MARCH 1976
Volume 29, No. 2

SOCIETY FOR RANGE MANAGEMENT

First Call for Papers

30th Annual SRM Meeting, February 14–18, 1977, Portland, Oregon

The program committee for the 1977 Annual Meeting is issuing a call for volunteer papers. It is the desire of the program committee to develop a meeting which will serve as a forum for interaction and exchange of information among scientists, educators, administrators, and managers who are concerned with the many aspects of range management. Papers which present new knowledge and ideas will be given special consideration. An attempt will be made to accommodate papers on any subject matter relevant to range management. All volunteer papers will be screened, and those that provide reasonable assurance of meeting the standards of high quality that the Society expects will be accepted. Concurrent sessions will be developed based upon the response received. Authors of volunteer papers should indicate the subject matter area(s) which is most appropriate for this paper.

Range Management
Grazing Management
Range Improvements
Economics
Ecology
Ecosystem Analysis
Education and Administration
Remote Sensing and Resource Inventory
Range Resources and Products
(1) Plants; (2) Livestock; (3) Wildlife; (4) Insects; (5) Watershed; (6) Timber;
(7) Recreation.

Procedure for submitting papers: (1) Submit an original and 2 copies of an abstract. An example of the format is given below. The abstract should be in final form, of 250–500 words and ready for publication. Abstracts will be published. Indicate the author who will be presenting the paper by placing an asterisk after his name. (2) On a separate page give the title of the paper, authors, mailing address of author to whom correspondence is to be addressed, subject matter area which is most appropriate (1st and 2nd preference), and a brief supporting statement indicating the significance of the paper.

Deadlines: The above information should be sent to the program committee chairman by **September 15, 1976** (student papers by October 15). Authors will be notified of acceptance of their papers by November 1 (students, November 1).

Send abstracts and correspondence concerning the 1977 meeting to **Dr. M. M. Kothmann, Chairman, 1977 SRM Program Committee, Dept. of Range Science, Texas A&M University, College Station, Texas 77843.**

Example for Abstract heading:

MINIMUM SEEDBED PREPARATION FOR SEEDING NATIVE GRASS HILLS IN WESTERN OREGON

Wayne D. Mosher*, Agricultural Extension Service, Roseburg, Ore., **Howard Hatfield**, rancher, Roseburg, Ore., and **William C. Krueger**, Rangeland Resource Program, Oregon State University, Corvallis.

With proper fertilizer programs and subclover establishment, forage production can be increased five to 10 times on many hill lands in Western Oregon, with greatly increased nutritive value for livestock. An attempt was made to identify factors limiting establishment of properly inoculated, broadcast seeded subterranean clover on open grass hills in Douglas County treated by burning of surface debris. . . .

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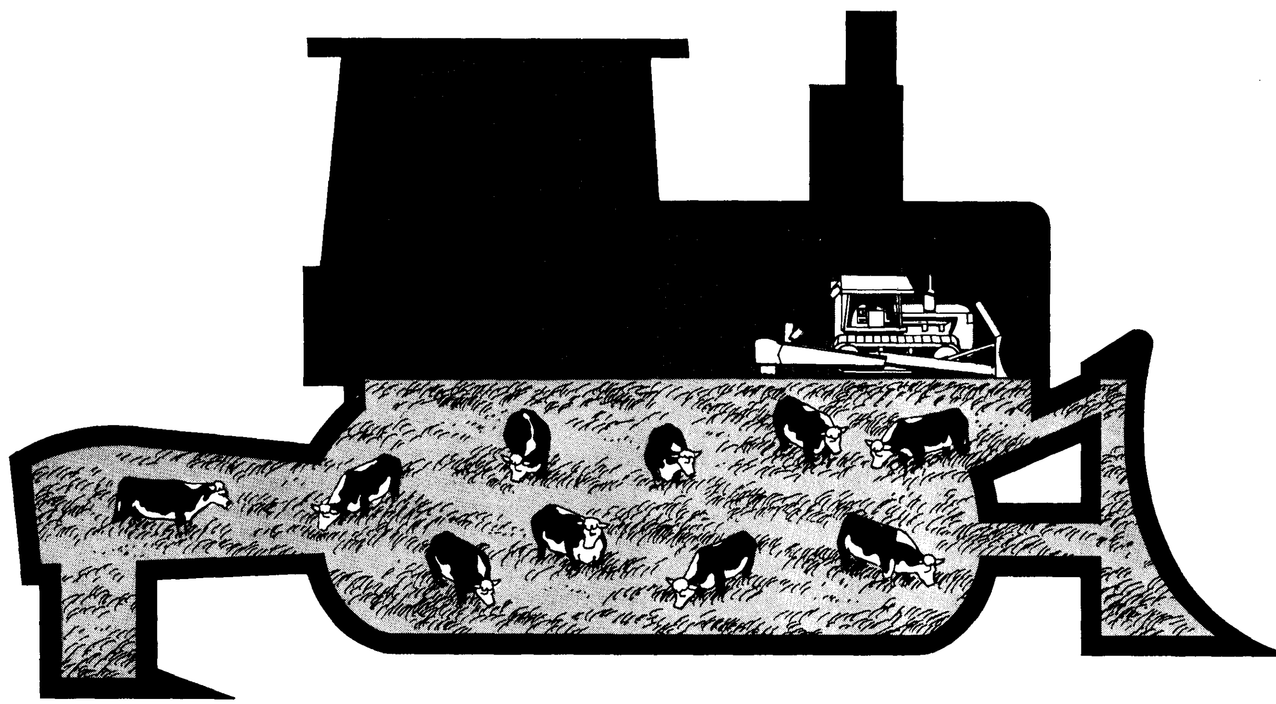

