstory. Numerous grasses and forbs made up the understory. Upland vegetation differed in that honey mesquite was dominant in the overstory.

Texas wintergrass (*Stipa leucotricha*), buffalograss (*Buchloe dactyloides*), sand dropseed (*Sporobolus cryptandrus*), slim tridens (*Tridens muticus*), vine mesquite (*Panicum obtusum*), sideoats grama (*Bouteloua curtipendula*), and threeawns (*Aristida* spp) were common grasses. Common forbs included pelletaria (*Abutilon incanum*), western ragweed (*Ambrosia psilostachya*), wine cup (*Callirhoe involucrata*), spectacle pod (*Dithyrea wislizenii*), spreading sida (*Sida filicaulis*), and silverleaf nightshade (*Solanum elaeagnifolium*). More prevalent browse species included ironwood (*Bumelia lanuginosa*), mistletoe (*Phorodendron villosum*), polecat bush (*Rhus aromatica*), and little-leaf sumac (*R. microphylla*).

Brush control on the study area ranged from no treatment to an attempt at total removal of brush and trees. Habitats studied included an untreated upland; an upland from which all trees and brush had been removed with a crawler bulldozer in 1972; an upland treated with 2,4,5-T and chained in 1957, resprayed in 1972; an upland treated with 2,4,5-T in 1964; an untreated valley bottom area; and a valley bottom area where mesquite and cacti had been selectively bulldozed in 1964.

The smallest habitat was 1,200 ha in size, an area which could accommodate 4.7 separate home ranges of white-tailed deer.

Methods

Percent cover and frequency of vegetation was taken along two randomly located 250-m line transects in each habitat. Four 8 × 15 m intensive sampling units, located 35 m apart, along each line were subdivided into four 2 × 15-m belts to obtain cover and frequencies of trees and shrubs. Data for grasses, forbs, succulents and small shrubs were obtained from three 30 × 30-cm quadrats in each belt.

A microhistological examination of deer feces was used to determine diets of deer. We collected 10 pellet groups of fresh feces from the center of each habitat during July, October, December (1971), and April (1972). Duplicate slides were prepared according to methods outlined by Sparks and Malechek (1968), Ward (1970), Flinders and Hansen (1972), Baumgartner and Martin (1939), and Baker and Wharton (1952). Ten fields per slide were examined at 100 magnification to obtain an estimate of the relative frequency of food items in deer diets (Free et al. 1971; Hansen and Reed 1975). We converted relative frequencies to particle densities (Fracker and Brischle 1944), and thence to relative percent dry weight of each food item identified in deer feces (Sparks and Malechek 1968). Individual food items were

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This report is a contribution of the College of Agricultural Sciences, Texas Tech University, Publications Number T-9-180.

Manuscript received January 1, 1978.

identified by comparing histological features identified in fecal fragments to a reference slide collection prepared from plants collected on the study area (Davies 1959; Brusven and Mulkern 1960; Storr 1961).

Kulczynski's mathematical expression of similarity (Oosting 1956) was used to relate similarities among habitats and diets.

Population estimates of the deer herd were obtained using a spotlight from a moving vehicle after dark.

Results and Discussion

Habitats

Table 1 shows the degree of similarity among habitat overstory and understory vegetation. The bulldozed valley and untreated upland were most similar in overstory to the untreated valley bottoms, whereas the understory of the sprayed upland and untreated valley bottoms most closely resembled that of the untreated upland habitat. The generally low similarities indicate the uniqueness and diversities of the habitat communities involved.

Honey mesquite was the most prevalent species of tree on the untreated river bottoms (55% relative frequency, 50% cover). Ironwood and hackberry (*Celtis occidentalis*) had relative frequencies of 22% and 16% respectively. Pecan, soapberry, walnut (*Juglans* sp), and buckeye (*Unganadia speciosa*) were scattered throughout the area. Tasajillo and mistletoe, which was parasitic to mesquite, were common with relative frequencies of 71% and 16%, respectively. Grasses accounted for 56% of the relative frequency and 70% of the cover of the understory.

Bulldozed valley bottoms had a more park-like appearance than untreated valley bottoms. Ironwood predominated in the overstory (44% relative frequency, 5% cover), mesquite was reduced to 32% relative frequency, and soapberry had increased to 16% relative frequency. Lotebush (*Ziziphus obtusifolia*) at 32% relative frequency had replaced tasajillo as the predominant shrub. Mistletoe had been reduced in prevalence in direct proportion to the reduction in Mesquite. Grass had a relative frequency of 60%, making up 56% of the ground cover in the understory.

The overstory of the untreated upland was primarily mesquite, hackberry and ironwood with relative frequencies of 41%, 18%, and 13% respectively. Elbowbush (*Forestiera pubescens*) and mesquite-parasitic mistletoe were prevalent browse species (relative frequencies of 7% and 31% respectively). Grasses and forbs were equally distributed. Pricklypear accounted for 5% of the total ground cover.

The bulldozed upland habitat was an open grassland, with grasses making up 55% of the relative frequency and 60% of the cover of the understory. Mesquite seedlings were the principal woody species present, with 28% frequency and <1% cover. Pricklypear and mistletoe were reduced to 1% of the total ground cover.

Mesquite was reinvading the sprayed upland site, having a relative frequency of 38% but accounting for only 3% of the ground cover. Ironwood catclaw (*Acacia* sp), elbowbush, hackberry, buckeye and lotebush all had relative frequencies about 5% and mistletoe had a

relative frequency of 19%. Grasses, with a relative frequency of 58%, were twice as prevalent as forbs. Pricklypear was the predominant midstory vegetation, making up 8% of the total cover.

Grasses were most prevalent on the sprayed-chained-resprayed site, accounting for 60% relative frequency and 87% of the ground cover. Mesquite and lotebush were common, with relative frequencies of 34% and 28%, respectively. However, these shrubs were young plants, as each contributed only 1% of the total cover.

Diets

Fifty-four (Table 2) of the 250 species of plants identified on the study area were ingested by white-tailed deer. Of the 54, 11 made up the bulk of their diet (Table 3).

Mistletoe was the single most important food, accounting for 35% of the over-all diet. Mistletoe was the prevalent dietary item on untreated habitats. Its prevalence in diets of deer decreased in relation to its decreased occurrence in the habitat. Mistletoe made up 80-90% of the relative dry weight (RDW) of winter and spring diets respectively, on untreated valley bottom, as well as 70% RDW of the winter diet on bulldozed valley bottom habitat. Mistletoe in spring diets in bulldozed valley bottoms declined to 19% RDW when ironwood browse increased in prevalence in the diet. Mistletoe usage was only 9% to 17% RDW, respectively, of the summer and fall diets of deer on treated valley bottom habitats and 1% to 6% RDW, respectively, of the summer and fall diets in untreated valley bottom habitats. It was also prevalent in the winter and spring diets on upland habitats. Ingestion of mistletoe was greatest on the sprayed upland site, where its frequency in the habitat was only about one-half that of the untreated upland site. High incidence of mistletoe in diets was also noted in the sprayed-chained-resprayed and the bulldozed upland habitats. This prevalence in the diet from habitats having a low frequency of hot plants (honey mesquite) can partially be explained by canopy structure of the plant community. The overstory in treated upland habitats consisted of short regrowth and new plants with the foliage readily accessible to deer. Mistletoe in this canopy was thus easily accessible to browsing deer.

Pricklypear was the second most important food item, accounting for 18% RDW of the total diet. Consumption of pricklypear was greatest on areas which had experienced more intense efforts at brush control (bulldozing and sprayed-chained-resprayed). Pricklypear was most prevalent in diets in bulldozed valley bottom habitats during summer and fall, when it made up 18% and 60% RDW, respectively, of the diet. With the exception of the fall diet (20% RDW) pricklypear was relatively unimportant in untreated valley bottom habitats. Pricklypear on bulldozed upland and sprayed upland sites made up 32% and 26% RDW, respectively, of fall diets; 27% and 18% RDW, respectively, of summer diets; and small amounts of spring and winter deer diets. In the absence of other available

Table 1. Symmetrical matrices of similarity indices (%) and Standard Errors of plant communities in various habitat types in north-central Texas.

Treatment	Untreated valley bottom	Dozed valley bottom	Untreated upland	S-C-S ¹ upland	Sprayed upland	Dozed upland
Untreated valley bottom		36.4±4.4	37.7±0.3	15.7±5.1	27.3±1.9	22.6±0.2
Bulldozed valley bottom	19.5±2.5		21.2±1.1	15.6±6.7	22.8±1.4	17.5±0.8
Untreated upland	13.4±0.7	9.4±1.1		11.8±3.5	35.1±0.8	20.4±1.8
S-C-S upland	13.6±1.4	15.9±1.4	15.8±1.4		16.7±4.0	26.0±5.6
Sprayed upland	18.9±3.2	14.0±2.0	20.1±2.8	19.9±5.2		18.0±1.9
Bulldozed upland	15.1±2.9	10.8±1.5	18.8±5.2	21.3±6.2	21.6±4.0	

¹ Sprayed-chained-resprayed

Table 2. Percent relative dry weight of food items in the diet of white-tailed deer in the Rolling Plains of north-central Texas.

Scientific name ¹	Common name	Season				Scientific name	Common name	Season			
		S ²	Su ³	F ⁴	W ⁵			S ²	Su ³	F ⁴	W ⁵
Grasses						<i>Galium virgatum</i>	Southwest bedstraw	1.1	Tr	-	-
<i>Andropogon</i> sp	Bluestems	-	0.4	-	-	<i>Gaura filiformis</i>		0.7	1.4	1.0	-
<i>Aristida</i> sp	Threeawns	Tr ⁶	Tr	Tr	0.2	<i>Heterotheca</i>					
<i>Aristida purpurea</i>	Purple threeawn	-	Tr	Tr	-	<i>canescens</i>	Camphor weed	7.5	0.7	-	0.5
<i>Bouteloua</i> sp	Grama	Tr	-	-	-	<i>Kochia scoparia</i>		Tr	-	-	-
<i>Bouteloua curtipendula</i>	Sideoats grama	-	0.6	0.2	0.2	<i>Lesquerella gordonii</i>	Bladder pod	0.5	0.5	-	-
<i>Bouteloua gracilis</i>	Blue grama	-	0.2	0.4	-	<i>Oenothera</i> sp	Primrose	0.3	-	-	-
<i>Buchloe dactyloides</i>	Buffalo grass	Tr	0.7	0.4	Tr	<i>Oxalis stricta</i>	Yellow wood sorrel	-	Tr	0.5	-
<i>Chloris</i> sp	Windmill grass	-	-	Tr	-	<i>Ratibida columnaris</i>	Cone flower	-	0.2	-	-
<i>Eragrostis</i> sp	Lovegrass	-	-	-	0.2	<i>Sida filicaulis</i>	Spreading sida	-	3.5	16.1	Tr
<i>Panicum ramisetum</i>	Bristle panicum	0.9	0.2	Tr	Tr	<i>Sida physocalyx</i>		-	Tr	-	Tr
<i>Schizachyrium scoparium</i>	Little bluestem	-	0.4	Tr	-	<i>Simisia calva</i>	Bush sunflower	-	1.5	3.7	1.0
<i>Sporobolus cryptandrus</i>	Sand dropseed	-	0.4	Tr	0.2	<i>Solanum</i> sp		Tr	-	-	Tr
<i>Stipa leuchotricha</i>	Texas wintergrass	0.2	-	-	0.6	<i>Solanum elaeagnifolium</i>	Silverleaf nightshade	4.8	2.9	1.9	3.0
<i>Tridens muticus</i>	Slim tridens	Tr	-	0.3	Tr	<i>Verbena bipinnatifida</i>	Dakota vervain	-	0.3	0.5	Tr
Forbs						<i>Xanthocephalum dracunculoides</i>	Annual broomweed	-	-	0.3	0.5
						Brush					
<i>Abutilon incanum</i>	Pelotazo	-	16.5	8.2	-	<i>Opuntia macrorhiza</i>	Pricklypear	6.5	21.5	30.0	14.5
<i>Allium drummondii</i>	Wild onion	-	-	-	Tr	<i>Acacia greggii</i>	Catclaw	-	-	-	Tr
<i>Amblyolepis setigera</i>	Huisache daisy	2.0	Tr	0.4	-	<i>Bumelia lanuginosa</i>	Ironwood	11.9	16.4	2.2	4.5
<i>Ambrosia confertiflora</i>	Ragweed	-	0.2	Tr	-	<i>Carya illinoensis</i>	Pecan	0.7	0.2	0.5	0.4
<i>Ambrosia psilostachya</i>	Western ragweed	0.3	1.8	0.5	2.9	<i>Celtis occidentalis</i>	Hackberry	-	0.2	-	-
<i>Ammoselinum popei</i>	Sand parsley	-	-	0.7	-	<i>Juglans nigra</i>	Black walnut	-	-	0.2	-
<i>Callirhoe involucrata</i>	Wine cup	0.2	1.2	1.5	-	<i>Phorodendron villosum</i>	Mistletoe	51.3	5.4	17.0	65.0
<i>Calyophrys serrulatus</i>	Yellow evening primrose	1.0	1.6	Tr	Tr	<i>Prosopis glandulosa</i>	Mesquite	5.8	1.7	2.0	5.1
<i>Chamaesaracha conoides</i>	False nightshade	Tr	0.2	0.5	-	<i>Rhus aromatica</i>	Polecat bush	-	15.8	1.9	0.5
<i>Cirsium ochrocentrum</i>	Yellow spine thistle	Tr	-	-	-	<i>Rhus microphylla</i>	Little-leaf sumac	-	2.0	0.7	-
<i>Desmanthus velutinus</i>		Tr	-	-	-	<i>Sapindus saponaria</i>	Soapberry	-	-	Tr	Tr
<i>Dithyrea wislizenii</i>	Spectacle pod	-	Tr	-	0.3	<i>Ungnadia speciosa</i>	Mexican buckeye	0.6	0.2	0.7	0.4
						<i>Ziziphus obtusifolia</i>	Lotebush			0.2	-
						Unknown		3.1	0.6	6.2	-

¹ From Correll and Johnson (1970).
² Spring=April
³ Summer=July
⁴ Fall=October
⁵ Winter=December
⁶ Tr=trace, 0.1% or less in diet

browse, pricklypear was the staple food of deer in the sprayed-chained-resprayed habitat. This is readily apparent when 94%, 75%, 82% and 28% RDW's of the fall, winter spring and summer diets respectively, consisted solely of pricklypear fruits and pads. Usage of this forage in untreated upland habitats was slight, ranging from a low of 0.4% RDW of the fall diet to 4% RDW of the spring diet.

Ironwood (9% RDW of total diet) was extensively browsed in all habitats during the summer, and during the winter and spring on habitats where brush had been treated. It was the most

Table 3. Relative percent dry weights of major food items in yearly diets of white-tailed deer in various habitats in north-central Texas.

	Untreated valley bottom	Bulldozed valley bottom	Untreated upland	Sprayed upland	S-C-S ¹ upland	Bulldozed upland
Mistletoe	50.9	23.2	33.9	44.6	7.6	16.8
Pelotazo	9.3	0.4	4.0	17.2	-	4.3
Pricklypear	5.9	20.8	2.1	12.1	69.8	29.7
Ironwood	6.6	20.4	8.4	4.2	3.8	8.6
Polecat bush	5.4	7.5	6.5	2.5	Tr ²	3.8
Mesquite	1.7	2.5	8.8	2.8	1.1	0.7
Spreading sida	2.3	3.0	10.4	3.0	Tr	8.9
Camphor weed	-	0.6	6.9	1.0	Tr	-
Silverleaf nightshade	3.3	1.5	3.0	0.9	8.3	1.3
Western ragweed	1.3	2.6	0.3	0.6	0.4	7.0
Bush sunflower	2.0	0.3	3.0	1.6	-	1.9
Other	11.1	17.1	12.7	9.5	9.4	17.0

¹ S-C-S=Sprayed-chained-resprayed
² Tr=trace, items occurring as 0.1% or less.

prevalent dietary item in spring (48% RDW) and summer (20% RDW) samples from the treated valley bottom habitat. It was second in importance (13% RDW) for the winter diet and was not identified in fall diets in bulldozed valley bottom areas. Ironwood in untreated valley bottom sites made up 21% and 5%, respectively, of the summer and winter diets but was unimportant as a deer food during the fall and spring. The use of ironwood by deer did not follow any general pattern in upland habitats. Ironwood made up 27% and 15% RDW respectively of the summer diet in the untreated and bulldozed upland habitats, and 5% and 2% RDW of the fall diets of deer for the same areas. In addition it constituted 5% RDW of the winter diet in the sprayed upland, and 15% and 5% RDW, respectively, of the spring diet of deer in the sprayed-chained-resprayed and sprayed upland habitats.

Polecat bush was a major food only in the summer diets of deer, when it accounted for 28%, 20%, 21%, 5% and 10%, respectively, of the RDW ingested in the bulldozed valley, untreated upland, untreated valley, bulldozed upland, and sprayed upland sites. With the exception of the untreated upland habitats, 5% RDW of the diet, polecat bush was only slightly browsed in fall and was not identified in spring or winter diets.

Forbs were important in diets of deer during the seasons of availability. Pelotazo was an important food in the sprayed upland habitat during the summer (44% RDW) and fall (25% RDW). It was also ingested in moderate quantities in the untreated upland habitat (13% RDW of diet), bulldozed upland (15% RDW of diet), and in untreated valley bottom (21% RDW of diet) habitat during summer. In addition, pelotazo made up 17% RDW of the fall diet in untreated valley bottoms. Spreading sida was ingested in fall while camphor weed (*Heterotheca canescens*) was a spring food in upland habitats. Silverleaf nightshade was ingested in all seasons, with the greatest use during summer, fall, and winter in untreated habitats and during spring in treated habitats. Bush sunflower (*Simsia calva*) was identified in fall diets, while western ragweed, with the exception of the dozed upland, was a winter food.

Honey mesquite twigs and pods were more frequent in the diet during winter and spring. However, mesquite pods were in short supply during these seasons, and were scarce on the study area. Deer season of use data does, however, agree with Krausman (1978), who reported mesquite in deer diets in Big Bend National Park during the periods May-June and August-October, and with Anderson et al. (1965), who reported diets from the Guadalupe mountains in southeastern New Mexico. The prevalence of this food in the diet when it was not abundant in the habitat indicates that deer were actively seeking mesquite. Mesquite is additionally important to deer because it is the host plant of mistletoe, the major food item of white-tailed deer in this locality.

Diet Comparisons

The greatest similarity between deer diets on a particular habitat and the forage available in the habitat was 8.9% for the sprayed upland. Similarity indices (S.I.) between diets and habitats were generally in the range of 4% to 6.5% similarities. The highest values were comparisons among valley habitats to all diets from all habitats with the exception of the sprayed-chained-resprayed habitat. The sprayed-chained-resprayed habitat compared to all diets, as well as the sprayed-chained-resprayed diet to all habitats, consistently produced the lowest values of similarity (<3%). The dozed upland habitat compared to dozed upland diet also had a S.I. of little more than 3%. These low S.I. indicate the severity of treatment to the habitat as

explained below.

The low similarity indices between diets and associated forage available on the habitats and between diets across habitats indicate the degree of selectivity exhibited by deer. In perusing the similarity indices for diets with habitat it was noticed that low values were associated with brush control treatments which had heavily reduced preferred foods in the habitat. We further noticed that decreases in this S.I. were paralleled by deer population that would be found in an area (Table 4). Areas of low similarity between diet and habitat generally had the lowest populations of deer.

Table 4. Density estimates of white-tailed deer in various habitats in north-central Texas.

Treatments	Deer/100 ha
Untreated valley bottom	7.3
Untreated upland	7.0
Bulldozed valley bottom	6.5
Sprayed upland	4.0
Sprayed-chained-resprayed upland	3.0
Bulldozed upland	2.0

Similarity indices among diets from different habitat types indicated that with the exception of the sprayed-chained-resprayed population, diets were generally about 65 to 69% similar. Diet comparisons between the sprayed-chained-resprayed population and other populations ranged from 29% to 45% similar, indicating that the forage complex on this habitat had been affected to the extent that white-tailed deer had been forced to markedly alter their diets (Table 3).

Discussion

Diets of white-tailed deer have been extensively studied at various seasons in numerous localities. Studies in Texas indicate that deer in south Texas are primarily grazers (Chamrad and Box 1968; Drawe 1968) while other studies indicate they are primarily browsers (Davis and Winkler 1968). Everitt and Drawe (1974) reported diets of deer varied in constituents and major composition in relation to individual community types on the same ranch. Our data support the findings of these later researchers.

Examination of fecal constituents showed that deer diets in the Texas Rolling Plains land resource area varied in relation to habitat manipulation. Mistletoe was predominant in deer diets on areas where trees infected with this parasite had been retained in the habitat. Pricklypear was the main food on areas which had experienced brush control measures aimed at elimination of brush species and hence elimination of mistletoe. In untreated habitat, browse was more prevalent in the diet, whereas cacti and forbs constituted the bulk of the diet in treated habitats.

Our data indicate that habitat manipulation which affects deer populations and habitat usage largely center around removal of preferred browse and the associated reduction in cover. Deer adapted to changes in habitat and food availability if adequate cover was retained in the habitat, while deer populations were reduced in areas with greatly reduced cover and a shortage of preferred foods. Selective removal of dense stands of brush with efforts to maintain mistletoe-infected trees and patches of pricklypear is recommended where deer populations are a part of land use plans for the Rolling Plains of Texas.

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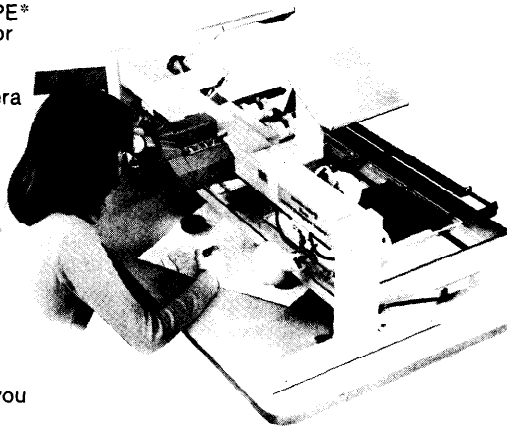
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The Effects of Nitrogen Fertilization on Water Use by Crested Wheatgrass

R.J. WILLIAMS, K. BROERSMA AND A.L. VAN RYSWYK

Abstract

The application of N fertilizer to crested wheatgrass on a dry rangeland site increased yields substantially. In the early part of the growing season when moisture was not limiting, soil moisture was withdrawn from the fertilized site at a higher rate than from the unfertilized plots. At later periods in the growing season the soil water potential curves paralleled each other with the fertilized crop growing under conditions of lower soil water potential. The decreased soil water potential was confirmed when the actual evapotranspiration, as measured by the energy balance method, was examined. The data indicate that for a period following rapid growth in the spring, the evapotranspiration of the fertilized block was less than that of the unfertilized. The soil water potential data indicate that seasonal evapotranspiration was slightly higher on the fertilized plot than on the unfertilized. The water use efficiency, in terms of biomass produced per unit of water used, was much greater for fertilized crested wheatgrass and resulted in increased yields.

The need for improved forage yields within the dry Interior grassland regions of British Columbia has been recognized for many years. In 1974 an intensive project examining the effects of nitrogen (N) fertilization on rangeland seeded with crested wheatgrass (*Agropyron desertorum*[Fisch.] Schutt.) was begun. As an integral part of this study, micrometeorological data on evapotranspiration were collected. The purpose of these data was to observe differences in how water was used by fertilized and unfertilized rangeland.

The benefits of nitrogen fertilizer on seeded and natural rangeland have been discussed by numerous authors. Sneva et al. (1968) found higher yields, increased seed heads, and more rapid maturity on fertilized crested wheatgrass range. Studies on the effects of fertilizer on the water use characteristics of rangeland grasses are controversial because not all were made in the same way. Some measure the amount, others the rate of water use. Smika et al. (1965) found that seasonal water use by nonirrigated fertilized native range was not significantly different from that of unfertilized range. Similarly, Lauenroth and Sims (1976) noted that in Great Plains grasslands, N fertilization did not increase the amount of seasonal soil water used but it

may affect the rate of water use. In addition, Sneva et al. (1958) observed that water use for fertilized crested wheatgrass was increased over unfertilized at early stages of development.

Viets (1962) recognized that fertilizer treatments increased water use efficiency (ie. the ratio of dry matter yield to water evapotranspired) of crops grown under dryland conditions. Similar results were observed by Bleak and Keller (1974) while studying fertilized crested wheatgrass. These authors estimated actual evapotranspiration (E) by the water balance method using measurements of soil moisture and precipitation.

The need for accurate measurements of E to explain the effects of fertilization on rangeland is evident from the work of Wight and Black (1972). These authors suggest that "water—as an immediate requirement for plant growth—does not limit production on rangeland ecosystems to the extent that nutrient availability does." Consequently, the purpose of the present paper is to accurately measure differences in the actual evapotranspiration and water use efficiency over a growing period, from adjacent fertilized and unfertilized crested wheatgrass test sites.

Materials and Methods

The experimental site was on an Orthic Black Chernozem soil (Canada Soil Survey Committee, Sub-Committee on Soil Classification 1978) at an elevation of 1,000 m approximately 13 km south of Kamloops. This soil is believed to be equivalent to a Typic Haploboll (U.S. Dep. Agr. 1975) with the following selected characteristics; 15 cm loam over 35 cm gravelly clay loam over compact gravelly clay loam glacial till; 2.3% C in top 15 cm; available water capacity (–0.3 to –15 bars percentage for 0–50 cm depth range 10 cm water, for 0–100 cm depth range 18 cm water. The data used in this study were collected during the summers of 1974 and 1975. The crop investigated was crested wheatgrass—an extremely drought-tolerant species. The study area had been seeded about 16 years earlier and the stand was well established and in excellent condition. In the spring of 1974 the plot with an area of 12 ha was divided, and a 3.2-ha block was fertilized with 150 kg/ha elemental nitrogen applied as ammonium sulphate-urea.

Soil moisture data were determined gravimetrically, and soil water potentials were measured using a Wescor HR-33T Dewpoint microvoltmeter and PT 51-10 thermocouple psychrometers. These soil data were collected concurrently at depths of 2.5, 10, 20, and 50 cm. Yields were measured by clipping all plant material in 1 m² at 5 cm above ground, oven drying, and weighing. The soil and yield data were obtained at three replicated locations, within each of the fertilized and unfertilized blocks, and averaged. These data were collected over the growing season approximately every 10 days.

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The technical assistance of Dr. R.G. Wilson, Dr. T.A. Black, Mr. D. Evans, and Mr. P.J. Smith is gratefully acknowledged.

The research is a cooperative investigation of the B.C. Min. Environ., Resource Analysis Branch, and Agriculture Canada, Res. Sta., Kamloops (Agr. Can., Kamloops, Contribution No. 272).

Manuscript received February 20, 1978.

Actual evapotranspiration was obtained using the energy balance approach shown in (1).

$$R_N = \lambda E + H + G \dots (1)$$

where R_N = net radiation flux
 λE = latent heat flux
 λ = latent heat of vaporization
 E = actual evapotranspiration
 H = sensible heat flux, energy used in heating or cooling the air without any change of state taking place
 G = soil heat flux

Equation (1) was transformed using the Bowen ration, β , of sensible heat flux (H) to latent heat flux (λE).

$$\beta = \frac{H}{\lambda E} \dots (2)$$

Substitution of $\beta \lambda E$ for H in (1) gives:

$$\lambda E = (R_N - G) / (1 + \beta) \dots (3)$$

Sargeant and Tanner (1967) showed that (2) could be solved in terms of the wet and dry bulb air temperature gradients ΔT_W and ΔT_D respectively, so that (2) becomes:

$$\beta = [(S/\gamma + 1)(\Delta T_W / \Delta T_D) - 1]^{-1} \dots (4)$$

where S = slope of the saturation vapour pressure curve
 γ = psychrometric constant

In this study the temperature gradients were obtained using a psychrometric apparatus similar to that described by Black and McNaughton (1971), with a sensor separation of 0.5 m. The lowest sensor was positioned approximately 0.5 m above the crop canopy. A complete description of the instrumentation is provided in Williams et al. (1978).

The actual evapotranspiration (E) data collection periods were June through August 1974 and July through August 1975. When weather allowed, the energy balance measurements were collected for a period of from 2 to 5 days on one test block (fertilized or unfertilized) and then immediately alternated for 2 to 5 days to the adjacent block. The energy balance equipment was operated for three such periods in 1974 and 2 in 1975. In both years long periods of inclement weather made operation of this electronic equipment impractical.

Results and Discussion

Figures 1a and 1b show a plot of $\lambda E / (R_N - G)$ vs R_N for the unfertilized and fertilized test blocks, respectively. The term $\lambda E / (R_N - G)$ represents the proportion of the R_N available at the surface which is used to support evapotranspiration. Wilson and Rouse (1972) have used the ratio of $\lambda E / (R_N - G)$ as an indirect measure of soil moisture stress. When this ratio is high, in excess of 0.84, soil moisture is not limiting. In our research the ratio was found to be less than 0.84 on all occasions, indicating moisture stress. The slope of the regression line in Fig. 1a shows that as R_N increases, the proportion of energy used in evapotranspiration is reduced. This result indicates that although the unfertilized plants are extracting water from the soil at time of high evaporative demand, stomatal closure is occurring so that the increased demand cannot be maintained.

Data for the fertilized block (Fig. 1b) show that when R_N values are low the energy used in evapotranspiration is very low. Further, as R_N increases the ratio of $\lambda E / (R_N - G)$ remains almost constant. These low values of the proportion of energy available for evapotranspiration are indicative of a severely limited supply of soil moisture. (The circled data point was omitted from the regression as it was observed during heavy rain and was considered not representative.)

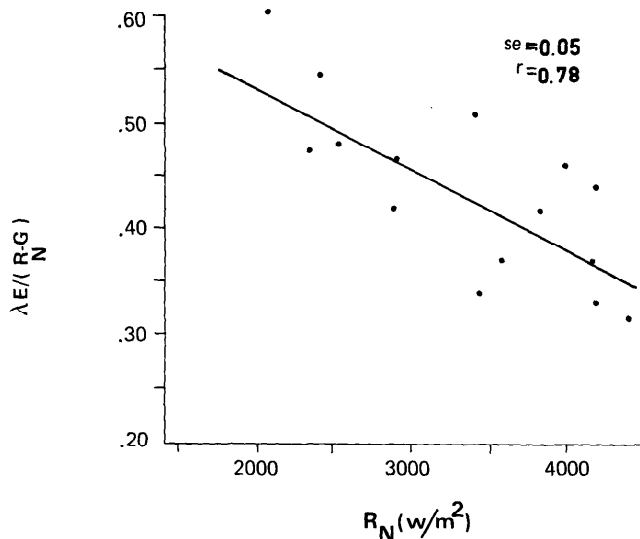


Fig. 1a. Ratio of energy used in evapotranspiration, $\lambda E / (R_N - G)$ vs net radiation R_N (watts per square metre), unfertilized.

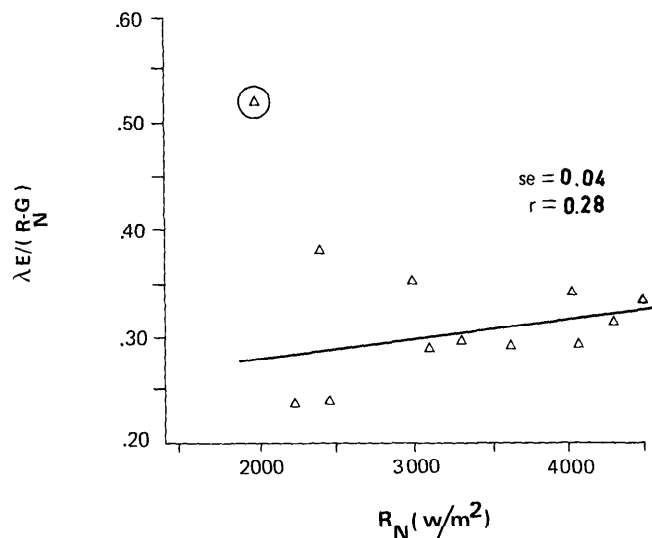


Fig. 1b. Ratio of energy used in evapotranspiration, $\lambda E / (R_N - G)$ vs net radiation R_N (watts per square metre) fertilized.

A comparison of Figures 1a and 1b indicates that in general a higher proportion of energy is used in evapotranspiration on the unfertilized block than on the fertilized in the period after rapid spring growth. The increased evapotranspiration of the unfertilized site is further evident in the August 1974 data (Fig. 2). The soil water potential data (Fig. 3) indicate that the fertilized crop was under more severe water stress than the unfertilized grass, a fact which is consistent with the lower rate of evapotranspiration over the fertilized plot at this time of the year. The yield data (Fig. 4), in contrast, indicate that the fertilized crested wheatgrass grows much more rapidly than the unfertilized early in the season, with the trend continuing to a lesser degree throughout the season. The soil water potential curves tend to verify this growth pattern. Rapid depletion of the fertilized plot's soil water occurred in the early part of the season when the soil was near field capacity. After this initial rapid extraction, the soil water potential curves for both plots parallel each other for the remainder of the season. At the end of the season, the fertilized plot has much lower soil water potential indicating that it is drier. This tends to verify the work of Black (1966) and Sneva et al. (1958), who noted that soil water was used more

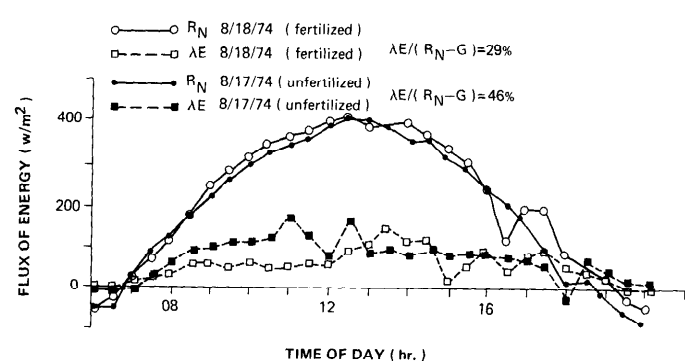


Fig. 2. Net radiation, R_N , and actual evapotranspiration AE , expressed as energy fluxes (watts per square metre), on consecutive days over an unfertilized and fertilized test site.

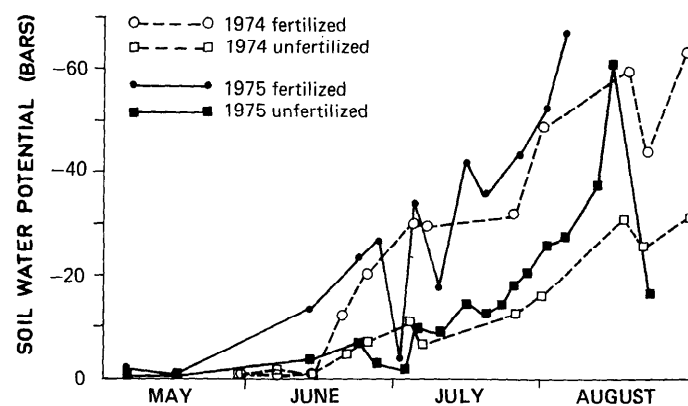


Fig. 3. Seasonal variation in soil water potential at 10 cm.

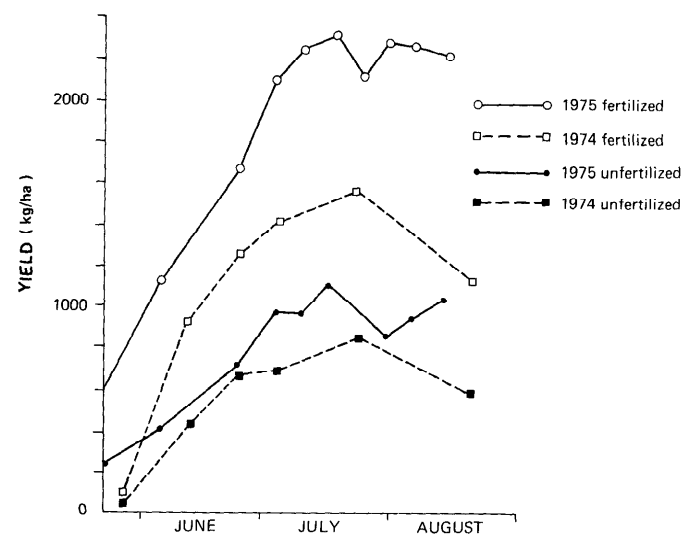


Fig. 4. Seasonal yield.

rapidly by fertilized grasses early in the season when water was not limiting.

Daubenmire (1972) noted that bluebunch wheatgrass (*Agropyron spicatum*) depleted the upper 20 cm of soil moisture by mid-May. Examination of our data indicates that the soil water potential decreased rapidly in May and early June. Unfortunately, energy balance data could not be collected during this critical period due to inclement weather and electronic difficulties.

The possibility that micrometeorological discrepancies between the two experimental blocks were responsible for the differences in evapotranspiration was examined. The gently sloping (U.S. Dep. Agr. 1951) terrain was slightly steeper on the fertilized block than on the unfertilized. This slope difference accounts for solar energy increase to the fertilized block during the growing season of less than 3% (Frank and Lee 1966). Soil water potential data showed that spring soil water, though not at field capacity, was virtually identical at both sites (Fig. 3). Consequently, the disparity in water use efficiency is attributable to the fertilizer application, not to microsite influences. Also, the increased water use early in the season did not result in any water shortage for fertilized crested wheatgrass in the following spring. The total seasonal water use on both test blocks, based on percent soil moisture at the end of August, was virtually identical. For example, the soil moisture at 10 cm in late August 1974 was 9.7% and 7.5% on the unfertilized and fertilized test sites respectively. As is shown in Figure 3, this slight difference in soil moisture resulted in a large difference in soil water potential. Data for 1975 and unpublished data for 1976 and 1977 indicate that winter recharge was similar in the fertilized and unfertilized soils. These data confirm the belief of Wight and Black (1972) that native nutrient cycling appears inadequate to supply nutrients at rates needed to maintain potential production levels demanded by the climate. This demonstrates the importance of having adequate nutrients at the beginning of the growing season when the rate of growth is high.

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Detecting Depth and Lateral Spread of Roots of Native Range Plants Using Radioactive Phosphorus

PAT O. CURRIE AND FREDERICK L. HAMMER

Abstract

Radioactive phosphorus (P^{32}) was used to measure root depth and lateral spread of four native plant species which had been subjected to heavy grazing for many years. Compared with root excavation measurements from an earlier study on the same area, rooting depths of all species tested were found to be quite similar by the two methods. Lateral spread differed substantially, however. Roots were found to have a greater lateral spread by the P^{32} estimate. The isotope method using autoradiography was found to be a sensitive method of determining depth and lateral spread of *in situ* plant roots in a mixed plant community.

A number of investigators have used radioactive phosphorus, P^{32} , to determine plant rooting characteristics (Aebersold 1953). Mathis et al. (1965) evaluated growth, activity, and varietal differences in cotton, corn, peanuts and tobacco roots using a tracer technique. Root growth of sorghums was measured by McClure and Harvey (1962) by use of radioactive phosphorus. Nye and Foster (1961) in Ghana determined the relative uptake and use of several short-term annual and perennial plants from various root zones using labelled P^{32} . Boggie et al. (1958) in Scotland use radioactive tracers to investigate plant root systems growing in peat and mineral soils. The methodology was found very useful in both soil types, and they suggested that P^{32} could be used to determine maximum rooting depth of each species composing a community. They also suggested it could be adapted for determining lateral spread of root systems. Their work was based on placement of P^{32} at different levels within the soil of four different grassland communities and measuring the specific activity of P^{32} uptake by each species. A modification of this technique was used in the present study to determine depth and lateral spread of roots of four major species in the ponderosa pine-bunchgrass type of Colorado. Results are compared with those for a root excavation technique used by Schuster (1964) from a study made on the same heavily grazed experimental sites.

Study Area

The work was conducted at the Manitou Experimental Forest 45 km northwest of Colorado Springs, Colo., at approximately 2,375 m elevation. Annual precipitation in this area averages about 400 mm

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Manuscript received March 23, 1978.

with nearly three-fourths occurring during the spring and summer growing season, from April through August. Soils are derived from Pikes Peak granite and they are a sandy loam or sandy clay loam with low fertility and moderate amounts of organic matter. These soils are porous when wet but very hard when dry.

Vegetation is characteristic of the ponderosa pine-bunchgrass type of the central and southern Rocky Mountains. It is characterized by a complex of plant communities with open grassland parks interspersed among irregular stands of ponderosa pine (Currie 1975). The most important forage species are Arizona fescue (*Festuca arizonica* Vasey) and mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.). Other abundant species include fringed sagebrush (*Artemisia frigida* Willd.), blue grama (*Bouteloua gracilis* (H.B.K.) Lag.), pussytoes (*Antennaria* spp.), and sedges (*Carex* spp.).

Arizona fescue and mountain muhly produce the most forage and cover on ungrazed areas, but both are reduced by continued, season-

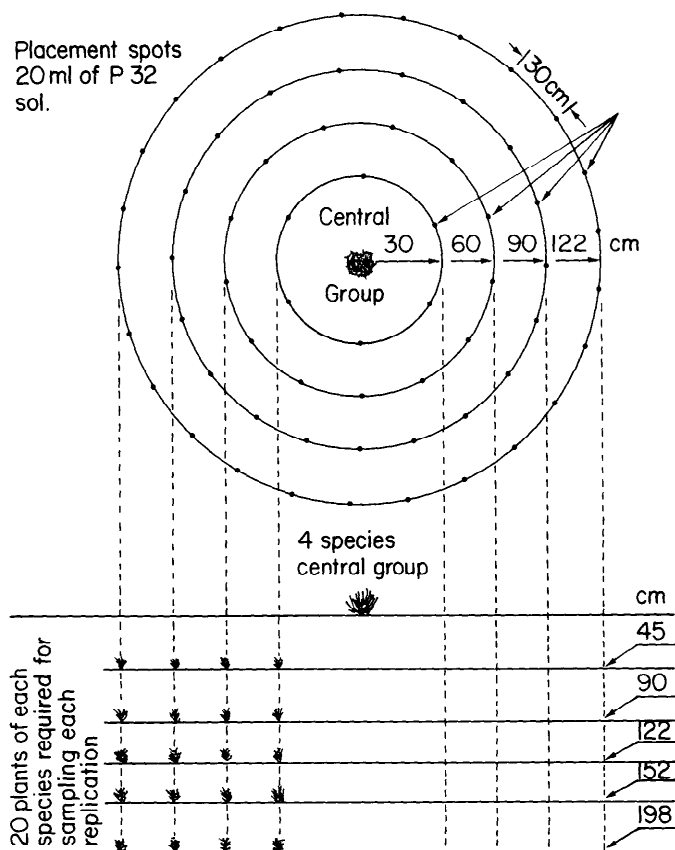


Fig. 1. Schematic diagram of drill hole arrangement for placement of P^{32} . Holes were drilled to one specific depth and concentric circle size around a closely associated grouping of four plant species at each site.

long grazing. The less desirable blue grama and fringed sagebrush become more abundant on heavily grazed ranges. The pastures used in this study had been grazed heavily since 1941. Effects of this grazing treatment on plants and animals are discussed in detail by Smith (1967). Specifically, pasture 1 described in this earlier research was used as the site for the present study.

Study Methods

Root study locations were confined to the open grasslands away from the direct influence of ponderosa pine. Each site selected had four species, Arizona fescue, mountain muhly, blue grama, and fringed sagebrush, growing in very close proximity to one another, usually within an area of 15 × 15 cm. Three replications were established, and each replication included 20 sites. Each site had holes drilled around the central plants at one of five depths and four lateral distances out from the plant grouping (Fig. 1). Thus, 240 plants, or 20 of each species in each replication, were required to sample all depths and lateral distances. For any given depth and distance, 4-cm diameter holes were drilled at 30-cm intervals surrounding the central plant grouping. Placement access holes were drilled into the soil using a pickup mounted, commercial soil auger. Soil was saved and replaced in each hole following the isotope placement.

Isotope material was injected using the continuous pipetting instrument described by Loewenstein (1965). Treble superphosphate in water was used as the carrier, and 20 ml of P^{32} solution was injected in each placement hole. The labelled P^{32} used was potassium dihydrogen phosphate ($KH_2P^{32}O_4$). It had a specific activity of 0.003 millicuries (.003 mc) per ml.

Care was exercised in lowering and lifting the probe to avoid touching the sides and contaminating soils above the desired placement levels. The probe was always moved outside the ring of placement holes to avoid an accidental drip onto plants to be monitored. An additional one-way Luer-Lok¹ connector was installed below the syringe and above the injection probe described by Loewenstein (1965). This safety feature did not permit leakage during movement from hole to hole. Also, the syringe was kept in an upright position when being moved to avoid any dripping and contamination.

Starting 12 days after the initial injection, plant crowns and leaves were monitored with an end window Geiger-Muller (G.M.)¹ counter to determine if P^{32} was being translocated. Because some roots might have been cut by hole drilling, monitoring with the G.M. counter was continued for several of the 14.3-day half-lives of P^{32} . It was assumed that new roots could move into the phosphorus banded zone, and this activity could be detected if the P^{32} activity remained sufficiently high. In this interim period, additional radioactivity tests on aboveground parts were made using autoradiography on nonscreen x-ray film. A few leaves, culms, or stems of each species were clipped to crown level. These samples were placed on sealed individual packets of x-ray film and allowed to expose in the laboratory for 12 hours. The film was then developed to determine if photons from the radioactive phosphorus had exposed the film.

Results and Discussion

Autoradiography was found to be much more sensitive than field monitoring using a G.M. counter. As shown in Figure 2, Arizona fescue readily exposed the x-ray film, and the amount of plant material and radioactivity, except for illustrative purposes, was in excess of that needed for analytical comparisons. Autoradiography also avoided the problem of detecting radioactivity from more than one plant species in the mixed community, as was encountered in using the G.M. counter. Individual species and plant parts from all portions of the crown

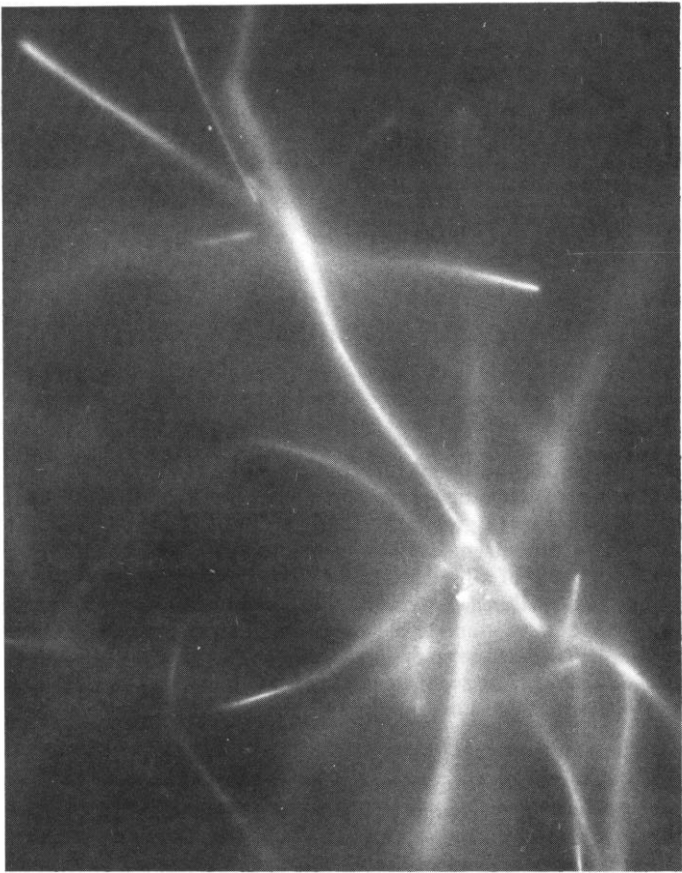


Fig. 2. Autoradiograph of Arizona fescue leaves and stems following translocation from roots. This method of radioisotope detection was found very useful and sensitive for evaluating depth and lateral spread of roots following translocation to aboveground parts. Aerial parts shown were from a site where P^{32} was injected to 46 cm deep and 30 cm out from the central grouping.

could be readily sampled and monitored for the translocation of the P^{32} . Thus, the problem of some roots picking up the phosphorus and translocating it to only one part of the crown or leaves in very small amounts did not occur, since samples were analyzed from all portions of each plant. Very small amounts of radiation, which only slightly exceeded background on a G.M. counter, also were readily detected.

All four species—Arizona fescue, mountain muhly, blue

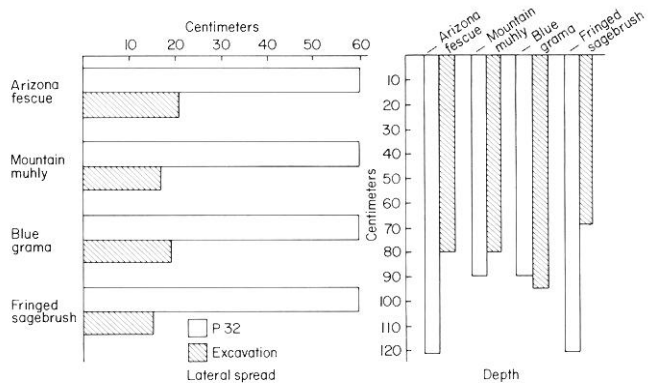


Fig. 3. Average lateral spread and average root penetration of four plant species on a heavily grazed range as measured with radioactive phosphorus and by the root excavation technique. (Adapted from Schuster 1964.)

¹ The use of trade names in this publication is for the information and convenience of the reader and does not constitute an official endorsement or approval of any product or service by the U.S. Department of Agriculture to the exclusion of others which may be suitable.

grama, and fringed sagebrush—had rooting depths and lateral root distributions which were quite similar and did not differ significantly. The maximum depth of penetration generally did not exceed 90 cm except for one individual plant of Arizona fescue and one fringed sagebrush. These two plants each reached a depth of 122 cm. These results on depth of rooting were quite similar to those of Schuster (1964) using the excavation technique (Fig. 3). The depths of penetration were also similar to those for a different species of fescue and other species growing on sand and sandy-loam soils reported by Boggie et al. (1958) in Scotland.

The lateral spread of roots, however, differed substantially from those determined by Schuster (1964) (Fig. 3). Roots of Arizona fescue, mountain muhly, blue grama, and fringed sagebrush were found to extend outward to about 60 cm by the isotope tracer technique. Occasionally, lateral spread reached only 30 cm for each of the four species, but at least one plant of each species had roots extending to the 60-cm lateral distance. These distances were somewhat less but more closely approximated lateral spread reported by Mathis et al. (1965) for plains bristlegrass. They reported a lateral spread of 76 cm for plants which had been clipped and about 100 cm for plants on unclipped plots.

The difference in measured lateral spread between the excavated and isotope monitored roots could be caused by several factors. The same plants and their root distributions were not measured during the same years or for exact comparative purposes in the two studies. Only one plane and a profile of usually less than 20 cm in thickness was sampled by the excavation-washing technique. Small segments of roots may have been cut off or lost in washing by the excavation technique; whereas, comparable roots remained intact or grew where the

isotope injection method was used. Other factors which gave an advantage to using isotope methodology included sampling from all planes within the soil in relation to individual plant crowns. The sample size for individual species was larger, which increased the opportunity to sample plants with greater root spread. This *in situ* method was nondestructive, which permitted sampling species in a competitive situation with root systems fully intact.

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Vegetation of the Willa Cather Memorial Prairie

ROBERT A. NICHOLSON AND MICHAEL G. MARCOTTE

Abstract

The purpose of this study was to analyze the interrelationships of the Willa Cather Memorial Prairie in terms of the characterizing species and types of vegetation. At each of 100 sample stand locations data were obtained on the 244-ha prairie in Webster County, Nebraska, to estimate percent basal cover and percent species composition. Estimates were analyzed quantitatively with the aid of vegetation ordination techniques, from which 15 vegetation types were discerned. Of the 15 types, two accounted for over 40% of the stands: a Kentucky bluegrass (*Poa pratensis*)-buffalograss (*Buchloe dactyloides*)-blue grama (*Bouteloua gracilis*)-type and a Kentucky bluegrass-sideoats grama (*Bouteloua curtipendula*)-big bluestem (*Andropogon gerardi*) type. Two secondary types accounted for another 16% of the stands, while the remaining 44% of the stands were fairly evenly dispersed within nine other types. Uplands were predominately Kentucky bluegrass, buffalograss, blue grama, and Japanese brome. Sideoats grama, little bluestem (*Andropogon scoparius*), and Kentucky bluegrass dominated hillside stands. Most abundant in lowlands were Kentucky bluegrass, sideoats grama, Japanese brome, and big bluestem. Due to the abundance of Kentucky bluegrass, late spring burning was prescribed to improve the condition and productivity of the prairie.

The continuum concept of vegetation has the premise that "communities occurring along continuous environmental gradients change continuously with gradual change in the density of each species" (Poole 1974). The above idea was expressed by Ramenskylin 1910 (Sobolev and Utekhim, in Whittaker 1973). However, Gleason (1917, 1929, and 1939) was the first strong advocate of the continuum, or individualistic concept.

Most ecologists reportedly accept the continuum concept (Poole 1974); however, others envision communities to be sufficiently distinct from one another that they can be thought of as quasi-organism (Clements 1916; Tansley 1920). A somewhat more modulated view of communities recognizes that discernible community zones exist, while the flora of the earth exhibits a continuum (Daubenmire 1966). The placement of vegetation stands into classes has been referred to as the *classification* concept.

Among the first to base research on the continuum concept were Curtis and McIntosh (1951), Brown and Curtis (1952),

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This research was financially supported primarily by a grant from Woods Charitable Foundation through the Midwest Office of the Nature Conservancy, Minneapolis, Minnesota. Additional remuneration was also received from the Research Committee of the Graduate Council and the Department of Biological Sciences, Fort Hays State University, Hays, Kansas.

Manuscript received July 11, 1977.

Whittaker (1956, 1967), and Goodall (1963) in which some form of *ordination* was utilized. Ordination of vegetation was apparently first defined by Goodall (1954) as an arrangement of species or stands in a uni- or multidimensional order by individual values. Ordination may also be defined as "the arrangement of ecological entities in a spatial model with a relatively small number of axes, in order to reflect the relationships between these entities in terms of the variables characterizing them" (Maarel 1969). In practice the divergence between classification and ordination is not great (Greig-Smith 1964).

Various ordination techniques may be utilized to arrange species or stands either directly or indirectly along an axis. The techniques used herein were of the indirect category, and information from the ordination procedures was used to order the stands, then classify them into types as connoted by the definition of Maarel (1969).

The area of study consisted of a 244-ha tract of Mixed Prairie located in the loessial region of south-central Nebraska (T. 1N, R. 11W, Sec. 35; 9.6 km south of Red Cloud, Webster County). It is bordered on the south by the Kansas state line and on the east by U.S. Highway 281. The Willa Cather Memorial Prairie consists of uplands that vary from level and gently sloping to steep topography on deep, silty soils, that developed from material derived from chalky limestone. The Geary-Holdrege-Kipson is the major soil association. Weaver and Bruner (1948) and Hopkins (1951) studied the vegetation of the loess hills in the central part of Nebraska. Remnant vegetation of the loessial region in southern Nebraska was characterized by Hulett et al. (1968) and Nicholson and Hulett (1969).

The Soil Conservation Service was asked to perform a range inventory in June 1976 in which two range sites were classified: silty (120 ha) and shallow limy (124). Range conditions for the silty and shallow limy sites were conservatively rated at 1.1 AUM/ha (fair) and 1.2 AUM/ha (good), respectively, for a total carrying capacity of 281 AUM.

Arithmetic means were calculated from weather data obtained between 1921 and 1950 at Red Cloud, Nebraska (National Oceanic and Atmospheric Administration 1974). The mean monthly low temperature of -3.2°C occurs in January; the mean monthly high temperature of 26.6°C occurs in July. The mean annual temperature and precipitation are 11.7° and 58.37 cm, respectively. June is the month with the highest mean monthly precipitation total, with 10.16 cm; January has the least monthly mean with 1.47 cm. The most frequent date of last spring freeze is May 1, whereas the first fall freeze is most often October 4; thus the mean growing season is 156 days.

In 1974, the study area was purchased by the Nature Conservancy as a memorial to Willa Carther; and during the 1975 and 1976 seasons, livestock grazing was discontinued. This study and several others were conducted to establish baseline ecological data to aid in future management and to allow documentation of vegetation changes. Resampling is tentatively scheduled for 1980, following several seasons of grazing, burning, and rest.

Methods

Field sampling encompassed mid-May through August 1975. Using the modified step-point method of Owensby (1973), 150 step-points were taken to obtain percent of basal cover and percent species composition at each of 100 stand locations.

Three different vegetation ordination techniques were initially utilized in this study (Marcotte 1976 a). These included the polar ordination (PO) technique of Bray and Curtis (1957); geometric ordination of Swan et al. (1969); and principal component ordination (PCO) of Goodall (1954), Dagnaliev (1960), Orloci (1966), Austin (1968), and others. For each of the three ordination techniques, one ordination based on percent species composition and one based on percent basal cover were performed. Values for the 18 most important species (> 0.3% species composition) were utilized as variables in the ordination procedures; hence the original data matrix was 18 by 100. Although intermediate results of the different kinds of ordinations were similar, species composition values using the polar ordination technique were judged most efficient; therefore vegetative interpretations reported herein were based solely upon the polar ordination. Gauch and Whittaker (1972), in a study comparing such techniques, advise the use of polar ordination because of its inherent accuracy and simplicity.

All numerical procedures were performed on an IBM 370/125 at Fort Hays State University Data Processing Center. For the polar ordination, a FORTRAN program—SIMCORD—was written (Marcotte 1976 b). Geometric ordination was computed with the FORTRAN program SDWORD (Hoag 1971). The FORTRAN program BMD01M was used for computing principal components (Dixon 1971).

Nomenclature used for the grasses was according to Hitchcock (1950), while Fernald (1950) was used for forbs. Voucher specimens were obtained and are on file in the Kearney Nebraska State College Herbarium (Dr. Ole Kolstad, Curator).

Results

Mean percent species composition for each of the 18 most important species over the entire area was calculated (Table 1). Kentucky bluegrass was the commonest of the seven most abundant grasses, followed by sideoats grama. Other species in descending order were: Japanese brome, buffalograss, little bluestem, blue grama, and big bluestem.

Species composition values for individual species were plotted on their respective stand locations on the ordination plane, one being drawn for each of the seven most abundant species of grasses. Each plane was then bisected with a single line, as straight as possible, so that stands with values greater than 10 were to one side of the line while stands less than 10 were to the other (Fig. 1). The tendency of certain stands to form such groups served as an objective basis for the classification of the stands into vegetation types. Intersecting bisect lines formed the boundaries of types on the ordination plane. From a practical point-of-view, this simplified the analysis of the vegetation and aided in visualizing ecological relationships. Means of species in the high and low sides of the bisect lines were calculated (Table 2). Using the bisect method, two primary, three secondary, and ten tertiary vegetation types were found. Of the ten tertiary types, one type had only one stand and two were

Table 1. Eighteen herbaceous species used in the data analysis.

Species common name	Species scientific name	Mean % sp comp
Kentucky bluegrass	<i>Poa pratensis</i>	27.6
Sideoats grama	<i>Bouteloua curtipendula</i>	17.7
Japanese brome	<i>Bromus japonicus</i>	8.6
Buffalograss	<i>Buchloe dactyloides</i>	8.6
Little bluestem	<i>Andropogon scoparius</i>	7.2
Blue grama	<i>Bouteloua gracilis</i>	6.2
Big bluestem	<i>Andropogon gerardi</i>	5.5
Sedges	<i>Carex</i> species	2.8
Tall dropseed	<i>Sporobolus asper</i>	2.5
Western ragweed	<i>Ambrosia psilostachya</i>	2.1
Scribner panicum	<i>Panicum scribnerianum</i>	1.5
Hairy grama	<i>Bouteloua hirsuta</i>	1.4
Western wheatgrass	<i>Agropyron smithii</i>	1.4
Missouri goldenrod	<i>Solidago missouriensis</i>	0.8
Field pussytoes	<i>Antennaria neglecta</i>	0.6
Sand dropseed	<i>Sporobolus cryptandrus</i>	0.5
Louisiana sagewort	<i>Artemisia ludoviciana</i>	0.3
Slimflower scurfpea	<i>Psoralea tenuiflora</i>	0.3

imaginary (Fig. 1). The mean species composition values for each of the most common forage species were calculated for each of the vegetation types; however a simplified form of the table was constructed to further clarify the character of the vegetation (Table 3). Six types were dominated by four of the seven species, seven types by three species, and two by two.

Types one through five contained stands in which the mean of the composition values for the blue grama was high (13.5%), while below the bisect line that separated blue grama types from the remainder of the stands, the mean for blue grama (3.3%) was low (Fig. 1, Table 2). Type one represented the extremes of both ordination axes and was predominately Kentucky bluegrass, buffalograss, and blue grama (Table 3). Type two, which was not found on the prairie, would have had a fourth dominant, sideoats grama, in addition to those of type one. Type three, also imaginary, was small and different from type two in that big bluestem would have replaced buffalograss. Type four was represented by only one stand in a small area of ordination. Types four, five, and six were defined by a bisect line that represented the stands with low values of Kentucky bluegrass,

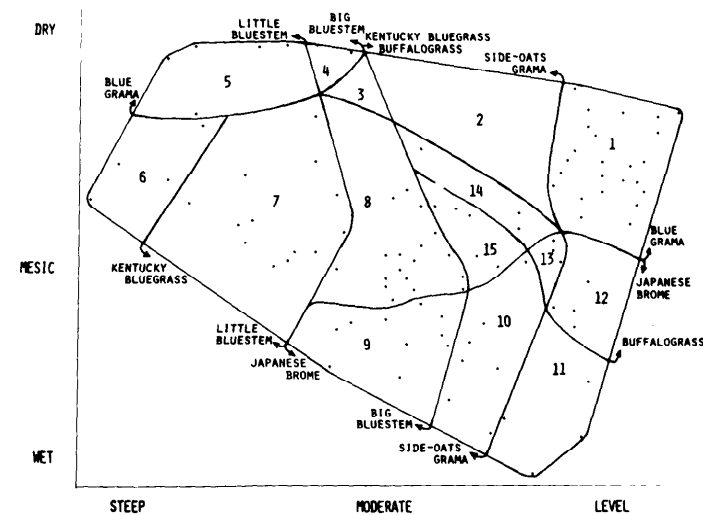


Fig. 1. Vegetation types are numbered 1-15. Dots indicate locations of 100 sample stands on the X (horizontal), Y (vertical) ordination. Bisect lines terminate with arrow directed toward the "high" side of the line and the species indicated. Levels of environmental gradients are indicated on ordination axes.

Table 2. Mean species composition values for stands on high and low sides of ordination bisect lines.

% comp.	Big bluestem	Little bluestem	Sideoats grama	Blue grama	Japanese brome	Buffalo-grass	Kentucky bluegrass
High	9.7	23.3	23.6	13.5	17.6	19.2	30.2
Low	1.1	2.8	5.7	3.3	5.4	2.6	2.9

while the mean for the stands to the right of the line was high. Type six represented the low extreme of the X-axis, and the left-most stand located there had the highest value of little bluestem of any stand.

Stands in types five, six, and seven had a high mean for little bluestem, while to their right, the mean of the remaining stands was low (Fig. 1 and Table 2). Big bluestem was found in abundance in types three through nine. In addition to big bluestem, types seven, eight, and nine were dominated by Kentucky bluegrass and sideoats grama. Japanese brome was abundant in types nine through 13; the top-most limit of these types was the bisect line for Japanese brome. The lower-most stand of the ordination plane was a stand that had the highest value for Japanese brome. Types 11, 12, and 1 were the only types in which sideoats grama composition was low. The area defining buffalograss abundance included types 1, 2, 12, 13, and 14 (Fig. 1, Tables 2 and 3).

Lines were also drawn on an ordination surface to illustrate groups of like topographic class: (1) upland, (2) hillside, and (3) lowland (Fig. 2). Upland stands tended to be most homogenous, while lowland and hillside stands were more scattered on the ordination surface, indicating a wider variety of types of vegetation in those classes. Superimposition of the topographic ordination (Fig. 2) over the types of vegetation (Fig. 1) revealed the relationships of the vegetation types to the topography.

Discussion

Types one and eight were called the primary vegetation types of Willa Cather Memorial Prairie, representing 43 of the 100 stands. The two types were quite different from one-another; however, but both had a high mean value of Kentucky bluegrass (>30%). On the plot of topographic classes, it was found that type one was exclusively found on the uplands and could

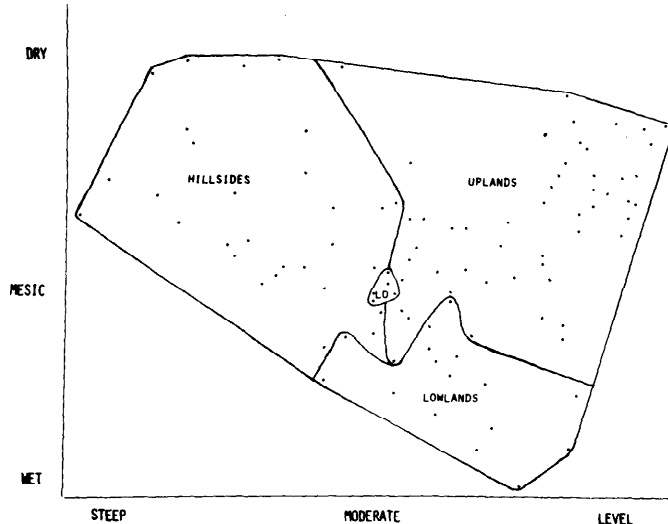


Fig. 2. Topographic classes of stands are indicted on ordination surface. Categories of environmental gradients are indicated on ordination axes.

therefore be expected to best characterize upland vegetation. Conversely, type eight had about equal numbers of stands in all three topographic classes.

The plot of topographic classes allowed hypothesizing underlying environmental gradients for the first two ordination axes (Fig. 1 and 2). The horizontal axis was assumed to represent a slope gradient, the vertical axis a soil water gradient. The driest, flattest stands were to the upper right, in the general position of type one. Dry, steep sites were to the upper left, while wet, steep sites were irrational and naturally not encountered in the sampling. Level, wet sites described conditions of lowland sites and corresponded to types 8 through 11. As would be expected with any normally dispersed variable, most stands fell near the center of the ordination plane, i.e. average of intermediates with respect to environmental conditions.

Upland sites in the Mixed Prairie ordinarily are dominated by blue grama and buffalograss, with blue grama normally much more abundant (Albertson 1937, Weaver and Alberston 1956, Weaver and Bruner 1948, and Weaver 1965). In a study of remnant grasslands in the loessial region of southern Nebraska, Hulett et al. (1968) found the upland dominated by blue grama and big bluestem. The Willa Cather Prairie has a history of

Table 3. Vegetation types discerned from the ordination analysis vs high mean (+) or low mean (-) of the seven most abundant grasses.

Type	Big bluestem	Little bluestem	Sideoats grama	Blue grama	Japanese brome	Buffalo-grass	Kentucky bluegrass	No. stands
1	-	-	-	+	-	+	+	24
2	-	-	+	+	-	+	+	0
3	+	-	+	+	-	-	+	0
4	+	-	+	+	-	-	-	1
5	+	+	+	+	-	-	-	4
6	+	+	+	-	-	-	-	4
7	+	+	+	-	-	-	+	13
8	+	-	+	-	-	-	+	20
9	+	-	+	-	+	-	+	10
10	-	-	+	-	+	-	+	8
11	-	-	-	-	+	-	+	4
12	-	-	-	-	+	+	+	3
13	-	-	+	-	-	+	+	3
14	-	-	+	-	-	+	+	3
15	-	-	+	-	-	-	+	3

overgrazing, which may account for the abundance of Kentucky bluegrass, the presence of Japanese brome, and the greater abundance of buffalograss than of blue grama. Kentucky bluegrass increases under heavy grazing and annual bromegrasses invade, whereas buffalograss may increase and blue grama would be expected to decrease (Branson and Weaver 1953; Weaver 1968). In a study of ungrazed remnant vegetation in the loessial plains region, Nicholson and Hulett (1969) found the following mean percent species composition values for the following species: Kentucky bluegrass—0.0; sideoats grama—19.0; Japanese brome—0.0; buffalograss—3.0; little bluestem—17.2; blue grama—5.8; and big bluestem—39.0. Presumably, grazing is the main factor that is responsible for differences between the Willa Cather stands and the prairie remnants. The lowland types tended to be characterized by abundant Kentucky bluegrass, sideoats grama, big bluestem, and Japanese brome (Fig. 1 and 2). Lowland sites in Mixed Prairie have been reported to be dominated by big bluestem, sideoats grama, and western wheatgrass (Weaver and Bruner 1948; Weaver and Albertson 1956). An understory of Kentucky bluegrass may also be encountered (Weaver 1965). Hulett et al. (1968) found similar lowland components in their study of remnant grasslands. According to Branson and Weaver (1953), the loessial lowlands are the most preferred of all grazing sites. This preference was attributed partly to the abundance of big bluestem and partly to the succulence of vegetation occurring there.

Hillsides were generally not lacking in Kentucky bluegrass except due to insufficient soil water (Fig. 1 and 2). Blue grama appeared not to be slope limited, but buffalograss, little bluestem, big bluestem, and sideoats grama did. Japanese brome appeared soil water limited as did blue grama and buffalograss, while to a lesser extent this was true for Kentucky bluegrass, big and little bluestem. The lines that define the types with abundances of big and little bluestem and sideoats grama are relatively parallel and vertical. Big bluestem exhibited a relatively narrow tolerance range on the slope axis and a wider range in the soil water axis, although a few dry stands had an abundance of big bluestem. The line defining blue grama abundance tended to be more parallel with the slope axis; however, most stands of blue grama were on the level, few were on the steep slopes, and none were on the moderate slopes or wet sites.

Little bluestem seemed to be limited to the drier, steeper slopes. Before the great drought of 1933–1940, little bluestem and sideoats grama were dominant on hillside sites (Albertson 1937, Weaver 1965). The drought resulted in hillside sites which were predominantly sideoats grama, big bluestem, (which reportedly replaced little bluestem), little bluestem, and blue grama (Weaver and Bruner 1948, Weaver and Albertson 1956). In their remnant grassland study, Hulett et al. (1968) found the hillside compositions dominated by sideoats grama, little bluestem, blue grama, and big bluestem. Hulett and Tomanek (1969), in a study of remnant prairies on shallow limy range sites in north-central Kansas, found little bluestem to be the most abundant species, followed by big bluestem and sideoats grama. The shallow limy range site often has relatively steep slopes and therefore calcareousness of surface soils would probably be positively correlated with slope. However, not all steep slopes sampled were shallow limy.

Important hillside species in the Willa Cather Prairie corresponded to those found in the above studies, except for the abundance of Kentucky bluegrass. This may indicate that,

although Kentucky bluegrass has increased as a result of improper grazing, it is not as abundant on the hillside as on the upland. The original species compositions of the hillsides have apparently been maintained due to the preference of cattle to graze more level sites.

Types two and three, which were imaginary, were conspicuous in that no stands were located there. Apparently such an association could not occur due to environmental or inter-specific limits. This was surprising, in that area on the ordination allotted to the imaginary type two was rather large, hence allowing a reasonable probability that a stand could occur there. Environmentally, types two and three were considered rational, yet no stands were found in the sampling that were located on dry, moderate slopes (Fig. 1 and 2). Moderate slopes tended to be more mesic while the most level and most steep slopes were drier.

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Certification of Range Management Consultants

Applications must be submitted by *October 1, 1979*, to be considered for certification in 1980. Applications Forms and Procedures for Certification in 1980 are available by request to the Executive Secretary. The Procedures have been revised, especially to include more detail on eligibility requirements, and published in the April issue of *Rangelands*. The Certification Panel welcomes suggestions for further revision, which should be sent to the Executive Secretary.

The Effects of Grazing Intensity on Annual Vegetation

MICHAEL D. PITT AND HAROLD F. HEADY

Abstract

Pastures grazed by sheep at moderate and 1½-, 2-, and 2½-times the moderate stocking rate from 1969-1973 were analyzed for relative changes in cover, herbage productivity, and botanical composition. All four pastures were less productive in 1973 than in 1969, but exhibited similar trends in cover and botanical composition regardless of grazing intensity. Only grazing at 2½ times the moderate stocking rate produced a residual decline in productivity following 1 year of rest from the grazing treatment. However, this decline in productivity was managerially negligible compared to other stocking rates, and would probably disappear within 2-3 years in response to the overriding influence of annual weather, especially precipitation, patterns.

Hormay (1944) suggested that moderate stocking rates provided the best grazing technique in the annual type. Old vegetation left on the ground at the end of each grazing season would enhance soil fertility, provide progressively improved range condition, and ultimately promote high livestock weight gains. Grazing either greater or less than this moderate level would produce changes in both total herbage productivity and relative botanical composition. Heady (1958) postulated that grazing occurred first on taller plant species, thereby increasing the relative proportion of shorter plant species. Alternatively, complete elimination of grazing animals encouraged taller annual plants relative to short plant species. Talbot et al. (1939), Talbot and Biswell (1942), and Jones and Evans (1960) all found that exclusion of grazing animals quickly led to grass dominance, particularly taller species, such as ripgut (*Bromus rigidus*). Biswell (1956) held the opinion that this increase in ripgut occurred at the expense of true clovers (*Trifolium* spp.) and bur-clover (*Medicago hispida*), with plant succession proceeding from forbs to soft chess (*Bromus mollis*), to wild oats (*Avena* spp.) to ripgut.

Biswell (1956) hypothesized that the impact of grazing on botanical composition in the annual type operated primarily by altering the accumulation of mulch. Heady (1958, 1961) supported Biswell's hypothesis by demonstrating that mulch exceeding 700 pounds per acre in Northern California encouraged taller grasses such as soft chess and ripgut. With no mulch accumulation small, unpalatable forbs such as goldfields (*Baeria chrysostoma*), smooth cat's ear (*Hypochoeris glabra*), and owl's clover (*Orthocarpus erianthus*) proliferated. With small amounts of mulch, diminutive, low-forage-value grasses such as little quaking grass (*Briza minor*) and silver hairgrass (*Aira caryophyllea*) abounded. Annual fescues (*Festuca* spp.)

and nitgrass (*Gastridium ventricosum*) peaked in percent botanical composition with intermediate amounts of mulch, while filaree (*Erodium* spp.) was not significantly influenced by varying amounts of mulch.

The amount of mulch present during germination exerts a major influence on total herbage productivity as well as botanical composition. Hooper and Heady (1970), at the Hopland Field Station in Northern California, discovered that removing all mulch prior to germination drastically reduced subsequent forage production compared to sites where mulch was not removed. Importantly, a single manipulation stimulated this response, and a moderate amount of mulch produced maximum herbage productivity.

Although mulch influences botanical composition and herbage productivity of the annual type within a particular growing season, these differences are temporary and tend to persist only so long as the grazing and/or clipping treatments are maintained. At the San Joaquin Experimental Range, both Talbot and Biswell (1942) and Bentley and Talbot (1951) noted no pronounced, long-term effects in total yield as a result of grazing at both light and heavy stocking rates. However, these results cannot be readily applied to other areas in the annual type where forage production potentials are confounded by local seasonal variability and/or microsite differences (Biswell 1956; Heady 1961; Smith 1970). Rossiter (1966) concluded that such microsite variabilities accounted for the lack of quantitative data describing the long-term impact of stocking rates on productivity and botanical composition throughout much of the annual type. This paper provides data describing the residual impact of grazing on annual vegetation occurring in the coastal mountain ranges of Northern California.

Location and Methods of Study

The study was conducted at the Hopland Field Station located in Mendocino County in the central portion of the coast mountain ranges. The climate of the area is subhumid to humid mesothermal. The winters are mild with occasional frost in valley bottoms, and infrequent, light snow at higher elevations. The average annual rainfall is 89 cm with virtually no rain falling between June and September. Fog occurs frequently in valley bottoms during late fall, winter, and early spring, and occasionally during the summer. Average summer and fall temperatures range from 20-25°C (Pitt 1975).

The pastures used in this study were initially fenced in 1953 to investigate the impact of continuous versus rotational grazing on both animal performance and vegetational response (Pitt 1975). Beginning in 1961, these pastures enclosing approximately 11 ha each were calibrated to equalize grazing intensity. Equal grazing intensity among pastures S1, S2, S3, and S7 occurred when: (1) lamb weights at 120

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Manuscript received February 20, 1979.

days were similar in all pastures, and (2) equal ewe weight loss at the end of the dry period occurred in all pastures.

The following grazing treatments existed in the summer of 1962: S1, S3, and S7 contained 13 sheep, while S2 supported 20 sheep. These pastures operated on a yearlong basis throughout the calibration period during which time numbers of animals were adjusted in each pasture to obtain as near equal gains and losses as possible per individual among all pastures. This grazing intensity was on the heavy side of stocking so that animals were under stress and their weights reflected pasture effects rather than effects due to inherent properties of individual animals. The number of sheep in each pasture at the end of the calibration period in the summer of 1964 constituted a standard stocking intensity for all future experiments.

The study investigating effects of different grazing intensities on annual vegetation began in the 1968-1969 grazing season. The calibrated stocking rate continued in pasture S3, while 1½-, 2-, and 2½-times the previous calibrated stocking rates were introduced into pastures S1, S7, and S2, respectively. All pastures were grazed on a continuous yearlong basis with the same animals, insofar as possible.

Vegetation was sampled twice each year: once at the beginning of the growing season in the fall of each year, and again at the end of the growing season in June. Each pasture contained 24 sampling locations consisting of a 1-m diameter wire mesh enclosure and an outside stake. Each enclosure occurred in a homogeneous sampling unit approximately 8 m in diameter. Enclosure and associated outside stakes were moved prior to each fall sampling date to a different but vegetationally similar spot within this sampling unit. Changes noted in botanical composition or herbage productivity throughout the course of the study were therefore not the result of repeated sampling of the same location.

Herbage productivity of each pasture was estimated by clipping a square plot 0.099 m² in size (1 ft²) to ground level at each sampling location, while botanical composition, cover, and height of annual vegetation were estimated with 30 points taken with a 10-point frame. All of these parameters, both inside and outside the enclosures, were estimated at the June sampling date, while only outside herbage productivity was measured at the fall sampling date.

Vegetational Responses

Tables 1, 2, 3, and 4 summarize data collected in pastures S3, S1, S7, and S2, respectively. Only those values for ungrazed June vegetation are listed. Vegetational parameters measured in June, the end of the growing season, characterize the yearly response of annual vegetation to each associated animal stocking rate. Measurements in ungrazed vegetation characterize the carryover effect of stocking rate from one year to the next. Since the cages are moved each year, ungrazed vegetation reflects the residual impact of stocking rate 1 year following removal of grazing. Alternatively, measurements in grazed vegetation primarily reflect vegetational variability within a single growing or grazing season and may not indicate the impact of stocking rate over time. Ungrazed June vegetation in 1969 represents baseline values and not the result of any stocking rate treatments. Ungrazed June vegetation in 1973 represents values resulting from 4 years of stocking rate treatment followed by 1 year of rest.

Table 5 summarizes results from a two-way analysis of variance analyzing the impacts of stocking rate and yearly variability on herbage productivity, cover, and botanical composition. Ungrazed June vegetation in 1969 was not subjected to any grazing treatment. Therefore, only 4 years of data, ungrazed June vegetation for the years 1970 through 1973 inclusive, were used in this analysis. Many researchers have described the dramatic impact of yearly weather patterns on annual vegetation (Talbot et al. 1939; Bentley and Talbot 1951; Heady 1956; Heady 1958; Naveh 1967; McNaughton 1968; Hooper and Heady 1970; Murphy 1970; Duncan and Woodmansee 1975; Pitt 1975). These studies all indicate that observed trends in standing crop, cover, and botanical composition in annual vegetation may be the result of annual weather patterns as well as stocking rate treatments. Therefore, the impacts of stocking rate, yearly variability, and particularly the

Table 1. Average percent botanical composition, cover (%), and standing crop (g/m²) on pasture S3, 1969-1973. Grazed at the moderate stocking rate.

Plant species	1969	1970	1971	1972	1973
<i>Aira caryophylla</i>	10.5	10.9	13.6	28.4	29.5
<i>Avena barbata</i>	3.1	3.8	5.0	5.6	0.3
<i>Bromus mollis</i>	18.3	19.6	14.9	19.4	30.9
<i>Bromus rigidus</i>	1.3	3.1	0.0	2.1	3.7
<i>Bromus rubens</i>	1.8	1.5	0.0	1.3	0.5
<i>Festuca</i> spp.	3.5	6.9	2.5	7.4	4.4
<i>Gastridium ventricosum</i>	0.4	1.4	1.3	0.6	0.5
<i>Hordeum</i> spp.	1.3	0.0	0.0	0.0	0.0
Other annual grasses	0.4	2.8	2.6	1.4	1.7
Perennial grasses and grasslike plants	2.2	0.0	4.3	1.7	0.0
<i>Medicago hispida</i>	0.0	0.0	0.0	0.0	0.0
<i>Trifolium</i> spp.	12.7	7.2	12.6	3.8	12.1
<i>Vicia</i> spp.	0.0	0.0	0.0	0.0	0.0
Other legumes	1.8	5.3	4.0	2.6	2.9
<i>Baeria chrysostoma</i>	0.4	0.7	0.0	0.5	1.3
<i>Carduus pycnocephalus</i>	0.0	0.0	0.0	0.0	0.5
<i>Daucus pusillus</i>	5.7	1.5	3.6	4.1	2.2
<i>Erodium</i> spp.	20.0	18.3	11.7	8.5	3.0
<i>Geranium</i> spp.	0.9	0.6	0.5	0.3	0.0
<i>Hypochaeris glabra</i>	2.6	4.0	2.8	3.0	2.0
Perennial forbs	3.9	6.2	1.8	2.6	0.5
Other early annual forbs	6.6	2.3	10.2	6.7	3.7
Other late annual forbs	2.6	2.7	2.2	0.0	0.3
Cover	31.8	36.2	40.1	66.9	75.3
Standing crop	226.0	168.9	201.2	167.9	202.3

Table 2. Average percent botanical composition, cover (%), and standing crop (g/m²) on pasture S1, 1969-1973. Grazed at 1½ times the moderate stocking rate.

Plant species	1969	1970	1971	1972	1973
<i>Aira caryophyllea</i>	14.5	0.6	13.8	41.1	31.4
<i>Avena barbata</i>	0.8	0.0	0.4	1.3	0.0
<i>Bromus mollis</i>	20.0	33.2	12.2	19.2	22.4
<i>Bromus rigidus</i>	0.0	1.4	0.0	0.0	0.2
<i>Bromus rubens</i>	3.4	10.3	8.4	7.4	2.7
<i>Festuca</i> spp.	1.3	2.2	3.0	6.2	2.3
<i>Gastridium ventricosum</i>	0.4	1.3	2.4	1.6	0.7
<i>Hordeum</i> spp.	0.0	0.0	0.0	0.0	0.0
Other annual grasses	0.4	0.0	0.0	0.3	0.0
Perennial grasses and grasslike plants	0.0	0.0	0.0	0.0	0.0
<i>Medicago hispida</i>	1.7	1.4	1.0	0.0	1.9
<i>Trifolium</i> spp.	23.8	17.2	17.2	5.3	13.9
<i>Vicia</i> spp.	0.0	0.0	0.0	0.0	0.0
Other legumes	4.3	2.8	7.7	2.7	4.7
<i>Baeria chrysostoma</i>	0.0	0.0	0.0	0.0	0.0
<i>Carduus pycnocephalus</i>	0.0	0.0	0.0	0.0	0.0
<i>Daucus pusillus</i>	4.3	2.2	6.3	5.9	2.5
<i>Erodium</i> spp.	16.6	16.1	8.8	1.6	5.6
<i>Geranium</i> spp.	0.4	0.0	1.6	1.2	1.0
<i>Hypochoeris glabra</i>	0.8	1.7	2.6	1.0	2.0
Perennial forbs	0.0	0.0	0.0	0.0	0.0
Other early annual forbs	5.1	3.9	13.5	5.3	8.5
Other late annual forbs	0.4	0.0	0.0	0.0	0.0
Cover	32.6	32.1	34.8	57.2	66.4
Standing crop	119.4	108.7	122.7	83.9	92.5

interaction of stocking rate and yearly variability must be evaluated carefully. Stocking rates were calibrated in terms of animal response. Tables 1 through 4 indicate that standing crop and botanical composition at the beginning of the study in 1969 varied tremendously among pastures. Therefore, a statistically

significant result for the main effect of stocking rate may reflect inherent pasture differences rather than variable responses to stocking rate. Indeed, only statistically significant interactions between stocking rate and year suggest a long-term response of annual vegetation to stocking rates. This response has truly

Table 3. Average percent botanical composition, cover (%), and standing crop (g/m²) on pasture S7, 1969-1973. Grazed at 2 times the moderate stocking rate.

Plant species	1969	1970	1971	1972	1973
<i>Aira caryophyllea</i>	10.9	4.2	18.1	37.7	28.3
<i>Avena barbata</i>	0.3	0.0	0.3	0.4	0.0
<i>Bromus mollis</i>	11.3	18.7	3.9	11.0	12.7
<i>Bromus rigidus</i>	0.7	1.2	0.0	0.0	0.0
<i>Bromus rubens</i>	1.0	0.3	0.4	0.0	0.2
<i>Festuca</i> spp.	9.6	10.9	11.3	10.2	13.1
<i>Gastridium ventricosum</i>	2.0	0.8	4.4	6.6	1.0
<i>Hordeum</i> spp.	0.7	0.3	0.0	0.0	0.0
Other annual grasses	1.3	0.7	0.8	0.2	0.6
Perennial grasses and grasslike plants	0.3	0.0	0.7	0.5	0.5
<i>Medicago hispida</i>	2.6	1.3	4.8	0.2	1.3
<i>Trifolium</i> spp.	8.9	5.8	6.7	2.6	12.8
<i>Vicia</i> spp.	0.0	0.0	0.0	0.0	0.0
Other legumes	0.3	0.7	0.5	1.5	0.4
<i>Baeria chrysostoma</i>	3.3	1.8	0.8	4.3	4.2
<i>Carduus pycnocephalus</i>	0.0	0.0	0.3	0.0	0.0
<i>Daucus pusillus</i>	2.6	0.6	2.7	0.5	0.9
<i>Erodium</i> spp.	31.1	37.5	11.9	12.1	11.5
<i>Geranium</i> spp.	0.7	0.0	0.9	0.0	0.9
<i>Hypochoeris glabra</i>	5.6	4.0	6.3	6.1	4.0
Perennial forbs	0.7	0.0	0.0	0.2	0.2
Other early annual forbs	4.6	11.1	15.1	5.6	7.2
Other late annual forbs	1.3	0.0	0.5	0.2	0.0
Cover	41.9	39.3	38.7	73.6	83.5
Standing crop	361.6	260.4	274.4	182.9	198.0

Table 4. Average percent botanical composition, cover (%), and standing crop (g/m²) on pasture S2, 1969-1973. Grazed at 2½ times the moderate stocking rate.

Plant species	1969	1970	1971	1972	1973
<i>Aira caryophyllea</i>	4.1	12.6	22.6	45.8	34.5
<i>Avena barbata</i>	16.4	3.5	0.3	0.0	0.0
<i>Bromus mollis</i>	15.4	21.2	10.3	24.2	18.2
<i>Bromus rigidus</i>	2.7	0.2	0.7	0.0	0.0
<i>Bromus rubens</i>	6.5	0.0	0.6	0.3	1.0
<i>Festuca</i> spp.	6.5	11.5	12.9	11.0	7.5
<i>Gastridium ventricosum</i>	0.0	0.2	1.5	0.7	0.5
<i>Hordeum</i> spp.	0.0	0.0	0.0	0.0	0.0
Other annual grasses	2.4	1.4	2.1	0.4	0.7
Perennial grasses and grasslike plants	0.0	0.0	0.0	0.2	0.2
<i>Medicago hispida</i>	2.0	0.0	0.0	0.2	0.0
<i>Trifolium</i> spp.	15.7	12.9	12.8	3.3	10.6
<i>Vicia</i> spp.	0.0	0.0	0.0	0.0	0.0
Other legumes	3.8	8.8	5.2	1.2	3.2
<i>Baeria chrysostoma</i>	0.0	0.0	0.0	0.0	2.1
<i>Carduus pycnocephalus</i>	0.0	0.0	0.3	0.0	0.0
<i>Daucus pusillus</i>	5.1	0.2	4.3	0.9	3.5
<i>Erodium</i> spp.	14.0	22.7	9.5	3.5	7.7
<i>Geranium</i> spp.	0.7	0.0	0.9	1.4	1.3
<i>Hypochoeris glabra</i>	0.3	0.5	2.1	1.3	3.3
Perennial forbs	1.0	0.0	0.0	0.2	0.0
Other early annual forbs	2.7	3.3	11.9	4.0	5.8
Other late annual forbs	0.7	0.7	1.2	0.5	0.0
Cover	40.7	53.2	44.2	77.8	81.5
Standing crop	349.8	273.4	251.8	193.7	149.6

occurred only if the trends in ungrazed June vegetation differ among pastures throughout the course of the study.

Grazing Effects

Only five plant groups including standing crop, cover, nitgrass, burclover, and filaree produced interactions between grazing levels and year of treatment that were significant at $p < 0.10$. All other plant groups responded similarly to each grazing treatment throughout the study period.

Fig. 1 illustrates the impact of grazing intensity on total standing crop attained in June following 1 year of rest. Herbage productivity in pastures grazed at the moderate level (S3) and 1½ (S1), and 2 (S7) times the moderate stocking rate followed virtually identical patterns during each year of the study.