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Rootplowing is one of the most effective methods ever devised for eradicating brush. It also breaks up hoofpan for better water retention and a better seedbed. And you can simultaneously reseed your rangeland as you plow.

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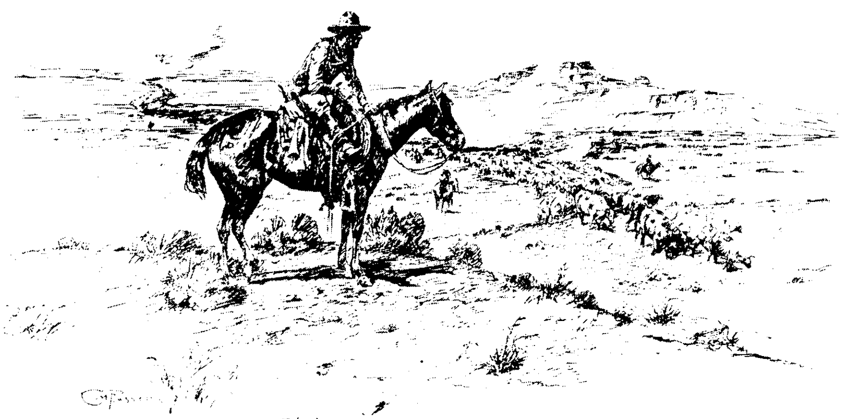
Land investment today builds tomorrow's profits. CATERPILLAR

SOCIETY FOR RANGE MANAGEMENT

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



THE TRAIL BOSS

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

The objectives for which the corporation is established are:

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

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

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

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

—to promote professional development of its members.

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

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

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

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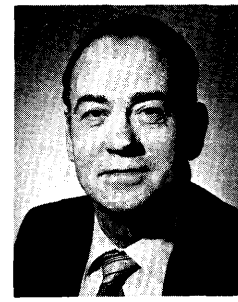
COVER: The extensive loblolly-shortleaf pine forests of the South can be managed to provide forage for white-tailed deer (see article by Robert M. Blair and Hans G. Enghardt, page 104). U.S. Forest Service photo.

President's Address:

From My Point of View



DILLARD H. GATES
President, Society for Range Management

This is a happy and memorable occasion for me, for many reasons. I was born and raised on a farm homesteaded by my great-grandfather of Custer County, Nebraska. I grew up in the community of Gates, Nebraska, one of a family of 16 kids. I have been accused by some of my "Conservationist" friends of being too production- and problem-oriented. Well, I submit that I have a right to be. If you don't think it was a problem for my dad to get enough production out of that dryland farm to feed a family the size of his, then you just don't understand ecology and what things were like during the drought years on the plains. So coming back to Nebraska is just coming home again. But coming to Omaha for this meeting of the Society for Range Management is also a bit nostalgic, for I attended my first annual convention of the American Society of Range Management in Omaha in January 1954 while I was a graduate student at Utah State University.

Things have changed since then, and I suppose mostly for the better. Look at this beautiful new hotel and compare it to the Fontanelle where the meetings were held then or to the Rome, where many of us students stayed. The Society has changed also, not only its name but its image, its visability, its perspective, its awareness of its role in the greater society of which we are all a part and I believe is developing a sense of purpose and a strategy for fulfilling its role.