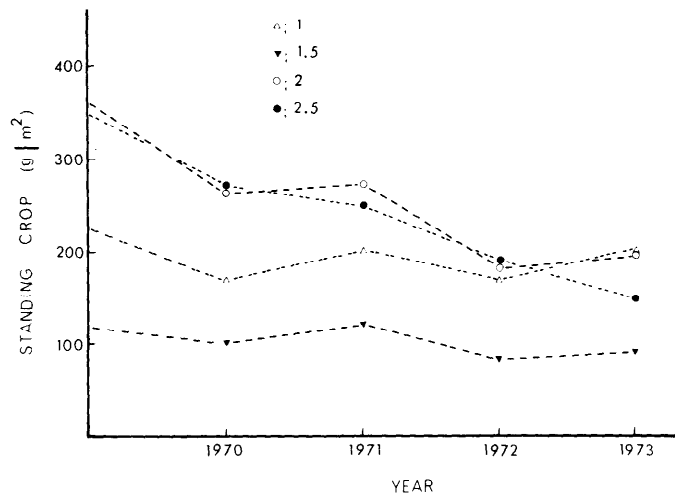


Fig. 1. Influence of moderate (1), 1½- 2-, and 2½-times the moderate stocking rate on standing crop (g/m²), 1969-1973.

Standing crop in all 3 pastures decreased from 1969 to 1970, increased the following year, declined from 1971-1972, and increased again following the final year of treatment. Only the grazing treatment at 2½ (S2) times the moderate stocking rate produced a downward trend in standing crop during all years of the grazing treatment. Pasture S2 was the most productive (394 g/m²) pasture in 1969, but supported only 149.6 g/m² in 1973. Pasture S7, grazed at twice the moderate stocking rate, experienced a smaller decline in productivity, falling from 361.0 g/m² in 1969 to 198.0 g/m² in 1973. Standing crop in the pastures grazed at both the moderate and 1½ times the moderate stocking rate remained approximately equal at the beginning and the end of the study. Herbage productivity in pasture S3 equaled 226.0 and 202.3 g/m² in 1969 and 1973, respectively, while pasture S1 supported 119.4 g/m² in 1969 and 92.5 g/m² in 1973. All four pastures were less productive in 1973 than they were in 1969. However, much of this decline in productivity probably resulted from poorer growing conditions at the end than at the beginning of the study. Pastures S3, S1 and S7 exhibited identical trends in standing crop regardless of grazing intensity, suggesting an overriding influence of changing weather patterns. Apparently only the very heavy grazing in Pasture S2, stocked at 2½ times the moderate stocking rate, produced a residual decline in standing crop following 1 year of rest from the grazing treatment.

Changes in herbage cover (Fig. 2) support this conclusion that only very heavy grazing produces residual impacts on annual vegetation. Yearly trends in percent cover, although significant at $p < 0.01$, were remarkably similar in pastures S3, S1, S7, and S2. Again, only pasture S2, grazed at 2½ times the moderate stocking rate, produced any relative reduction ($p < 0.05$) in percent cover as a result of grazing intensity. However, even this decline was unimportant in absolute terms

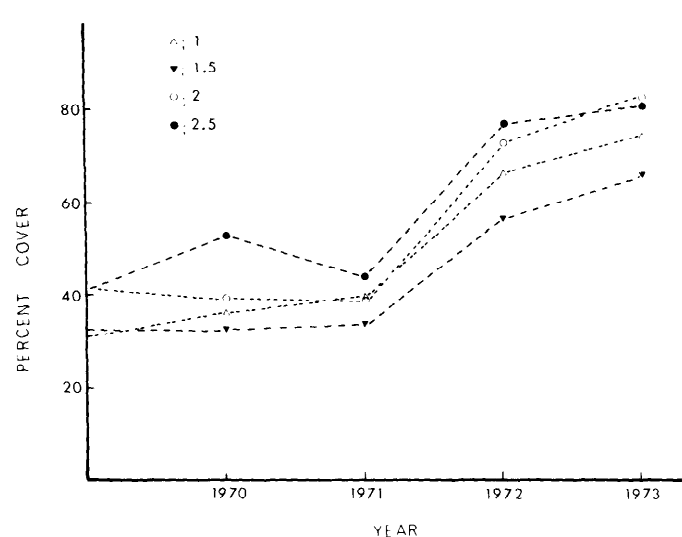


Fig. 2. Influence of moderate (1), 1½-, 2-, and 2½-times the moderate stocking rate on percent cover, 1969-1973.

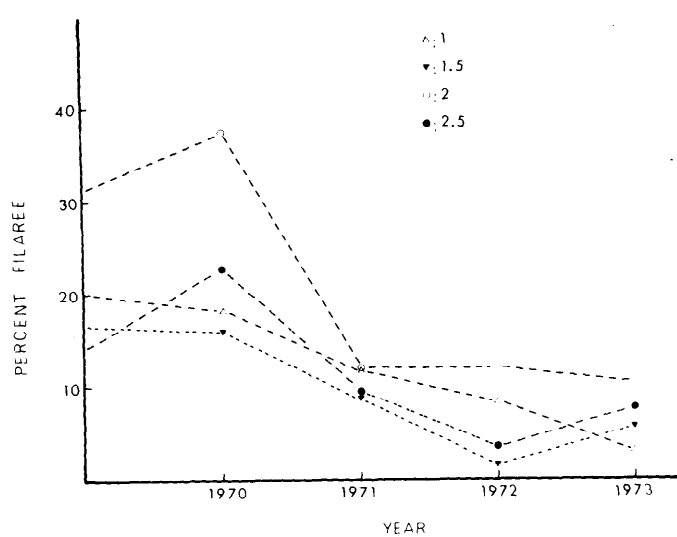


Fig. 3. Influence of moderate (1), 1½-, 2-, and 2½-times the moderate stocking rate on proportion of filaree (*Erodium* spp.), 1969-1973.

as cover in S2 increased from 40.7 to 85.5% during the study period.

Any changes in standing crop and percent cover must be associated with corresponding changes in botanical composition. Both nitgrass ($p < 0.01$) and bur-clover ($p < 0.10$ in Table 5) produced significant interactions between grazing intensity and yearly variability. However, nitgrass comprised only a very small portion of the vegetative cover, averaging 0.5, 0.7, 1.0, and 0.5% in June 1973, in pastures S3, S1, S7 and S2, respectively. The significant interaction for nitgrass resulted primarily from the exceptionally high value of 6.6% botanical composition in pasture S7 in June of 1972. However, this unique value for nitgrass probably arose from some factor other than grazing intensity, as all pastures supported small proportions of nitgrass both at the beginning and the end of the study.

Bur-clover, like nitgrass, comprised only small proportions of the vegetative cover in all pastures throughout the study period (Tables 1-4). Therefore, statistically significant interactions for these two plant species between grazing and year of treatment cannot explain the relative changes in herbage productivity and cover observed in pasture S2. These changes can be explained only by associated changes for plant species such

as filaree and soft chess, which composed significant portions of the total vegetative cover on the sheep/deer pastures.

Filaree, a successional plant species, commonly occupies disturbed or heavily grazed sites. Conversely, this plant species declines on undisturbed or lightly grazed areas where taller annual plant species are favored. These relationships are illustrated by Figure 3 ($p < 0.05$ in Table 5). Percent botanical composition for filaree declined in all four pastures from 1970-1972, indicating that filaree probably responded more to changing weather patterns than to different grazing intensities. From 1972 to 1973, however, filaree increased in all pastures except S3, which was grazed at the lightest stocking rate. Apparently, weather patterns during the last year of study initiated an increase in percent composition for filaree except in areas (pasture S3) where moderate grazing and relatively undisturbed conditions discouraged the growth of filaree.

In contrast to filaree, soft chess typically increases in response to undisturbed conditions and subsequent accumulating mulch. From 1970-1972, percent botanical composition of soft chess followed identical directional trends in all four pastures (Fig. 4). Like filaree, however, soft chess displayed different trends among grazing treatments during the last year of study. Only the heaviest stocking rate (pasture S2) produced a

Table 5. Summary of the impact of grazing intensity on botanical composition and standing crop at the Hopland Field Station, 1970-1973.

	Ai Ca ¹	Av Ba	Br Mo	Br Ri	Br Ru	Fes	Ga Ve	Hor
Stocking Rate (S)	***2	****	****	****	****	****	****	
Year (Y)	****		****	*			****	
S × Y			*		*		****	
	Ann G	Per G	Me Hi	Tri	Leg.	Ba Ch	Ca Py	Da Pu
Stocking Rate (S)	****	*	****	****	****	****		****
Year (Y)			*	****	*	***		***
S × Y			**		*			
	Ero.	Ger	Hy Gl	P Fbs	E A Fb	L A Fb	Cover	S. Crop
Stocking Rate (S)	****		****	****	***	****	****	****
Year (Y)	****	**			****	**	****	****
S × Y	***						***	***

¹ Symbols for plants and plant categories as given in Tables 1-4.

2 **** = significant at $p < 0.01$.

*** = significant at $p < 0.05$.

** = significant at $p < 0.10$.

* = significant at $p < 0.20$.

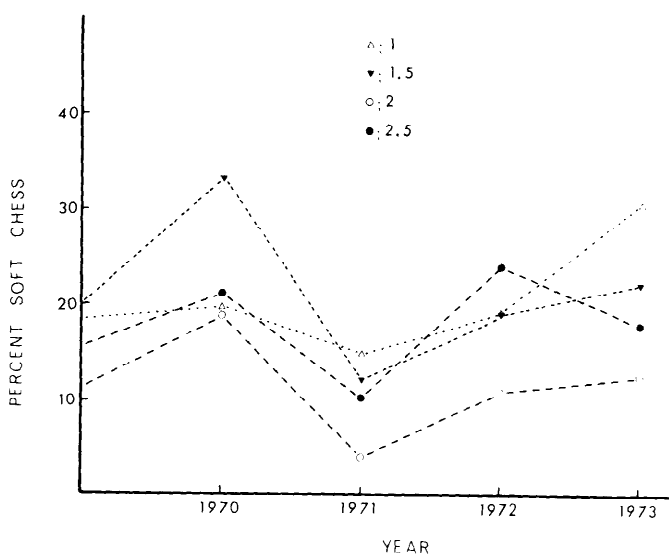


Fig. 4. Influence of moderate (1), 1½-, 2-, and 2½-times the moderate stocking rate on proportion of soft chess (*Bromus mollis*), 1969-1973.

decline in botanical composition for soft chess, which increased in all other pastures. Moreover, the most dramatic increase for soft chess for the period 1972-1973 occurred in the moderately grazed pasture S3, which produced the only observed decline for filaree during this same year.

Conclusions

Soft chess and filaree occupy climax and intermediate stages of plant succession, respectively. From 1972-1973 these two plant species displayed opposite trends in botanical composition as a function of earlier grazing intensity. Soft chess increased in response to moderate grazing pressure (pasture S3) but decreased in response to heavy grazing pressure (pasture S2). Conversely, filaree declined under moderate stocking while increasing under heavy stocking rates. These results indicate that extremes of grazing intensity can produce residual impacts on botanical composition of soft chess and filaree for at least 1 year following removal of grazing animals. These residual impacts are consistent with the successional stages of soft chess and filaree and may result from the influence of different levels of mulch on germination and subsequent growth. However, mulch accumulation as a function of grazing intensity does not exert as much influence on botanical composition as do variable weather patterns. From 1970-1972, both filaree and soft chess responded similarly among all four pastures regardless of grazing treatment. Thus, grazing intensity only infrequently exerted a 1-year residual impact on botanical composition. Even this residual impact, because of the more significant influence of annual weather patterns on botanical composition of annual vegetation, would rarely last 2 or 3 years.

These same conclusions also apply to cover and herbage productivity, which responded similarly among all four pastures throughout the study period. Although very heavy grazing apparently depressed forage production during the final year of study, absolute productivity differences between moderate and heavy grazing pressures remained managerially insignificant. Moreover, annual variability for both cover and productivity within each stocking rate was more pronounced than the relative differences between stocking rates. Therefore, the residual influences of grazing on cover and total forage production are negligible when compared to these same influences of annual weather patterns. Indeed, following only a single year of rest from grazing animals, both cover and forage production in all four pastures generally responded to annual growing conditions as if no previous grazing treatments existed. Finally, results from this study give further confirmation that the California annual grassland is tolerant to a wide range of stocking rates and degrees of herbage utilization.

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Application of an Herbivore-Plant Model to Rest-Rotation Grazing Management on Shrub-Steppe Rangeland

THOMAS A. HANLEY

Abstract

A graphical model of a discontinuously stable herbivore-plant system is used to demonstrate analytically relationships between the amount of rest, stocking rate, and seasons of use in rest-rotation livestock grazing management on shrub-grass ranges. All three of these components are important and their interaction determines the system's response. Important points applicable to management are enumerated.

The science of range management is based on an understanding of the interactive effects of plants and herbivores on long-term forage production and range condition. A livestock grazing management system is one of the chief means of manipulating herbivore-plant interactions in efforts to improve the range resource and ensure a sustained yield of goods and services. A variety of grazing management systems have been applied to various ranges (e.g., Anderson 1967; Valentine 1967; Heady 1970; Stoddart et al. 1975), but basically there are three major categories: (1) those based on continuous grazing, (2) those involving some type of deferment, and (3) those involving systematic rotation of the livestock. It is of prime importance that whatever management system is used must be tailored to the specific requirements of the range resource (Anderson 1967).

Rest-rotation grazing management, as championed by Hormay (1970; Hormay and Evanko 1958), involves the use of deferment and rest ("rest" means that a pasture is not grazed at all in a given year) along with a rotation of livestock from pasture to pasture. Based on the philosophy that plants must be allowed time to recover vigor following defoliation, it typically involves various combinations of resting a pasture for one or more years, deferring grazing until after seed maturity of specified "key" species, and season-long grazing. It is intended to promote the vigor and seedling success of forage species by rest and deferment, promote seed planting of forage species by the mechanical action of animal movement following deferment, reduce ill effects of repeated overuse of preferred areas (such as near water) that commonly occur with continuous grazing, and increase animal productivity as a consequence of increasing forage productivity.

Recently it seems that many misconceptions have developed concerning the applicability and successful design of rest-rotation grazing management systems. The need for a more general understanding of the applications of deferred and rest-rotation grazing management has been pointed out by

Hyder and Bement (1977). A better understanding of the dynamics of herbivore-plant systems should provide a stronger basis upon which to assess the consequences of a particular grazing management plan.

Considerable attention in the ecological literature has been given to analysis of predator-prey systems. Rosenzweig and MacArthur (1963) were first to show how graphical techniques, supplemented by mathematical analysis of the system behavior near equilibrium points, can be used to study the general stability properties of simple predator-prey systems. In a logical extension of the trophic relationships of predator-prey models, Noy-Meir (1975) has demonstrated a graphical analysis of herbivore (predator)-plant(pre) interactions. He described a simple model of grazing systems and analyzed its stability, seeking answers to the following questions: "(1) What are the conditions for a specific grazing system (a given animal with a given vegetation) to be stable at a constant 'stocking rate' (animal density)? (2) How does stability change with stocking rate? and (3) What is the relation between productivity, stability, and stocking rate?" It was found that in terms of system stability, five basic situations, or cases, could be distinguished.

The purpose of the present paper is to extend Noy-Meir's analysis of herbivore-plant systems in general to rest-rotation grazing management of shrub-steppe range in the Great Basin, U.S.A., in particular. Only one of his cases will be considered, that of a discontinuously stable system with two distinct non-zero steady states and liable to extinction. Though the assumptions of such models can rightfully be questioned, there is considerable empirical evidence that their use in range systems is justified (Noy-Meir 1975).

The Model

Analysis of stability is based on changes in vegetation biomass with respect to time:

$$\frac{dV}{dt} = G - C = G(V) - c(V)H,$$

where V =vegetation biomass per unit area, G =plant growth rate (biomass/time), c =consumption (intake) rate per animal, H =herbivore density, and C =consumption rate (by herbivore population at given H) per unit area. Herbivore density is assumed to be held constant at a given stocking level. The reader is referred to Noy-Meir (1975) for discussion of the implicit assumptions and a more detailed explanation of this and other cases.

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The author wishes to express his appreciation to Imanuel Noy-Meir of the Hebrew University of Jerusalem, Israel, for his stimulating ideas, helpful suggestions, and permission to use his figures.

Manuscript received February 5, 1978.

The shape of the $G(V)$ and $C(V)$ curves (Fig. 1) determines which of Noy-Meir's cases is appropriate for a given system. The vegetation parameter (V) for livestock grazing systems in the Great Basin represents tall perennial bunchgrasses characteristic of the region. These are species such as bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), needlegrasses (*Stipa* spp.), basin wildrye (*Elymus cinereus*), and Indian ricegrass (*Oryzopsis hymenoides*) (Franklin and Dyrness 1973). Shrubs and other vegetation are not included, and the model does not deal with interspecific competitive relationships among plants. It is assumed that perennial bunchgrasses will respond to the proper sequence of rest and grazing, and analysis is directed at the grass-herbivore interface only.

The general form of the $G(V)$ curve is well established for grasses (Donald 1961; Brougham 1955, 1956). The sigmoidal shape of the $C(V)$ curve determines that the system is of a discontinuously stable nature. Entirely different results would follow if a curve of another shape were used, and this model would not be appropriate. The sigmoidal shape of the $C(V)$ curve is appropriate for grasses on a shrub-grass range, because, as grass abundance decreases due to increasing herbivore grazing pressure, the shrub interspaces are depleted first, leaving surviving plants protected under the shrubby species (Tueller and Blackburn 1974); thus it becomes increasingly difficult for livestock to "search-out" these remaining individuals. The shrubs are therefore important as a structural feature of the environment in this model. The fact that these grasses are liable to extinction, given a large enough herbivore density (H), is commonly demonstrated by their absence in areas receiving concentrated livestock use, as near water sources (Robertson and Kennedy 1954).

The superimposition of the growth and consumption curves (Fig. 1) demonstrates the system behavior for a given herbivore

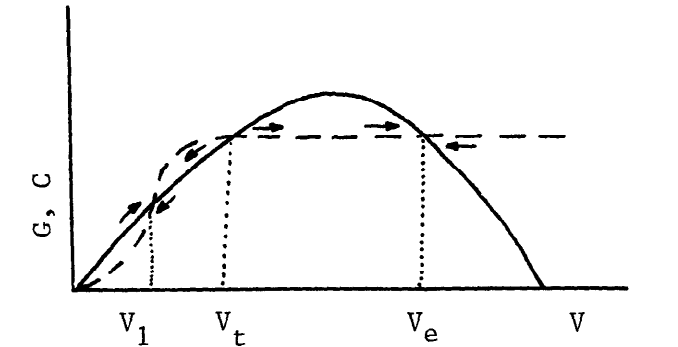


Fig. 1. Superimposition of $G(V)$ (solid line) and $C(V)$ (dashed line) curves at given H ; two equilibrium points (V_e and V_1) separated by a turning point (V_t). Redrawn from Noy-Meir (1975).

density (H). Intersections of the two curves are points of equilibrium. The direction of vegetation change surrounding an equilibrium point determines whether it is a stable equilibrium (from which small perturbations result in the system returning to the equilibrium point) or an unstable equilibrium (from which small perturbations result in the system moving toward a different equilibrium point). It is seen that there are two stable and one unstable equilibrium points in the present model (Fig. 1). Stable equilibrium points occur at V_1 (low level equilibrium plant biomass) and V_e (high level equilibrium plant biomass). (The intersection at $V=0$ is of course a third stable equilibrium point, extinction, from which there can be no change.) The unstable equilibrium point occurs at V_t (turning point of plant

biomass) and represents a critical threshold where a slight perturbation to the right will move the system to V_e , and a slight perturbation to the left will move the system to V_1 . Herbivore productivity at V_1 is lower than at V_t or V_e .

The stability properties of this system may perhaps be more easily visualized with Noy-Meir's mechanical "ball-in-container" analogue (Fig. 2). The ball is at equilibrium in either

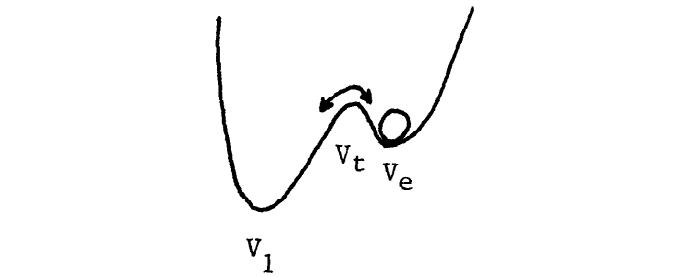


Fig. 2. A "ball-in-container" analogue to the two steady-states model. Redrawn from Noy-Meir (1975).

pocket, but sufficient rocking or steady force can move it across V_t , and it will come to rest in the other pocket.

The effects of H can be seen by superimposition of a series of $C(V)$ curves (for different values of H) on the $G(V)$ curve (Fig. 3). The (V, H) values of the intersection of a family of these

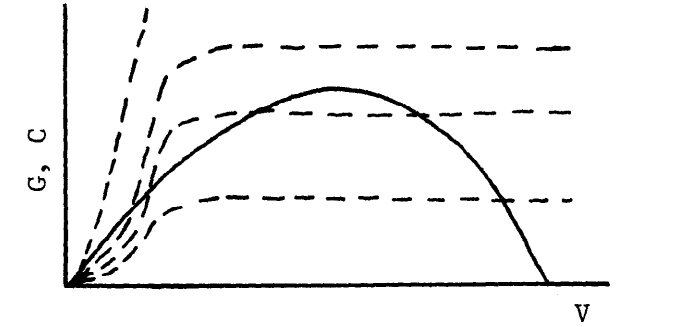


Fig. 3. Effect of varying herbivore density H on the $C(V)$ curve (dashed lines). Redrawn from Noy-Meir (1975).

curves may be determined and plotted (Fig. 4) to provide a graph of the zero-change isocline of the vegetation in the herbivore-vegetation phase plane (Rosenzweig and MacArthur 1963). This graph shows that at low herbivore densities the system will have a single, stable equilibrium point with high

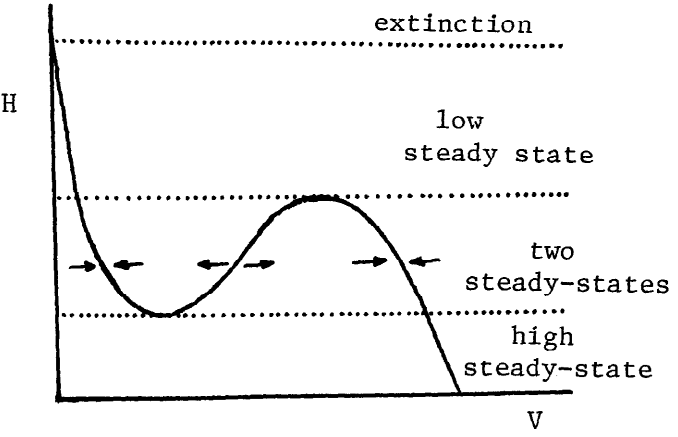


Fig. 4. The effect of varying herbivore density H on vegetation biomass at equilibrium; the zero-change isocline of the vegetation in the herbivore-vegetation phase plane. Redrawn from Noy-Meir (1975).

plant biomass. As H increases, the system passes through a region of having two steady-states and one turning point (as in Fig. 1) to a region with a single, stable equilibrium point with very low plant biomass, and finally to extinction.

Changes in animal productivity (P) with respect to H can be examined by plotting the values of C against those of H from Figure 3. This is shown in Figure 5. Maintenance (M) is a linear function of H , and net animal productivity is the difference between P and M . Thus the $P(H)$ curve rises in a continuous convex form until maximum animal productivity is reached; but slightly beyond that point steady-state productivity drops suddenly to a much lower level or even to zero. As the point of maximum animal productivity is approached, V decreases toward V_t , and when V and V_t merge, vegetation productivity may drop suddenly to the lower level due to random variability

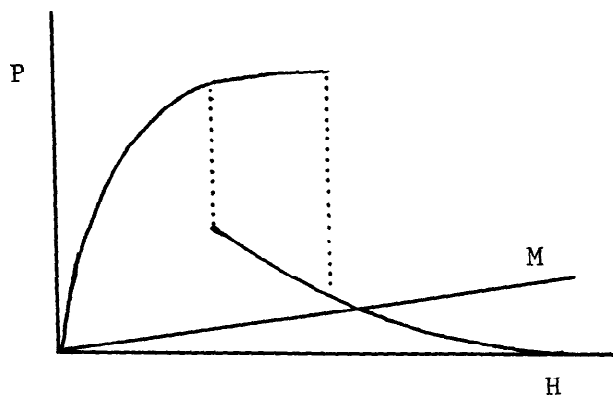


Fig. 5. Gross herbivore productivity P at equilibrium, as a function of herbivore density H . M is the cost of maintenance. Redrawn from Noy-Meir (1975).

alone. Thus Noy-Meir (1975) has pointed out that in such a system "animal productivity may remain very high even when the system is on the verge of a catastrophic collapse. Animal condition is not a sensitive indicator of the state of such a system." Furthermore, he pointed out that within the intermediate range where two levels of productivity are possible, a higher stocking rate will be associated with a higher probability of a transition from high to low relative to a transition from low to high steady-states.

Applications to Rest-Rotation Grazing Management

Analysis of rest-rotation grazing management is not explicit in the model, because the model represents a continuous process. However, the effects of rest-rotation can be assessed by considering the periodic perturbations imposed on the equilibrium point brought about by the alternate years of grazing, deferment, and rest. Noy-Meir (1975) has pointed out that the benefits of rotation over continuous grazing management should be expected to be quite different depending upon which steady-state the system is in. If a continuous grazing system is at the high level equilibrium, the introduction of severe perturbations in the form of a rest-rotation system may be enough to inadvertently push the system past the turning point to the low level equilibrium. On the other hand, if the system is already at the low level equilibrium, the rest-rotation management may be enough to shift the stability to the high level equilibrium. In short, Noy-Meir believed that if the system is already in a high level steady-state, we may only lose by perturbing it; if in the low level steady-state, we may gain; and that if the perturbations are not sufficient to change steady-states, there should be no

significant difference between rotational and continuous grazing.

Assuming now that the system is already in the low steady-state (this assumption appears quite reasonable for much of Great Basin rangeland today—e.g., U.S.D.I. Bureau of Land Management 1974; Box et al. 1976), the model can yield insight into questions regarding the importance of the amount of rest, stocking rates, and seasons of use in rest-rotation grazing management systems. These are areas in which many of the misconceptions about rest-rotation grazing management presently lie (Hyder and Bement 1977).

Amount of Rest

Resting a pasture has the effect of temporarily reducing the herbivore density to zero, leaving the change in V with respect to time dependent only upon the $G(V)$ curve:

$$\frac{dV}{dt} = G(V).$$

Thus when grazing pressure is removed from a system at low steady-state, V will always move toward the right (will increase) in the model. The rate at which it increases in a real range system will depend upon the vigor of the grasses at the time the pasture is rested. The longer the rest period, the nearer will V approach V_t . Even if V_t is not reached during a given rest period, however, if grazing pressure between rest periods is not sufficient to return V to V_t it is possible that V will eventually reach V_t and from there shift to the high level steady-state (V_e). The requirement, of course, is that the amount of rest provided for the vegetation to recover vigor be sufficient to exceed all losses suffered during the grazing periods between rest periods. In terms of the "ball-in-container" analogue (Fig. 2), the rest must be sufficient to eventually rock the ball over V_t to V_e .

According to Hormay (1970), "the key plant in deciding the amount of rest needed is the species that needs the most rest to regain vigor after it has been completely defoliated during the critical green period." Rest periods could be as short as 1 year for Indian ricegrass (Cook and Child 1971) or 14 to 26 months for western wheatgrass (*Agropyron smithii*) (Trlica et al. 1977); but where 6 to 8 years of rest may be required for Idaho fescue and bluebunch wheatgrass (Mueggler 1975), such stringent rest requirements are seldom met. An inadequate rest period will allow V to temporarily increase but will not be sufficient to "rock the ball" to the high level steady-state. Such ranges may look better under a rest-rotation grazing management system, but it is unlikely that management will attain its goal, if that goal is to move the equilibrium to the high level steady-state.

Stocking Rates

Stocking rates during a grazing period determine the force which the herbivore population will exert on the vegetation. In terms of Figure 3, this force is proportional to the difference between the $C(V)$ and $G(V)$ curves and increases with herbivore density. If grazing pressure is sufficient to negate the gains made by vegetation during the rest periods, the system will remain in the low level steady-state. It is also important to note that with a large enough H the vegetation may be forced to extinction, from which point no amount of rest or change in stocking rate can move it.

As demonstrated in Fig. 5, herbivore density is a very critical factor in the productivity of discontinuously stable systems. The greater the value of H , the greater will be the probability of changing from high to low steady-states. This also has major

significance for management once the high steady-state has been reached—too great an increase in stocking rate may inadvertently push the system back to low level productivity. This is especially important on desert ranges, where precipitation is so highly variable. It seems to be a common misconception that stocking rate is not an important factor in rest-rotation grazing management systems (Hyder and Bement 1977).

Seasons of Use

The major effect of seasons of use in this model is that a later turnout date will result in less grazing pressure during the growing season than will an earlier turnout date for a given stocking rate (animal density). Seasons of use thus affect grazing pressure, and their effects on the system are similar to those of stocking rate. At a given herbivore density, the amount of green biomass consumed will increase with the length of time that the grazing period extends into the growing season. However, the response of plants to grazing varies greatly seasonally. Generally, plants are most sensitive to grazing during the period of maximum growth and corresponding minimum carbohydrate reserves (Cook and Stoddart 1963; Donart and Cook 1970; Cook and Child 1971; Krall et al. 1971); but this is also the time when they are of greatest forage value to livestock (Hormay 1970). Consequently, an optimal combination of seasons of use with stocking rates should be sought.

Summary and Conclusions

A highly simplified model of an herbivore-plant system has been used to demonstrate some general concepts applicable to rest-rotation grazing management on shrub-steppe ranges. Although it is far from representing a complete picture of a rangeland grazing system, it is useful in demonstrating several important, but frequently misunderstood, relationships involving amounts of rest, stocking rates, and seasons of use, and their relation to system stability and productivity. The important points applicable to management can be listed as follows:

- 1) In discontinuously stable systems, herbivore productivity may remain high even when the system is on the verge of collapse. Animal condition is therefore a poor indicator of the state of such a system.
- 2) Given adequate rest and the proper grazing treatment, a high level equilibrium may be reached where vegetation biomass and herbivore productivity are much greater than was previously possible at a lower level of system stability.
- 3) The amount of rest required to effect a change from low to high steady-states is directly related to the herbivore grazing pressure.
- 4) Stocking rates have a direct bearing on the magnitude of herbivore grazing pressure. Low stocking rates will favor a change from low to high steady states and will maintain a high level equilibrium. Conversely, high stocking rates will favor a change from high to low steady-states and will maintain a low level equilibrium. It is conceivable that with a high enough stocking rate, the system may be forced from a low level equilibrium point to extinction.
- 5) Seasons of use also have a direct bearing on the magnitude of herbivore grazing pressure. Later turnout dates will result in less grazing pressure during the growing season than will earlier turnout dates for a given stocking rate (herbivore density).

Response of plants to grazing and quality of forage vary seasonally, however, and the optimal combination of stocking rate and seasons of use must be sought for a given herbivore grazing pressure.

Therefore, the amount of rest, stocking rate, and seasons of use are all important and interrelated components of a rest-rotation grazing management plan. The optimal mix of all three is what is considered tailoring the grazing management to the range resource. With proper management, discontinuously stable herbivore-plant systems have the potential for stability at a relatively high level of production and vegetation biomass. Once there, fine tuning of herbivore productivity must continue to be based on vegetation response.

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Establishing Kleingrass and Bermudagrass Pastures using Glyphosate and Tebuthiuron

J.R. BAUR

Abstract

Tebuthiuron and glyphosate were applied at 1.1 and 2.2 kg/ha in 1976 before land preparation for the sprigging of Coastal Bermudagrass or seeding of kleingrass in the claypan region of Texas. Tebuthiuron at 1.0 kg/ha was re-applied in February 1977 either as the 80% wettable powder spray or as 3.2-mm or 1.6-mm extruded pellets, to a set of plots superimposed across the 1976 plots. Kleingrass top-growth production in 1977 was increased by the preplanting treatment with glyphosate in both rates and tebuthiuron at the low rate. Tebuthiuron at 2.2 kg/ha prevented establishment of kleingrass. Bermudagrass cover was significantly increased by a preplanting application of tebuthiuron at 1.1 kg/ha, but was not affected by preplanting application of glyphosate. Tebuthiuron at 2.2 kg/ha had no effect (beneficial or detrimental) on Bermudagrass cover. Crude protein content was higher in kleingrass from plots treated in 1976 with tebuthiuron at 1.1 kg/ha than in kleingrass from the control plots. No differences in grass stands were attributed to formulation of tebuthiuron re-applied in 1977.

The conversion of marginal or unmanaged native pastures to productive pastures depends on the successful establishment of high-quality forage species. Development of new herbicides may offer improved means of accomplishing this conversion by controlling competitive vegetation during the establishment period. The first objective of this study was to evaluate the effects of preplanting applications of glyphosate [N-(phosphono methyl) glycine] and tebuthiuron {N-5 (1, 1-dimethyl-ethyl)-1,3,4-thiadiazol-2-yl]-NN'-dimethylurea} on the establishment of Coastal Bermudagrass (*Cynodon dactylon* (L.) Pers.) and 'Selection 75' kleingrass (*Panicum coloratum* L.).

Following establishment of high-quality forage species, it is desirable to maintain the pasture at a high level of productivity. This is best accomplished by controlled grazing, fertilization, and weed control. The second objective of this study was to evaluate the effectiveness of tebuthiuron in three formulations for control of broadleaf weeds in established Coastal Bermudagrass and kleingrass pastures, and to determine productivity and grass quality in the kleingrass pasture after treatment.

Materials and Methods

The research was conducted in Leon County, in the Texas claypan region near Leona, Texas. Two sites were selected, one for establishment of a Bermudagrass pasture, the other for a kleingrass pasture.

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The research is a cooperative investigation of the Agric. Res., Sci. and Educ. Admin., U.S. Dep. Agr., and the Texas Agricultural Experiment Station, Department of Range Science, Texas A&M Univ., College Station 77843.

The author wishes to thank Mr. F.L. Thompson, Leona, Tex., for the unlimited use of the Spring Creek Ranch, for providing fences, and for land preparation.

Manuscript received January 16, 1978.

The Bermudagrass site was a 0.5-ha clearing located on a deep sand adjacent to a flowing creek. The soil was of the Patilo series, classified as a grossaremic paleustalf, loamy, siliceous, thermic. The kleingrass site was a 1.2-ha clearing with a 2% slope. The soil on this site was similar to the Patilo, but had a much thinner surface layer than on the Bermudagrass site. The sites were about 0.4 km apart. Ten plots, 4.5 by 100 m, were planted with Coastal Bermudagrass and 10 plots, 4.5 by 150 m, were seeded with kleingrass. Both sites were fenced to prevent livestock grazing. Rainfall during the study was measured with a rain gauge at the Bermudagrass site.

1976 Preplanting Treatments

Duplicate plots at each site were sprayed with tebuthiuron (80% a.i. wettable powder) at 1.1 or 2.2 kg/ha on January 21, 1976, or with glyphosate (isopropylamine salt formulation) at 1.1 or 2.2 kg/ha on March 22, 1976. Two plots at each site were not treated and served as controls. Sprays were applied with a 4.5-m tractor-mounted boom calibrated to deliver 187 liters/ha. During the first week of May 1976, both sites were repeatedly disced until a suitable seedbed had been prepared. Discing was done only in the direction of the plots to minimize movement of the herbicides across plot boundaries. On May 20, 1976, Coastal Bermudagrass sprigs were hand broadcast at a rate of 440 kg/ha and covered by discing. On the same day, 2.2 kg (viable seed)/ha of 'Selection 75' kleingrass were drilled 0.6 to 1.2 cm deep. The stand density of both grasses was visually evaluated on October 14, 1976.

In March 1977, eight plots, 9.1 by 45 m, were superimposed across the 1976 preplanting treatment plots at both sites. On March 9, 1977, duplicate plots at each site were treated with tebuthiuron at 1.1 kg/ha as an aqueous spray in 187 liters/ha or as extruded pellets, 1.6 mm or 3.2 mm in diameter. The extruded pellet formulations were 20% a.i. and were applied with a self-propelled broadcast distributor. Two plots at each site remained untreated. Both sites were fertilized with 13-13-13 at 448 kg/ha on May 14, 1977.

Evaluation

On March 8, 1977, (before the 1977 subplot treatments were applied), the kleingrass stand was evaluated by estimating the percent cover of established plants in a 0.6-m length of five alternate rows in each subplot. The starting point in each subplot was randomly selected by a blind toss of a range pole. All remaining evaluations were made on the basis of the 4.5- by 9.1-m subplots created when the 1977 treatments were superimposed across the 1976 treatments.

On the 22nd and 23rd of June, 1977, kleingrass subplots were clipped and sampled for yield and quality evaluation. Three 56- by 91-cm swaths were cut 5 to 8 cm above ground level in each subplot with an electric hedge clipper. The vegetation from each swath was separated into broadleaf weeds and kleingrass. Each fraction was weighed and two subsamples were weighed, dried at 60°C, and reweighed for moisture determination.

On July 5, 1977, the botanical composition of Bermudagrass subplots was evaluated by estimation of foliar cover. Cover of Bermudagrass of broadleaf weeds, and of less desirable grasses, was visually estimated in ten 0.5-m square areas in each subplot. The

category of "less desirable" grasses included dallisgrass, carpetgrass (*Axonopus affinis* Chase.), crabgrass (*Digitaria* sp.), threeawns (*Aristida* sp.), and field sandbur (*Cenchrus incertus* M.A. Curtis). Broadleaf weeds were primarily croton, with some common ragweed (*Ambrosia artemisiifolia* L.), coneflower (*Rudbeckia* sp.), and curly dock (*Rumex crispus* L.). Sedges (*Carex* sp.) and rushes (*Juncus* sp.) also occurred. The ten areas were delineated by a 0.5-m square steel frame that was positioned uniformly in each subplot. Cover within each frame was estimated independently by two evaluators.

Protein Analysis

Subsamples of kleingrass taken for moisture determination from the control subplots and subplots treated with tebuthiuron in 1976 and 1977 were used for the protein determinations. A total of three 10-g samples of kleingrass was separated from two combined samples taken from each subplot. The dry grass was ground to pass a 20-mesh screen in a Wiley mill. Total organic nitrogen was determined for duplicate

0.5-g aliquots of each grass sample by the micro Kjeldahl method (AOAC 1960). Crude protein was calculated as $6.25 \times$ total organic nitrogen.

Statistical Analysis

All data were subjected to analysis of variance. Significant means ($p=0.05$) were separated by the use of Duncan's multiple range test (Steel and Torrie 1960).

Results and Discussion

1976 Preplanting Treatments

In October 1976, about 20% of the Coastal Bermudagrass had survived and was established in the control and glyphosate-treated plots. No Coastal Bermudagrass survived in the tebuthiuron-treated plots. This poor establishment was attributed in

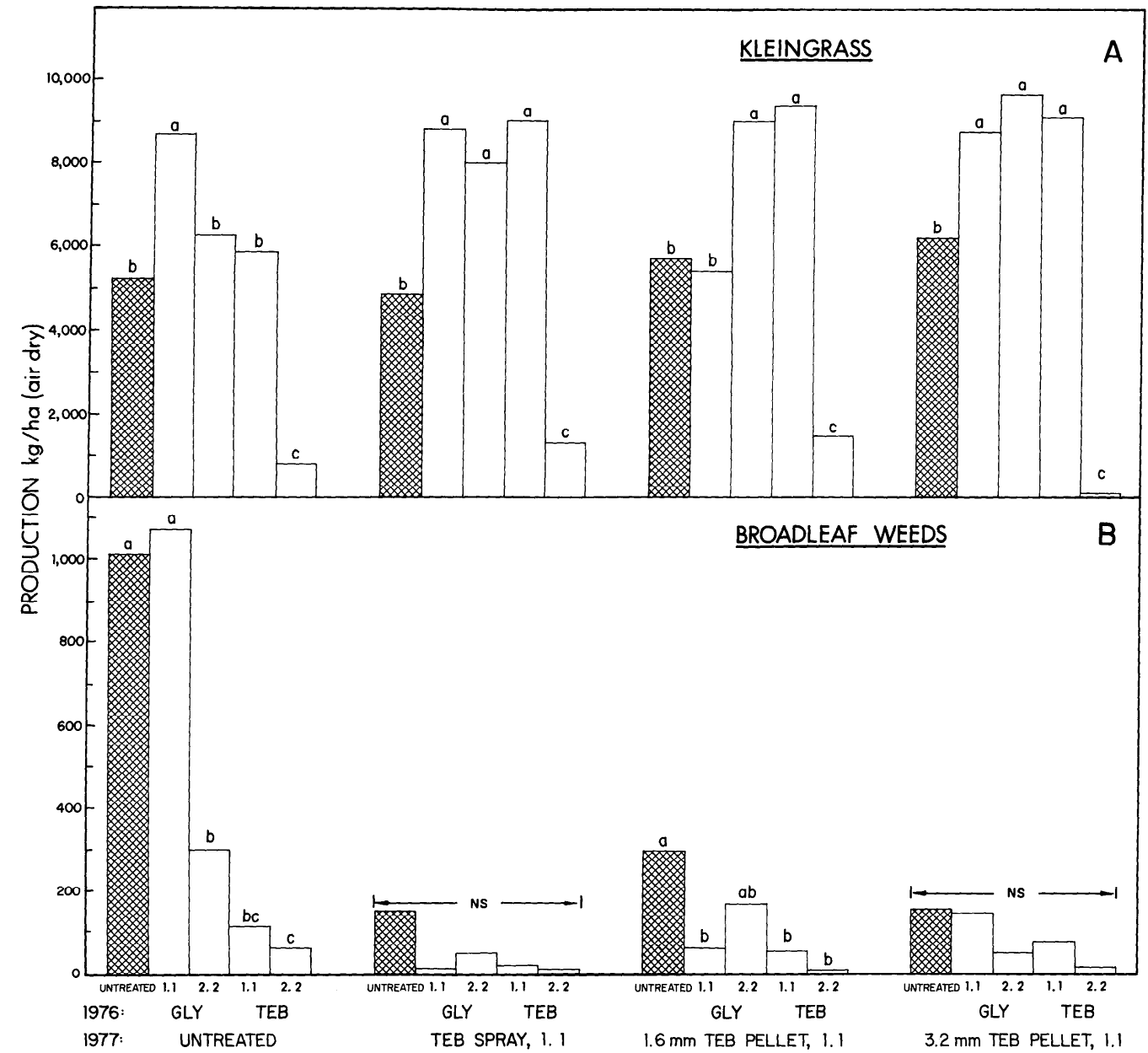


Fig. 1. Production of kleingrass (A) and broadleaf weeds (B) with and without preplanting treatment in 1976 with glyphosate (GLY) or tebuthiuron (TEB) at 1.1 or 2.2 kg/ha in 1976 and treatment with tebuthiuron at 1.1 kg/ha in one of three formulations in 1977. Each bar represents the average of six 56- by 91-cm harvest areas equally distributed between two subplots. Within any set of five bars, the same letter above the bars indicates that they are not significantly different at the 5% level. NS=no significant differences.

part to late planting and a dry summer. Weed cover appeared to be greater in the glyphosate-treated plots than the tebuthiuron-treated plots. Common Bermudagrass cover was highest in the tebuthiuron-treated plots.

Tebuthiuron at 1.1 kg/ha suppressed weed cover and permitted a kleingrass cover of 71%. The higher rate of tebuthiuron (2.2 kg/ha) prevented establishment of kleingrass, but not of invading common Bermudagrass and dallisgrass (*Paspalum dilatatum* Poir.). Kleingrass cover was 56 and 61% for plots treated with glyphosate at 1.1 and 2.2 kg/ha, respectively. Average cover in the control plots was 60%. The glyphosate plots supported a moderate infestation of broadleaf weeds, primarily woolly croton (*Croton capitatus* Michx.).

Kleingrass production in plots that received preplanting treatments of glyphosate at 2.2 kg/ha or tebuthiuron at 1.1 kg/ha in 1976 (no 1977 treatment) was equivalent to that of the control (Fig. 1A). Kleingrass production was increased by glyphosate at 1.1 kg/ha and was severely reduced by tebuthiuron at 2.2 kg/ha. Broadleaf weed control was good with both tebuthiuron treatments and with glyphosate at the high rate; glyphosate at the low rate was ineffective (Fig. 1B).

1977 Treatments

Regardless of the 1977 herbicide applications, kleingrass production in all subplots treated with tebuthiuron at 2.2 kg/ha in 1976 (preplanting) was less than that found in plots that had not received this treatment (Fig. 1A). For subplots treated with tebuthiuron at 1.1 kg/ha in all three formulations applied in 1977, production of kleingrass was significantly greater within those given preplanting treatments of glyphosate at 1.1 and 2.2 kg/ha and tebuthiuron at 1.1 kg/ha than in those left untreated in 1976, with one exception. The exception was production from subplots treated with glyphosate at 1.1 kg/ha before planting in 1976, and then treated with 1.6-mm tebuthiuron pellets in 1977. Production in these subplots was equivalent to that in the control subplots (Fig. 1A).

The 1977 tebuthiuron treatments controlled broadleaf weeds satisfactorily on all subplots. Control was, however, slightly better on subplots that had also received preplanting treatments with either herbicide in 1976 (Fig. 1B). The increases in kleingrass production can be partially attributed to the removal of the competitive effects of broadleaf weeds. Comparisons among the graphs that represent kleingrass production and broadleaf weed control on subplots not treated in 1976 indicated that there were no differences in weed control among the three formulations of tebuthiuron applied at 1.1 kg/ha in 1977 (Fig. 1).

The successful establishment of kleingrass and the satisfactory weed control in subplots that received the preplanting treatment with tebuthiuron at 1.1 kg/ha might be attributed to the residual properties of this herbicide. Earlier work (Baur 1978) showed that tebuthiuron at 1.1 kg/ha controlled annual weeds for 261 days with 68 cm of rainfall and allowed the subsequent establishment of annual ryegrass [*Lolium perenne* L. (including *L. multiflorum* Lam.)]. The conditions in the current study were 118 days and 45 cm rainfall between herbicide treatment and seeding. A second factor that could have influenced kleingrass production was the apparent tolerance of this species to tebuthiuron applied in the dormant season (Baur et al. 1977).

The effectiveness of glyphosate as a preplanting treatment is shown by the increased production of kleingrass in most of the treated subplots compared with control subplots (Fig. 1A). These increases probably resulted from the initial reduction in

weed seedlings in 1976 before kleingrass seeding. The lack of a residual effect of glyphosate (Sprankle et al. 1975) precludes prolonged weed control during the establishment of the kleingrass seedlings.

For all 1977 treatments, except the 3.2-mm tebuthiuron pellets, levels of crude protein were significantly higher in kleingrass foliage from subplots given preplanting treatment with tebuthiuron at 1.1 kg/ha than in plants from untreated subplots or subplots given preplanting treatment with tebuthiuron at 2.2 kg/ha (Fig. 2). The higher production (Fig. 1A) and higher crude protein content (Fig. 2) for kleingrass from

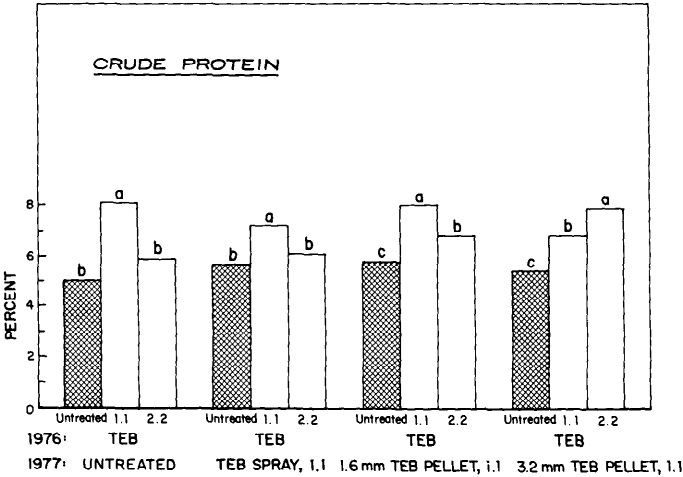


Fig. 2. Crude protein content of kleingrass with and without preplanting treatment with tebuthiuron (TEB) at 1.1 or 2.2 kg/ha in 1976 and treatment with tebuthiuron at 1.1 kg/ha in one of three formulations in 1977. Each bar represents the average of 12 determinations equally distributed between two subplots. Within any set of three bars, the same letter above the bars indicates that they are not significantly different at the 5% level.

subplots given tebuthiuron at 1.1 kg/ha as a preplanting treatment, compared with kleingrass from the untreated subplots, demonstrated the effect of reduced weed competition.

The highest crude protein level noted was 8.2%. One explanation of the low protein levels is that no effort was made to separate leaves from stems. Levels of 13% and 5.5% were reported for kleingrass leaf and stem fractions, respectively (Polk et al. 1976).

Preplanting application of glyphosate at 1.1 or 2.2 kg/ha had little or no effect on Bermudagrass cover, regardless of the application of tebuthiuron the following season (Fig. 3A). Preplanting treatment with tebuthiuron at both rates, with no treatment in 1977, significantly increased Bermudagrass cover over that of the untreated control subplots. In subplots given a preplanting treatment with tebuthiuron and retreated in 1977, Bermudagrass cover was equivalent to that in subplots that were not given any preplanting treatment, and was sometimes significantly greater than that in subplots given a preplanting treatment with glyphosate. This finding suggests that a dormant-season application of tebuthiuron to established Bermudagrass might be beneficial during the next growing season. The estimates of broadleaf weed cover (Fig. 3B) support this conclusion. Subplots treated only in 1976 had weed cover estimated to be three to four times that found in subplots treated in both 1976 and 1977.

The reduction in Bermudagrass cover in subplots given glyphosate in 1976 (preplanting) was due partially to subsequent broadleaf weed competition, which was decreased by the

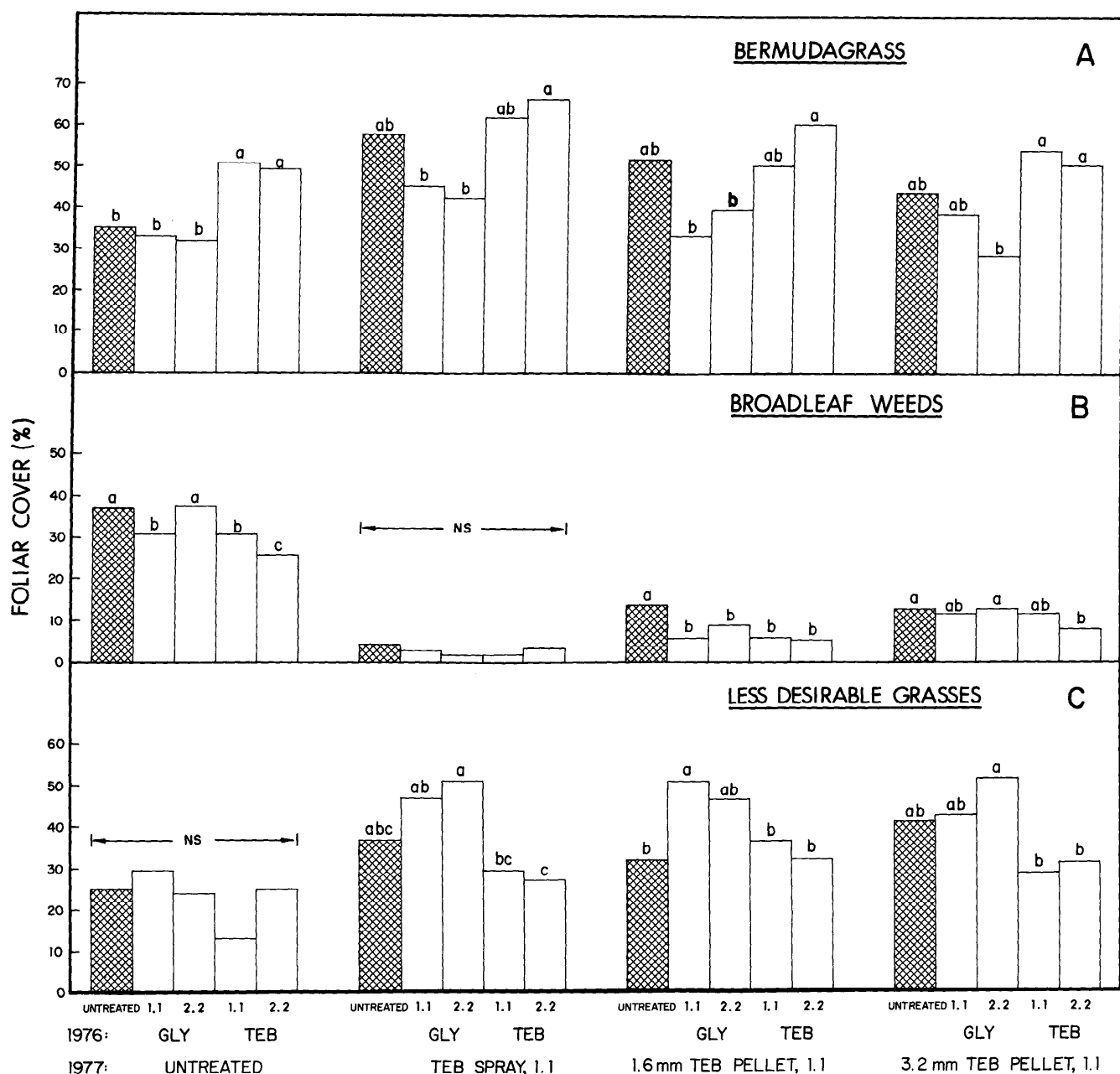


Fig. 3. Foliar cover (%) of Bermudagrass (A), broadleaf weeds (B) and less desirable grasses (C) with and without preplanting treatment with glyphosate (GLY) or tebuthiuron (TEB) at 1.1 or 2.2 kg/ha in 1976 and treatment with tebuthiuron at 1.1 kg/ha in 1977. Each bar represents the average of two independent visual estimates of twenty 0.5-m² quadrats equally distributed between two subplots. Within any set of five bars, the same letter above the bars indicates that they are not significantly different at the 5% level. NS=no significant differences.

preplanting application of tebuthiuron. The reduced Bermudagrass cover in these subplots apparently allowed establishment of less desirable grasses, whereas subplots that received tebuthiuron as a preplanting treatment (1976) had significantly lower covers of less desirable grasses (Fig. 3C).

Subplots treated only in 1976 (preplanting) had the lowest cover of less desirable grasses and the highest cover of broadleaf weeds (Fig. 3B, C). Broadleaf weed control from application of tebuthiuron at 1.1 kg/ha in 1977 resulted in increased cover of Bermudagrass in the subplots given preplanting treatment with tebuthiuron and the less desirable grasses in the subplots given preplanting treatment with glyphosate (Fig. 3A, B, C).

Differences in Bermudagrass cover attributable to the formulation of tebuthiuron that was applied in 1977 were slight. The

spray treatment gave slightly better control of broadleaf weeds than did the pellets.

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Economics of Using Cotton Gin Trash as a Supplemental Feed for Range Cattle

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Abstract

The economic use of alternative supplemental feeds was evaluated for a 2,024-ha cow-calf ranch operation in the Texas Rolling Plains. Particular interest was focused on the use of gin trash as a supplemental feed. The estimated value of gin trash compared with alternative supplemental feeds ranged up to \$23.75 per ton. Potential ranch carrying capacity and annual net income were expanded with a supplemental feeding program including gin trash.

Returns to rangeland resources may be increased by supplemental feeding. Supplemental feeding programs may be used to expand carrying capacity, improve performance on rangeland, and relieve grazing pressure when range conditions are poor.

On the Texas Rolling Plains, typical supplemental feeds used are range cubes, protein blocks, cottonseed meal, and alfalfa hay or other roughage during winter months. Ranges in this region are dominated by warm-season species that usually furnish adequate amounts of quality forage from April to November. In the remaining dormant months, however, the range tends to be deficient in protein, phosphorus, vitamin A, and sometimes energy, particularly with heavy stocking rates.

Cotton gin trash is a relatively cheap and abundant by-product available from gins in the Southern High Plains of Texas. Gin trash is used currently in commercial feedlot rations in the Texas-Oklahoma Panhandle as a substitute for traditional roughages and is available in bulk form directly from gins or in pellet form from processors.

The major purpose of this paper was to evaluate the economic use of alternative supplemental feeds on a cow-calf ranch in the Texas Rolling Plains, with particular reference to use of gin trash as a supplemental feed.

Methodology

Nutritive Value of Gin Trash

Basic nutritive values of supplemental feed ingredients including cotton burrs, the principal component of gin waste, have been determined by the National Academy of Sciences (1970). A laboratory analysis of Hi Pro Feeds of Friona, Texas, indicates that 0.45 kg of representative ground gin trash in this region contains 0.46 megacalories net energy for maintenance (mcal NEM), 0.15 mcal net energy for gain (mcal NEG), .19 kg total digestible nutrients (TDN), .037 kg crude protein (CP), .014 kg digestible protein (DP), and .009

kg crude fat.¹ Gin trash in the Texas High Plains is composed largely of cotton burrs but also contains immature bolls, stems, leaf material, and other matter.

Limited information is available on the palatability or acceptability of gin trash by beef cattle. A feeding performance test by Sherrod et. al (1970) indicated that the intake of cotton burr pellets offered free choice to beef steers was only 49.5% that of alfalfa pellets offered free choice. Thompson and co-workers (1976) reported that ground cotton burrs, whole burrs, and cotton seed hulls have comparable acceptability. In the case of some feedlot users, molasses is mixed with gin trash to increase acceptability and also furnish additional energy in rations.

Nutrient composition data and alternative market prices assumed for different supplemental feeds compared in this study are given in Table 1. It was assumed that 1.5 kg of gin trash would be wasted for each kg consumed by range cattle, when fed in bulk form. With pelleted gin trash, there should be near 100% feeding efficiency.² Use of urea for supplemental protein was restricted to a maximum of 10% of total protein intake in the study to prevent toxicity problems. Other restrictions included in the analysis were to eliminate urea as a supplement, and also eliminate silage use, as silage is not available in some ranching areas.

Nutritive Value of Range

The estimated nutrient composition of rangeland grasses in the Texas Rolling Plains varies over the year (Table 2). Both the digestible protein content and metabolizable energy decline as grasses mature in the fall. For example, digestible protein content of blue grama and buffalograss in winter is only 25 and 64%, respectively, of that in summer.

Nutrient composition data for rangeland in Table 2 were utilized in this study to evaluate the economic returns of using gin trash and other supplemental feeds identified in Table 1 for a cow-calf operation on a 2023.5-hectare ranch. Only one half of the total available range grass was assumed to be consumed per year to prevent overgrazing of the range. The estimated weighted average utilizable yield obtained with the distribution of range sites assumed in Table 2 was 440 kg air dry weight per acre or 2.20 million kg total for a 2023.5 ha ranch.

Nutritive Requirements of Range Cattle

Each cow-producing unit (CPU) on the 2023.5-ha ranch study site included a mature cow and calf and fractional parts of a replacement heifer and a breeding bull, comprising a total of 1.423 animal units per CPU³. Estimated nutrient requirements per cow-producing unit decline during the fall as calves are weaned and marketed (Table 3).

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Manuscript received March 6, 1978.

¹ Personal interview with Mr. Keith Hansen, animal nutritionist, Hi-Pro Feeds, Friona, Texas.

² Feeding efficiency in this context refers to the amount of feed consumed relative to the amount available for consumption.

³ One 453.6 kg cow, the calf weaned in seven months at 220 kg, 0.04 of a 680.4 kg bull and 0.10 of a 229.4 kg heifer. A 90% calf crop and a 10% replacement rate for cows was assumed.

Table 1. Average nutrient composition and alternative market prices for supplemental feeds in the Texas Rolling Plains.

Supplemental feed	Nutrient composition				Alternative market prices (\$/ton)		
	DP ^a	ME ^b	CA ^c	P ^d	High	Medium	Low
Milo	0.063	2.575	0.004	0.002	\$100.00	\$ 80.00	\$ 60.00
Cottonseed meal	0.313	2.502	0.002	0.001	210.00	145.00	80.00
Phosphate rock	0.000	0.000	0.330	0.180	130.00	95.00	60.00
Molasses	0.018	3.009	0.009	0.001	85.00	57.50	30.00
Alfalfa pellets	0.118	2.053	0.012	0.002	105.00	76.50	48.00
Commercial supplement ^e	0.139	2.381	0.012	0.011	127.00	127.00	127.00
Silage	0.019	1.012	0.001	0.001	20.00	15.00	12.00
Alfalfa hay	0.114	1.854	0.010	0.002	70.00	54.50	30.00
Urea	2.240	0.000	0.000	0.000	200.00	200.00	200.00
Cotton gin trash	0.015	1.515	0.007	0.002	10.00	variable	4.00

^a DP, Digestible protein in kilograms per kilogram of supplement.

^b ME, Metabolizable energy in megacalories per kilogram of supplement.

^c CA, Calcium in kilograms per kilogram of supplement.

^d P, Phosphorus in kilograms per kilogram of supplement.

^e Commercial range ration.

Table 2. Estimated seasonal nutritive composition and vegetative composition of rangeland grasses, Rolling Plains of Texas.

Seasonal nutritive composition	Blue grama	Sideoats grama	Mesquite grass	Buffalograss	Tobosagrass	Silver bluestem	Low quality grasses ^a	Other grass ^b
Vegetative composition (%) ^c	35	2.5	10	25	5	5	10	7.5
Spring period:								
Digestible protein ^d	5.7	5.8	4.2	5.2	5.6	6.6	0	3.0
Metabolizable energy ^e	2.47	2.43	2.27	2.43	2.29	2.45	0	2.20
Summer period:								
Digestible protein ^d	4.75	3.4	3.2	2.2	3.5	3.4	0	2.0
Metabolizable energy ^e	2.45	2.16	2.10	1.79	2.23	2.36	0	1.76
Fall period:								
Digestible protein ^d	3.8	3.2	2.2	1.6	2.4	2.7	0	1.4
Metabolizable energy ^e	2.20	2.32	1.92	1.81	2.20	2.40	0	1.54
Winter period:								
Digestible protein ^d	1.2	1.3	1.0	1.4	2.7	1.5	0	1.0
Metabolizable energy ^e	1.61	1.94	1.68	1.90	2.29	2.34	0	1.32

^a Palatability of low quality grasses is extremely low and they may not be grazed if other species are available.

^b Digestible protein content of other grasses is assumed to be low as these grasses are of secondary choice.

^c Reported in USDA-SCS Range Conservation Technicians Guide, Section II-E, Deep Hardland Soils, Area 7.

^d Units in percent of 90% dry matter. Source: Maddox (no date).

^e Units in megacalories per kilogram of forage. Source: Maddox (no date).

Calves were assumed to be born in February and weaned in September. Only replacement heifer calves were assumed to be retained over winter, which reduced nutrient requirements per cow-producing unit in the winter period.

Analysis of Supplemental Feeding Programs

Benefits from supplemental feeding for range cattle are reported in various studies. Newlson (1971) reported increased gains for beef

calves on winter range with supplemental cottonseed meal, liquid protein supplement, and molasses. Denham (1967) reported increased gains from steers on native short grass with supplemental grain and protein. With 1.81 kg of sorghum per day, steers consumed one-quarter less grass than steers without supplement.

The approach taken in this study was to compare available nutrients from rangeland and additional supplemental feeds with estimated major nutritive requirements of a cow-calf operation on a 2,023.5-ha ranch in the Texas Rolling Plains. Supplemental feeding was used to increase ranch carrying capacity with specified nutrient requirements per cow-producing unit. Returns from supplemental feeding with gin trash relative to other conventional supplemental feeding programs were based on the estimated additional livestock income generated on the 2023.5-ha ranch. It was assumed that no additional labor or equipment costs were required for alternative supplemental feeding programs. Cost data for cow-calf production were derived from available extension budgets. Calf income was based on a price of \$0.99 per kg of marketable weight. Only the results for selected supplemental feeding programs are reported in this paper.

Returns from Supplemental Feeding

The estimated net income obtained per cow-producing unit, excluding costs of rangeland use and supplemental feed, was \$116.26. This estimate incorporated an average marketable calf

Table 3. Seasonal nutritive requirements per cow-producing unit, Rolling Plains of Texas^a.

Season of year	Digestible protein (kg/CPU) ^b	Metabolizable energy (mcals/CPU) ^b	Calcium requirement (kg/CPU) ^c	Phosphorus requirement (kg/CPU) ^c
Spring	53.53	1,874.50	2.13	1.77
Summer	68.52	2,439.03	2.72	2.17
Fall	58.54	2,234.65	2.21	1.84
Winter	31.55	1,438.47	1.09	1.10
Total	212.15	7,986.65	8.16	6.88

^a A cow-producing unit is defined as a 453.6-kg cow, a 220-kg calf, 0.04 of a 680.4-kg bull, and 0.10 of a 299.4 kg-replacement heifer.

^b Sources are Maddox (no date) for cows and calves, and National Academy of Sciences (1970) for other cattle.

^c National Academy of Sciences (1970).

weight of 176 kg per cow-producing unit, income from cull cow sales, average cash expenses of \$46.60 per cow-producing unit, and average overhead expenses of \$41.62 per cow-producing unit. Rangeland cost per cow-producing unit varied with changes in carrying capacity. Rangeland use was priced at \$7.41 per ha per year, or \$6.19 per ton of annual utilizable yield.

With no supplemental feeding, estimated carrying capacity of the 2023.5-ha ranch was only 254 cow-producing units and net ranch income was \$14,760. With supplemental feeding, the ranch could potentially carry a much larger number of cow-producing units with a corresponding increase in estimated annual net ranch income (Table 4).

Alternative range cattle feeding programs for the 2023.5-ha ranch with and without use of gin trash are shown in Table 4 for two sets of feed supplement prices. With Price Set 1, the potential annual net ranch income was \$25,000 with 504 cow-producing units in the gin trash feeding program. Estimated annual net income was \$20,000 with 428 cow-producing units when gin trash was excluded from the feeding program. All available range grass was assumed to be utilized during the first three periods of the year in the gin trash feeding program and a combination of gin trash and alfalfa hay was fed in winter. Consumption per cow-producing unit amounted to 2 tons of gin trash and 0.2 tons alfalfa hay in winter. In the alternative feeding program without gin trash, the range was utilized in all periods with some supplementation of alfalfa hay in winter. Cottonseed meal was used to supplement range grass in summer, and some alfalfa hay was used in the fall in both feeding programs.

Silage and urea were considered as additional supplemental feeds available with Price Set 2. Potential annual net ranch income was \$37,000 with 662 cow-producing units in the gin

trash feeding program under Price Set 2 conditions (Table 4). Estimated annual net income was \$28 thousand with 454 cow-producing units in the alternative feeding program without gin trash. With Price Set 2 conditions, all available range grass was utilized during the first three periods in both feeding programs. In both programs, the range grass was supplemented with urea in spring, with alfalfa hay in summer, and alfalfa hay in fall. Gin trash was used in both fall and winter in the gin trash feeding program along with some hay and urea. A combination of silage, hay, and urea was used during the winter period in the alternative feeding program.

A price of \$7.00 per ton for all gin trash used was assumed in both price sets for supplemental feeds (Table 4). A feeding loss of 1.5 kg of gin trash for each kg consumed was assumed in the analysis. With 100% feeding efficiency, up to \$17.50 could be paid per ton for gin trash. Other results obtained in the study with different combinations of feed supplement prices indicated that \$9.50 per ton was the upper price limit for gin trash, which is equivalent to \$23.75 per ton with 100 percent feeding efficiency for gin trash.

Results obtained in this study were for a specific ranch situation with range grass production assumed in Table 2, with prices of supplemental feeds reported in Table 1, with assumed nutrient requirements per cow-producing unit defined in Table 3, an assumed rangeland use cost of \$7.41 per ha, and a price of \$0.99 per kg for calves marketed. Changes in these assumed conditions would affect the value of supplemental feeding, including use of gin trash as a supplemental feed. The estimates of potential ranch income and carrying capacity apply only to this assumed ranch situation. The results may differ for other ranch situations. Results also need to be verified with actual

Table 4. Selected supplemental feeding programs for a 2023.5-hectare ranch in the Texas Rolling Plains with and without use of gin trash as a primary supplement.

Seasonal use of range and supplement	Feed price set 1 ^a		Feed price set 2 ^b	
	With trash ^c	Without trash ^d	With trash ^e	Without trash ^f
Spring:				
Rock phosphate (1,000 kg)	0.45	0.41	1.04	0.73
Range Grass (1,000 kg)	576.9	489.69	700.62	480.63
Urea (1,000 kg)	n/a	n/a	1.18	0.82
Summer:				
Range grass (1,000 kg)	758.68	643.10	884.42	900.88
Alfalfa hay (1,000 kg)	-0-	-0-	116.66	-0-
Cottonseed meal (1,000 kg)	35.11	29.80	-0-	-0-
Urea (1,000 kg)	n/a	n/a	2.04	1.40
Fall:				
Rock phosphate	0.49	0.41	-0-	0.64
Gin trash consumed (1,000 kg)	-0-	n/a	1,575.41	n/a
Range grass (1,000 kg)	865.27	734.41	614.94	818.46
Alfalfa hay (1,000 kg)	70.58	59.92	1.04	31.89
Urea (1,000 kg)	n/a	n/a	1.72	1.18
Winter:				
Gin trash consumed (1,000 kg)	918.66	n/a	1,572.02	n/a
Range grass (1,000 kg)	-0-	332.76	-0-	-0-
Silage (1,000 kg)	n/a	n/a	-0-	627.95
Alfalfa hay (1,000 kg)	90.99	122.61	-0-	9.62
Urea (1,000 kg)	n/a	n/a	0.64	0.64

^a Assumed prices per ton of \$127 for commercial supplement, \$80 for milo, \$146 for cottonseed meal, \$58 for molasses, \$76 for dehydrated alfalfa, \$96 for phosphate, \$54.50 for alfalfa hay, and \$7 for gin trash. (Urea and silage were excluded from program)

^b Assumed prices per ton of \$127 for commercial supplement, \$60 for milo, \$178 for cottonseed meal, \$86 for molasses, \$106 for dehydrated alfalfa, \$130 for phosphate, \$15 for silage, \$60 for alfalfa hay, \$200 for urea, and \$7 for gin trash.

^c Estimated ranch carrying capacity was 504 cow-producing units and annual net income \$25,000 with this program.

^d Estimated ranch carrying capacity was 428 cow-producing units and annual net income \$20,000 with this program.

^e Estimated ranch carrying capacity was 662 cow-producing units and annual net income \$37,000 with this program.

^f Estimated ranch carrying capacity was 454 cow-producing units and annual net income \$28,000 with this program.

feeding program experiments to evaluate performance of range cattle on gin trash rations.

Summary and Conclusions

Implications of this analysis are that supplemental feeding may be used to increase ranch carrying capacity and expand income potential. The problem of selecting a profitable supplemental feeding program for range cattle is comparable to other ration formulation problems, i.e., availability and costs of alternative feed inputs must be compared with nutrient requirements of cattle to determine which feeding program will produce the best returns to a ranch operation. One particular problem in ranch applications is that rangeland production is highly variable due to changing weather conditions, and the nutrient composition of range grass is also subject to seasonal change.

The approach taken in this study was to determine the average species composition and seasonal nutrient composition of rangeland grasses on a representative 2023.5-ha ranch in the Rolling Plains. Only one half of the available range grass was assumed to be used in each year to prevent overuse of the range resource. Returns to the ranch operation were based on an assumed market price of \$0.99 per kg for calves. Use of alternative supplemental feeds at varying prices was evaluated to determine the impact on ranch carrying capacity and potential income, with particular reference to gin trash as a range supplement.

Effects of alternative supplemental feeding programs on the ranch operation varied with the price levels assumed for supplemental feeds. With no supplemental feeding, the 5000-acre ranch produced a \$17,760 annual net income with a carrying capacity of 254 cow-producing units. Some selected results reported in this paper indicated that the ranch could

potentially produce \$37,000 annual net income with a carrying capacity of 662 cow-producing units if intensive supplemental feeding programs were employed. Cotton gin trash was determined to be a valuable supplemental feed for range cattle and was utilized extensively in programs at a price level of \$7.00 per ton. If feeding efficiency was 100 percent rather than 40 percent, a price of \$17.50 could be paid for gin trash without changing the analysis. Nutrient requirements for digestible protein, metabolizable energy, calcium, and phosphorus were considered in the supplemental feeding programs. Some additional supplementation for other nutrient requirements may be required with a heavy concentration of gin trash in rations. The results of this analysis should be verified with actual feeding trials to evaluate performance of range cattle on feeding programs containing a high percentage of gin trash.

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Effects of Temperature and Moisture on Phenology and Productivity of Indian Ricegrass

L.C. PEARSON

Abstract

Growth in Indian ricegrass commenced in the spring when soil temperatures stayed at 4°C for at least 3 or 4 days. Maximum plant size was attained when (1) soils warmed up early in the spring, (2) soil temperatures were relatively low later in the spring, and (3) additional water was supplied during the spring growth period. Higher soil temperature late in the vegetative phase of growth delayed anthesis approximately 3 days for each degree Celsius above 10°C. Additional moisture early in the season also delayed anthesis. Relatively reliable estimates of foliage biomass and seed biomass were made from measurements of average and/or maximum plant height, average length of longest leaf on each culm, maximum seed stalk height, clump diameter, and number of culms per plant. Measurements of biomass of needleandthread grass indicate that the generalized formulas presented here should be applicable to other cool-season bunchgrasses.

Although slight differences in temperature and moisture conditions from year to year affect rangeland productivity, the degree of the effect and the way in which these differences affect individual species have been little studied. Blaisdell (1958) observed that growth and development in grasses during the early part of the growing season are closely correlated with soil temperature, while development during the latter part of the growing season is more closely associated with precipitation. Additional observations indicate that shrubs are generally most productive during late winter and early spring, forbs later in the spring, and grasses in the late spring and early summer (Blaisdell 1958; Pearson 1965). In the northern half of the intermountain area, cool-season bunchgrasses are the most important range plants from the point of view of total productivity as well as of topgrowth production utilized by range livestock and wild game.

Indian ricegrass (*Oryzopsis hymenoides* [Roem. and Shult.] Ricker), is a relatively abundant species of greatest significance in the middle stages of ecological succession on sandy soils (Chadwick and Dalke 1965). It is frequently associated with needleandthread grass (*Stipa comata* Trin. and Rupr.), but is usually less abundant. It is highly palatable to livestock and wild game and is of anthropological interest because it was important

to Indians as a food supply. It is a long-lived grass forming large clumps which eventually become "doughnut-shaped" as a result of the oldest culms dying. Large, open seedheads provide positive identification of Indian ricegrass, even at a distance (Robertson 1977a, b). Because it is an important species in Curlew Valley on the Utah-Idaho border, it was chosen for a model of the cool-season bunchgrasses at the Desert Biome sites, U.S. International Biological Program (IBP) there.

The main objective of this study was to ascertain the general configuration of the growth curve of Indian ricegrass and how it is affected by small changes in temperature and moisture: predictions of this species' contribution to the total energy budget under varying climatic conditions can then be made. To reach this objective, measurements were made of soil temperature and moisture and plants were irrigated in late May and late June of 1971. Secondary objectives included (1) estimating dry weight from linear measurements so that productivity can be studied without destructive sampling, and (2) investigating the reliability of Indian ricegrass as a model for productivity of other cool-season grasses such as needleandthread grass.

The study was conducted at four sites in the vicinity of Rexburg, Idaho, and two sites in Curlew Valley (Fig. 1). Five of the six sites were moderately-to-heavily grazed by cattle and/or sheep; one, the Ricks College site, was not grazed. Data were analyzed with the aid of the Ricks College Computer Center and the Ecology Center at Utah State University: data are stored under the following DSCODES at Utah State University: A3UPC01, 02, 03, 04, and 05.

Methods

To analyze the pattern of growth and development, two kinds of data were utilized. (1) Every 15 to 20 days from May 20 to August 4, 1971, 35 plants were excavated, brought into the laboratory, carefully cleaned of soil, and separated into root, crown, foliage, and fruit-seed portions, which were then oven dried at 65°C and weighed. Dry weight was plotted against time, and separate free hand curves were drawn on clear sheets of plastic for foliage, roots, crowns, and fruits (Fig. 2). Methods outlined by Ezekiel (1941) for curvilinear relationships between two variables were followed. The curves were made as simple and smooth as possible to represent our best least-square estimate of biomass change with time consistent with our present knowledge of photosynthesis, food storage, and translocation in plants. Generalized formulas for several geometric figures were compared with these curves. Coefficients for the formulas were read into the computer and then automatically and systematically varied: the resulting computer-generated curves were covered with the plastic sheets on which the curves from the data had been produced and when an essentially perfect fit for any major section of the curve was found,

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This study was supported by funds from the Desert Biome Project, US/IBP. Neal Hayes and David Merkley, Ricks College students, gathered much of the data; several other Ricks students also worked on the project. Gordon Hoagland, Mathematics Department, wrote the FORTRAN program for the analysis of the 1972 data and reviewed some of the other computer programs; Sam Brewster, Jr., Biology Department, offered helpful criticisms and suggestions. Fred Wagner, of Utah State University and associate director of the Desert Biome, and the personnel at the Ecology Center, Utah State Univ., were always very helpful as well as patient during the course of the study, and their assistance is gratefully acknowledged.

Manuscript received March 10, 1978.

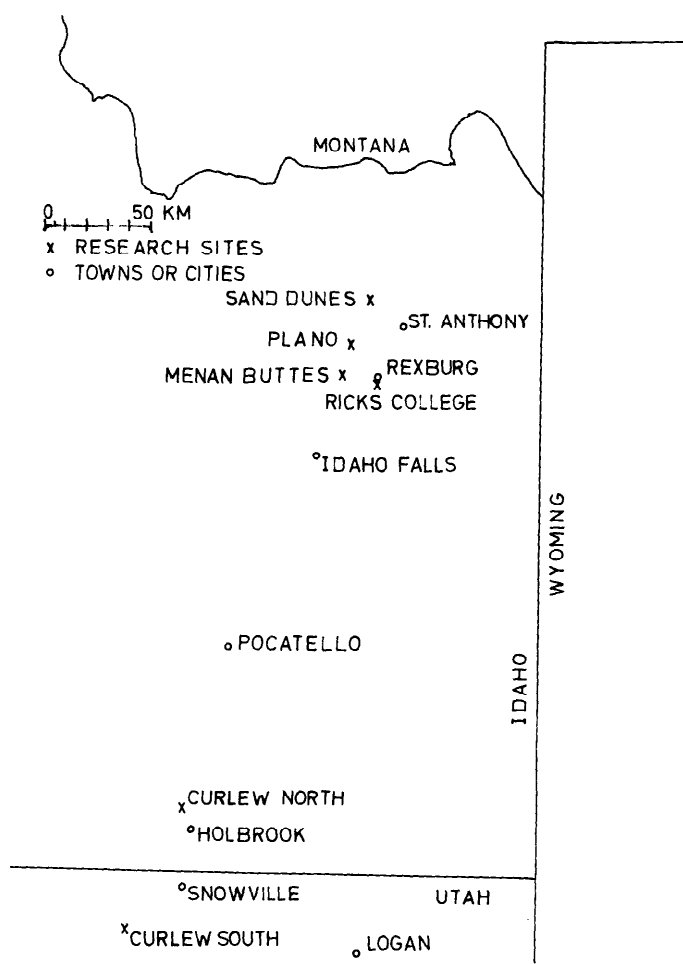


Fig. 1. Map of eastern Idaho and northern Utah showing the location of the six study sites.

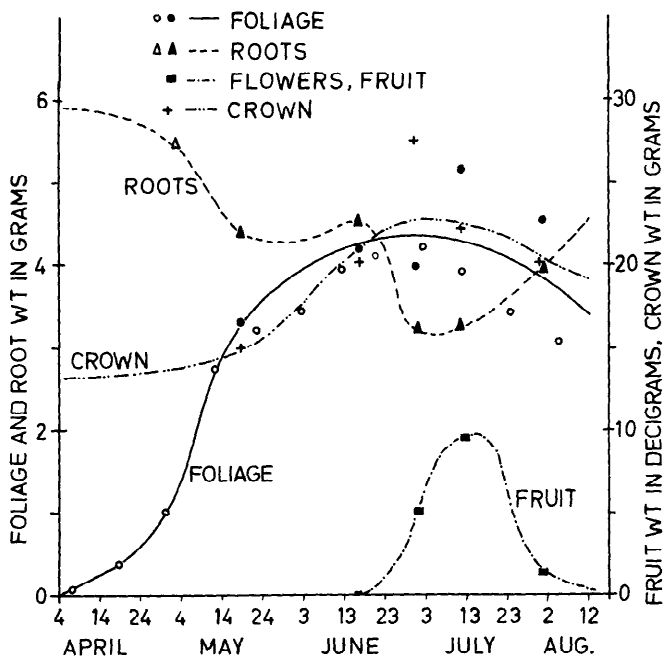


Fig. 2. Pattern of growth in Indian ricegrass at the four Rexburg sites in eastern Idaho in 1971. Each open circle or triangle is the average estimated weight of 281 plants; each of the closed symbols and crosses is the average harvested weight of 35 plants (or of 20 plants prior to June 18).

the coefficients were recorded and kept. (2) Every 10 days from May 15 until August 5, 1971, each plant was examined and the number of culms per plant, maximum leaf length, length of each leaf on each of five randomly chosen culms, average number of leaves per culm, crown diameter (at 0, 120, 240 degrees from north-south), maximum height of the seed heads, number of seed heads per plant and average number of seeds per head were carefully measured. From these measurements, dry weights of the 281 living plants were estimated and these estimated weights were also plotted against time on the plastic sheets. Soil temperature was measured at 20-cm depth on the north side of and adjacent to each plant, precipitation for the week was recorded, and subjective evaluations were made of the amount of grazing on each plant and of the percent weed cover adjacent to each plant. Additional measurements were made of many of the plants in the spring of 1972, 1973, and 1975.

These data were obtained from 281 Indian ricegrass plants and 49 needleandthread grass plants selected on the basis of uniformity and proximity to each other at the four Rexburg sites, plus 51 Indian ricegrass plants in Curlew Valley. The experimental design for the main study at Rexburg was a modified 7×8 factorial with five replications of 50 plants each; the additional 31 plants, 6 or 7 in each replication, provided a "reserve" in case of gopher or other damage. At the time of selection, plants as nearly alike as possible on the basis of number of culms, crown diameter, and height were placed in blocks of seven. Eight such blocks of seven were grouped together to make up each of the five replications. The seven plants in each block were harvested the same day, one block from each replication on each harvest date. This design was used in order to obtain more meaningful comparisons (lower standard errors) among the different irrigation treatments, but it was at the expense of a higher standard error for harvest date differences and probably accounts for some of the discrepancy in Figure 2 between harvest dry weight and estimated dry weight, especially on the July 10 and August 1 harvests. Harvesting was by shovel, care being taken to obtain all of the roots. Careful screening of the soil around some of the plants after excavation indicated that loss of roots never exceeded 1 or 2% of the total root dry weight in this study.

Numbered stakes exactly 1 meter north of each plant identified the individual plants; the distance and direction from one stake to the next in sequence was recorded in the field book. Adjacent to each stake, a partially buried metal can served as a rain gauge. A film of oil in the can reduced evaporation between measurements. All 330 plants in the Rexburg area were measured on the same day (if possible—or on consecutive days) at 10-day intervals; the Curlew Valley plants were measured less often.

The seven irrigation treatments included every possible combination of 0, 4, and 8 cm of water and early (May) and late (June) application, viz., 0-0, 4-0, 8-0, 0-4, 0-8, 2-2, and 4-4 cm. For the first two harvest dates, only one irrigation treatment could precede harvesting and hence the total of 50 instead of 56 plants in each replication.

Within each block of seven plants, assignment to irrigation treatment was random. Plants were irrigated by hand using buckets and an irrigation frame made of metal, 60 cm square and about 15 cm high. The frame was so placed that the plant was in the middle of the framed area and it was then driven into the soil just deep enough to form a dam. When 14.4 liters of water were poured into the frame, the equivalent of 4 cm precipitation had been applied to that area.

The dry weights of 142 harvested plants were compared with number of culms, plant height, and other linear measurements taken on these same plants just prior to harvesting. With help of the computer, formulas for estimating dry weight from these parameters were derived. To aid in this, some of the plants harvested in 1972 were divided into individual culms and individual roots prior to weighing and further measurements made of culm diameter, leaf width, leaf length, root diameter, number of branch rootlets per root, and root length.

Results

Every 2 to 3 weeks, beginning May 20, 35 plants were harvested, dried, and weighed; the average dry weights are shown in Figure 2 (closed symbols and crosses). Approximately every 10 days, beginning April 7, the dry weight of each of 281 plants was estimated from the number of culms, maximum leaf length, average leaf length, crown diameter, and number of seeds. Averages of these estimated weights are shown in Figure 2 as open circles or triangles. On the last two harvest dates, foliage harvest weight was considerably greater than the estimated weight probably because the plants in the blocks harvested on those dates happened to be larger initially.

The dry weight of the foliage, indicated in Figure 2 by the solid line, increased very slowly at first, increased at an accelerating rate until shortly before anthesis, increased more slowly until maturity, and finally decreased. Fruit weight (solid rectangles) increased very rapidly following the onset of anthesis and decreased almost as rapidly as the seeds matured and were either consumed by insects or other animals or disseminated by wind or animals. The dry weight of the crowns—the woody, perennial portion of the plants at or just below ground level from which both the green shoots and roots originate—also gradually increased until the peak of anthesis and then decreased. Thus, simple, smooth curves could be drawn when 1971 dry weights were plotted against time for these plant parts. Root dry weights, on the other hand, changed more erratically (Fig. 2 dashed line).

Rates of growth were different at the different sites, being most rapid at the Curlew Valley south site and slowest at Plano. These differences were probably due to both environmental and genetic factors (McMillan 1959, 1961). Of the four Rexburg

sites, growth began earliest and was most rapid at the south-facing Menan Butte site, where it commenced in late March in 1971 and the first of April in 1973; growth was almost as rapid at the Sand Dunes site (note the high values for coefficients B and C in Table 1), where it began the latest but where the soil warmed up quickly.

Examination of Figure 2 suggests that Indian ricegrass goes through four distinct phenological stages. Our observations of other cool-season bunchgrasses indicate that they go through the same stages. These, together with substages, are indicated in the following outline:

1. Sprouting stage in spring as dormancy is broken
2. Vegetative growth stage
 - a. Logarithmic phase
 - b. Decelerating phase
3. Anthesis and maturation stage
 - a. Weight increase phase
 - b. Weight decrease phase
4. Dormancy stage
 - a. Summer-fall phase
 - b. Winter phase

During the sprouting stage, foliage weight increases but total plant weight decreases as food reserves in the roots are heavily drawn upon. Observations made in 1971, 1973, and 1975 indicate that growth in the spring begins when soil temperatures at the 15-cm depth have warmed up to about 4°C and remain there for at least 3 or 4 days. Experiments conducted in the spring of 1977 by Ricks College students with crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) indicate that it takes about a week at the "critical" temperature or lowest temperature at which sprouting will occur but is somewhat

Table 1. Comparison of environmental conditions at the six sites, 1971 beginning dates of the phenological stages of Indian ricegrass, and 1971 growth rate coefficients for use in Formulas (1) to (5).

	Curlew South	Curlew North	Plano	Menan Buttes	Ricks College	Sand Dunes
Elevation	1290 m	1310 m	1520 m	1550 m	1530 m	1620 m
Soil and topography	deep clay, flat	shallow, sandy, rocky; east facing slope	shallow, sandy, rocky; flat	shallow to mod. deep lava ash; volcano; south facing slope	mod. deep lava ash; gentle north facing slope	very deep, stabilized dunes; rolling
Avg annual ppt	16 cm	32 cm	19 cm	22 cm	26 cm	28 cm
Range in ppt	—	—	13-27 cm	—	18-35 cm	—
May 1971 ppt ¹	—	—	10 (8-10) mm	10 (10-10) mm	10 (10-10) mm	9 (6-10) mm
June 1971 ppt ¹	—	—	28 (28-31) mm	28 (25-34) mm	29 (9-37) mm	25 (10-67) mm
July 1971 ppt ¹	—	—	2.8 (0-18) mm	9.5 (1-26) mm	29 (4-55) mm	19 (4-44) mm
Avg soil temp						
May 1971	15.0 C	10.5 C	18.5 C	10.3 C	9.16 C	9.07 C
June 1971	—	—	18.3 C	17.3 C	17.2 C	15.4 C
July 1971	26.5 C	17.9 C	25.0 C	25.1 C	22.9 C	20.7 C
Grazing history	moderate	moderate	heavy	moderate	none	moderate
Beginning date of ²						
Stage 1	10 March	20 March	10 April	22 March	3 April	12 April
Stage 2a	22 March (L=12)	2 April (L=13)	26 April (L=16)	6 April (L=15)	18 April (L=15)	27 April (L=14)
Stage 2b	17 April (J=38)	2 May (J=43)	26 May (J=46)	28 May (J=52)	18 May (J=45)	27 May (J=44)
Stage 3a	1 May	1 June	16 June	12 June	14 June	21 June
Stage 3b	24 May	25 June	1 July	21 June	30 June	5 July
Stage 4	15 June (K=97)	10 July (K=110)	16 July (K=97)	6 July (K=105)	19 July (K=105)	2 August (K=112)
Growth coefficients						
Formulas (1 to 5)						
A	.028	.027	.023	.028	.025	.026
B	.072	.066	.063	.069	.064	.065
C	.036	.026	.028	.024	.023	.030
D	.0024	.0026	.0036	.0034	.0030	.0038

¹ Average monthly precipitation for all 49 plant locations for which July data were gathered followed by the range in precipitation in parentheses. One plant each at Ricks College and Menan Buttes received 0 precipitation in July according to the record; these were ignored in showing the range and in calculating the average.

² L, J, and K are the number of days from the time of sprouting in the spring to the beginning of stages 2a, 2b, and 4, respectively. All dates are for 1971. K in formulas 1 to 5 is not the same as K₁ in formulas 6 to 8.

faster at slightly higher temperatures. During the sprouting stage, foliage production appears to be essentially linear; in 1971 it lasted about 15 days (Table 1, Fig. 2).

The vegetative growth stage begins when the compensation point is reached—i.e. when daily photosynthesis equals daily respiration—and continues until the beginning of anthesis. As foliage weight increases, the amount of chlorophyll and hence the rate of photosynthesis also increase during the first part of this stage (2a); during the second part of the stage (2b) foliage dry weight increases less rapidly. We would expect root weight to continue to decrease during the first part of this stage as stored food is used in sending out new shoots and to increase in the second part as photosynthate from the foliage is translocated to the roots. Our 1971 data appear to confirm this (Fig. 2).

The anthesis and maturation stage begins when the first florets emerge from the boot and continues until the seeds mature and the plants become dry. Foliage dry weight increased during the first part of this stage (3a) in 1971 at the same rate as in the late vegetative stage (2b). Just before the seeds matured, however, foliage dry weight began to decrease (Stage 3b). Flowers, fruits, and seeds increased in weight until just before maturation and then decreased. Root weight decreased as flowers and fruit formed and then increased as the tops approached maturity (Fig. 2).

The dormancy period can arbitrarily be divided into two phases: the summer-fall phase (4a), characterized by little litter accumulation, which lasted until about December 15 in 1971, and a winter phase (4b), characterized by the tops and leaves being battered down by wind and snow so that a relatively small percentage of the old seed stalks were still standing by April 1972. During the first part of the stage, there appeared to be considerable translocation of food substances into the roots (Fig. 2).

When the foliage curve in Figure 2 was compared with 120 computer-generated growth curves, the following formulas were obtained:

- Stage 1—

$F_{i+1}=F_i+A$

(1)
- Stage 2a—

$F_{i+1}=F_i+BF_i$

(2)
- Stages 2b, 3—

$F_{i+1}=F_i+CF_i-DF_i^t$

(3)
- Stage 4—

$F_{i+1}=F_i-\frac{F_i}{365-K}$

(4)

Where F_i is the foliage weight of a plant on the i th day after sprouting begins in the spring, F_{i+1} is the foliage weight on the day after the i th day and F_k is the foliage weight on the day when $i=k$. Values for A,B,C,D, and K are given in Table 1. The t factor in formula (3) is an exponent consisting of two parts: a time factor and a vigor factor. As the computer automatically “experimented” with different exponents to produce a curve that would exactly match this portion of Figure 2, it came up with a formula which can be expressed this way:

$$t = \frac{I+L}{2(J-L)} + \frac{4}{F_i}$$

(5)

The values for J and L are found in Table 1 for 1971 conditions. The values for all of these coefficients vary according to temperature and moisture conditions from year to year as well as from site to site; much of our research was aimed at analyzing the cause and extent of some of this variation.

Formulas for root growth, crown growth, and seed growth can be found in the unpublished reports of the US/IBP Desert Biome (Pearson 1975) but are not included here as they are more complicated, less precise, and of less direct interest to range

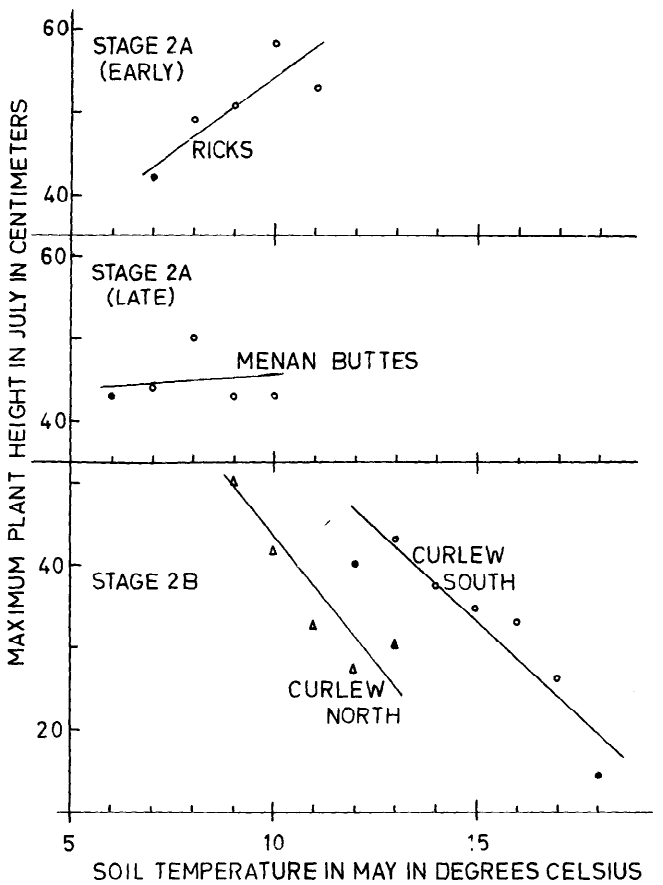


Fig. 3. Effect of soil temperature at 20-cm depth in early May on total plant height reached later in the season. In early May the Ricks College plants were in the early logarithmic phase of growth, the Menan Buttes plants were in late logarithmic phase, and the Curlew Valley plants were in the decelerating phase of growth. Closed symbols indicate average height of 1 to 3 plants; open symbols indicate average height of 4 to 10 plants.

managers.

In 1971, soil temperature adjacent to each plant was measured every 10 days; in 1973 some additional measurements were made. Within sites, temperatures varied as much as 6° Celsius from one plant to another at any given moment; additional variation occurred from site to site. The locations that were the warmest in May were not necessarily the warmest in June. At the Sand Dunes site, higher soil temperatures during stage 2b (late vegetative growth stage) delayed anthesis, 3 days for every increase of 1°C above 10°C. Earlier, during stage 2a, no correlation was noted between soil temperature and date of anthesis; however, Blaisdell (1958) reported that earlier anthesis was associated with higher stage 1 temperatures.

Maximum plant height was also correlated with soil temperature (Fig. 3). During early stage 2 the correlation was positive and relatively high. Each increase of one degree in soil temperature at this time produced 3.2 cm additional height at the Ricks College site. Gradually, the correlation became negative. By the middle of stage 2, there was no correlation between soil temperature and final plant height ($b = -.1$ at Menan Buttes). Each increase of one degree during late stage 2 resulted in a decrease in final plant height of 4 cm at Curlew South and 6 cm at Curlew North. Correlation between maximum plant height and soil temperature was statistically significant at the Curlew IBP sites and at Ricks College.

During 1971, 2,964 measurements of crown diameter were

Table 2. Harvest weight (g) of 104 Indian ricegrass plants following irrigation in May and June 1971. Weight of crowns was highly variable and has been excluded. Weights followed by different letters are significantly different by the SNK test ($P < .05$). Foliage weight differences, July 1, were highly significant (F test: $P < .01$).

	Harvest dry weight (grams)			
	Foliage	Roots	Seeds	Total
July 1, 1971, Harvest				
5 plants given no water	2.22a	4.00	.258	6.48
10 plants watered only on May 31	3.39b	2.99	.448	6.83
10 plants watered only on June 25	4.46c	2.50	.447	7.41
10 plants watered both in May and June	4.82c	4.41	.621	9.85
plants given no water	2.22a	4.00	.258	6.48
15 plants given 4 cm water	3.92b	3.57	.510	8.00
15 plants given 8 cm water	4.53c	3.03	.501	8.06
Least significant difference	.56	2.89	.448	—
July 12, 1971, Harvest				
4 plants given no water	2.75	4.96	.438	8.15
10 plants watered only on May 31	5.29	3.61	.819	9.72
10 plants watered only on June 30	4.97	3.87	1.029	9.87
10 plants watered both in May and June	5.29	1.80	1.010	8.12
4 plants given no water	2.75	4.96	.438	8.15
15 plants given 4 cm water	5.33	3.56	.979	9.87
15 plants given 8 cm water	4.70	2.61	.927	8.24
Least significant difference	1.98	1.83	1.52	—
August 4, 1971, Harvest				
5 plants given no water	3.02	3.28b	.058	6.36
10 plants watered only on May 31	5.49	3.18b	.122	8.79
10 plants watered only on June 30	4.93	3.52b	.355	8.81
10 plants watered both in May and June	4.77	1.92a	.313	7.00
5 plants given no water	3.02	3.28	.058	6.36
15 plants given 4 cm water	5.79	2.54	.247	8.58
15 plants given 8 cm water	4.54	3.20	.279	8.02
Least significant difference	2.51	.81	.182	—

made, 988 in each of three directions: 0°, 120°, and 240° from north-south. Differences among the three directions were very highly significant ($F=27.0$, $P=2.78 \times 10^{-12}$). The crowns tended to elongate in the north-south direction so that at 0° (N-S) the average crown was 7.924 cm, at 240° (ENE-WSW) 7.430 cm, and at 120° (WNW-ESE) 7.340 cm. Apparently the additional warmth at the south and southwest sides of each clump in the early spring caused more rapid growth at 0° and 240° resulting in a measureable asymmetry over a period of years. The probability that differences were due to chance alone is so low that for practical purposes it can be considered an impossibility.

Average annual precipitation at the Plano site is about 19 cm, varying from 13 to 26 cm over the years. The other Rexburg sites are about 15% to 45% wetter than Plano (Table 1). In 1971, there were no discernable differences in precipitation among sites or among individual plants within sites prior to June 15. After June 15, both kinds of differences were pronounced (Table 1). Precipitation in May was 10 mm at almost every one of the gauges. June precipitation varied considerably: from 9 to 37 mm at the Ricks College site and from 10 to 67 mm at the Fremont County sand dunes. July precipitation varied at least as much. Some of the plant-to-plant variation was probably due to differences in evaporation of water from the gauges that occurred despite the film of oil in each gauge. The precipitation differences apparently came too late to affect the phenology of Indian ricegrass as no significant correlation between precipitation and growth or development of individual plants was detected at any of the four sites. Differences in growth and development among sites were significant, however, being greater at the wetter sites and least at Plano.

The irrigation treatments, on the other hand, increased

foliage production and the increases were highly significant ($P < .01$) for the July 1 harvest and closely approached significance on the other harvest dates (Table 2). The late irrigation was the more effective.

Estimates of increase in dry weight made from linear measurements were also significantly higher ($< .05$) for plants irrigated in June (Table 3). Each centimeter of water applied increased foliage production .32 g per plant according to the harvest data, or .09 g per plant according to the estimated increase data; the discrepancy between the two values suggests a deficiency in the formula used to estimate dry weight in 1971. The early irrigation did not increase foliage production unless a relatively large amount of water (8 cm) was applied; even a small amount of water (2 cm) applied late increased foliage production, however (Table 3).

Seed weight also appeared to be increased by irrigation, the differences approaching significance at all three dates (Table 2). Root biomass, on the other hand, seemed to be decreased by irrigation, suggesting that additional water stimulated translocation of food reserves from the roots to the tops more than it improved rate of photosynthesis. The decrease was statistically significant for the August 4 harvest. At the Ricks College site, which was the only site at which grazing was excluded, the increase in the number of shoots per plant of the following spring was greatest on the irrigated plants. At all of the sites, the irrigated plants showed more evidence of grazing by livestock, rodents, or insects than the non-irrigated plants; this was most pronounced at Plano, where differences were statistically significant. On a scale of 0 = no evidence of grazing to 50 = evidence of very heavy grazing, plants receiving no irrigation scored 14, those irrigated only on June 25 scored 21.5, those irrigated only on May 31 scored 28.5, and those irrigated both

Table 3. Effects of irrigation on increase in estimated biomass and on date of anthesis. Biomass measurements were made on 140 Indian ricegrass plants at the Rexburg sites in the middle of May and middle of July; date of anthesis data are from 35 plants at the Fremont County Sand Dunes site.

	Increase in est. dry wt.			Time to beginning anthesis	
	No. plants	Foliage (g)	Seed (g)	No. plants	No. days
Plants given no water	20	.33a	.58	5	70 a
Plants watered only on May 31	40	.45b	.50	10	81.5 b
Plants given no water until June 30	40	.65c	.78	10	73.5 a
Plants watered in both May and June	40	.67c	.74	10	80 b
Plants given no water	20	.33a	.68	5	70 a
Plants given 4 cm water	60	.54b	.77	15	75 a
Plants given 8 cm water	60	.64b	.56	15	82 b
Least significant difference		.15	NS		5
Specific treatments					
0-0	20	.33a	.68	5	70 a
4-0	20	.31a	.58	5	80 bc
8-0	20	.59b	.42	5	83 bc
0-4	20	.61b	.81	5	70 a
0-8	20	.69b	.74	5	77 b
2-2	20	.69b	.93	5	75 ab
4-4	20	.64b	.54	5	85 c

times scored 29.

Percent of ground between clumps of grass covered by annual weeds increased during the spring of 1971 until June 24, when it reached 10.9%. As the weeds matured and dried, their cover declined to 1.7% on July 14 and 0.35% on August 3. On August 3, percent weed cover was significantly higher near plants that had been irrigated, the difference being due primarily to the early irrigation and directly proportional to the amount of water applied.

Over 150 Indian ricegrass plants were harvested in 1971 and an additional 22 in 1972; comparisons between the weights of the harvested plants and their linear dimensions led to the development of several formulas (Pearson 1975). Foliage dry weight and the fruit-seed dry weight were quite accurately estimated from the following formulas:

$$Y_f = K_1 ACL + K_2 D + K_3 (SN)^{1/2} + K_4 \quad (6)$$

$$Y_f = 8.15 \times 10^{-5} ACL + .18D + .054 (SN)^{1/2} - .61 \quad (7)$$

$$Y_s = .00495SN + .0029A - .0026H - .0158 \quad (8)$$

where Y_f =foliage dry weight in grams and Y_s =seed head dry weight in grams, A =average leaf length in cm, C =number of culms per plant, L =average longest leaf in cm, D =average crown diameter in cm, S =number of seeds per head, N =number of seed heads per plant, and H =average height of the seed stalks in cm. Formula (6) is a generalized formula for use with any cool season bunchgrass once the coefficients K_1 , K_2 , K_3 , and K_4 have been ascertained by harvesting a number of plants. Formulas (7) and (8) apply to Indian ricegrass growing at the Rexburg sites in 1971 and 1972. Good estimates of foliage and seed head dry weights were obtained with these two formulas at all six sites; nevertheless, Indian ricegrass growing at other locations or time might require some slight adjustments of the four coefficients in each formula.

Obtaining accurate estimates of foliage or seed dry weight depends on making accurate and reproduceable measurements of the necessary linear dimensions. The following aided us in making our measurements: (1) Four long galvanized spikes were driven into the ground around each plant at the time of the first measurement so that the heads of the spikes were flush with the top of the crown where the new green foliage originates, and all subsequent measurements of leaf length and plant height were made from the tops of these spikes. (2) A light-weight,

steel measuring device (calipers) for obtaining crown diameter was prepared; it has two parallel sides which can be adjusted to any width from 0 to 50 cm by sliding one arm along an iron rod welded at right angles to the other arm. (3) Three brightly colored rods, each about 30 cm long, were used to divide the plant into seven sections so that keeping track of the number of culms counted was better facilitated. Our earliest estimates were made without the aid of these devices and were less accurate

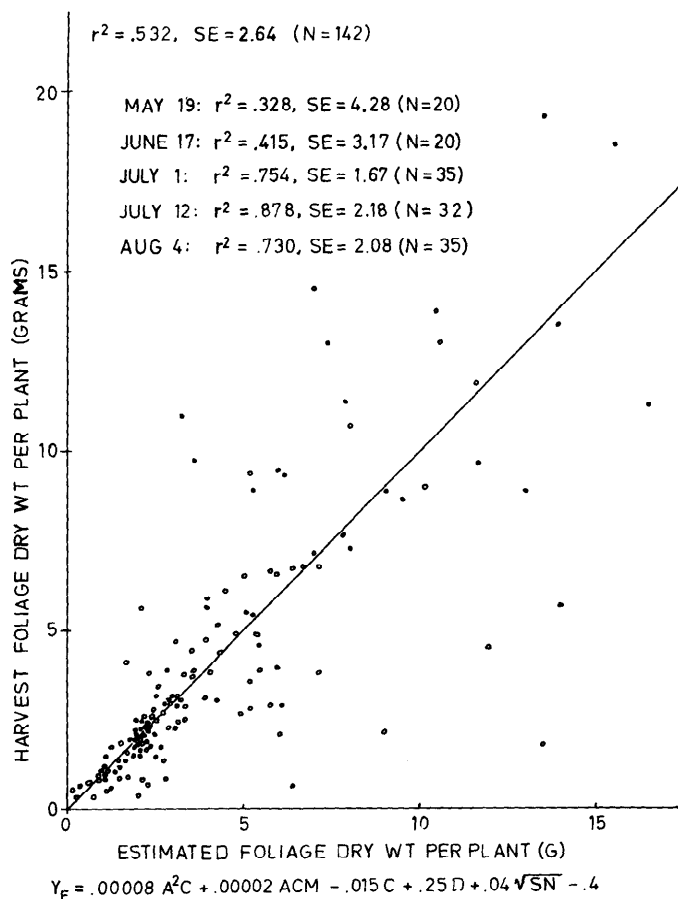


Fig. 4. Scatter diagram plotting actual dry weight against estimated dry weight of foliage. Better correlations were obtained later in the season as measuring of the parameters used to estimate dry weight became more consistent. M is maximum leaf length: see text following formulas (6) to (8) for other symbols.

than the later estimates.

Figure 4 is a scatter diagram of harvest dry weight plotted against estimated dry weight. The formula used was slightly different from formula (7) as we did not keep average longest leaf (L) data in 1971. Correlation was better later in the season. As the parameters needed were more consistently measured, r^2 increased from .328 in May to .878 in July. In August, tips of leaves were brittle and often broke as the plants were handled, making accurate estimation of leaf length more difficult. When average longest leaf data became available in 1972 there was further improvement in estimating dry weight.

Needleandthread grass went through the same phenological stages as Indian ricegrass but reached maximum size somewhat earlier. Irrigation increased the amount of foliage produced and delayed the time of reaching maximum leaf length. The 2 cm application of water in late May had no effect on production, but each additional centimeter of water increased foliage dry weight in July by about .15 g per plant. Each centimeter of water applied May 31 delayed leaf length attainment about 2 days. This prolonging of stage 2a (logarithmic growth stage) should account for at least part of the increase in weight associated with early irrigation of the plants. The early irrigation also retarded flowering of some of the plants at the Ricks College site, one of them by about 30 days. The June 25 irrigation seemed to stimulate a second spurt of growth immediately following irrigation, especially at the Menan Buttes site.

Discussion and Conclusions

A change in weather during one phenological stage may produce a markedly different response in Indian ricegrass from an identical weather change during a different phenological stage. This needs to be kept in mind when managing rangeland. Pearson (1964) suggested that many of our ranges could support larger populations of livestock with less damage to the range if more attention were paid to the season of grazing. A critical period during which cool season bunchgrasses are very susceptible to overgrazing seems to be phenological stages 2b, 3a, and 3b, (from the beginning of the decelerating phase of the vegetative growth stage through the anthesis and maturation stage). During this time, grazing should be greatly reduced or even totally eliminated if the desirable species are to be properly protected. If the spring is cool or moist, the beginning dates of these stages will be later, which should allow early spring grazing to continue longer; however, the ending dates will also be later, necessitating holding animals off the range longer into the summer.

Examination of Figure 2 helps explain why management of grazing is so critical during the late vegetative and anthesis stages: the roots during much of this time are losing weight, and this tendency is more pronounced when more moisture is available. The study of roots and their contribution to the total energy budget of a plant is a difficult task and therefore frequently ignored. It takes much more time to excavate and weigh roots than other plant parts and much more care must be exercised in handling roots as they easily break. Nevertheless, we cannot analyse accurately the patterns of growth and development in plants without adequate information on root mass.

The advantages of estimating dry weight from plant height, leaf length, and other linear measurements include: (1) ease of evaluating a large number of plants in a short period of time, (2) ability to make successive measurements on the same plant and

thus observe its rate of growth more accurately, (3) less damage to the ecosystem, and (4) selection of similar plants for grouping into replications prior to beginning an experiment which may or may not involve harvesting later on. There was good correlation in this study between estimated dry weight and harvest dry weight for foliage and seed stalks. It was more difficult to estimate root weight and crown weight accurately. However, number of roots per plant was rather highly correlated with crown diameter while the weight of individual roots was positively correlated with average leaf length and negatively correlated with number of seed heads: consequently, even root biomass was estimated fairly accurately in 1971, suggesting that it may be possible to develop good formulas in which we can place confidence for future work. We ascertained that it took 14 to 20 man minutes per plant on the average, dependent on the experience of our data gatherers, to gather and record all of the linear measurements needed to estimate the weight of the plant, and 2½ to 3½ man hours per plant to harvest, weigh, and record the actual dry weight data of the same plant. Hence, any success in estimating even foliage dry weight accurately can be of great time saving value in studying the effects of moisture, temperature, or other factors of the environment on the phenology and productivity of rangeland species. We recommend the use of devices similar to those we employed in this study to improve the accuracy of estimating dry weight.

Indian ricegrass begins growth slightly later than most of its associates among the cool season bunchgrasses. According to Blaisdell (1958), the sprouting stage for Sandburg's bluegrass (*Poa secunda* Presl) begins while soil temperatures are about 0°C, or as soon as the snow disappears; for Nevada bluegrass (*Poa nevadensis* Vasey ex Scribn.) and prairie junegrass (*Koeleria cristata* (L.) Pers.) it begins slightly later, and for bluebunch wheatgrass (*Agropyron spicatum* (Pursh.) Scribn. and Smith), thickspike wheatgrass (*A. dasystachyum* (Hook.) Scribn.), and needleandthread grass it begins still later, or about the same time as Indian ricegrass. Also, according to Blaisdell, Indian ricegrass matures more rapidly than most other cool-season grasses. Sandburg's bluegrass and needleandthread grass matured even more rapidly than Indian ricegrass at the six sites included in this report.

From the configuration of the growth curve of Indian ricegrass, four phenological stages are apparent. If the soil warms up rapidly during the first of these, yields will be better than if the season is late or the soil remains cold. Increased soil moisture is usually accompanied by lower soil temperatures and therefore seems to be nonbeneficial during this stage of development. During the second or vegetative growth stage, moisture is of greater significance. Higher soil temperature at this stage is generally associated with low soil moisture and is therefore no longer beneficial. Judging from our observations on needleandthread grass, Indian ricegrass should provide a good model for other cool season bunchgrasses. As we learn more about the phenology and productivity of the important grasses, management of rangeland becomes more meaningful.

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Impact of Various Range Improvement Practices on Watershed Protective Cover and Annual Production Within the Colorado River Basin

IRADJ K. HESSARY AND GERALD F. GIFFORD

Abstract

During 1976 a study of annual production and cover (litter + rock + vegetation) on various range improvement practices was conducted in Utah, Colorado, New Mexico, and Arizona. The range improvement practices studied included gully plugs, contour furrowing, pitting, pinyon-juniper chaining, and various sagebrush control treatments.

Results from studies of annual production on treated vs untreated sites indicated that: (a) about 33% of the contour furrowed sites had significant increases in annual production. Best responses were found on loam and clay loam soils, while soils of sandy loam or clay texture indicated a poor response to treatment. Soils classified as typical ustifluvents and ustollic haplargids were most favorable in terms of increased production; (b) annual production on pinyon-juniper chainings was significantly increased across a variety of soil types (growth of trees excluded). The greatest increases in production were measured on sites with loam soils classified as typic haplustolls; (c) neither of the two pitting treatments on a clay and a sandy clay loam site indicated increased annual production; (d) less than 50% of the various sagebrush treatments indicated increased annual production. There appears to be a general trend for best responses on loam soils, though significant decreases in production were also indicated on this type of soil; (e) plowing was the least successful sagebrush treatment studied.

Best cover responses on the various range improvement practices were found on contour furrowing treatments on sandy clay loam and loam textured soils and on typic torriorthent or ustic torriorthent soil types. Though significant cover increases due to chaining of pinyon and juniper were noted on 57% of the treatments, on a variety of soil textures and soil types, the

increases were uniformly small (tree cover included) and no clear pattern emerged with either soil texture or soil type. Only about 20% of the various sagebrush treatments showed significant increases in cover; 10% indicated decreased cover, and there was no impact on cover on the remaining 70% of the treatments. Pitting treatments in this study had no impact on cover.

Age of contour furrow treatments made little difference as to whether there was a significant increase or decrease in either production or cover. Cover data from pinyon-juniper chainings indicate either that significant increases in cover (if they occur) are slightly more dramatic on more recent treatments, or that treatments approximately 11 years old represent conditions most ideal for enhanced cover. The former interpretation is probably more nearly correct. Production data suggests that pinyon-juniper sites chained since 1964 are not as favorable in terms of increased production as those chained prior to 1964. Age of sagebrush treatment had no impact on significant changes in cover; however, a general trend indicated that production increases are slightly higher for more recent sagebrush ripping and sagebrush chaining treatments than for older ones.

The upper and lower Colorado River basins, rapidly growing in population and size, face increasing problems concerning water quality. The concern is particularly noticeable in terms of the increasing dissolved solid content of the Colorado River itself. The growing awareness that chemical constituents are an integral part of the hydrologic system has led to a greater emphasis on determining sources and causes of dissolved solids and their relationship to physical system parameters. One particular aspect of current interest is the determination of the impacts of various rangeland manipulation treatments on salinity. If such impacts can be identified, then strategies may be developed for decreasing the salinity problem and improving water quality. The major emphasis of this study is directed to the practical application of range improvement practices for eventual formulation of land management programs that may

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The research was supported jointly by the Bureau of Land Management (Contract 52500-CTS-16) and the Utah Agricultural Experiment Station, Project 412. The authors would like to thank Dr. Al Southard, Department of Soils and Biometeorology, Utah State University, for his assistance in classification of soils. Journal Paper 2280, Utah Agricultural Experiment Station.

Manuscript received March 28, 1978.

influence infiltration and surface run-off and help reduce the diffuse salt production from wildland watersheds.

The objective of this study was to determine the impact of existing land treatments on watershed cover and annual production. Reviews of the impact of various range improvements practices on selected watershed characteristics have recently been given by Gifford (1975) and Wight (1975).

General Description of Study Area

The 73 study sites are located primarily in Utah, Colorado, and New Mexico, with one site in Arizona. The range improvement practices studied included contour furrowing (11 sites), pitting (2 sites), pinyon-juniper chaining (14 sites), gully plugs (6 sites), and various sagebrush control treatments (40 sites). The sites in Utah (32 sites) lie primarily in Grand, Emery, Carbon, and San Juan counties; in Colorado (12 sites) Montrose, Gunnison, Dolores, and San Miguel counties; in New Mexico (28 sites), Valencia, Sandoval, Rio Arriba, and San Juan counties; and Maricopa county in Arizona (1 site).

The highest point among the sites is 2,438 m above sea level in San Juan county in Utah, and the lowest is 396 m in Maricopa county in Arizona. The Canyonlands country, located in the Colorado plateau province, is characterized by many deep, rugged canyons through which flows the Colorado River. The major part of the area is composed of tablelands, or mesas, and the topography is undulating to gently rolling. In Colorado and New Mexico the terrain is gentle, and the sites are located mainly on recent alluvium and alluvial fans. Generally, pinyon-juniper chaining practices are located at higher elevations in rougher terrains than are most of the other improvement practices. The mean annual temperature among the various sites ranges from 9.4°C to 11.6°C. Most of the sites, except those at higher elevations, have a mesic soil temperature regime. The higher elevation sites are considered frigid.

Precipitation varies markedly among the sites, with the average annual precipitation varying from 18 cm to almost 75 cm. The climate is characterized by cold winters and relatively hot and dry summers, with the highest rainfall in August, September and October, and the lowest during May and June. Much of the precipitation in summer falls as showers and the resulting moisture is rapidly evaporated or transpired.

Parent material on the study sites varies. Most of the soils on the gully plug sites, and also on a few contour furrow sites, were formed on parent materials derived from soft shale and sandstone of Cretaceous and early Tertiary ages called the Mancos formation (Wilson 1975). Other sources of parent materials include a brown mantle of eolian sediments, calcareous sandstones, glacial tills, hardshales, and recent or old alluvial deposits. Soils at high elevations (Mollisols, Alfisols) are commonly leached, well developed, and acid in reaction. This is due to higher precipitation, lower temperature, and coniferous type trees. On sites where annual rainfall is lower, leaching of carbonates from the soil is not well developed (Aridisols), and there has been little translocation of clay in the profile (Wilson 1975).

Vegetation on the various sites varies with elevation, amount of precipitation, seasonal distribution of moisture, and soil characteristics. In general, native plant communities in the lower valleys, plains, mesas, and plateaus, where the climate is semiarid and average annual precipitation is low, are dominated by grasses, shrubs, and forbs. Species such as mat saltbrush (*Atriplex corrugata*), nuttall saltbush (*Atriplex nuttallii*), fourwing saltbush (*Atriplex canescens*), shadscale (*Atriplex confertifolia*), greasewood (*Sarcobatus vermiculatus*), Indian ricegrass (*Oryzopsis hymenoides*), and galleta (*Hilaria jamesii*) are most dominant in saline soil sites. However, on sites with less salt, true mountain mahogany (*Cercocarpus montanus*), bitterbrush (*Purshia tridentata*), gamble oak (*Quercus gambelii*), serviceberry (*Amelanchier alnifolius*), rabbitbrush (*Chrysothamnus viscidiflorus*), snake weed (*Xanthocephalum sarothrae*), big sagebrush (*Artemisia tridentata*), alkali sacaton (*Sporobolus airoides*), sand dropseed (*Sporobolus cryptandrus*), and blue grama (*Bouteloua gracilis*) are found. At higher elevations pinyon-pine (*Pinus edulis*)

and Utah juniper (*Juniperus osteosperma*) are the dominant species that are found mainly on mountain slopes, plateaus, and foothill terraces on shallow and stony areas where the climate is dry-subhumid.

During the period from 1945 to 1970, vegetation conversion practices were attempted on the various study sites. The primary purpose of the conversion practices was to improve range condition through increasing soil moisture, grazing capacity, and nutritional value of forage. Crested wheatgrass (*Agropyron cristatum*), tall wheatgrass (*Agropyron elongatum*), western wheatgrass (*Agropyron smithii*), Russian wildrye (*Elymus junceus*), side-oats grama (*Bouteloua curtipendula*), alkali sacaton (*Sporobolus airoides*), sand dropseed (*Sporobolus cryptandrus*), sweet clover (*Mellilotous officinalis*), and fourwing saltbush (*Atriplex canescens*), are the main species which were seeded on the various sites.

Methods and Procedure

This study was initiated early in 1976. Job documentation reports and information from the appropriate Bureau of Land Management districts on the age of various range improvement treatments, acreage involved, geographic location, and methods of applying treatments were used for determining the approximate number of sites to be sampled. Topographical maps were used to determine the general location of various sites, while field visits established the exact location of sampling sites. Specific criteria such as the representativeness of the general area were considered in final site selections.

A "treated" and nearby similar "untreated" sampling site, each with an area of approximately 23,409 m² (2.3 ha), were selected for each treatment location. All on-site measurements and observations were taken only once at each site. Statistical evaluations were made of treated vs untreated conditions within a given location for a single sampling date.

Soil at all sites was classified in the field according to procedures outlined in U.S. Dep. Agr. Handbook No. 436 (1975).

Current year's production of all species present (green weight estimates were later converted to air-dry weight) in "treated" and nearby "untreated" sites was measured using a double-sampling technique modified after the weight estimate method (Pechanec and Pickford 1937). Production was not determined on gully plug treatments. Samples were taken along transect lines using a circular 0.89-m² (9.6-ft²) hoop at intervals of 18 m between plots. Twenty-five random plots were selected and measured on each area and every fifth plot (beginning with the first) was also clipped. Regression techniques were used to adjust all estimated plots. Production measurements were taken only on ungrazed or lightly grazed portions of each treatment site.

Canopy and ground cover (including litter and rock) of all species were measured on all sampling sites using the step-point method of sampling (Evans and Love 1957). Fifty points were read on each of four transects, for a total of 200 points per treatment. As with production measures, cover measurements were taken only on ungrazed or lightly grazed portions of each treatment site.

Results

Production Measures

Contour Furrowing

Figures 1 and 2 indicate significant changes in annual production on various contour furrowing projects as a function of soil texture and soil type, respectively. From Figure 1 it is evident that a poor response to contour furrowing is generally associated with sandy loam and clay soils. In this study, no significant increases in production were noted on sites with soils in these textural classes. Increased production due to furrowing was measured on one site (out of two) on loam soils and on one site (out of three) on clay loam soils. There were no significant decreases in production as a result of contour furrowing on either the loam or clay loam soils.

From Figure 2 it is apparent that production on contour furrowing treatments is significantly increased on typic usti-

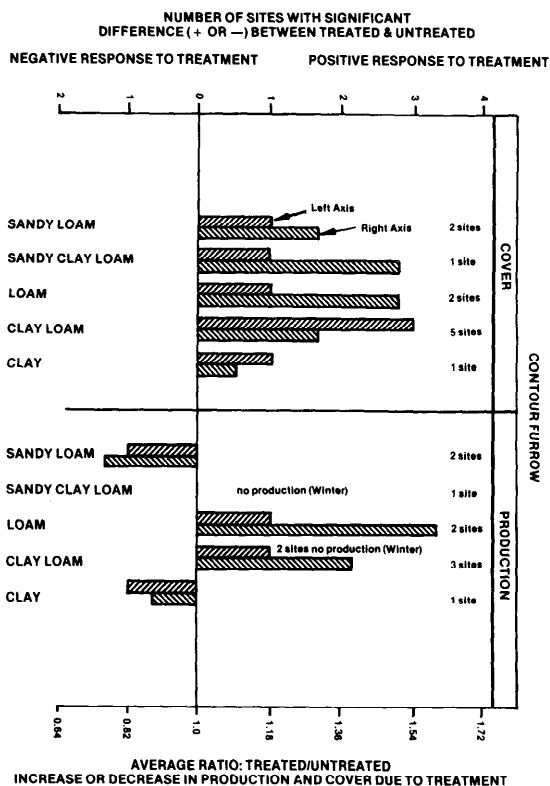


Fig. 1. Response of cover (vegetation, litter, rock) and production (all species) on various contour furrowing projects as a function of soil texture. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred (either + or -).

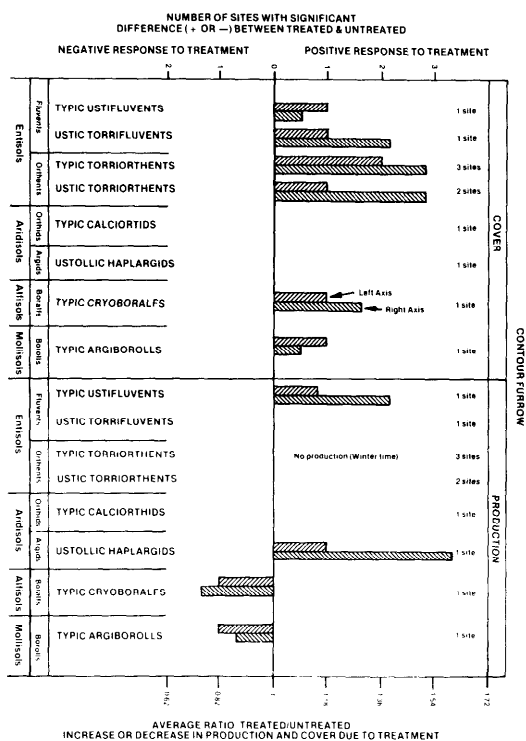


Fig. 2. Response of cover (vegetation, litter, rock) and production (all species) on various contour furrowing treatments as a function of soils. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred (either + or -).

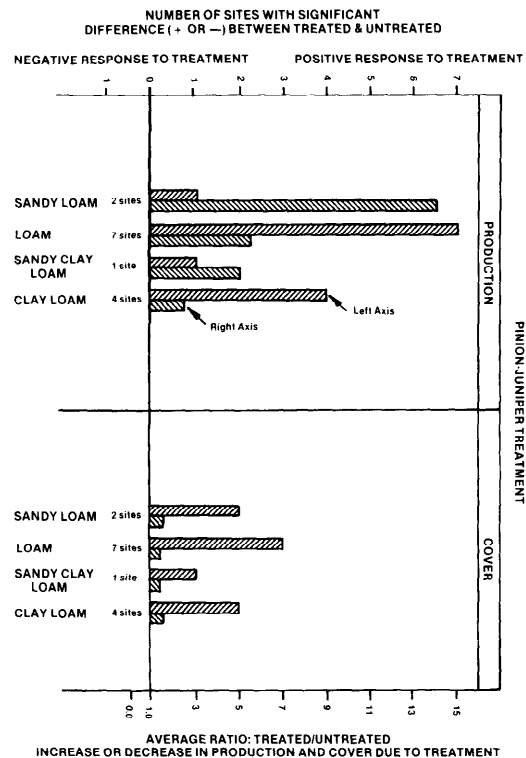


Fig. 3. Response of cover (vegetation, litter, rock) and production (all species excluding pinyon and juniper trees) on various pinyon-juniper treatments chaining and seeding) as a function of soil texture. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred (either + or -).

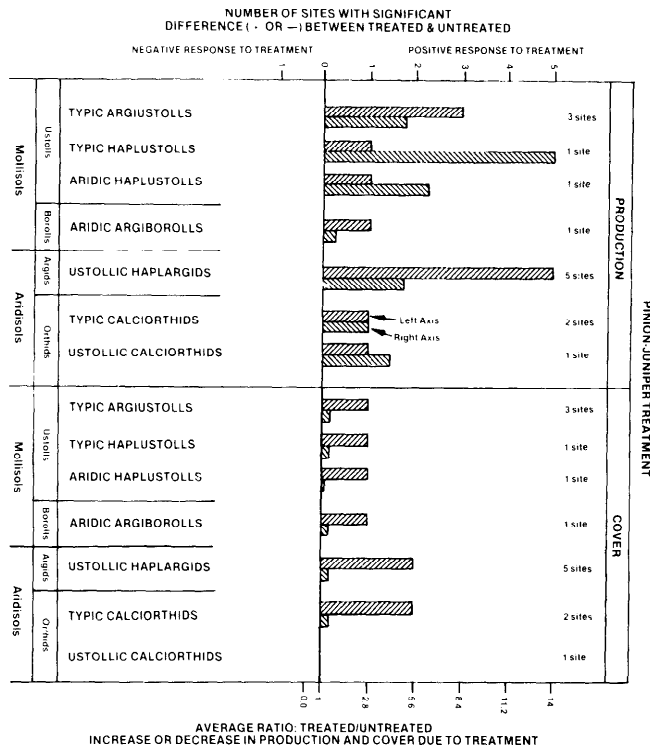


Fig. 4. Response of cover (vegetation, litter, rock) and production (all species) on various pinyon-juniper treatments (chaining and seeding) as a function of soils. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred (either + or -).

fluvients and ustollic haplargid soils. Annual production on contour furrowed sites with typic cryboralf and typic argiboroll soils was significantly decreased (one site each). No significant changes in annual production were measured on sites with other soil types.

Pinyon-Juniper Chaining

Figure 3 shows the impact of pinyon-juniper chaining on annual production as a function of soil texture. There was a significant increase in production on nearly all chained sites. The greatest increase in production was measured on sites with coarser loam soils, with lesser increase on sites with clay loam soils.

Figure 4 indicates that annual production was significantly increased across a variety of soil types. The greatest increase was on one site characterized by a typical haplustoll.

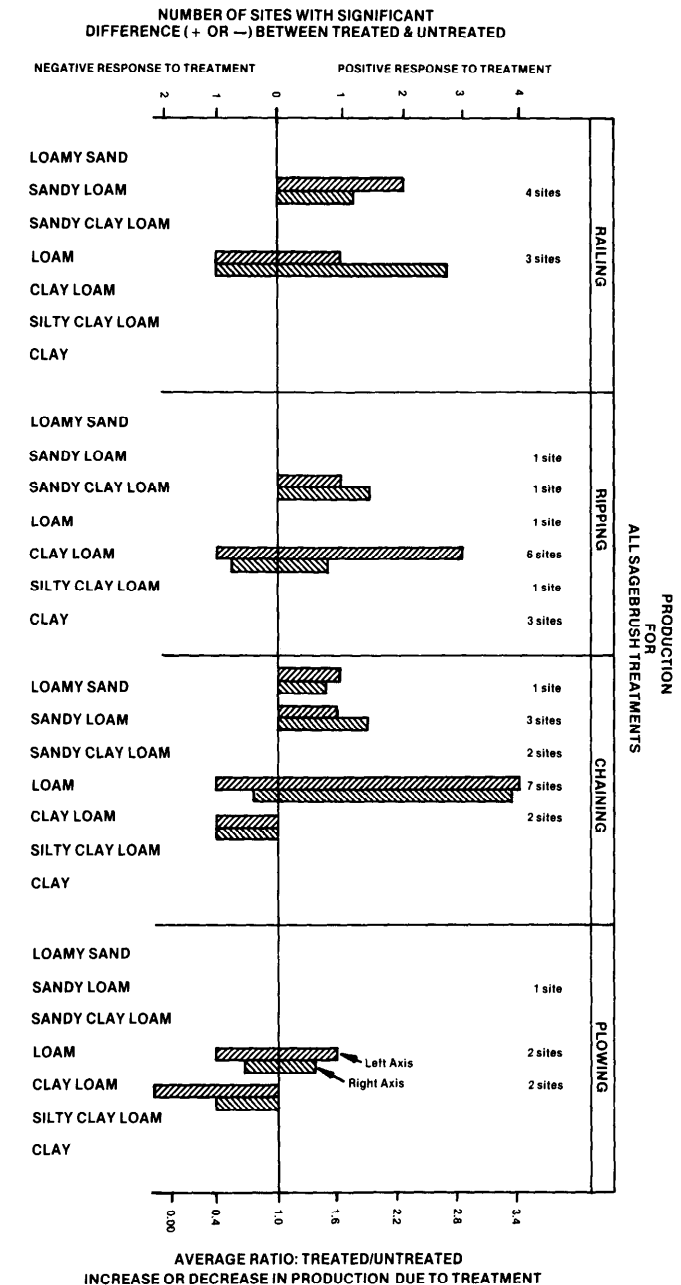


Fig. 5. Response of production (all species) on various sagebrush treatments as a function of soil texture. For each pair of bars the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred either + or -.

Pitting

On the two pitting treatments a significant reduction in annual production due to treatment was noted on clay soils, while on a sandy clay loam site no impact of pitting was measured. Soil on the former site was classified as a typic torriorthent and on the latter site as a typic torrifluvent.

Various Sagebrush Treatments

Figures 5 and 6 show the variable production response among various sagebrush treatments as a function of soil texture and soil type, respectively. There appears to be a general trend for sagebrush treatments to be most successful on loam soil, though significant decreases in production were noted for three treatments on loam soils. Plowing was the least successful sagebrush treatment studied.

Sagebrush Railing

Figure 5 indicates that annual production was significantly increased on two out of four sites on sandy loam soils and on one of three sites on loam soils. Annual production on one site with

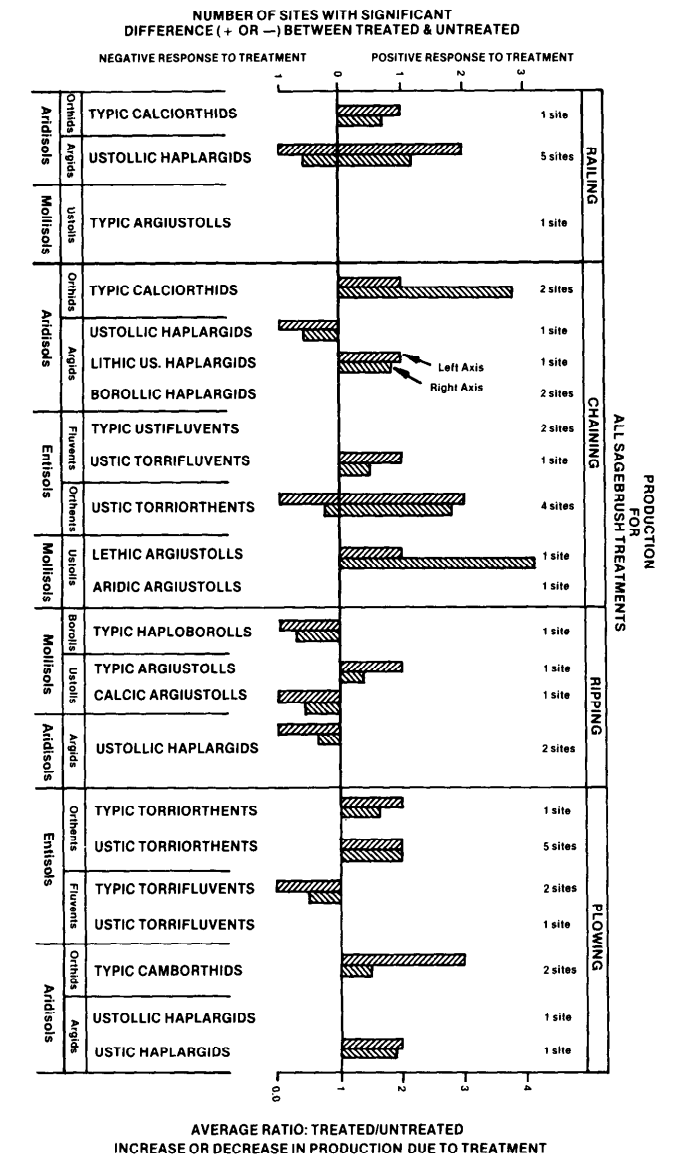


Fig. 6. Response of production (all species) on various sagebrush treatments as a function of soil type. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant difference ($P=0.1$) occurred (either + or -).

loam soil was significantly decreased due to raiing.

Figure 6 indicates that annual production on two of the five sites on ustollic haplargid soils was significantly increased due to railing, while production on one site with the same soil type was significantly decreased. Annual production on a single site on typical calciorthid soils significantly increased due to treatment.

Sagebrush Ripping

Five of 13 sagebrush ripping sites showed a significant increase in annual production due to treatment. As shown in Figure 5, one site was on sandy clay loam soil, three sites were on clay loam soils, and one site was on a clay soil. One site (out of 13.), on clay loam soil, had significantly less production on the treated portion.

From Figure 6 it is apparent that most favorable response to ripping occurred on typic torriorthents, typic camborthids, and ustic haplargids. Sites on other soil types either responded

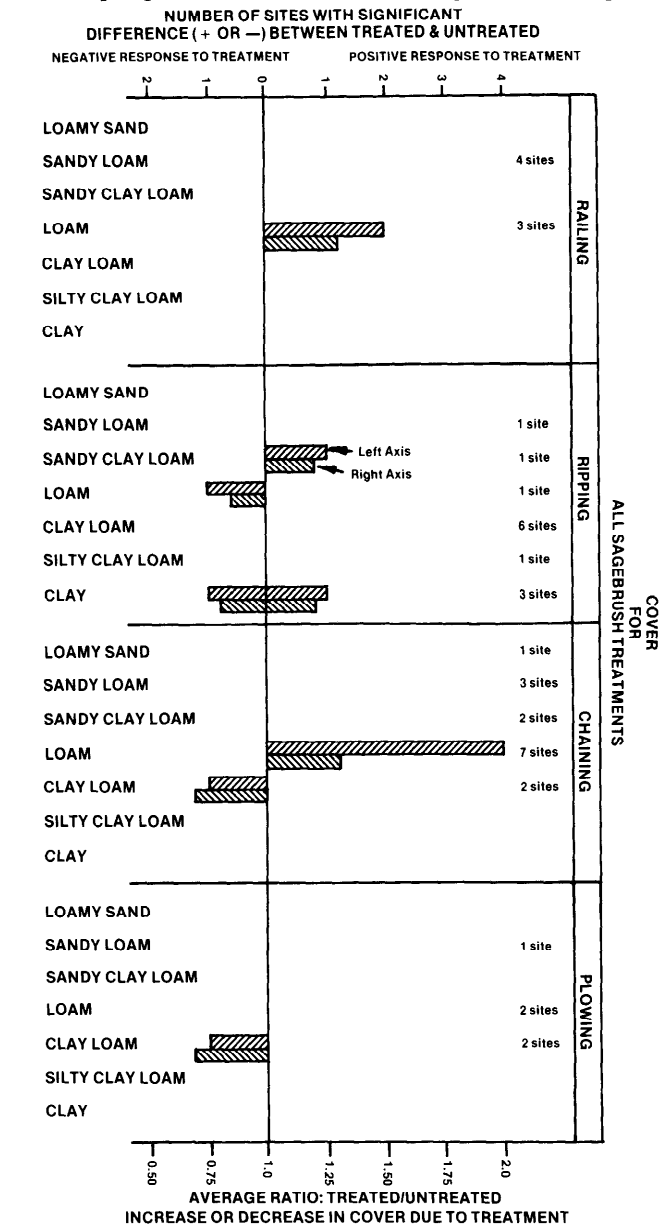


Fig. 7. Response of cover (vegetation, litter, rock) on various sagebrush treatments as a function of soil texture. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred (either + or -).

negatively to treatment, showed no response whatsoever, or showed a poor response to treatment (for example, one site out of five on ustic torriorthents).

Sagebrush Chaining

The most favorable response to chaining sagebrush was on loam soils, though not all sites showed a significant response to treatment and one site showed a significant decrease in production due to treatment (Figure 5). The most favorable sites appeared to be those on sandy clay loam and clay loam soils.

Figure 6 shows a mixed response to soil type, though the greatest increases in production were noted on typic calciorthids and lithic argiustolls. The least favorable sites were on ustollic haplargids, borollic haplargids, typic ustifluvents, and aridic argiustolls.

Sagebrush Plowing

Plowing was effective in increasing production on one site

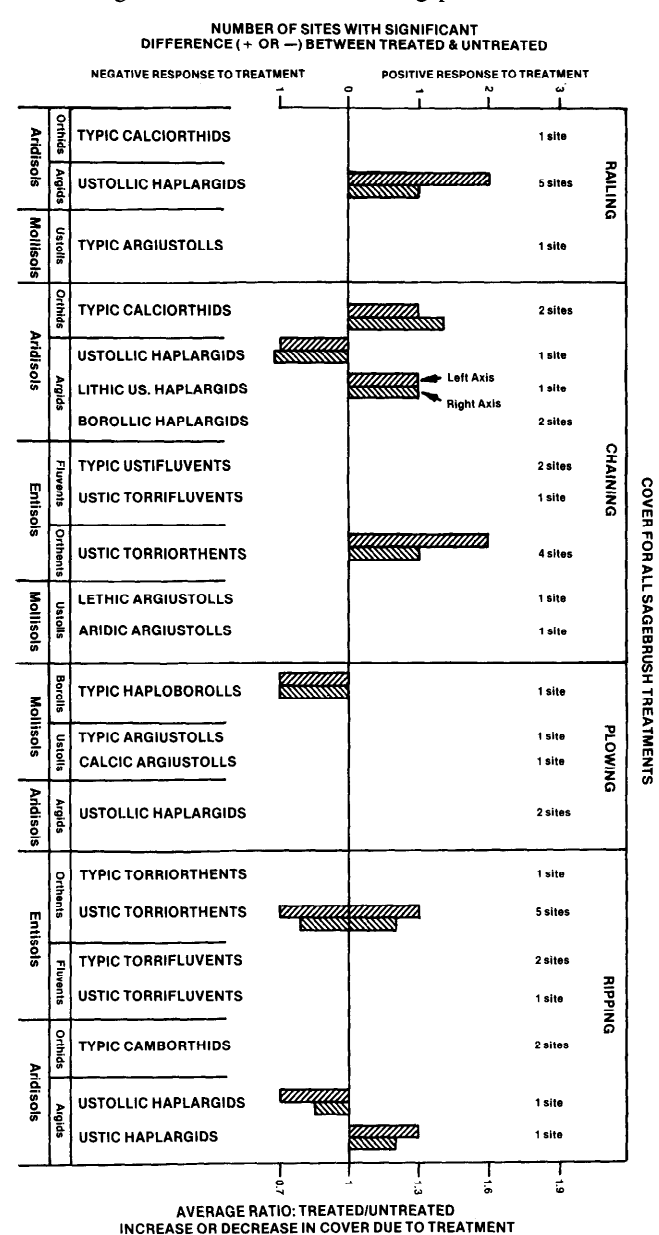


Fig. 8. Response of cover (vegetation, litter, rock) on various sagebrush treatments as a function of soils. For each pair of bars, the left bar corresponds to the left axis and the right bar corresponds to the right axis. Site numbers above or below each set of bars represent total number of sites sampled within a given category. Bars represent only those sites where significant differences ($P=0.1$) occurred (either + or -).

out of five. Soil on the one favorable site was classified as a typic agriustoll (Fig. 6).

Cover Measures

Contour Furrowing

Cover on 7 of 11 contour furrow treatment sites increased across a broad spectrum of soil textures and soil types (Figs. 1 and 2). Cover increases were greatest on sandy clay loam and loam textured soils and on typic torriorthent and ustic torriorthent soil types.

Pinyon-Juniper Chaining

Though cover increases due to chaining were noted on 8 of 14 pinyon-juniper sites on a variety of soil textures and soil types, the increases were uniformly small (Fig. 3 and 4). No clear pattern emerged from either soil texture or soil type.

Pitting

Significant changes in percent cover due to pitting were not detected on either the sandy clay loam or clay textured site sampled in this study, and so were not illustrated.

Various Sagebrush Treatments

Railing

As indicated in Figure 7, the only sites showing increased cover on railed treatments were those with a loam texture and with soils classified as ustollic haplargids (Fig. 8). Four sites with sandy loam soils showed no response to railing in terms of either increased or decreased cover.

Ripping

Cover responses to ripping treatments on sagebrush sites were mixed and generally not impressive (Fig. 7 and 8). Recommendations based on either soil type or soil texture are not evident at this time.

Chaining

The only sites showing increased over due to chaining were four of seven sites on loam soils (Fig. 7) classified as typic claciorthids, lithic ustollic haplargids, or ustic torriorthents (Fig. 8). Cover response to chaining was otherwise nil or negative.

Plowing

Of the five plowing treatments sampled, not a single one indicated increased cover on the treated area (Fig. 7 and 8). One site on clay loam soils indicated a significant decrease in cover on the treated area.

Impact of Treatment Age on Production and Cover

Contour Furrowing

Age of treatment made little difference as to whether there was a significant increase or decrease in either production or cover on contour furrowed sites.

Pinyon-Juniper Chaining

Figure 9 indicates the impact of age of treatment on significant changes in production and cover due to chaining pinyon and juniper. Figure 9a suggests either that significant increases in cover (where they occur) are slightly more dramatic on more recent treatments (linear interpretation) or that treatments which are approximately 11 years old represent conditions most nearly ideal for enhanced cover (assuming again that an increase in cover occurs) (curvilinear interpretation). The former interpretation is probably more nearly correct. A linear interpretation of the data points also suggests that any cover differences that may exist would disappear after about 30 years.

Data shown in Figure 9b suggests that pinyon-juniper sites chained since 1964 are not as favorable in terms of increased production as those chained prior to 1964 (1969 data point ignored). This is understandable in that the pinyon-juniper sites with greatest potential would probably have been chained first. Another possible explanation is that a period of transition or establishment exists for about 10 years, followed by increasing

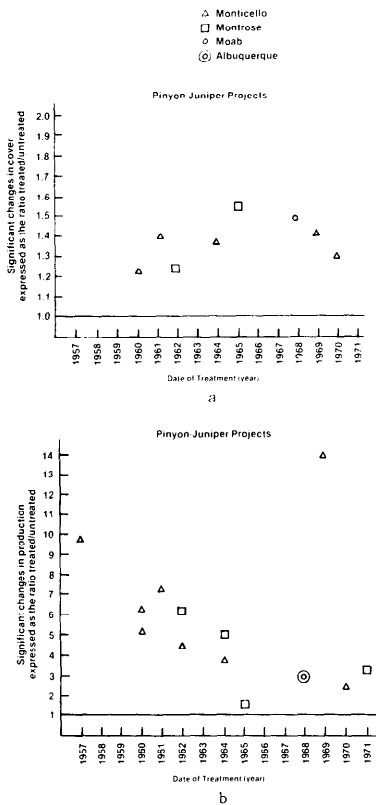


Fig. 9. Impact of age of treatment on significant changes in cover (a) and production (b) due to chaining pinyon-juniper.

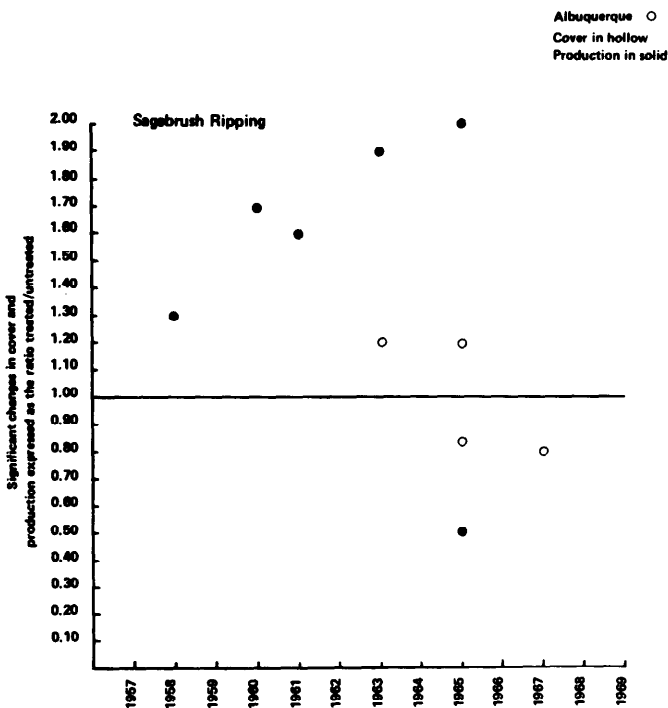


Fig. 10. Impact of age of treatment on significant changes in cover and production due to sagebrush ripping.

rates of production as shown for older treatments.

Various Sagebrush Treatments

Sagebrush Railing

There was little evidence that age of treatment (within the limits of this study) had any impact on measured site response.

Sagebrush Ripping

Significant increases or decreases in cover or ripped sagebrush sites showed no apparent trend with respect to age of treatment, as shown in Figure 10. If one ignores the 1965 production data plotted at 0.50 in Figure 10, then a trend indicates that production increases (if they occur) are slightly more dramatic for more recent treatments than for older ones, and that increases, once established, might be expected to last for about 20 years.

Sagebrush Chaining

Data indicates no clear pattern as to the influence of age of chaining treatment on significant changes in either production or cover.

Sagebrush Plowing

Plowing treatments sampled in this study were nearly all detrimental in terms of increasing cover or production on the treated site, regardless of age of treatment.

Summary and Conclusions

During 1976 a land treatment study was conducted in Utah, Colorado, New Mexico, and Arizona. The range improvement practices studied included gully plugs, contour furrowing, pitting, pinyon-juniper chaining, and various sagebrush control treatments. Specific objectives of this study were to investigate the impacts of the various range improvement practices on watershed cover and annual production. The following summarize the various findings:

1. About 33% of the contour furrowed sites indicated significant increases in annual production. The best responses were associated with loam or clay loam soil textures. Soils classified as typical ustifluvents or ustollic haplargids were most favorable in terms of increased production, while production on soils classified as typical cryoboralfs or typical argiborolls decreased significantly.

2. Annual production significantly increased due to pinyon-juniper chaining across a variety of soil types (growth of trees excluded on both treated and untreated sites). The greatest increases in production were associated with loam soil sites classified as typical haplustolls, while the smallest increases were on sites characterized by aridic argiborolls.

3. From the two pitting treatments a significant reduction in annual production due to treatment was noted on a clay soil classified as a typical torriorthent, while on a sandy clay loam site classed as a typical torrifluent no impact of pitting was measured.

4. Less than 50% of the various sagebrush treatments showed increased annual production. Sagebrush treatments appear to be most successful on loam soils, though significant decreases in production were noted for 23% of the treatments on loam soils.

Plowing was the least successful sagebrush treatment studied.

5. Cover of 67% of contour furrowed sites increased across a variety of soil textures and soil types. Cover increases were greatest on sandy clay loam and loam soil and typical torriorthent or ustic torriorthent soil types.

6. Increases on cover due to chaining were noted on 57% of the pinyon-juniper sites across a variety of soil textures and soil types. However, the increases in cover were uniformly small (tree cover included on both treated and untreated sites), and no clear trend was indicated with either soil texture or soil type.

7. Significant changes in cover due to either of the two pitting treatments were not detected.

8. Increases in cover were noted on 29% of the railed sagebrush sites with no impact on cover for the remaining 71%.

9. Increases in cover were noted on 27% of the chained sagebrush sites. Seven percent indicated reduction in cover and the remaining 66% showed no impact on cover.

10. Significant reductions in cover were noted on 20% of the plowed sagebrush sites. The remaining 80% of the plowing treatments had no impact on cover.

11. Increase in cover was noted on 15% of the ripped sagebrush sites. Fifteen percent indicated reduction in cover and the remaining 70% had no impact on cover.

12. Age of contour furrowing treatments made little difference as to whether there was a significant increase or decrease in either production or cover.

13. Increases in cover (where they occur) are either slightly more dramatic on more recent pinyon-juniper chainings or on those treatments which are approximately 11 years old and represent conditions most ideal for enhanced cover (if it occurs). The former interpretation is probably more nearly correct. Production data suggest that pinyon-juniper sites chained since 1964 are not as favorable in terms of increased production as those chained prior to 1964.

14. Age of sagebrush treatments had no impact on increases or decreases in cover; however, some general trends indicated that production increases (if they occur) on select sagebrush treatments are slightly more dramatic for more recent treatments than for older ones.

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Stem Cutting Propagation of Big Sagebrush (*Artemisia tridentata* Nutt.)

EDUARDO ALVAREZ-CORDERO AND C.M. McKELL

Abstract

Vegetative propagation of big sagebrush (*Artemisia tridentata* Nutt.) is often desirable to preserve valuable characteristics of ecotypes for use in disturbed site rehabilitation and range research. Previous research is not clear with regard to procedures for sagebrush propagation.

Three experiments were designed to define the influence of synthetic auxin rates, plant dormancy and individual source plants on rooting performance of big sagebrush stem cuttings. Cuttings obtained in the winter during plant dormancy showed greater rooting activity than those collected from actively growing plants. Synthetic auxin, Indolebutyric acid (IBA) treatment, increased root formation as a function of increased auxin concentration but was unable to overcome factors causing seasonal dormancy in cuttings. Source plants varied in the rootability of cuttings. Care should be exercised in selecting only plants that have a high capability for rooting of cuttings.

Big sagebrush (*Artemisia tridentata* Nutt.) is one of the most important shrubs in the western United States because of its wide distribution and value in providing habitat and food for domesticated and wild animal species. The many ecotypes of big sagebrush are adapted to a variety of sites, thus making it desirable for disturbed site rehabilitation. A method for asexual propagation of big sagebrush is needed to permit direct reproduction of promising ecotypes. This would avoid the delay inherent in breeding and field-testing programs.

Information on cuttage propagation of big sagebrush is particularly scarce. One of the earliest references to sagebrush propagation is by Taylor (1927, p. 84), who indicated that *Artemisia tridentata* cuttings rooted to a lesser degree than *A. abrotanum* when short, twiggy cuttings were taken along with a short portion of main stem (a heel cutting) in July and August. Wallace and Romney (1972, p. 95) found that big sagebrush cuttings were easy to root when succulent, vigorous material from young plants was treated with 0.3% indolebutyric acid (IBA) and maintained in a mist chamber. Others have mentioned using big sagebrush rooted cuttings in their investigations but provided no clues as to how the material was propagated (Lunt, et al. 1973). We report here the results of three experiments conducted to define the influence of synthetic auxin rates, plant dormancy, and individual source plants on rooting performance of big sagebrush stem cuttings.

Methods

General Procedures

This work relied on a basic procedure developed during 1975. The preliminary work and other relevant information were described by Alvarez-Cordero (1977).

Cuttings were prepared in the field from terminal and lateral twigs, with intact terminal buds. Hand clippers were used to take the material from the base of the previous season's growth. The cuttings, which ranged in length from 8 to 12 cm were treated and planted within 36 hours after collection.

Leaves and buds were removed from the basal portion of each cutting. The defoliated portion of each cutting was dipped in water and afterwards into a talc-base indolebutyric acid¹ IBA mixture. Each cutting was lightly tapped to remove excess powder. Control cuttings were treated only with water. The basal portion of each cutting was then inserted into a peat pellet² previously expanded with water.

A wooden frame covered with a clear-plastic film was built on top of a glasshouse bench to serve as a rooting chamber. Automatically regulated stem pipes under the bench provided uniform heating. Water spray applied daily insured adequate moisture conditions.

The number of rooted cuttings in the treatment combinations were expressed as a percentage. These data were subjected to angular (inverse sine) transformation prior to analysis. The appropriate analysis of variance procedure, followed by Duncan's new multiple range test were applied to the data from the three experiments. Details of each experiment are described below.

Response to IBA Concentration: Experiment 1

To test the stimulative effect of IBA on sagebrush adventitious root production, *Artemisia tridentata* spp. *vaseyana* stem cuttings were treated with various concentrations of commercially available IBA. The source plants were randomly selected from a natural stand growing on gravelly soil in the mouth of Green Canyon, located about 6 km northeast of Logan, Utah. All sampled plants were growing within a 100-m radius on an alluvial terrace. Approximately 30 cm of snow lay on the ground when the cuttings were obtained on February 3, 1976. One hundred cuttings were taken from each of four plants during the early morning hours.

All four plants were mature and dormant (inactive) at the time of cutting collection. Five treatments were applied in a randomized complete-block design: control (no IBA applied), 0.1% IBA, 0.3% IBA, 0.8% IBA, and 2.0% IBA. Twenty cuttings from each plant were assigned to each treatment. All cuttings were identified as to their plant origin to assess the performance of each source plant. After planting, the cuttings were placed in plastic trays with drainage holes. The trays were then placed inside the clear-plastic enclosure.

Cuttings were kept in the rooting facility for 52 days. During the rooting period the daytime ambient temperature ranged from 20 to 23°C. Night temperature was maintained above 13°C.

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Manuscript received April 2, 1978.

This study was conducted as a project of the Institute for Land Rehabilitation, Utah State University, and was supported by funds from the White River Shale Project, Sun Energy Development Co.

¹ Utilizing Hormodin No. 1, 2, 3, and 2.0% IBA preparation sold by Merck Chemical Chemical Division, Merck & Co., Inc., Rahway, N.Y. 07065, U.S.A.

² Jiffy No. 9 compressed and sterilized propagation pellets (ph 5.5 to 6.0) sold by the Porter Walton Company, 470 W. 600 So., Salt Lake City, Utah.

Influence of Date of Collection on the Effectiveness of IBA Treatments: Experiment 2

A second experiment was designed to test the influence of plant dormancy on rooting of IBA-treated cuttings taken during the transition from dormancy to active growth. Source plants were *Artemisia tridentata wyomingensis* randomly selected from an area near the experimental revegetation site for two prototype oil shale lease tracts 6 km south of Bonanza, Utah. Twenty mature plants, uniform in size and vigor and exhibiting few or no signs of grazing damage on their stems, were permanently identified. The plants selected were located on moderately sloping terrain within an area of approximately 4.5 ha. The plant cover of the area was typical of the *Atriplex confertifolia* Torr. & Frem. vegetation type described in the baseline vegetation study conducted on the tracts (VTN, 1977).

Cuttings were collected four times (March 26, April 10, April 24, and May 8) to encompass the approximate period from growth initiation (budshoot activation) to active vegetative growth at the end of spring. A randomized, complete-block design was used to assess the affects of a control treatment (no IBA), a low concentration (0.3% IBA) and a high concentration (2.0% IBA) of synthetic auxin. A set of five different plants was assigned to each of the four sampling dates. At each date, 90 cuttings were taken from each plant and equally divided among the IBA treatments. Thus, five replicates of 30 cuttings were subjected to each treatment, at each sampling/date combination.

A fine mesh screen of galvanized metal was added to the rooting facility and the cutting-pellet units were placed directly on the screen instead of in plastic trays. The duration of the rooting period was set arbitrarily at 40 days. Air and peat pellet temperatures were monitored inside the rooting facility from March 26 to June 16, when the last sample of cuttings was evaluated. Peat pellet temperature averaged 19°C and air temperature averaged 23°C. On sunny days, a more pronounced temperature increase occurred in air than in pellets. The number of sunny days during the rooting period of each of the four sampling groups of cuttings was approximately equal.

Rootability Differences among Source Plants: Experiment 3

Experiment 3 was designed to test the rootability of cuttings taken over a period of time from the same source plants. This experiment was carried out simultaneously with experiment 2, using additional plants of subspecies *A. wyomingensis* randomly selected in the same locality. A randomized complete-block design was used to compare the performance of cuttings collected from five source plants four times (March 26, April 10, April 24, and May 8). Thirty cuttings were taken from each source plant at every sampling. All cuttings were treated with 2.0% IBA and placed with those of Experiment 2 for an identical rooting period.

Results and Discussion

Three factors proved crucial to the successful propagation of big sagebrush stem cuttings: (1) stimulation of adventitious root production with IBA treatments, (2) date of collecting cuttings,

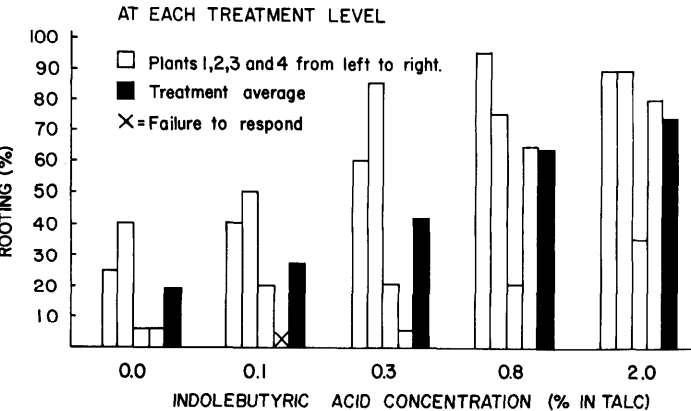


Fig. 1. Rooting response of cuttings of four plants of big sagebrush (*ssp. vaseyana*) as affected by five levels of chemical treatment.

(3) and inherent rootability of the stock plant being propagated.

In general, rooting increased as a function of the increase in concentration of IBA applied (Fig. 1). The rooting of subspecies *vaseyana* cuttings treated with 0.8% IBA was significantly higher than was observed in untreated cuttings or in those receiving 0.1% IBA. The highest level of IBA (2.0%) stimulated significantly more rooting than occurred in control cuttings and more than that of cuttings given 0.1 and 0.3% IBA. The effects of the two highest IBA levels did not differ statistically.

The results obtained with subspecies *wyomingensis* cuttings indicated that 2.0% IBA was more effective than 0.3% IBA in rooting cuttings obtained in the spring. All cuttings not receiving IBA failed to produce adventitious roots, whereas those given the low level of auxin exhibited a significant amount of rooting. Cuttings treated with the high auxin level exhibited a significantly more vigorous rooting performance (21% average rooting over all spring dates) than those given the low IBA concentration. Apparently 2.0% IBA was more effective than 0.3% IBA in overcoming the low rootability of cuttings from certain source plants (Fig. 2). Cuttings from every source plant

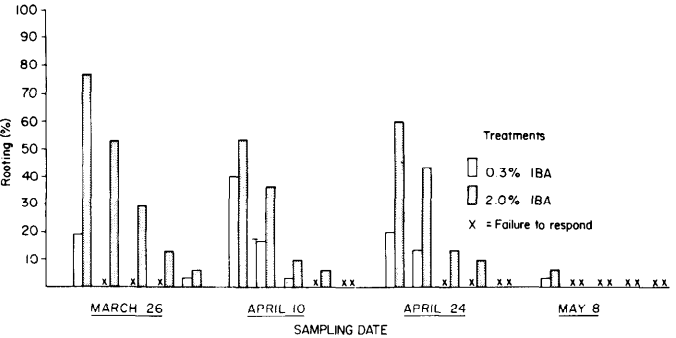


Fig. 2. Rooting of big sagebrush (*ssp. wyomingensis*) stem cuttings at four spring sampling dates in response to a low and a high concentration of indolebutyric acid. (Each bar shows percentage rooting of 30 cuttings).

that responded to the low IBA level exhibited their highest performance with the high IBA treatment. In addition, the high treatment level was effective on six of the twelve source plants whose cuttings failed to respond to the low level of IBA.

There were no significant ($P=0.05$) interactions between IBA treatments and spring dates of collecting cuttings. All

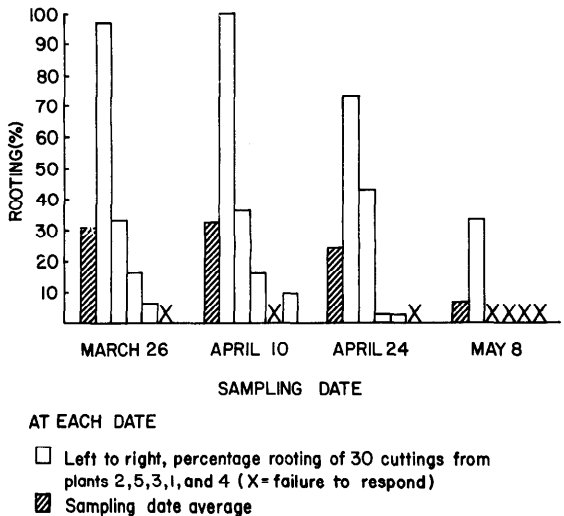


Fig. 3. Rooting performance of big sagebrush (*ssp. wyomingensis*) cuttings taken from five plants at four periods of spring growth. All cuttings were given 2.0% indolebutyric acid.

cuttings of *A. wyomingensis* subspecies that did not receive an IBA treatment failed to root. Ability to respond to the IBA treatment was practically nonexistent in the cuttings taken in May (Fig. 3). This indicated that IBA could not compensate for the loss of rootability that occurs as plants enter the active period of vegetative growth.

The decline in rooting ability observed as the growing season advanced may have been related to developments in the sagebrush stems that signal the internal expansion of an interxylary cork cambium (ICC) layer typical of many *Artemisia* species (Diettert 1938; Moss 1940). During the latter part of April, we observed vertical hairline fissures appearing on some stems of some of the subspecies *A. wyomingensis* plants of the stand sampled. By the last cutting harvest on May 8, these fissures had become more pronounced and generalized in the stems, in many cases being up to 2 mm wide and ranging from 10 to 20 mm in length. The observed splitting corroborates the occurrence of radial increases in the stems mentioned by Daubenmire (1975). Further work on this observation in relation to rooting appears warranted.

Marked differences in rooting occurred among the five plants of subspecies *wyomingensis* (Fig. 3). The rooting of cuttings obtained from plant 2 was significantly higher than that of cuttings from the other four plants. Similarly, cuttings from two of the four plants of subspecies *vaseyana* tested in February averaged above 60% rooting (plants 1 and 2) and had significantly better rooting than did cuttings from the other two plants (Fig. 1). The basic cause of rootability variations among big sagebrush plants has not yet been determined but it is probably genetic in nature and results from morphological and physiological differences. No observable differences in appearance were noted among plants with high and low rooting abilities in our studies.

Conclusions

Cuttings of big sagebrush exhibited marked seasonality in their ability to produce adventitious roots. Cuttings obtained in the winter during the quiescence-dormancy stage showed more rooting activity than those collected from actively growing plants.

The indication that auxin treatments were ineffective against the factors determining low seasonal rooting (Nanda 1970) was verified in this investigation. However, the use of IBA is recommended to increase rooting performance of winter and early spring cuttings.

It is crucial to identify plant sources that will give cuttings of high rootability. Evaluation of experimental results with sagebrush cuttings should be made in relation to the known rootability of source plants used.

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Variability in Predicting Edible Browse from Crown Volume

F.C. BRYANT AND M.M. KOTHMANN

Abstract

Biomass estimates were made with regression techniques using crown volume and weight relationships. The log-log function yielded the highest coefficient of determination for Vasey shin oak, plateau oak, Texas persimmon, and honey mesquite. A quadratic function was best for woollybucket bumelia, littleleaf sumac, agarito, and pricklyash. Sugar hackberry showed equally high coefficients with either the linear or quadratic. Coefficients of determination for catclaw acacia, elbowbush, and skunkbush sumac generally were low regardless of the type of regression equation used. When sampled at various periods over the year, predictive accuracy declined for Vasey shin oak and plateau oak through fall and winter but rose again in spring and early summer. For both species, the log-log function was best from late summer to winter but during spring and early summer the quadratic function was best.

Browse biomass commonly is recognized as one of the most difficult of all vegetation components to measure (Blair 1958). Even so, the information has been valuable to foresters for measuring potential flammability (Brown 1976) and to range scientists for estimating utilization by herbivores (Dalrymple et al. 1965; Ferguson and Marsden 1977), forage available to herbivores (Bryant 1977), productivity of herbivores (Leigh et al. 1970), or the response to brush control (Bentley et al. 1970; Scifres et al. 1974). Thus, numerous methods have been developed for inventory of browse or shrub yield. Some of these different methods have been reported by Harniss and Murray (1976).

Recently, techniques used for predicting browse yield have included linear regressions of crown volume on the weight of plants to predict yield. Crown volume requires at least two measurements of the plant in addition to weight, and is well suited because a combination of measurements is usually better than any single measurement (Cook 1960). Also, volume generally yields a better relationship to weight than surface area to weight (Lyon 1968). These volume-weight relationships have usually included only one species (Lyon 1968; Scifres et al. 1974; Rittenhouse and Sneva 1977). Only Bentley et al. (1970) has dealt with more than one shrub species. Previous studies have not examined the same species at different sampling dates within a 1-year period to determine the impact of defoliation on the precision of the predictive equations. Lyon (1968) has, however, found that the precision of regression equations varied with range site for the single species being studied.

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This article is TA 14210 from the Texas Agricultural Experiment Station.
Manuscript received April 28, 1978.

The objective of this research was to evaluate the use of various regression functions for the prediction of biomass from crown volume for several browse species and for selected species at different sampling dates.

Methods and Materials

Crown volume and weight relationships were used on several browse species to estimate the availability of edible browse to herbivores. Two of the species were evaluated at different sampling dates over a 1-year period.

An 8-ha study site was selected at the Texas Agricultural Experiment Station, Sonora, Texas (Fig. 1). The site had been rootplowed 7 years prior. All available browse was in a young age class and less than 2.2 m tall. Since 1970, the browse had received light used by cattle, sheep, Angora goats, and white-tailed deer (*Odocoileus virginianus* L.).

In August, 1975, the density for each species was estimated using either point-center-quarter (Cottam and Curtis 1956) or the corrected-point-distance technique (Laycock and Batcheler 1975), depending on the degree of aggregation. Two transects, 322 m long, were used and points were established every 30.5 m. The distance to the nearest individual of each species was measured and its height and diameter at the widest point were recorded. Height and diameter measurements were converted to conical volume using the formula

$$V = \frac{\pi r^2 h}{3}$$

where

r =radius and h =height.

The mean crown volume was calculated for each species on the study site. Conical volume was selected because most species grew in a "V" shape. Sample size used to estimate mean crown volume varied from 11–102 individuals, depending upon the species.



Fig. 1. Study site at the Texas Agricultural Experiment Station near Sonora, Texas.

Table 1. Coefficients of determination (r^2 or R^2) and coefficients of variability (CV) for twelve browse species sampled in August, 1975, based on various regressions of weight on crown volume.

Species	Sample size	Calculated sample size ^a	Mean weight/plant (g)	Linear		Quadratic		Log-log		Semi-log	
				r^2	CV	R^2	CV	r^2	CV	r^2	CV
Vasey shin oak	16	6	50	.95*	23	.95*	24	.98*	7	.52*	32
Woollybucket bumelia	10	10	14	.95*	37	.99*	21	.90*	37	.65*	68
Plateau oak	17	12	70	.92*	33	.95*	27	.96*	7	.56*	21
Littleleaf sumac	13	25	10	.93*	44	.97*	29	.92*	40	.42*	106
Agarito	15	22	14	.92*	44	.98*	24	.85*	22	.41*	44
Pricklyash	14	17	55	.92*	38	.93*	39	.90*	16	.57*	34
Sugar hackberry	16	41	22	.89*	60	.89*	62	.72*	29	.60*	34
Texas persimmon	12	25	125	.89*	45	.89*	47	.92*	13	.68*	26
Honey mesquite	13	78	51	.68*	81	.68*	85	.90*	23	.50*	52
Catclaw acacia	14	21	1	.35*	42	.42	42	.62*	623	.35*	818
Elbowbush	13	10	4	.27	29	.45*	26	.58*	20	.24	26
Skunkbush sumac	11	126	1	.02	105	.24	98	.20	128	.07	139

* Significant at the .05 level.

^a Calculated sample size = $\left(\frac{t_{.05} \times \sqrt{\text{Variance}}}{d} \right)^2$ where $d=20\%$ of mean weight.

In the same month, 12 to 17 individual plants of each species with a wide range of volumes were measured to obtain crown volume estimates for the independent variable in the regression equations to be developed. After these measurements were taken, the plants were harvested and leaves and new growth twigs were picked. The picked portions were air-dried and weighed to estimate the weight of edible browse on each individual. This weight estimate served as the dependent variable.

Several regression equations were evaluated for suitability as predictive equations. These equations included linear ($y=a+b_1x$), quadratic ($y=a+b_1x_1+b_2x_1^2$), log-log ($\log y=a+b \log x_1$), and semilog ($\log y=a+bx_1$) functions, where y =weight and x_1 =volume. The coefficients of determinations and coefficient of variability were used to select the equation which best predicted weight per plant. Total edible biomass could be estimated by multiplying weight per plant \times plants per ha.

Edible browse for two oak species was estimated at several periods throughout the year by harvesting an additional 15 to 20 plants each period. In this way, new equations to predict weight per plant were developed for each period. The sampling periods corresponded to forage availability: (1) in autumn before frost; (2) in winter before active spring growth; (3) in spring after primary plant growth; and (4) in July after one year of continuous grazing on the study site.

Results and Discussion

Variability among Species

The relation between edible biomass of different browse plants and crown volume was best expressed with either log-log or quadratic regression equations, except for one species, sugar hackberry (*Celtis laevigata* Willd.) (Table 1). Weight of sugar hackberry was predicted equally well with either a linear or quadratic equation. In general, the linear regression equation was a good predictor, but the quadratic and log-log regression had higher coefficients of determination (r^2 or R^2) and lower coefficients of variability. The semi-log ($\log \text{ weight} = b_0 + b_1x_1$) was consistently less satisfactory than any of the other equations.

The way in which predictability (r^2 or R^2) was affected by the quadratic or log-log equations depended upon the species. Estimates for species such as woollybucket bumelia (*Bumelia lanuginosa* (Nutt.) Clark), littleleaf sumac (*Rhus microphylla* Engelm, ex Gray), agarito (*Berberis trifoliolata* (Moric.), and pricklyash (*Zanthoxylum clava-herculis* (Gray) Wats.) were best fitted with quadratic regression equations. These species generally were similar in that their current growth was primarily

Table 2. Coefficients of determination (r^2 or R^2) and coefficients of variability (CV) for plateau oak and Vasey shin oak at selected dates based on various regressions of weight on crown volume.

Species	Date	Sample size	Calculated sample size ^a	Mean weight/plant (g)	Linear		Quadratic		Log-log		Semi-log	
					r^2	CV	R^2	CV	r^2	CV	r^2	CV
Plateau oak	8/75	17	12	70	.92*	33	.95*	27	.96*	7	.56*	21
	11/75	20	41	60	.81	61	.81	63	.92	12	.68	23
	2/76	18	250	20	.62	149	.66	146	.77	54	.79	54
	5/76	18	36	35	.84	57	.98	22	.90	15	.59	30
	7/76	15	7	30	.96	25	.97	22	.93	10	.62	23
Vasey shin oak	8/75	16	6	50	.95	23	.95	24	.96	7	.52	32
	11/75	15	89	25	.65	87	.65	90	.69	29	.57	34
	5/76	17	12	40	.89	34	.90	33	.88	14	.72	22
	7/76	15	7	36	.96	24	.97	24	.85	12	.71	16

* All r^2 or R^2 were significant at the .05 level.

^a Calculated sample size = $\left(\frac{t_{.05} \times \sqrt{\text{Variance}}}{d} \right)^2$ where $d=20\%$ of mean weight.

leaves with little twig elongation. The rate at which they produced this growth seemed to vary with age of the plant (i.e. assuming plants increased in crown volume with increasing age). The new growth on younger plants was greater per unit volume than growth on older plants. Apparently, the increase in weight was rapid at first, then leveled off gradually. Sampling more plants with large crown volumes would have helped clarify this relationship. Unfortunately, there were few of these large plants on the study site.

The log-log regressions accounted for the most variation in Vasey shin oak (*Quercus pungens* var. *vaseyana* (Buckl.) C.H. Muller), plateau oak (*Q. virginiana* var. *fusiformes* (Small) Sarg.), Texas persimmon (*Diospyros texana* Scheele), and honey mesquite (*Prosopis glandulosa* Torr.). These plants showed greater variability in weight among the larger (older) plants, possibly due to the lack of uniformity in either growth or the degree to which they were browsed. The r^2 for the linear equation in honey mesquite accounted for only 68% of the variability in edible biomass while the log-log equation accounted for 90%. Scifres et al. (1974) used a linear equation on honey mesquite and reported a high correlation ($r=.98$). They sampled plants that ranged from seedlings to large trees; whereas, plants with less range in volume were measured in this study. They also sampled more plants with larger volumes, which may have accounted for the higher correlation found in their study.

Those plants that were best fitted with a log-log equation also produced the most edible biomass per plant, with the exception of pricklyash. Thus, plants that produce more edible forage may yield a higher r^2 with a log-log equation. Rittenhouse and Sneva (1977) also found a log-log relationship to be a better predictor of biomass on big sagebrush (*Artemisia tridentata* Nutt.) plants in Oregon. Bentley et al. (1970) used a log-log relationship on several species in California and got good correlations ($R=.93$ to $.97$) when the plants were grouped into volume classes. Placing the plants in volume classes might have helped the correlations in this study.

Data from catclaw acacia (*Acacia greggii* (Gray), elbow-bush (*Forestiera pubescens* Nutt.), and skunkbush sumac (*Rhus aromatica* Shinnery) resulted in poor r^2 regardless of which equation was used (Table 1). Both catclaw acacia and elbow-bush had extremely irregular growth forms compared with the other species. The growth of skunkbush sumac was similar to woollybucket bumelia which yielded a linear r^2 of .95. The reason for the poor predictability for these species was unclear. Apparently, edible biomass was either too small for a good relationship or was not well associated with conical volume. Obviously, the proper variables were not selected.

Sample size is an important consideration in any estimate of biomass. The actual sample size for most species, when compared with the calculated sample size, was acceptable except for skunkbush sumac, honey mesquite, and sugar hackberry (Table 1). More plants of these species should have been harvested.

Variability among Sampling Dates

For plateau oak and Vasey shin oak, the r^2 declined as utilization and shedding of leaves reduced forage availability

(Table 2). The deciduous Vasey shin oak was not harvested in February since it had little edible foliage. It appears sample size should be increased during seasons of heavy utilization or low availability if the r^2 is to be improved.

The log-log equation provided the best r^2 from late summer through winter, probably due to variability in foliage among individual plants. In late spring and early summer, the quadratic equations best fit the data. Herbivores on this range appear to increase their use of browse from autumn to winter and use it comparatively little during late spring and early summer (Bryant 1977). Thus, sample size should be increased and a log-log equation should be used if availability is determined during periods of heavy browsing.

Conclusion

The equation which should be used to predict weight from crown volume depends upon the plant species and the sampling date. For robust species with ample edible biomass per plant but with inherent variability among plants, the log-log function may yield best results. Other species may require a quadratic function for the best results. Species with irregular growth forms and little available foliage may require special treatment for prediction of weight. Sample size should definitely be increased when plants are being heavily browsed because different degrees of utilization may increase the variability in weight among plants.

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Sequential Development of Shoot System Components in Eastern Gamagrass

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Abstract

The sequence of development of shoot system components was studied from early November 1976 through October 1977 in eastern gamagrass. Tiller production and compound shoot development began in late spring and continued until the first killing frost in mid-October. On shoots initiated in 1977, root development began in early August and peaked in September. Single shoots developed one to six mature phytomers during their first growing season. Reproductive shoot development was first noted in early May, peaked in late May, and continued into October. The proaxes of tillers, single shoots, and compound shoots perennated through the 1976-77 winter dormant period. Shoots that over-wintered as tillers had advanced to the single shoot stage by late August 1977 and had produced from 8 to 20 mature phytomers by the end of the growing season. Compound shoots initiated before 1977 developed into reproductive shoots or died by late May 1977. From May through July high percentages of the shoot system components were in the tiller and reproductive shoot stages. During this period vegetative propagation would probably not be feasible and the use of proper management practices might be more critical than during other periods.

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] has long been recognized as one of the most productive and palatable native grasses of the bottomlands in the southeastern United States. Yields of 168 to 279 metric tons of green grass per hectare were reported by Magoffin (1843). Gamagrass is so palatable that most natural stands have been greatly reduced through preferential grazing by animals (Rechenthin 1951). Hitchcock and Clothier (1899) noted that the hay was nutritious. Characteristics of gamagrass which have hindered its widespread use include inadequate seed production and inferior seed quality, difficulties in vegetative establishment, and lack of persistence under improper grazing (Killebrew 1878; Wilcox and Smith 1905; Polk and Adcock 1964; Ahring and Frank 1968).

The stembase structure of eastern gamagrass has often been referred to as rhizomes (Holm 1929; Hitchcock 1951; Weatherwax 1954; and Wilks 1972). Certain morphological characteristics of this important crown structure of eastern gamagrass, i.e. nonelongated internodes, elaborate true leaves and intravaginal branching habits, do not coincide with definitions of rhizomes given by Strasburger et al. (1903), Arber (1934), Evans (1958), Sharman (1945) or Youngner (1969). The term "proaxis" has been applied to the stembase of timothy [*Phleum pratense* L.] (Evans 1927 and 1958) and to blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Stued.] (Stubbendieck and Burzlaff 1971), and refers to the nonelongated internodes that may have fully developed green leaves. Consequently, we consider "proaxis"

to be the appropriate term for the stembase structure of eastern gamagrass.

The proaxis of grasses consists of basal phytomers with very short or nonelongated internodes. A phytomer is a unit of a shoot consisting of a leaf, an internode, an axillary bud or bud potential, and a node (Gray 1879; Evans and Grover 1940; Hyder 1974). Proaxis phytomers contribute to forage production, quality, and perenniality in many grasses. Two to four basal or proaxis phytomer numbers were reported in Indiangrass [*Sorghastrum nutans* (L.) Nash] and switchgrass [*Panicum virgatum* L.] and 12 to 15 were found in little bluestem [*Schizachyrium scoparium* (Michx.) Nash] (Rechenthin 1956). Basal phytomer numbers of other grasses have been reported by Evans (1958), Stubbendieck and Burzlaff (1971), and Sims et al. (1973).

Eastern gamagrass is a very complex species, both taxonomically and cytologically (Cutler and Anderson 1941; Anderson 1944). Newell and deWet (1974) showed statistically that this species "consists of highly variable populations encompassing a wide range of morphological entities." It is obvious that tremendous variability exists among populations of eastern gamagrass, and we do not suggest that the results of this study of one genotype will apply to all others.

Despite the potential of eastern gamagrass as an important forage species, little is known about its developmental morphology. Our objective was to determine the sequence of development of shoot system components in eastern gamagrass. Such knowledge may prove useful in (1) formulating the cultural and utilization management practices needed to maximize forage production; (2) determining the reproductive-vegetative cycle and the peak and span in reproductive shoot development to help overcome certain seed production limitations; and (3) determining the shift in proportions of vegetative structural components and rooting characteristics so that the most favorable dates for vegetative propagation can be determined. It is essential to know how shoot perenniality, phytomer growth rates, and vegetative expansion through tillering contribute to productivity and stand longevity. Such knowledge is basic to the development of sound management practices.

Materials and Methods

Plant material used through this study was obtained from an individual crown of eastern gamagrass growing in a windmill enclosure on the Southern Plains Experimental Range near Fort Supply, Oklahoma. The crown was subdivided into propagules that were uniform in size. This plant material, designated accession WW-1002, had a semi-prostrate growth habit and dark green foliage. It is similar in appearance to other naturally occurring gamagrass colonies found along creeks and protected lowland habitats in northwest Oklahoma and the Texas Panhandle.

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Propagules were transplanted into the field on a 91- × 91-cm centers at the U.S. Southern Great Plains Field Station, Woodward, Okla., in June 1975. The soil of the experimental area is a Carey silt loam (Thermic Typic Argiustolls). During 1976-77, irrigation water was applied as required to bring the total precipitation up to 7.5 cm per 10-day period. The plants were left undisturbed during the growing season and the accumulated standing forage was removed by burning in March 1976 and 1977. The presence or absence of charred plant material subsequently facilitated the separation of shoots which were initiated prior to 1977 from those initiated following the 1977 burn.

Shoots were classified according to the terminology of Stubben-dieck and Burzlaff (1970). Young lateral shoots with the leaf of the first complete phytomer growing beyond the prophyllum and bud-scale leaf, but which had not yet produced a root, were classified as tillers. Shoots with at least one root, but without secondary shoots, were classified as single shoots; and shoots giving rise to secondary shoots were classified as compound shoots. Shoots with at least one partially elongated seed stalk internode were classified as reproductive shoots. These structural components of the shoot system are shown in Figure 1.

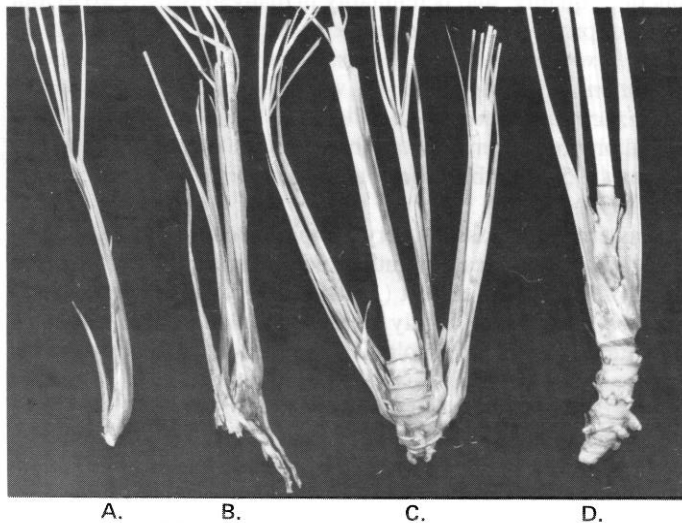


Fig. 1. Structural components of the shoot system of eastern gamagrass: (a) tiller; (b) single shoot; (c) compound shoot; (d) reproductive shoot.

The sequence of development was determined by examining crown components twice monthly from November 1976 through October 1977. The proportions of the various structural components are expressed herein as percentages of the number of total active structural units (TASU), or as percentage of the number of active structural units initiated before 1977 (ASU before 77). We considered active structural units to be the total number of active crown components present at the time of examination; dead shoots and spent proaxes that had terminated growth prior to 1977 were therefore excluded. The number of shoots classified ranged from 121 to 441 (Avg. 256 TASU) for each examination interval.

The number of roots developed by single shoots was recorded on each examination date from January through October 1977. These data are presented as a percentage of the total number of shoots that had developed given numbers of roots. The number of shoots examined varied from 30 to 138 (Avg. 74) on the different examination dates.

The number of mature phytomers developed on single shoots was also recorded on each examination date from January through October 1977. A useful characteristic was found which facilitated the determination of mature phytomer numbers. When a phytomer of accession WW-1002 had matured to the extent that its components (blade, sheath, and internode) are fully elongated, a dark band formed around the shoot at the junction of the internode and the sheath. By locating the lowermost internode on the shoot which is not fully elongated, and consequently without the accompanying dark band, a specific point in

shoot development is determined. The phytomers below this point are considered to be "mature phytomers." The number of mature phytomers on a shoot was thus determined by counting the leaves (or internodes if leaves were missing) between the lowermost immature phytomer and the prophyllum and bud scale leaves or their leaf scars. The data are presented as the percentages of the total number of shoots that had developed given numbers of mature phytomers.

Results and Discussion

Crowns of eastern gamagrass consisted of tillers, single shoots, compound shoots, and reproductive shoots in various stages of development. These structural components were held together by a woody proaxis chain and underwent a series of changes in an orderly fashion.

Tillers

Tillers Initiated before 1977

Tillers made up 30 to 40% of the TASU during winter dormancy, November 1976 to February 1977, and 25 to 35% thereafter through May 5, 1977 (Fig. 2A). The percentage of tillers increased to 48% by May 20 apparently as an indirect result of the decrease in TASU from mortality of compound shoots. The percentage of tillers declined steadily between May 20 and August 8, and by August 23 all tillers had produced roots and were thus classified as single shoots. Shoots that remained in the tiller stage until August 1977 were at least 10 months of age.

Tillers Initiated during 1977

Lateral buds first developed to the tiller stage in late May or early June (Fig. 2A). Tiller production continued until October 13, resulting in an age differential of 4 months in tillers initiated in 1977. About 60% of the shoots initiated in 1977, primarily those initiated late, did not produce roots during the 1977 growing season, but remained in the tiller stage, representing 25 to 30% of the TASU during September and October.

Single Shoot Development

Single Shoots Initiated before 1977

Each mature phytomer usually produced no more than one root which developed opposite the lateral bud on the ventral surface of the shoot. Production of two roots by the same phytomer and production of roots on the dorsal surface of single shoots were rare. Root initiation usually took place after the phytomer was mature, but occasionally a root grew from the most basal, immature phytomer. Single shoots occasionally had as many as 13 roots, but most had 10 or less.

Single shoots made up 33 to 45% (Avg. 41%) of the TASU between November 1976 and February 1977 (Fig. 2B). In January and February 1977, 69% of the shoots had one or two roots; 57% of such shoots had no more than four mature phytomers (Table 1). In the same two months less than 10% of the shoots had five or more roots, all of which had five or more mature phytomers developed, indicating they had probably been initiated during 1975.

In March and April 1977 the percentage of single shoots was slightly higher (Avg. 48%) than during the preceding months (Fig. 2B). The percentage of shoots with one or two roots remained about the same, but the percentage with only two to four mature phytomers had increased to 75% (Table 1), indicating that the rate at which tillers were rooting had increased since the previous examination period.

During May the percentage of single shoots decreased to 26% (Fig. 2B), apparently as a direct result of their transformation to reproductive shoots. The percentage of single shoots increased

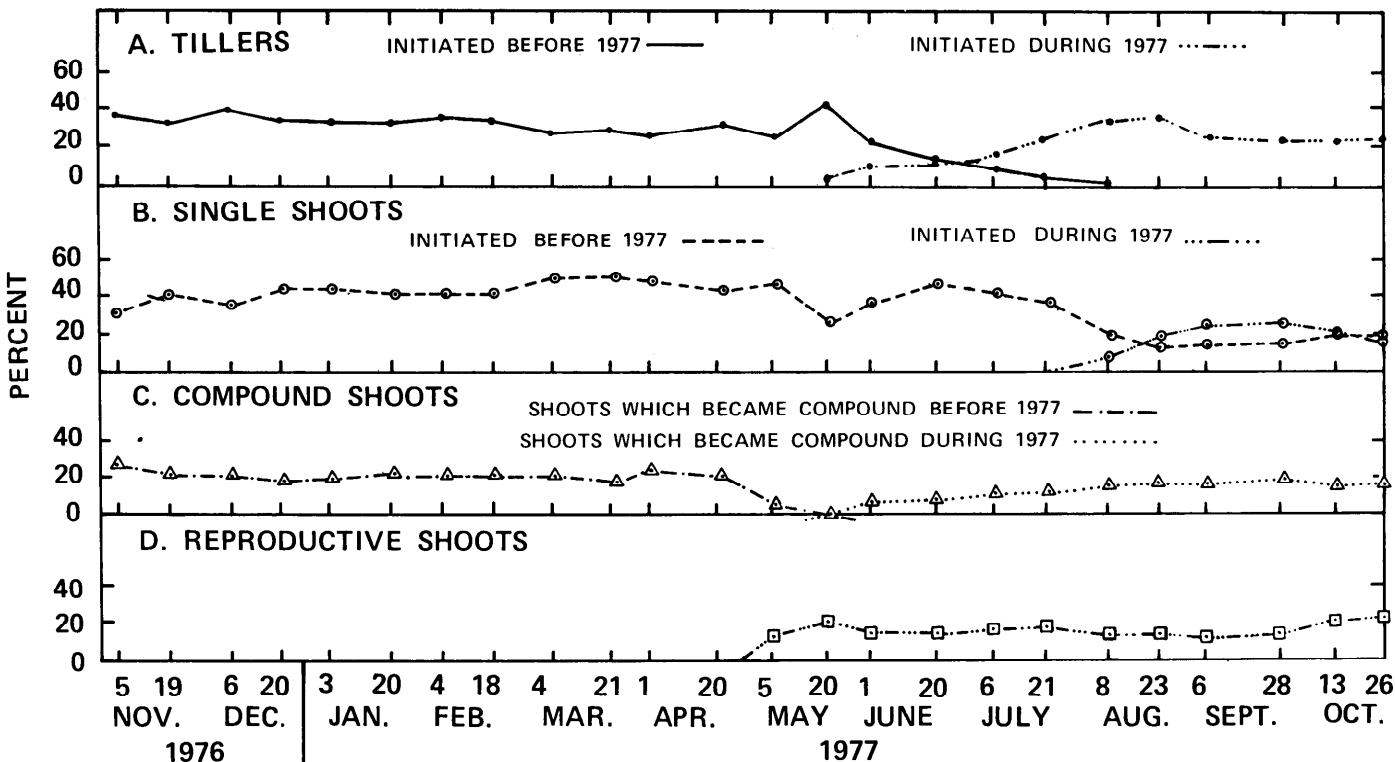


Fig. 2. Percentage composition of total active structural units in shoot systems of eastern gamagrass from November 1976 through October 1977; (a)

tillers; (b) single shoots; (c) compound shoots; (d) reproductive shoots.

during June, suggesting that the rate at which tillers were rooting exceeded the rate at which reproductive and compound shoots were developing from single shoots.

In early summer, from June 20 to July 21, 1977, the percentage of single shoots remained nearly constant as development of new single shoots was about equal to the transformation of older single shoots. For ASU before 1977, the rate of tiller decline was about equal to the rates of increase in percentages of reproductive and compound shoots (Fig. 3). The percentage of single shoots decreased during August and leveled off in September to comprise 30 to 35% of the ASU before 1977 (Fig. 3) and about 20% of the TASU (Fig. 2B).

The rate at which mature phytomers were developing increased more rapidly than the rate at which tillers were rooting during July through October, as indicated by the increase in the percentage with only one to four roots (Table 1). These changes parallel the decline and depletion of the tiller source (Fig. 3). All single shoots initiated before 1977 had developed at least eight and no more than 20 mature phytomers by the date of first killing frost (October 13, 1977).

Single Shoots Initiated in 1977

The development of single shoots began with the rooting of 1977-initiated tillers between July 21 and August 8 and continued into September (Fig. 2B). The single shoots that developed from these tillers produced no more than six mature phytomers and five roots during the 1977 growing season. More than 75% of the single shoots produced only one or two roots. From August 8 through September 6, less than 15% of the shoots had produced three or more mature phytomers; whereas from September 28 through October 26, about 90% had produced three or more (Table 2). Occasionally, roots were observed on the most basal immature phytomers.

Development of Compound Shoots

Compound shoots made up from 18 to 28% (Avg. 22%) of the

TASU from November 5 to April 20, 1977 (Fig. 2C). The percentage of compound shoots had decreased to 7% by May 5 and no compound shoots were observed on May 20. This

Table 1. Percentage of single shoots¹ of eastern gamagrass that developed various numbers of roots and mature phytomers in consecutive 2-month intervals from January to October 1977.

Range in number of roots	Range in number of mature phytomers						
	2-4	5-7	8-10	11-13	14-16	17-20	All (2 to 20)
Jan.-Feb.							
1-2	57	42	0	0	0	0	69
3-4	13	79	3	5	0	0	22
5-6	0	86	7	7	0	0	5
7-10	0	14	14	43	29	0	4
March-April							
1-2	75	23	1	1	0	0	68
3-4	24	62	12	2	0	0	22
5-6	0	55	22	22	0	1	6
7-10	0	0	14	36	43	7	4
May-June							
1-2	33	53	15	0	0	0	54
3-4	12	59	22	4	1	1	29
5-6	0	45	36	7	12	0	13
7-10	0	6	41	12	23	18	4
July-Aug.							
1-2	29	29	29	14	0	0	15
3-4	7	26	45	20	3	0	34
5-6	2	15	46	31	3	2	27
7-10	0	1	34	45	10	10	25
Sept.-Oct.							
1-2	0	6	19	31	38	6	9
3-4	0	4	12	31	42	12	16
5-6	0	10	12	30	38	10	25
7-10	0	2	4	28	51	15	50

¹ Initiated before the 1977 growing season. The number examined varied from 135 to 259 (Av. 208) in the different examination periods.

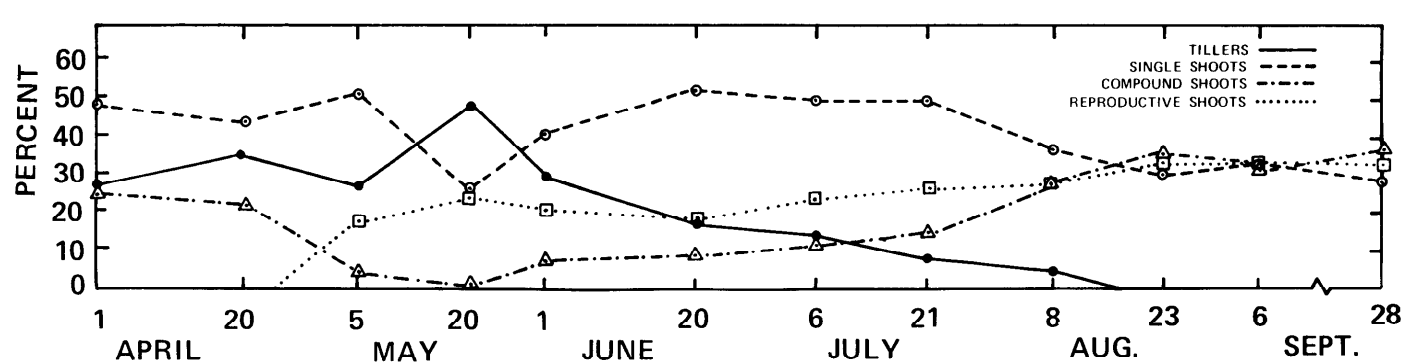


Fig. 3. Percentage composition of shoot-system components initiated before 1977 in eastern gamagrass from April through September 1977.

depletion was a direct result of mortality and of transformation into reproductive shoots. The primary shoots of compound vegetative shoots examined during this period appear to have developed from tillers initiated in 1975; developed into single shoots in 1975 or 1976 which produced secondary shoots in 1976; and to have developed into reproductive shoots in May 1977. Primary axes were about 2 years old when they reached vegetative maturity.

In 1977, compound shoot development began about June 1 simultaneously with tiller production by single shoots (Fig. 2C). The rate of compound shoot development increased during the midsummer growth period (July through August). About 38% of the ASU before 1977 and 15% of the TASU were compound shoots at the end of the 1977 growing season.

Development of Reproductive Shoots

During the 1977 growing season, reproductive shoot development was first noted on May 5, approximately 35 days after the beginning of spring growth. The rate of reproductive shoot development was highest from May 5 to May 20 and 25% of the TASU were reproductive shoots on May 20 (Fig. 2D) (reproductive to vegetative shoot ratio, 1:3). The percentage of reproductive shoots decreased slightly during June, then gradually increased to a peak of 33% of the ASU before 1977 in September. From May through October, the percentage of reproductive shoots ranged from 15 to 25% (Avg. 17%) of the TASU.

Vegetative shoots were apparently 1 to 2 years old at the time of development into reproductive shoots. The proaxes of reproductive shoots had 8 to 28 complete phytomers (Avg. 16). Reproductive shoots developed from both compound vegetative shoots and from single shoots. In May and June more than 60% of the reproductive shoots initiated from single shoots, whereas from August to October more than 60% initiated from com-

pound shoots. This increase in the initiation of reproductive shoots from compound shoots apparently was due to single shoots developing into compound and reproductive shoots simultaneously.

Conclusions

Vegetative expansion and renewal through tillering is an important factor in the production potential of a species or strain. Management practices that affect the rate of tillering during the tillering period from June through frost may affect the production potential in the following years.

The proaxes of all vegetative structural components perennated through one or more winter-dormant periods. Shoot longevity contributes to stand persistence and forage productivity.

May appears to be the critical month for developmental shifts in structural components. Shifts from vegetative to reproductive shoots and mortality of the primary shoots of vegetative compound shots in May resulted in a decrease in the percentage of vegetative shoots. Vegetative expansion through tillering began in early June, but these new tillers did not root until early August. Therefore, the use of proper management practices during the critical period from May through July may prove to be extremely important.

Stand establishment with vegetative propagules appears to be least feasible from May through July. The decrease in the percentage of vegetative shoots and the high percentage of tillers (unrooted shoots) during this period contributed to a scarcity of propagation components suitable for successful vegetative propagation. From the standpoint of morphological development the chance of successful vegetative propagation would appear to be highest after the rooting of tillers in August and before the critical developmental period that begins in May. Factors such as the adequacy of carbohydrate reserves and the response of vegetative propagation components to temperature and other weather conditions will also affect the success of vegetative propagation.

The indeterminate growth of reproductive shoots of accession 1002 would extend seed production, making the timing of seed harvest difficult. The discovery or development of genotypes that have a more determinate pattern of reproductive shoot growth, and the development of cultural practices or chemical treatments that induce determinate reproductive shoot production should decrease problems associated with seed production and harvesting.

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Table 2. Percentage of single shoots¹ of eastern gamagrass that developed various numbers of mature phytomers in two examination periods from August 8 to October 26, 1977.

Examination dates	Number examined	Number of mature phytomers					
		1	2	3	4	5	6
Aug. 8, Aug. 28, and Sept. 6	203	44	43	12	1	0	0
Sept. 28, Oct. 13, and Oct. 26	246	1	10	40	38	11	1
Aug. 8 through Oct. 26	449	20	25	27	21	6	1

¹ Initiated during the 1977 growing season.

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Cattle and Calf Losses to Predators—Feeder Cattle Enterprises in the United States

C. KERRY GEE

Abstract

National losses to predators of beef cattle and calves on farms and ranches with 20 or more cows and market feeder calves or yearlings were investigated. Data are from a sample survey of about 1,800 producers in five major feeder cattle regions. Losses to dogs, coyotes, and all other predators were estimated. Percentage losses are small, but financial losses reach into millions of dollars.

Predators, particularly coyotes, are a concern to many livestock producers in the United States. Periodic reports of predator losses by cattlemen have attested to the existence of a problem for this industry, although its magnitude has not been known. Sheep and lamb losses to this cause have already been quantified. The Economics, Statistics and Cooperatives Service (ESCS), U.S. Department of Agriculture estimate 1974 losses to coyotes alone at more than 1.25 million lambs and adult sheep in 15 Western States with a value in excess of \$27 million (Gee et. al. 1977). Predator problems have also been identified as an important contributing factor in the declining Western States sheep population (Gee et. al. 1977).

Methods

In view of the deficiency in cattle and calf loss data, ESCS included questions on this subject as part of a comprehensive industry survey in 1976.¹ Numbers compiled through personal interviews with a random sample of about 1,800 farmers and ranchers represented 1975 calendar year losses. Sample design and data collection were by the Statistics Division, ESCS.

The population of beef cattle producers included all those in major feeder cattle producing regions of the continental United States with 20 or more beef breeding cows who marketed feeder calves or yearlings during 1975. This excluded farms where

cattle are fed for slaughter and farms with no beef breeding cows. The ESCS has identified five feeder cattle regions (Fig. 1). These include all continental States except 11 in the Northeast, which have only a small proportion of the nation's beef cattle inventory. The population as defined for estimating losses to predators included

80% of total beef breeding cows in the 50 States. Numbers for each region are in Table 1.

The survey questionnaire, designed to gather information on management practices, production, and costs as well as inventories and losses, was filled out by professional U.S. Dep. Agr. enumerators during personal interviews with producers. Interviews were conducted in January 1976. Loss estimates called for in the questionnaire included number of cattle and calves lost to all causes, disease, theft, dogs, coyotes, and other predators. Cattle were defined as those weighing 500 pounds

Table 1. Numbers of beef breeding cows in survey population and United States, 1975.

Geographical area	Beef cows in herds of 20 head or more where feeder calves and yearlings (1,000 head) are produced	Total beef cows (1,000 head)
Region		
Southeast	9,368	10,959
Northcentral	6,041	10,459
Great Plains	7,193	8,413
Southwest	10,477	11,004
West	3,414	3,865
All regions	36,493	44,700
Outside of regions		772
U.S. total		45,472

Source: Compiled from numbers reported in U.S. Dep. Agr., Econ. Res. Serv., Livestock and Meat Statistics—supplement for 1975, Stat. Bull. No. 522, June 1976.

Table 2. Farms and ranches reporting beef cattle and calf losses to predators, feeder cattle businesses, U.S. beef cattle regions, 1975.

Cause of loss	Region					
	South-east	North-Central	Great Plains	South-west	West	All regions
	Percent of farms and ranches					
	Cattle ¹					
Dog	1	3	3	1	2	1
Coyote	3		1	1	2	1
Other predators	3	3	3	3	3	3
	Calves ²					
Dog	10	4	2	4	1	4
Coyote	2	6	14	15	27	12
Other predators	4		1	4	2	2

¹ Loss of cattle weighing 500 pounds or more.

² Loss of calves prior to weaning.

³ Values greater than zero but less than one when rounded to whole numbers.

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Manuscript received March 17, 1978.

¹ This project was completed by the Commodity Economic Division's Meat Animal Research Group consisting of Roy Van Arsdall of the University of Illinois, Calvin Boykin at Texas A and M University, Henry Gilliam at North Carolina State University, and the author.

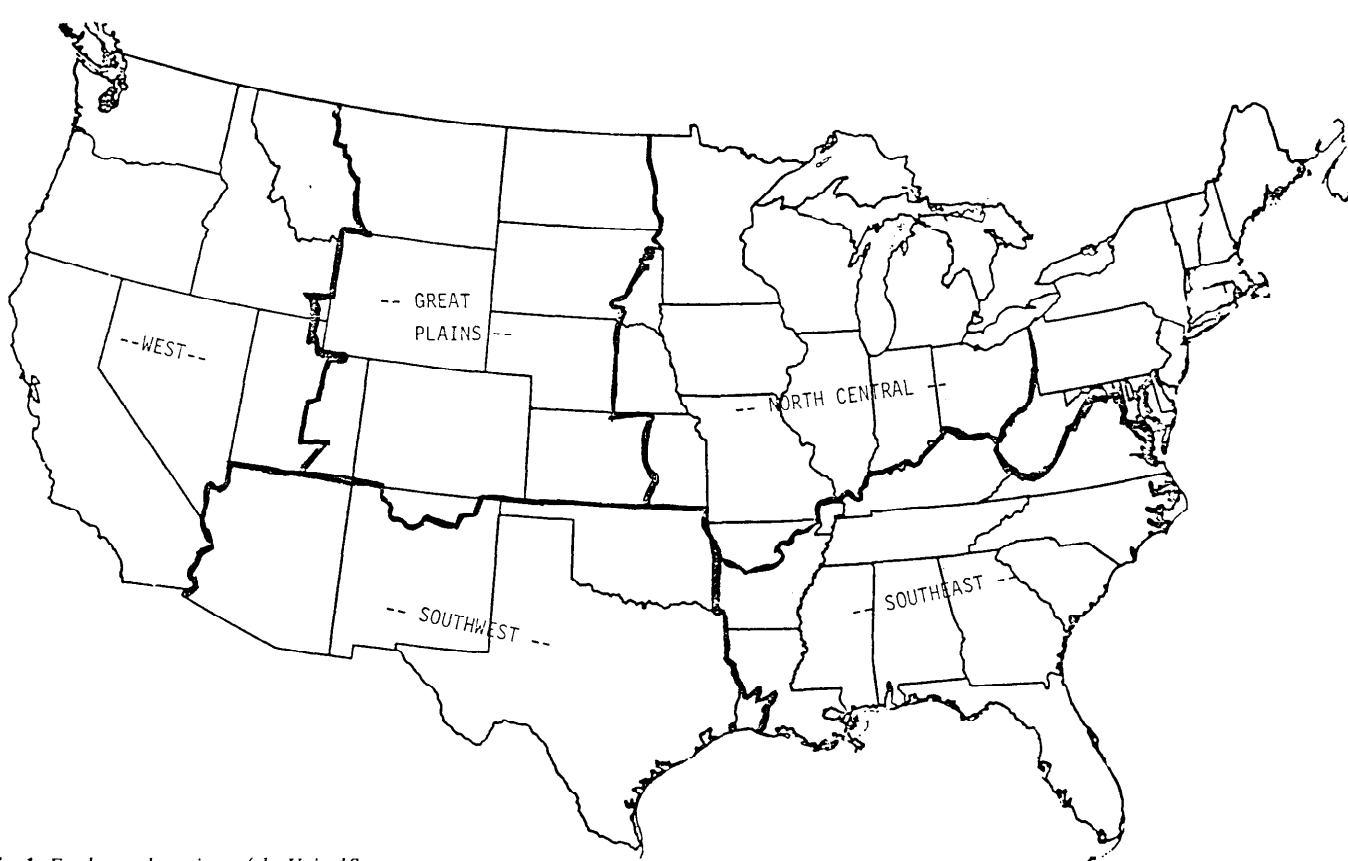


Fig. 1. Feeder cattle regions of the United States.

Table 3. Farms and ranches with different levels of calf losses before weaning, feeder cattle businesses, U.S. beef cattle regions, 1975.

	Region					
Loss interval ¹ (percent)	South- east	North- central	Great Plains	South- west	West	All regions
Dogs—percent of farms and ranches						
No loss	90	96	98	96	99	96
Up to 5.0	9	4	2	4	1	4
Over 5.0	1					2
Total	100	100	100	100	100	100
Coyotes—percent of farms and ranches						
No loss	98	94	86	85	73	88
Up to 5.0	2	6	14	13	26	12
Over 5.0				2	1	2
Total	100	100	100	100	100	100
Other predators—percent of farms and ranches						
No loss	96	100	99	96	98	98
Up to 5.0	3		1	4	2	2
Over 5.0	1					2
Total	100	100	100	100	100	100

¹ Calves lost before weaning as a percentage of calves born alive.

² Values greater than zero but less than one when rounded to whole numbers.

or more. Calves were those weighing less than 500 pounds and produced on the farm or ranch. Calf losses occurring between birth and weaning were reported separately from losses of calves after weaning. This summary presents just those calf losses

which occurred prior to weaning.

Numbers of cattle and calves lost are producer best estimates. No means were available for verification of losses by a disinterested party.

Results

Farms and Ranches with Losses from Predators

Few producers (about 2%) report losses to predators of cattle weighing 500 pounds or over (Table 2). These livestock are large and strong enough to withstand most attacks. Calf deaths prior to weaning are much more common. For the combined regions, 12% of producers reported losses of calves to coyotes. Dogs and other predators (kinds were not specified in the survey) were problems to a smaller proportion of producers—4% and 2%, respectively. The greatest percentage of producers (27%) with coyote problems were in the West. A rapid decline occurs in percentages among regions from west to east. In contrast, dogs are a hazard for the largest segment of producers (10%) in the Southeast region but are less important in the more western regions.

These geographical differences are consistent with sheep statistics. Sheep and lamb deaths to coyotes are most serious in Western states but drop off rapidly in Central and Eastern States,

Table 4. Cattle and calf losses to various causes as a proportion of total losses, feeder cattle businesses, U.S. beef cattle regions, 1975.

Cause of loss	South-east	North-central	Region		West	All regions
			Great Plains	South-west		
Percent of cattle losses ¹						
Dog	1	3	3	1	3	3
Coyote	3		3	1	1	3
Other predators	2	3	3	2	3	1
All predators	3	3	1	4	1	2
All other causes	97	100	99	96	99	98
Total losses	100	100	100	100	100	100
Percent of calf losses ²						
Dog	13	2	3	2	4	2
Coyote	3	4	4	22	9	8
Other predators	4		3	5	3	1
All predators	20	6	5	29	13	11
All other causes	80	94	95	71	87	89
Total losses	100	100	100	100	100	100

¹ Loss of cattle weighing 500 pounds or more.

² Loss of calves prior to weaning.

³ Values greater than zero but less than one when rounded to whole numbers.

Table 5. Estimated numbers and value of cattle and calf losses to predators, feeder cattle businesses, U.S. beef cattle regions, 1975.

Item	Region					All regions
	South-east	North-central	Great Plains	South-west	West	
1,000 head of cattle						
Dog	3.3	.3	.2	.9	.3	5.0
Coyote	.3		.5	2.2	.6	3.6
Other predators	5.2	.3	.2	4.4	.2	10.1
Total	8.8	.6	.9	7.5	.9	18.7
1,000 head of calves						
Dogs	41.2	5.2	2.5	5.9	8.7	63.5
Coyote	8.3	13.1	27.4	67.4	16.9	133.1
Other predators	12.3		2.5	14.8	.6	30.2
Total	61.8	18.3	32.4	88.1	26.2	226.8
1,000 dollars cattle and calves ¹						
Dog	5,536.5	673.5	335.9	885.6	1,083.0	8,514.5
Coyote	1,036.2	1,532.7	3,314.3	8,363.2	2,107.5	16,353.9
Other predators	2,567.5	65.1	335.9	2,686.4	70.2	5,725.1
Total	9,140.2	2,271.3	3,986.1	11,935.2	3,260.7	30,593.5

¹ Based on national weighted average 1975 prices per head for cattle and calves.

² Less than .1 when rounded to one decimal place.

where dogs become the greatest problem (Gee 1977).

Magnitude of Losses

Predators killed less than 1% of the January 1 inventory of beef cattle in the survey population weighing 500 pounds or more. Calf deaths to this cause between birth and weaning were about 1% of calves born alive. In the West and Southwest regions, calf losses exceed the average, reaching 3.7% and 1.3%, respectively. Most producers with calf kills lose less than 5% of their calf crop to any one predator

(Table 3). This is much less than with sheep, where about one-third of producers lose in excess of 5% and one-fourth lose more than 10% of their lamb crop to coyotes (Gee July, 1977).

Losses to predators are not great when measured as a percentage of total losses among cattle and calves (Table 4). Just 2% of all cattle deaths and 11% of calf deaths prior to weaning are from this source. In two regions predators cause a much larger percentage of total calf loss: the Southeast (20%) due to the influence of dogs, and the Southwest (29%) because of coyotes.

Value of Losses

Estimated numbers of beef cattle and calves in the survey population killed by predators in 1975 are 18.7 thousand and 226.8 thousand, respectively, for a total of 245.5 thousand head (Table 5).

Deaths of beef cattle and calves may seem unimportant when expressed as percentages. But the total value lost by producers, \$31 million, is impressive (Table 5).² Slightly over \$16 million is attributed to coyotes and nearly \$9 million to dogs. Financial loss from coyotes is more than one-half of that lost to this predator by western sheep producers in 1974 (\$27 million). Cattle and calf loss to all predators is probably within 10-15% of the value of Western sheep and lambs lost to all predators, although precise dollar estimates for the latter value have not been made.

Discussion

These estimates of cattle and calf losses to predators are based on the sample survey method which relies on producer judgment of numbers lost to each cause. In addition to normal sampling errors, errors in estimation may occur due to deficiencies in producer memory and incorrect diagnosis as to cause of death. However, it is assumed that these errors are off-setting. There are as many producers who underestimate losses to a particular cause as there are producers who overestimate these numbers. It is important to recognize this assumption when using data collected through this method. The cost of eliminating these sources of error is so great as to be prohibitive in estimating industry losses where large samples are necessary.

² Cattle are valued at \$217 and calves \$117 per head. Weights are assumed to be 1,000 pounds, 650 pounds, and 450 pounds for mature cattle, yearlings, and calves, respectively. Prices are based on numbers for 1975 published in U.S. Dep. Agr., Econ. Res. Serv. Livestock and Meat Statistics-Supp. for 1976. Stat. Bull. No. 522, June 1977.

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Control of Mixed Brush with Tebuthiuron

C.J. SCIFRES, J.L. MUTZ, AND W.T. HAMILTON

Highlight: Tebuthiuron pellets, 10 or 20% active ingredient, aerially applied at 2.24 kg/ha active ingredient resulted in excellent control of whitebrush, spiny hackberry, and Berlandier wolfberry in South Texas mixed brush. At 2.24 to 3.36 kg/ha active ingredient, the herbicide appears promising for control of lotebush, blackbrush acacia, ceniza, Texas colubrina, javalin-abrush, guajillo, guayacan, desert yaupon and twisted acacia. Rates of 3.36 to 4.48 kg/ha active ingredient, applied as tebuthiuron pellets, appeared promising on huisache but only partially controlled honey mesquite. Tebuthiuron was ineffective on lime pricklyash, Texas persimmon, pricklypear, and tasajillo.

Drift damage to adjacent agricultural crops from some herbicide sprays and the rigid timing requirements for foliar sprays have prompted investigation of dry herbicide formulations for brush management. Dry herbicides, pellets, or granules greatly reduce drift potential.

Soil applications of dry herbicides may extend the effective time span for control of woody plants compared to foliar herbicide applications. With conventional sprays of herbicides such as 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] and 2,4,5-T + picloram (4-amino-3,5,6-trichloropicolinic acid), applications must be synchronized with foliar development of target species and specific environmental conditions conducive to maximum absorption and translocation of the herbicides. This restricts treatment for most woody plants to a relatively short period each spring or fall. Moreover, conventional sprays applied at the proper time for control of a species such as honey mesquite (*Prosopis glandulosa* var. *glandulosa*) may be only partially effective for control of many associated woody species.

Dry formulations of several herbicides have shown promise for control of some of the more important woody plants of South Texas, many of which are not highly susceptible to foliar-applied herbicides. Pelleted picloram effectively controls Macartney rose (*Rosa bracteata*) (Scifres 1975a), Texas persimmon (*Diospyros texana*) (Scifres 1975b), redberry juniper (*Juniperus pinchoti*) (Scifres 1972), lotebush (*Condalia obtusifolia*) (Scifres and Kothmann 1976), pricklypear (*Opuntia* spp.) (Hoffman and Dodd 1967), live oak (*Quercus virginiana*), huisache (*Acacia farnesiana*), and yaupon (*Ilex vomitoria*) (Bovey et al. 1969).

With the exception of relatively high rates of karbutilate [*tert*-butyl]-carbamic acid ester with 3-(*m*-hydroxyphenyl)-1,1-dimethylurea] on certain soils, soil-applied herbicides have not appeared promising for control of honey mesquite (Scifres et al. 1977). A relatively new herbicide, tebuthiuron [*N*-5-[1,1-

dimethylethyl]-1,3,4-thiadiazol-2-yl)-*N*, *N'*-dimethylurea] has shown promise for control of several woody species which are serious range management problems (Bovey et al. 1975). The objective of this study was to evaluate the control of woody plants with aerial applications of tebuthiuron pellets to south Texas mixed-brush communities.

Materials and Methods

Tebuthiuron pellets (10% active ingredient and approximately 0.32 cm diameter) were aerially applied at 1.12, 2.24, 3.36, and 4.48 kg/ha active ingredient on May 15, 1974, to plots 31 by 322 m (1 ha) near LaPryor, Texas. The herbicide was applied with a spreader normally used for aerial seeding and fertilizer application (Scifres 1977). Each treatment was duplicated in a randomized complete block design. Immediately after herbicide application, the experiment was fenced to exclude grazing by domestic livestock.

On May 22, 1975; June 21, 1976; and July 20, 1977, vegetation response was evaluated by stratifying the community into woody and herbaceous components. In 1975, woody plants were evaluated using the point-center quarter method (Cottam and Curtis 1956) for assessment of stand density, foliar cover, and community composition. At 25 points, equally spaced down the center of each plot, distance to the nearest plant in each quadrant was measured, species recorded, percentage canopy reduction visually estimated by two workers, and, if the plant was completely defoliated, presence or absence of vegetative sprouts was noted. Hereafter, plants completely defoliated and not resprouting will be referred to as "killed." In 1976 and 1977, two workers estimated canopy reduction by species down the center of each plot.

Soil samples were recovered from the study area immediately after treatment for characterization of chemical and textural components. At each of three locations, samples were recovered from 0 to 8, 8 to 15, and 15 to 30 cm deep. Organic matter content by acid digestion and titration, pH on a 1:4, soil: water slurry, and textural components by the hydrometer method were determined on triplicate subsamples from each depth at each sampling location.

Since tebuthiuron was initially applied under experimental permit from the Environmental Protection Agency, it was required that grazing animals be excluded by fencing. Due to these and other constraints, it was not possible to duplicate the experiment near LaPryor. For example, 10% active ingredient pellets were available only for the LaPryor location. Sites were treated near Sinton, Tilden, and Pearsall, Texas, for comparative purposes using pellets containing 20% active ingredient. Tebuthiuron was aerially applied on September 25, 1975, near Sinton at 2 and 3.36 kg/ha. Herbicide was applied in 13.7-m wide swaths to plots 51.2 by 457.2 m (2.3 ha). An untreated plot was included for reference, and treatments were evaluated as described for the study near LaPryor in August 1975; June 1976; and July 15, 1977.

On November 20, 1975, tebuthiuron pellets were aerially applied at 1 and 2 kg/ha to a whitebrush-dominated site near Tilden. Plots were 52 by 483 m (2.5 ha) and, as at Sinton, separated by untreated buffers 20.3 in wide. An untreated plot was included for comparison. On July 7, 1977, plots were evaluated as described for those near Sinton. The sites near Sinton and Tilden were fenced to exclude grazing by domestic livestock, and soil analyses were conducted as described for

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This research was supported in part by Lily Research Labs., Greenfield, Ind. The Chaparral Ranch, LaPryor; Leo Welder Ranch, Sinton; Dick Horton Ranch, Tilden; and Tom Haalf Ranch, Pearsall, Texas, provided land for the conduct of this research. Soil surveys of the LaPryor site by Michael Brown and Jack Stevens are appreciated. Manuscript received November 10, 1977.

the experiment near LaPryor.

A final experiment was installed on the South Texas Plains near Pearsall to evaluate tebuthiuron for control of blackbrush acacia (*Acacia rigidula*) and guajillo (*Acacia berlandieri*), 1 to 1.5 m tall, which had been shredded 2 years previous to the experiment. On May 18, 1976, tebuthiuron was applied to 12.5-by 40-m plots at 1.5 and 4.4 kg/ha with a broadcast spreader attached to a rubber-wheeled tractor. The experiment was designed as a randomized complete block with each treatment duplicated. July 20, 1977, canopy reduction of individual plants and those completely defoliated and not resprouting were recorded in a transect 2 m wide down on the center of each plot.

Soils, Vegetation and Rainfall on the Study Sites

The soils of the study site near LaPryor were primarily Tonio sandy clay loam (fine loamy, mixed, hyperthermic Ustollic Haplargids) (Table 1) with interspersed Chacon clay loam. The Tonio series consists of deep, well-drained, moderately permeable soils. Solum thickness is 100 to 150 cm over weakly to strongly cemented sandstone.

Table 1. Characteristics of soil from study sites in South Texas where aerial applications of tebuthiuron pellets were evaluated for control of mixed brush.

Depth (cm)	pH	Organic matter (%)	Textural components(%)		
			Sand	Silt	Clay
<hr/>					
Tonio series (LaPryor)					
<hr/>					
0-8	7.8	1.03	55	27	18
8-15	7.6	0.78	48	32	20
15-30	7.7	0.24	50	27	23
<hr/>					
Willacy series (Sinton)					
<hr/>					
0-8	6.2	1.52	69	13	18
8-15	6.3	1.28	70	13	17
15-30	6.5	0.86	66	12	22
<hr/>					
Clareville series (Tilden)					
<hr/>					
0-8	6.6	1.96	60	15	25
8-15	6.9	1.21	53	15	32
15-30	6.8	1.44	51	15	34

The study site near LaPryor was level to gently rolling and in fair range condition. The area supported an average of 405 honey mesquite trees/ha, from 3 to 4 m tall, which formed the overstory. The most abundant woody species, guayacan (*Porlieria angustifolia*), constituted over one-third of the population density (750 plants/ha) but the plants rarely exceeded 1 m tall. Other important species were whitebrush (*Aloysia lycioides*) (292 plants/ha), twisted acacia (*Acacia tortuosa*) (150 plants/ha), spiny hackberry (*Celtis pallida*) (136 plants/ha), and guajillo. Associated species (5 to 75 plants/ha) were catclaw acacia (*Acacia greggii*), blackbrush acacia, lotebush, Texas colubrina (*Colubrina texensis*), Texas persimmon, vine ephedra (*Ephedra antisiphilitica* var. *antisiphilitica*), leatherstem (*Jatropha dioica* var. *dioica*), allthorn (*Koeberlina spinosa*), Berlandier wolfberry (*Lycium berlandieri* var. *berlandieri*), javalinabrush (*Microrhamnus ericoides*), desert yaupon (*Schaefferia cunefolia*), and ceniza (*Leucophyllum frutescens*).

The area near LaPryor normally receives about 56 cm of rainfall annually. After application of the tebuthiuron on May 15, no rainfall was received until July 12, when 1.78 cm fell over a 3-day period. Beginning in late August, rainfall was higher than normal with 49.58 cm received before January 1975 bringing the annual total to 58.09 cm. Total precipitation was 42.49 cm in 1975 and 66.91 cm in 1976. Rainfall was typically distributed in both years, with major peaks

occurring in the spring (April-June) and fall (September-October). From January 1, 1977, to the final evaluation in August 1977, 23.51 cm of rainfall were received.

The soil of the Sinton study site was sandy loam to 30 cm deep over sandy clay loam to 60 cm deep. The soil was predominately of the Willacy series with minor inclusions of Sinton series. The Willacy series is a member of the fine-loamy, mixed, hyperthermic family of Udic Argiustolls.

The Sinton site was a gently sloping lowland supporting greater than 50% canopy cover of huisache with scattered honey mesquite, spiny hackberry, Texas persimmon, pricklypear, tasajillo (*Opuntia leptocaulis*), and lotebush. The 30-year average rainfall for the Sinton area is 72.5 cm. Within a month following application of the tebuthiuron pellets in late September, 5.13 cm of rainfall were received. Total rainfall for 1975 was 64 cm, and was 109 cm for 1976. From January 1, 1977, until final evaluation in July 1977, 47.9 cm of rainfall had been received on the study area.

Soil of the site near Tilden was of the Clareville series, a member of the fine, montmorillonitic, hyperthermic family of Pachic Argiustolls. Solum thickness is typically 75 to 150 cm with dark gray loam A horizons and clay loam Bt horizons. These soils are well drained with slow to medium surface runoff and are of moderately slow permeability. Soils of the immediate study site were sandy loams to 30 cm over clay loam.

The experiment near Tilden was located on a bottomland site supporting an almost solid cover of whitebrush with scattered honey mesquite, spiny hackberry, and lotebush plants. Only 1.55 cm of rainfall were received the first 60 days following tebuthiuron application near Tilden. However, 95.5 cm were received in 1976 with 24 cm occurring from March through June. From January 1, 1977, to final evaluation in July 1977, 32.4 cm of precipitation occurred on the study area.

Soil of the Pearsall location was Olmos gravelly loam, a member of the loamy skeletal, carbonatic, hyperthermic, shallow family of Petrocalcic Calciustolls. These soils have a dark grayish brown A horizon with over 35% coarse fragments and are underlain by a thick bed of caliche at 30 cm.

The experiment near Pearsall was located on an upland site supporting a mixture of blackbrush acacia and guajillo about 1 m tall. Rainfall was higher than normal, 105 cm, in 1976 when compared to the average of the last 10 years, 72.7 cm. The month after application of the tebuthiuron pellets, 20 cm of rainfall were received. During the 14-month study period, 120 cm of rainfall occurred on the study area.

Results and Discussion

At 1 and 2 years after application of the 10% tebuthiuron pellets near LaPryor, honey mesquite canopy was only slightly reduced with applications of 1.12 and 2.24 kg/ha active ingredient (Table 2). Percentage canopy reduction of honey mesquite increased as tebuthiuron rate increased, regardless of evaluation date, with 54% of the canopy removed at 3 years after application of the high rate.

At 3 years after application, no honey mesquite were killed where the low rate of tebuthiuron was applied (Table 2). Percentage of the trees killed by 2.24 kg/ha was not significant. At 3.36 kg/ha, 16% of the honey mesquite were killed, and 34% of the trees were dead where the high rate was applied. However, response of honey mesquite to tebuthiuron was highly erratic within a rate of application. Completely defoliated trees were often within 10 m of trees with little or no canopy reduction.

Near Sinton, no canopy reduction of honey mesquite was apparent in July 1977 where 2 kg/ha active ingredient of the 20% tebuthiuron pellets were applied in late September 1975, and only 10% canopy reduction occurred where 3 kg/ha were applied (data not shown). No honey mesquite control resulted in

Table 2. Canopy reduction (%) of honey mesquite, guayacan, twisted acacia, and guajillo at 1, 2, and 3 years after aerial application of various rates (active ingredient) of pelleted tebuthiuron near LaPryor, Texas, 1974.

Species	Year after treatment	Tebuthiuron rate (kg/ha) ¹				
		0	1.12	2.24	3.36	4.48
Honey mesquite	1	0a	11 ab	23 bc	44 de	75 g
	2	0a	14 ab	21 bc	63 ef	69 fg
	3	0a	6 ab	22 bc	40 cd	54 def
	3	0a	13 ab	15 ab	22 ab	21 ab
Guayacan	1	0a	13 ab	15 ab	22 ab	21 ab
	2	0a	32 b	57 c	73 c	76 c
	3	0a	17 ab	62 c	70 c	72 c
Twisted acacia	1	0a	40 bc	28 b	72 d	71 d
	2	0a	32 b	57 cd	73 d	76 d
	3	0a	43 bc	58 cd	70 d	74 d
Guajillo	1	0a	55 bc	76 cde	91 ef	92 ef
	2	0a	47 b	61 bc	98 f	94 ef
	3	0a	57 bc	67 bcd	70 cd	84 de

¹ Means within a species followed by the same letter are not significantly different at the 95% level.

July 1977 where 1 or 2 kg/ha active ingredient of the tebuthiuron pellets were applied in November 1975 near Tilden.

Although there was a trend for increasing canopy damage with increased tebuthiuron rate, no rate of tebuthiuron significantly reduced the canopy of guayacan at 1 year after application near LaPryor (Table 2). The response of guayacan to any given application rate was highly variable during the first growing season after application. Most plants exhibited some degree of chlorosis and many completely defoliated and re-foliated at least three times during the year following treatment. The defoliation cycle was apparently regulated by rainfall, with defoliation occurring after significant precipitation followed by repienishment of the canopies as the soil gradually dried. At 2 and 3 years after application, defoliation levels of guayacan were increased as compared to the year after treatment, with the higher rates resulting in a canopy reductions of greater than 70%. At 3 years after application, 4% of the guayacan were killed by 1.12 kg/ha active ingredient of tebuthiuron, 28% by 2.24 kg/ha, 37% by 3.36 kg/ha, and 55% were killed by the highest rate of the herbicide. Near Tilden, the guayacan was undamaged at 18 months after application of 1 or 2 kg/ha. No guayacan was present on the research near Sinton. Guayacan is a desirable species for white-tailed deer (*Odocoileus virginianus*) but occurs in excessive quantities on much of the South Texas Plains and Coastal Prairie. Therefore, achieving only partial control of this species was considered desirable.

Control of twisted acacia was also improved the second year

Table 3. Canopy reduction (%) guajillo and blackbrush acacia populations killed (%) by July 20, 1977, after two application rates (active ingredient) of pelleted tebuthiuron with ground equipment on May 18, 1976, near Pearsall, Texas.¹

Tebuthiuron rate (kg/ha)	Guajillo		Blackbrush acacia	
	Canopy reduction	Killed	Canopy reduction	Killed
0	0a	0a	0a	0a
1.5	46 b	21 b	47 b	21 b
4.4	100 c	97 c	97 c	72 c

¹ Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's new multiple range test.

Table 4. Canopy reduction (%) of whitebrush, spiny hackberry, and desert yaupon at 1, 2, and 3 years after aerial application of various rates (active ingredient) of pelleted tebuthiuron near LaPryor, Texas, in 1974.

Species	Year after treatment	Tebuthiuron rate (kg/ha) ¹				
		0	1.12	2.24	3.36	4.48
Whitebrush	1	0a	100 b	100 b	100 b	100 b
	2	0a	96 b	98 b	99 b	99 b
	3	0a	90 b	90 b	99 b	99 b
Spiny hackberry	1	0a	91 bcd	96 cd	98 d	94 cd
	2	0a	77 bc	99 d	99 d	99 d
	3	0a	74 b	86 bcd	85 bcd	97 d
Desert yaupon	1	0a	86 de	90 e	87 de	91 e
	2	0a	66 bcd	63 bc	59 bc	69 cd
	3	0a	48 b	6abc	60 bc	73 cde

¹ Means within a species followed by the same letter are not significantly different at the 95% level.

after tebuthiuron application compared to the first year (Table 2). The lower herbicide rates, 1.12 and 2.24 kg/ha, reduced the twisted acacia canopies by 32 to 57% at 2 years after treatment, whereas the higher rates resulted in canopy reductions of 73 to 76%. Canopy reduction of twisted acacia at 3 years after application was no different than after 2 years, regardless of application rate. Percentage of twisted acacia killed by 1.12 to 3.36 kg/ha of tebuthiuron in the experiment near LaPryor was 4% or less. However, 51% of the plants were killed by the high rate after 3 years. Twisted acacia near Tilden was unaffected at 18 months after application of tebuthiuron at 1 or 2 kg/ha.

No twisted acacia existed on the Sinton site but there was a heavy stand of huisache. At 19 months after treatment, canopy reduction of huisache was 51 and 81% where 2 and 3.36 kg/ha were applied, respectively. The lower rate killed 24% of the huisache, and 66% were killed by the higher rate.

Guajillo, another woody species desirable in certain quantities as deer browse, was present at the LaPryor and Pearsall locations. At 1.12 and 2.24 kg/ha, active ingredient tebuthiuron reduced the guajillo canopies by 55 to 76% the year after treatment with no increased control by the second or third year after treatment near LaPryor (Table 2). However, at the higher tebuthiuron rates, defoliation of guajillo exceeded 90% at 1 and 2 years after treatment. By 3 years after application of 3.36 and 4.48 kg/ha of tebuthiuron, average canopy reduction was 70 and 84%, respectively. At 3 years after application, 20% of the guajillo population was killed by the lowest tebuthiuron rate, 29% by 2.24 kg/ha, 42% by 3.36 kg/ha, and 64% by the highest rate.

Response of guajillo to 1.5 kg/ha tebuthiuron applied with ground equipment near Pearsall (Table 3) was similar to the response to 1.12 kg/ha near LaPryor (Table 2). The higher rate near Pearsall completely defoliated the guajillo population and 97% of the plants were showing no signs of life at the time of evaluation (Table 3).

Whitebrush, a serious management problem on some of the most productive rangelands of South Texas, is difficult to control with conventional chemical and mechanical methods. However, whitebrush is apparently highly susceptible to tebuthiuron based on results of this study. At all application rates, the canopies of whitebrush were completely defoliated at 1 year after treatment near LaPryor (Table 4). A few plants showed signs of recovery after 2 years but average defoliation levels exceeded 95% regardless of tebuthiuron rate. Although recovery of whitebrush was evident at 3 years after application of tebuthiuron at the lower rates, near complete control resulted

where the higher rates were applied. Although no whitebrush was present on the study site near Sinton, it dominated the Tilden study area. At 18 months after treatment with 1 kg/ha near Tilden, whitebrush canopy reduction was 88% and 25% of the plants were dead. Where tebuthiuron was applied at 2 kg/ha, the whitebrush population was completely controlled at the final evaluation. Since whitebrush may occur in solid stands, tebuthiuron has excellent potential for improvement of rangeland infested with this troublesome species.

Spiny hackberry is another common component of South Texas mixed-brush stands which is usually only partially controlled by conventional aerial sprays. Like whitebrush, spiny hackberry was apparently highly susceptible to tebuthiuron. The year after application, defoliation of spiny hackberry exceeded 90% regardless of tebuthiuron rate (Table 4). At 2 years after application, defoliation was near complete where at least 2.24 kg/ha of tebuthiuron were applied. Although some recovery of spiny hackberry was evident 3 years after application of 1.12 to 3.36 kg/ha near LaPryor, average canopy reduction was 97% where 4.48 kg/ha were applied. Where the highest herbicide rate was applied, 91% of the spiny hackberry was killed. Average canopy reduction of spiny hackberry near Sinton was 68 and 93% where 2 and 3.36 kg/ha of tebuthiuron were applied, respectively. Where 2 kg/ha were applied, 30% of the plants were killed and 90% were killed by the high rate after 19 months. Near Tilden, spiny hackberry canopies were reduced by 56 and 100%, and 47 and 100% of the plants were killed where 1 and 2 kg/ha of tebuthiuron were applied, respectively.

Desert yaupon responded favorably to tebuthiuron application the year after treatment near LaPryor (Table 4). However, regardless of application rate, recovery of desert yaupon was evident during the second growing season and defoliation was less than 70% following application of the highest rate. Canopy reduction after 3 years was no different than after 2 years, regardless of application rate. No desert yaupon occurred on the study sites near Tilden and Sinton.

Blackbrush acacia near Pearsall responded similarly to guajillo with 47% canopy reduction after treatment with 1.5 kg/ha of tebuthiuron and 97% canopy reduction after treatment with the high rate (Table 3). Based on these results and observations from near LaPryor, at least 2 to 3 kg/ha of tebuthiuron may be required for moderate to high control levels of blackbrush acacia.

Several other species were present on the study areas but their distribution did not allow statistical analyses of their responses

to tebuthiuron. Observation of several of these species at all locations indicate that Berlandier wolfberry may be highly susceptible to 2.24 kg/ha or more tebuthiuron since canopy reduction usually exceeded 80% and more than 25% of the plants were killed. Lotebush, Texas colubrina, ceniza, and javalinabrush appeared to be moderately susceptible with 50 to 80% overall canopy reduction but with less than 25% of the plants killed by 2.24 kg/ha. Lime pricklyash (*Zanthoxylum fagara*) and Texas persimmon appeared to have a low order of susceptibility to the herbicide with pricklypear and tasajillo virtually unaffected by high rates of application.

Based on results of these studies, tebuthiuron appears to hold excellent potential for control of several problem woody species on South Texas rangeland. Although not highly effective on honey mesquite, the herbicide may have use following application of other brush control methods which have controlled the honey mesquite and released troublesome secondary species. Tebuthiuron appears highly promising for control of whitebrush since the species often occurs in almost solid stands on the more productive rangeland soils of South Texas. Although this study was not designed to compare formulations, there was no apparent difference in brush control with the pellets containing 10 or 20% active ingredient.

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Element Content of Crested Wheatgrass Grown on Reclaimed Coal Spoils and on Soils Nearby

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Abstract

Fairway crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] was analyzed to determine the possible effects of coal spoils at the Dave Johnston Mine, Wyoming, on the chemical composition of this widely used reclamation species. Concentrations of 8 of the 26 elements tested by analysis of variance showed significant differences between the samples growing in 10-15 cm of topsoil covering the spoils and samples from soils nearby. Samples from the mined areas showed about 50% higher concentrations. Concentrations of manganese and uranium, however, were about 150 and 200% higher, respectively. Concentrations of the trace elements cobalt, manganese, and zinc—essential in animal nutrition—ranged from deficient levels in “control” samples to adequate or marginal levels in samples from reclaimed spoils. The phosphorus content of grasses that grew on spoil material was two-thirds that of the control grasses, to the point where the former may be nutritionally deficient as a cattle forage.

Crested wheatgrass was sampled at the Dave Johnston mine at the southern edge of the Powder River Basin in Wyoming as part of a larger study designed to assess the effects of reclaimed spoils on the element concentrations in vegetation from eight surface coal mines in the Northern Great Plains (Erdman and Ebens 1975). This species of wheatgrass dominates the revegetated spoil banks at the Dave Johnston Mine, as it does at many of the surface mines that were sampled.

The Dave Johnston Mine is located about 24 km northeast of Glenrock, in Converse County, site of Pacific Power and Light Company's Dave Johnston powerplant.

Crested wheatgrass is used both as a forage for cattle (Blincoe and Lambert 1972) and for land reclamation (Bauer et al. 1976). It is used more widely for reseeding purposes than any other grass, and has been recommended for reseeding depleted rangelands in semiarid regions (Sotola 1940). Along with brome-grass, it has been a widely used cultivated grass in the Canadian Prairies (Heinrichs and Carson 1956). Its nutritional value and palatability are high when the plant is green and succulent, but decrease as it becomes mature (Sotola 1940; Pingrey and Dortignac 1959). This cool-season grass apparently does not retain its forage value through the summer grazing season as do many of the native warm-season grasses (Heinrichs and Carson 1956). For this reason optimum utilization of such pasturage might require rotational grazing.

Methods

Sampling was conducted on July 24, 1974, when growth of wheatgrass was at the mature seed stage of development. A three-level analysis of variance design was used. The purpose of the first level was to assess differences in element concentrations between crested wheatgrass growing on spoil materials and on soils native to the site (topsoil borrow). The second level was included to estimate the degree of uniformity in the element contents of wheatgrass within the two substrate types. A third level, based on the analyses of duplicates or splits of each sample, was included to estimate the laboratory precision (reproducibility). This precision was satisfactory for all elements but mercury, so the variability observed in the data was, for the most part, natural.

Ten samples were collected at randomly selected locations within two tracts of reclaimed spoil piles. Two of these locations were within a 19-ha tract that had been seeded in autumn 1969 with a seed mixture that included standard crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult]. The remaining eight locations were within a 45-ha tract seeded in autumn 1972. The seed mixture in this latter tract included Fairway crested wheatgrass [*A. cristatum* (L.) Gaertn]. Both tracts had been covered with 10-15 cm of topsoil prior to seeding, but the kind of surface material at the sampling locations varied considerably, ranging from spoil material (mixed overburden and coal) to as much as 15 cm of topsoil.

The predominant soils in the area are mapped (U.S. Soil Conservation Service 1970) as Haplargids, used mostly for range and some irrigated crops.

The only sites available for collecting control samples of crested wheatgrass were two topsoil borrow areas adjoining the active mine. The upper 10-15 cm of topsoil and vegetation had been removed with self-loading scrapers and spread over the reshaped spoils. One of the areas, 12 ha, was seeded in spring 1972; the other area, 28 ha, was seeded in autumn of the same year. Both borrow areas were seeded with Fairway crested wheatgrass. The concentrations of elements observed in these borrow-area samples were generally close to the concentrations found in crested wheatgrass growing in native soils in western North Dakota (unpublished data).

We clipped the mature grass samples about 15 cm above the ground surface in order to minimize soil contamination. Samples were then placed in cloth bags, taken to the U.S. Geological Survey laboratories, and pulverized in a Wiley mill. The resulting homogenized material was divided into two equal portions. The number of samples for this study was therefore doubled from 20 field samples to 40 laboratory samples. These 40 samples were then placed in a randomized sequence, thereby transforming any systematic laboratory error that may be present into a random error.

A weighed portion of each sample was burned to ash in a muffle furnace in which the heat was increased 50°C per hour to a temperature of 550°C and held at this temperature for 14 hours. The resulting ash was then weighed to determine the ash yield. Weighed aliquots of the samples were wet ashed, according to methods described by Harms and Papp (1975), in order to determine the

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Authors thank W. Cary, T.F. Harms, M.J. Malcolm, and C.S.E. Papp, who performed the chemical analyses at the Denver Laboratories of the U.S. Geological Survey. Approval to sample at the mine was granted by James Sarvey, Pacific Power and Light Company. Manuscript received March 9, 1978.

concentrations of those elements that would be volatilized and lost by burning.

Methods of analysis used for these volatile elements were atomic absorption spectrophotometry for antimony and arsenic, a turbidimetric method for total sulfur, flameless atomic absorption for mercury, a fluorimetric method for selenium, and a selective ion electrode method for fluorine. The methods of analysis and the elements determined in the ash were: atomic absorption—cadmium, calcium, cobalt, lithium, potassium, silicon, sodium, and zinc; colorimetry—phosphorus; and fluorimetry—uranium. The remaining elements reported were analyzed by emission spectrography.

When concentrations of some elements (cobalt, molybdenum, uranium, and vanadium) fell below the limits of detection, means were estimated by techniques developed by Cohen (1959) and described for geochemical applications by Miesch (1967). Because the analysis of variance requires a completely numerical data set, we arbitrarily assigned values equal to 0.7 of the lower limit of detection of a given element to samples whose concentrations were too low to be measured.

We transformed the concentrations of all elements to logarithms because their frequency distributions tend to be more nearly symmetrical on a logarithmic scale than on an arithmetic scale. The geometric mean was used to estimate the most typical concentration and is convenient for comparing the element content of the samples of crested wheatgrass taken from the two type of substrate.

Results and Discussion

Of 26 elements tested by analysis of variance eight showed significant differences in concentrations between the two areas (Table 1). Concentrations of cadmium, cobalt, fluorine, manganese, uranium, vanadium, and zinc in samples that grew on spoils ranged from about 30–200% higher than those grown in the borrow areas. Conversely, the phosphorus content in

Table 1. Geometric mean concentrations and observed ranges of elements in crested wheatgrass from topsoil borrow areas and from reclaimed spoil areas.¹

Element	Topsoil borrow areas		Reclaimed spoil areas	
	Mean	Range	Mean	Range
Al, %	0.069	0.030-.27	0.11	0.041-.37
B, ppm	15	11-28	17	11-48
Ba, ppm	12	6-22	10	6-22
Ca, %	.26	.22-.30	.23	.16-.35
² Cd, ppm	.054	.016-.15	.082	.034-.15
³ Co, ppm	.069	<.054-.13	.099	<.058-.44
Cr, ppm	.27	.11-.60	.40	.16-1.1
Cu, ppm	2.8	1.6-6.0	3.2	1.6-5.9
² F, ppm	4.5	3-6	6.2	3-10
Fe, ppm	190	81-350	270	120-740
Hg, ppm	.011	.01-.02	.011	.01-.02
K, %	1.1	.90-1.4	1.2	.72-1.6
Li, ppm	.82	.29-1.8	1.3	.58-4.0
Mg, %	.12	.08-.17	.11	.08-.17
³ Mn, ppm	16	5.6-36	39	23-140
Mo, ppm	.39	<.38-.58	.43	<.39-.84
Na, ppm	8.4	3.6-22	11	3.5-21
³ P, %	.13	.09-.19	.084	.041-.17
S, total, %	.17	.10-.27	.18	.09-.33
Se, ppm	.23	.10-.60	.27	.10-.70
Si, %	1.2	.7-1.9	.98	.44-1.9
Sr, ppm	25	16-39	25	14-41
Ti, ppm	16	3-50	26	11-74
² U, ppm	.021	<0.21-.067	.062	<.028-.55
² V, ppm	.63	<.54-.98	.82	<.69-1.5
³ Zn, ppm	20	13-28	26	18-32

¹ Data are based on 10 samples and their analytical duplicates from each area; concentrations are expressed on a dry basis.

² Means are significantly different at the $P < 0.05$ level.

³ Means are significantly different at the $P < 0.01$ level.

samples from the spoil tracts was about two-thirds that in the samples collected from the control areas.

Two elements of environmental concern, but for which only very limited data are available, are antimony and arsenic. Their detection ratios (that is, the ratio of the number of samples in which the element was detected to the total number of samples analyzed) and ranges in dry matter follow: antimony, 0:40 <0.05 ppm; arsenic in wheatgrass from the topsoil borrow areas, 1:20, <0.05-0.05 ppm, and in wheatgrass from the reclaimed spoil areas, 10:20, <0.05-0.09 ppm. Arsenic appears to be higher in samples from the spoil, judged by the differences in detection ratios.

It is clear from these results that reclaimed spoils can affect the element composition of crested wheatgrass to a measurable degree. The next and more difficult problem is to assess these differences as they might bear on productive post-mining land use. How will these geochemical alterations affect the nutritional requirements of range plants or of livestock that utilize the forage?

Possible deficiencies in elements essential to vegetation have attracted a major interest in mine-spoil reclamation efforts. The most notable element is phosphorus. Our analyses for phosphorus in crested wheatgrass confirm the conclusions of Sandoval et al. (1973) that the available phosphorus in spoil materials derived from the Fort Union Formation is generally very low (Table 1), and is the most pronounced fertility limitation to successful revegetation of reclaimed spoil banks. The fact that wheatgrass is reasonably well established at the Dave Johnston Mine, however, is evidence that this is not a severe limitation to land reclamation.

The potential deficiency of phosphorus for cattle production, however, may be of some importance. Minimum phosphorus requirements of range cattle vary to a degree, but a recommended dietary level of 0.13% has appeared quite consistently in the literature (Whitman et al. 1951). Recent estimates are considerably higher (see, for example Church et al. 1971). Whereas the phosphorus content of wheatgrass that we sampled from the borrow areas may have been marginal for cattle, the phosphorus concentrations in the grasses from the reclaimed spoils are clearly lower. Whitman et al. (1951) state, however, that phosphorus deficiencies even in native grasses on normal range often occur before the end of the summer season and certainly by early autumn. Other workers concur that pasture and range forage are commonly deficient in phosphorus (Church et al. 1971; Knox and Watkins 1958). The 0.084% level for phosphorus given in Table 1 is not unusual in crested wheatgrass. It is similar to those levels reported for crested wheatgrass from Canada (Heinrichs and Carson 1956) and is identical to the average of 13 samples collected from the western United States over the past several years (unpublished data, U.S. Geological Survey). On the other hand, phosphorus levels reported by Sotola (1940) are more similar to those in the samples from the borrow areas. Moreover the optimum calcium-to-phosphorus ratio of 2:1 (Heinrichs and Carson 1956) is closely approximated in the latter samples. Phosphorus supplements, such as bone meal, are commonly provided in range cattle operations (Knox and Watkins 1958) and should be considered in livestock production on reclaimed coal lands.

The problem of potentially toxic elements is a more difficult one. The slight but significantly higher concentrations of cobalt and zinc in the spoil-associated wheatgrass may be of little consequence, because most problems associated with these elements have involved deficiency diseases in livestock (Lee 1975).

Judging from results reported by Blincoe and Lambert (1972), the cobalt and zinc levels in wheatgrass from the Dave Johnston Mine area are not abnormally high. In fact, zinc may be marginal for livestock production. Probable dietary requirements for these elements are 0.1 and 30-40+ ppm, respectively (Church et al. 1971). Cobalt levels in Standard crested wheatgrass from northeastern Nevada are reported to be ten to one hundred times greater than those given here (Lambert and Blincoe 1971).

The concentrations of manganese are similar to those reported by Blincoe and Lambert (1972). The probable dietary requirement for this essential trace element is 20 ppm (Church et al. 1971).

Significantly higher concentrations of cadmium and fluorine are also noted for those samples that grew on spoils. There is some indication that acid spoils promote fluoride uptake in plants (National Research Council 1974). The average pH of 6.2 for the spoils that we sampled (Erdman et al. 1978) is lower than the pH of 7.2 which is typical of the surface horizon soils of the Powder River Basin (Tidball 1975). The toxicity of fluorine to livestock is well known; chronic fluorosis in grazing animals has occurred widely throughout the world. However, the fluorine concentrations in all samples of crested wheatgrass from the Dave Johnston Mine are well below levels at which normal performance in livestock may be affected (Church et al. 1971); natural forage normally contains 2-20 ppm fluorine on a dry-weight basis (Gough and Shacklette 1976). The cadmium concentrations are also within the ranges found in other native plants (Connor and Shacklette 1975).

We have found no evidence in the literature that vanadium concentrations pose any problems. Vanadium is relatively nontoxic to animals (Gough and Shacklette 1976).

As for uranium, we know of no recognized critical levels in forage, even though this element is radioactive and can be highly toxic (Sax et al. 1951). It should be noted that higher than normal performance in livestock may be affected (Church et al. clover and alfalfa from these spoils (unpublished data of the authors), as well as in the wheatgrass.

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TECHNICAL NOTES

The Effect of Nitrogen, Phosphorus and Potassium Fertilization on Chemical Content of Sheep Diets

J. J. DOYLE

Abstract

Sixteen mixed breed sheep, 1-2 years old and fitted with esophageal fistulas, were allotted at random to four range pastures in southeastern South Dakota. Two of the pastures (4.9 and 5.3 ha) were treated with 67.2 kg of N, 33.6 kg of P, and 89.7 of K/ha, whereas the other two pastures (6.9 and 7.3 ha) received no fertilizer treatment. Esophageal extruded samples were collected at two time periods (June-July and August) from all animals in the four pastures. Ash, N, cellulose and energy content were determined on all extruded samples. Fertilizer treatment had no significant effect on the nutritive content of the diet selected by the sheep. However, time of collection had significant effects on the protein and energy content of the diet selected. A significant fertilizer-collection period interaction was observed for percentage of ash.

Measurement of the nutritional value of the diet of grazing animals is difficult. Grazing animals commonly have available to them a wide range of potential food in the form of different plant species, each with its particular physical and chemical characteristics and each with different densities and growth forms. From this available forage, the grazing animal exercises a high degree of selection, the mechanisms of which appear to be based on subtle chemical and physical differences affecting smell, taste and touch (Kreuger et al. 1974). The methods used for measuring the nutritional value of diets of grazing animals have been reviewed by Harris et al. (1967), Van Dyne (1969), and Theurer et al. (1976).

Because little information is available concerning the diets of grazing animals in South Dakota, the following experiment was conducted to determine the effect of N, P, and K fertilization of a lowland native pasture on the nutritional value of the diet of grazing fistulated sheep.

Experimental Procedures

The experiment was carried out on a range pasture in southeastern South Dakota. The climate is a continental type. The mean annual temperature is 6.5°C; the range in monthly mean temperature is from -11.3°C in January to 22°C in July. The mean temperature was 17.5°C during the first collection period and 22°C during the second. The average annual precipitation was 51.8 cm; of this, 41.4 cm or 80% fell during the growing season (April to September).

The experimental area was a native pasture with wet, poorly drained soils of the Solomon and Lamoure series (Westin et al. 1959). The most important plants in the pasture were bluegrasses (*Poa* spp.), red top (*Agrostis alba* L.), prairie cordgrass (*Spartina pectinata* Link),

wheatgrasses (*Agropyron* spp.), sedges (*Carex* spp.), and a variety of forbs. The pasture had been overgrazed for many years and was in poor range condition when rated according to the method of Dyksterhuis (1949).

Sixteen mixed-breed sheep, 1-2 years old and fitted with esophageal fistulas, were allotted at random to four range pastures. Two of the pastures (4.9 and 5.3 ha) were treated with 67.2 kg of N as ammonium nitrate, 33.6 kg of P as treble superphosphate, and 89.7 kg of K as potassium chloride/ha. The other two pastures (6.9 and 7.3 ha) received no fertilizer.

Experimental data were collected during two periods. Period 1 was in June-July, and period 2 was in August. In late July, all pastures were mowed for hay because the stocking rate of the sheep was not high enough to prevent the pastures, especially those fertilized, from maturing early. The herbage available during period 2 was consequently of higher nutritional value than that available during period 1 because pastures during period 2 had less mature forage and more young succulent growth.

Esophageal samples were collected on four mornings and four afternoons during each experimental period by means of plastic-lined, screen-bottom bags strapped to each animal's neck. A representative subsample of each esophageal sample collected was frozen for chemical analyses at a later date. Dry matter determinations on all samples were made by drying them at 60°C for 48 hours in a forced-air oven. Representative samples of the dried material were analyzed in duplicate for N, energy, and ash using standard procedures (A.O.A.C. 1960). Energy content of composite duplicates was determined in a Parr Adiabatic Bomb Calorimeter¹. Cellulose was determined in duplicate by the method of Crampton and Maynard (1938).

Analyses of variance using least squares procedures were conducted on all measurements (Harvey 1960).

Results and Discussion

Ash Content of Esophageal Extrusa

The over-all mean value of the esophageal extrusa ash content was 12.5% on an oven-dry basis (Table 1). The ash content was higher in the diet selected by the sheep grazing the unfertilized pastures than in those grazing the fertilized pastures in June (12.6 vs 11.2%) but was higher (13.5 vs 12.8%) in the diet of the sheep grazing the fertilized pastures in August ($p < 0.05$, Table 1). The mean ash content values were greater in August than in June. This finding agrees with data reported by Van Dyne and Heady (1965), who found that sheep grazing dry annual ranges selected forage higher in ash content in August and September than in July.

Protein Content of Esophageal Extrusa

The over-all mean protein content of the esophageal extrusa was

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Journal article from the SEA-Federal Res., Western Region, U.S. Sheep Exp. Sta., Dubois, Ida., in cooperation with the University of Idaho, Moscow.

The author wishes to acknowledge the assistance of South Dakota State University for the administration of the experimental area at the time of the study.

Manuscript received January 13, 1978.

¹ Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Table 1. Means of esophageal extrusa chemical components.

Period and treatment	Ash oven dry (%)	Protein (%)	Cellulose, (%) organic matter	Energy, (Kcal/g organic matter)
June				
Unfertilized	12.60 ^{ab}	14.89 ^{ab}	28.63 ^a	4.51 ^{ab}
Fertilized	11.16 ^{a*}	16.33 ^{ab}	28.05 ^a	4.60 ^{ab}
Mean	11.88 ^{ab}	15.61 ^{a**}	28.34 ^a	4.56 ^{a*}
August				
Unfertilized	12.80 ^{ab}	18.38 ^{ab}	26.83 ^a	4.72 ^{ab}
Fertilized	13.52 ^{b*}	20.64 ^{ab}	24.73 ^a	4.69 ^{ab}
Mean	13.16 ^{ab}	19.51 ^{b**}	25.78 ^a	4.72 ^{b*}
Unfertilized mean	12.70 ^{ab}	16.64 ^{ab}	27.73 ^a	4.62 ^{ab}
Fertilized mean	12.34 ^{ab}	18.49 ^{ab}	26.39 ^a	4.65 ^{ab}
Over-all mean	12.52 ^{ab}	17.57 ^{ab}	27.06 ^a	4.64 ^{ab}

Data with different letters as superscripts are significantly different.

* $p < 0.05$

** $p < 0.01$

17.6% protein on an organic matter basis (Table 1). The highly significant difference ($p < 0.01$) found between collection periods (Table 1) in the protein content of the forage selected by the sheep is to be expected. After mowing in late July, regrowth occurred in all pastures, and the sheep selected a higher protein diet than in June when the pastures were long. This finding is a reversal of the usual trend of a decline in protein intake with advancing date of harvest. Van Dyne and Heady (1965) found that the protein content of the diet selected by sheep on dry annual range was higher in early summer than in later summer. However, the data in this study included the effects of fertilization and mowing.

In both collection periods, the protein percentage of the esophageal extrusa was highest from sheep grazing the fertilized pastures than from sheep grazing the unfertilized pastures (Table 1). Woolfolk et al. (1975) reported similar data for cattle grazing nitrogen-fertilized bluestem ranges.

Cellulose Content of Esophageal Extrusa

The mean cellulose percentage of the diet selected by the sheep was 27.1% on an organic matter basis (Table 1). In comparison, Cook et al. (1965) found that the cellulose content of the diet of sheep grazing good summer range pasture was 25% on an organic matter basis. There was no significant differences due to fertilization or to collection periods. Woolfolk et al. (1965) reported that N fertilization had no effect on the cellulose content of the diet selected by esophageal fistuled cattle grazing bluestem ranges. Grimes (1967), however, found that the cellulose content was lower on N fertilized pastures than on pastures not fertilized with N.

Energy Content of Esophageal Extrusa

The mean energy content of the diet selected by the sheep was 4.6

Kcal/g on an organic matter basis (Table 1). This value is somewhat lower than the 4.9 Kcal/g in July and 4.7 Kcal/g in August (assuming 12% ash) reported by Van Dyne and Heady (1965) for sheep grazing dry annual range. The diet selected by sheep in June was 0.16 Kcal/g lower in energy content than that selected by the sheep in August ($p < 0.05$, Table 1). Van Dyne and Heady (1965) reported contrasting data for sheep on dry annual summer range. However, the cutting of the pasture in late July influenced the results reported here.

In conclusion, it may be stated that under the conditions of this study, no significant effect of fertilizer treatment on the nutritive content of the diet selected by grazing sheep was found. Time of collection, however, did have a highly significant ($p < 0.01$) effect on the protein content and a significant ($p < 0.05$) effect on the energy content of the diet selected. A significant ($p < 0.05$) fertilizer-collection period interaction was observed for percentage ash.

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BOOK REVIEWS

Plant Geography. By Rexford Daubenmire. Academic Press, New York. 1978. 388 p. \$21.50

In writing this book, Daubenmire has taken a decidedly different approach than the one usually seen in plant geography texts. He chose to emphasize ecologic aspects of North American vegetation types rather than presenting detailed floristic descriptions which illustrate basic principles. Thus, concepts such as plant migration and evolutionary trends receive proportionately less emphasis than descriptions of individual plant communities. This approach has considerable merit from a management viewpoint, and it tends to make the book more readable than many plant geography texts. Unfortunately, several topics suffer from too brief a discussion, and some contain errors which seriously affect the overall quality of the book.

The book is organized into two major parts. The first part is a succinct summary of some of the more important concepts of floristic plant geography. This brief discussion (38 pages) is well organized and provides an overview of several factors which have contributed to present-day floristic composition in plant communities. In general, I feel that much of the discussion is too brief. Dissemination efficiency, for example, receives only a two-page consideration, while the important subject of evolution is hardly mentioned at all. While it is easy to find fault with what isn't included, it is perhaps more appropriate to comment on what is discussed. In general, Daubenmire succeeds very well in presenting the highlights of floristic plant geography, and this section of the book essentially introduces the second part of his book.

The second part concentrates on ecologic plant geography and makes up the major portion of the book. In it, individual vegetation types in North America are characterized according to their climatic, edaphic and successional relations. Brief consideration is also given to principal vertebrates in vegetation types, and types of land use are likewise discussed. In essence, this section is a review of existing literature with little new information presented. As a result, some vegetation types receive more extensive treatment than others, according to how thoroughly they have been studied. While this could cause problems, Daubenmire does a commendable job of integrating available information into a composite description of vegetation types.

Perhaps the most serious criticism of the book is that it apparently received only a superficial proof-reading. This resulted in a variety of errors which should have been eliminated. In the section dealing with the steppe region, for example, literature is incorrectly cited; an illustration is erroneously cross-referenced; and typographic and syntactic errors are frequent. In addition, some tenuous assumptions and conclusions are drawn which seem to have little, if any, experimental evidence. On page 199, for example, we are told that "heavy grazing. . . is far more detrimental to the taller grass layer, presumably since animals graze all species to about the same level and this takes a greater proportion of the shoots of the taller species." It seems that a speculative statement like this one should not be included unless it can be supported by published literature. A more conscientious editing effort should have been made to moderate such statements.

The bibliography contains some 442 references, but very few are more recent than 1970. While this may correlate well with publishing trends in descriptive community ecology, recent advances in evolution, genecology, physiological ecology, and other relevant

fields have been largely overlooked. The index appears to have been added almost as an afterthought. While it does a good job of cross-referencing individual species, there are few other individual headings contained. Thus it is frequently necessary to thumb through the entire text to determine if a particular topic is addressed.

In general, the book is well organized and written although annoying errors tend to reduce its effectiveness. It will probably find greatest acceptance as a supplementary text for undergraduate and graduate classes studying community ecology. It will also be of interest to those who seek a descriptive reference for vegetation types found in North America.—*Richard S. White*, Miles City, Montana

Measurements of Grassland Vegetation and Animal Production. Edited by L. 't Mannetje, Bulletin 52 Commonwealth Bureau of Pastures and Field Crops. Commonwealth Agriculture Bureaux, Farnham Royal, Bucks, England, 1978. 260 p. £10.00 UK, \$24.00 post-free.

This reference is composed of 8 chapters. The editor, Dr. L. 't Mannetje, presents an introductory chapter which includes an extensive definition of grasslands and criteria for their measurements. He also prepared the chapter (4) on measuring quantity of vegetation. The remaining chapters were prepared by 6 other research scientists, each writing about a specialized field of grassland research. The goal was to present a critical review of methods to assess grassland vegetation and associated animal production. Topics covered by these scientists include: Statistical Aspects of Vegetation Sampling by G.A. McIntyre (Chap. 2); Measuring Botanical Composition of Grassland by F.C. Tothill (3); Sample Preparation and Chemical Analysis of Vegetation by A.D. Johnson (5); Animal Production Studies on Grasslands by F.H.W. Morley (6); Measuring Animal Performance by F.L. Corbett (7); Pattern-seeking Methods in Vegetation Studies by M.B. Dale (8).

This book was intended to complement and not replace Miss Dorothy Brown's 1954 publication, *Methods of Surveying and Measuring Vegetation*. The present book deals exclusively with vegetation used primarily by domestic animals. It also presents newer developments such as *in vitro* digestibility and fistulation relating to animals and the use of capacitance meters, pattern analysis, and other statistical techniques made possible by the advent of computer technology. Thus it serves to update the earlier publications.

In general, this book probably serves best as an in-depth literature review of the subject matter covered. It covers a large and complex subject matter area with good comprehension. In most instances a critical analysis is given, complete with advantages, disadvantages, conclusions and other pertinent features. In some instances, however, the authors fail to point out the qualities of measurement methods and their value to evaluating grassland vegetation. Typographical or word errors are few and the book is set in easy-to-read type with excellent subject matter delineations. Research workers will find this book of value as a reference work in research methodology. Those teaching measurement techniques related to animal production and grassland vegetation will find this book particularly useful.—*Pat O. Currie*, Miles City, Montana

Position Description Executive Secretary—Society for Range Management

Responsibilities

A. The Society for Range Management is an organization incorporated under the laws of the State of Wyoming and governed by the "Articles of Incorporation" and the "Bylaws". The Executive Secretary shall be the chief administrative officer of the Society accountable to the Board of Directors and under the general supervision of the President. He/she also shall serve as corporate secretary and treasurer.

B. The responsibilities of the Executive Secretary assigned in the Bylaws are:

ARTICLE IV. SECTION 6. The executive secretary shall be accountable to the Board of Directors, and under the general supervision of the president. He will be expected to attend all meetings of the Board of Directors and of the Society, and shall be responsible for a record of the business conducted at such meetings. He shall supervise the Society's offices and its employees, maintain suitable membership records, reporting monthly to each Section the membership changes within that Section, conduct the correspondence of the Society, and keep full records of the same. The executive secretary shall also serve as treasurer and fiscal agent for the Society, collecting all dues payable to the Society and Sections, and all other monies due to the Society, depositing the same in the name of the Society, and making such expenditures as are authorized by an approved budget. He shall be responsible for maintaining suitable books of account, which shall be independently audited periodically as directed by the Board of Directors, prepare annual and interim financial reports for the Board of Directors, and be responsible for all financial or other reports required by law. The executive secretary also shall present an operational report of the Society at the annual meeting and perform such other duties as the Board may assign to him from time to time. He may be bonded in a suitable amount as decided by the Board of Directors and at the Society's expense.

C. In addition to the responsibilities assigned in the Bylaws, the Executive Secretary shall assist the Board of Directors, Editors, committees, and appointed representatives, thus serving as coordinating officer for Society affairs and exercising leadership for policies and programs approved by the Board of Directors.

II. Specific Responsibilities (Figures in parentheses approximate the percentage of time allocated to each of the four activity areas.)

A. *Duties as Coordinating Officer (50%):*

1. Carry out duties, assignments and discharge responsibilities assigned by the Board of Directors.
2. Seek and recommend to the Board ways the Society may better serve its objectives throughout the World by improving its programs, services and activities.
3. Keep the Board informed on a continuing basis as to Society actions and progress, making sure incoming Board members are informed of past administrative actions and policies.
4. Seek and originate opportunities to represent the Society and to project its image by speaking to groups of the general public, other Societies, organizations, Society Sections and members.
5. As directed by the Board of Directors, maintain liaison and promote Society objectives and programs with legislative bodies, government resource and environmental agencies, and appropriate conservation, professional, scientific and user-group organizations; or assist Society members who are appointed specifically to do this as Society representatives.
6. Assist the educational and informational program and projects of the Society through appropriate committees, such as helping to prepare and distribute brochures, films, visual aids and other informational materials; responding to inquiries and personal contacts regarding the Society; and attending selected meetings.
7. Submit for Board approval an annual work plan for the Denver office, outlining procedures and the necessary resources. Effectively carry out the President's approved work plan for the Society.
8. Seek and develop new sources of funds for Society programs and projects within guidelines established by the Board of Directors.

B. *Duties as Corporate Secretary (15%)*

1. Issue official notices of all Society business meetings, record the minutes thereof and assure their publication and distribution.
2. Issue ballots to the membership as required, send bills for annual membership renewals, and place his signature on necessary documents for the Society for Range Management as defined in the Articles of Incorporation and the Bylaws.
3. Submit annual reports to Board and to the membership.
4. Make all necessary reports required by law.

C. *Duties as Treasurer (15%):*

1. Handle the fiscal assets of the Society and manage its accounts and investments in accordance with the Bylaws and as instructed by the Board of Directors.
2. Prepare necessary fiscal reports.
3. Assist in the preparation of an annual budget for submission to and approval of the Board of Directors.
4. Cooperate with those making audits, preparing financial statements and other analyses of Society business affairs.

D. *Duties as Business Manager (20%):*

1. Supervise and conduct the business operations of the Society at its headquarters.
2. Employ and supervise the office staff to assure the Society's many services are conducted properly and efficiently to the benefit of all members, including correspondence; computerized membership records; ballots and reports; collection of dues and other monies; payment of bills; bookkeeping of accounts; background material for developing budgets, annual, and interim reports; and keeping the minutes of meetings. Help plan, coordinate, and manage the annual and summer meetings of the Society, except the technical program which is the responsibility of the program committee.
3. Manage monies or other resources from grants to the Society including accounting and reports required by the grantor.
4. With assistance from the staff, serve as managing editor and provide service requested by the editors of *The Journal of Range Management*, *Rangelands (Rangeman's Journal)*, Section newsletters, and other publications or activities of the Society.
5. Work on operational and sales activities related to the Society's Life and Sustaining Membership, and other programs as approved by the Board of Directors.

III. Supervision Received:

The Executive Secretary works under the general supervision of the President and is accountable to the Board of Directors. Under the broad policies of the Society and direction from the Board of Directors the Executive Secretary shall: (1) direct the office staff and his/her own personal energies in a manner that is effective and efficient and (2) represent and speak for the Society. The Executive Secretary will receive an annual written performance evaluation from the Board of Directors based on the major duties described in the position description. This evaluation will be coordinated by the President and discussed personally with the Executive Secretary.

IV. Desired Qualifications

Trained and/or experienced in the art and science of management of rangelands. Need not hold a degree in range management but must have had training in the sciences basic to the field and be able to understand writings and hold discourse with people who are involved in the science and application of rangeland management.

Have demonstrated administrative ability through business management training and/or successfully holding an administrative position.

Possess the interest in and ability to be a SRM spokesman on policy and philosophy of SRM and the rangeland management profession before legislative, governmental, scientific, conservation, rangeland user and SRM groups, and to the general public.

Possess the interest in and ability to be a SRM spokesman on policy and philosophy of SRM and the rangeland management profession before legislative, governmental, scientific, conservation, rangeland user and SRM groups, and to the general public.

Possess the interest in and ability to promote the international aspects of the SRM and the rangeland management profession.

Should be interested in and skillful in communicating Society affairs orally and in writing.

Should be a member of the Society for Range Management and have participated in its activities through Section, Committee or Society offices.

Be able to speak and write Spanish.

Experience in working with volunteers.