Without meaning to detract from the dedication, or the enthusiasm, or the wisdom of the founders of the Society, I am most pleased with the changes that have taken place in the membership itself. The charter members laid the foundation, and upon it has grown a membership of young scientists, educators, administrators, land managers, stockmen, and conservationists the likes of which we have not seen before. They are well trained, articulate, dedicated and anxious to get on with the job. As they "get on with the job," the Society for Range Management will continue to change, but based upon long-established principles, as it meets new challenges and responsibilities.

I would like to spend a few minutes this evening briefly commenting on some of the accomplishments of the Society during the past year. I will not dwell on them long. To a large degree, the real accomplishments of the Society are made out in the field where the people are, where the grass grows, so you know as much about them as I do. But, we have moved ahead as a Society, and I would like to share some of these activities with you.

Given on February 18 at the 29th Annual Meeting of the Society for Range Management at Omaha, Nebraska.

Accomplishments

Membership: It appears we have about recovered from the decline in membership which followed last year's dues increase. Renewal percentages are ahead of last year. It looks like we are growing again. But membership is still too small to give the clout commensurate with the importance of rangeland resources around the world. As of January 1, 1976, membership was 5,223. We are moving ahead, but we still have a long way to go.

Regional Commissions: The decision of the Society for Range Management to enter into a cooperative program with the Old West Regional Commission was probably one of the most significant actions taken during the life of the Society. It was an aggressive step forward that directly involves the Society with programs and problems out on the ground. Our accomplishments to date are that the Society is deeply involved in action programs committed to improving management of rangeland. The true measure of accomplishments cannot be made until programs have been fully implemented and evaluated.

However, interim evaluations can be made and progress noted. The interest that has developed by the Four-Corners and Pacific Northwest Regional Commissions in the Old West program is firm evidence of the growing belief that significant accomplishments are being made, and that rangelands and the people who benefit from them will be better off as a result of the programs.

International Rangeland Congress: The Society for Range Management has long recognized its international role and has a membership drawn from over 45 countries. The Society has participated in a limited way in a variety of international programs over the last several years. The time has come and the opportunity is here for us to become more involved. We plan to do so.

At the Mexico City meeting of the Society, the Board of Directors finally responded to the gentle nudging of Dr. Harold Heady and agreed to underwrite the first International Rangeland Congress. Since that time, and under the leadership of Dr. Heady, a central organizing committee and all functional committees for planning and implementing the Congress have been formed. Many of you have agreed to serve on one of these committees; others will be requested to participate as program plans develop. The Congress for the first time will focus international attention on rangelands, that portion of the landscape that accounts for nearly 50 percent of the land surface of the earth. It will bring together range scientists, educators, administrators, managers, and conservationists from around the world. It will provide an opportunity for exchange of information among them and between them and other segments of international communities concerned with management of renewable natural resources to feed, clothe, and house an expanding world population.

A first mailing of a brochure explaining the purposes and objectives of the Congress has occurred. Responses are being tabulated and evaluated. The First International Rangeland Congress is scheduled for Denver, Colorado, in August, 1978. Your help and support is solicited to assure the success of what should be a benchmark occasion in international rangeland resource management.

Publications: The Society for Range Management can be justifiably proud of the publications that carry its name. The *Journal of Range Management* under the tutelage of Editor Bert Reid continues to be recognized and accepted around the world as the professional and technical journal in its subject matter area. However, the *Journal* merely reflects the scientific and professional calibre of the authors whose work it carries. That being the case, how could it be otherwise than top notch?

Rangeman's Journal, which became a reality about one and one half years ago as a result of the patience and dedication of Dr. Jeff Powell, has now completed its first full year of publication under the continued strong leadership of Danny Freeman. It too has established its place in the sun and provides a valuable nontechnical dimension to our repertoire.

There has been a lot of other activity in the Publications Department of the Denver office. Publications include three committee handbooks, proceedings of the range plant symposium, a sciential report on rangeland reference areas, and reprints of *Rangeland Hydrology,* the *Glossary*—now in its third printing—and *Benchmarks.* Requests for additional publications have been made. Our responsibilities and the need for publications are recognized. However, there is a problem of available resources and cash flow. To some degree, publication of additional material is dependent upon the sales of items already printed and for sale by the Denver office. If more members availed themselves of the opportunity for automatic purchase of Society publications, it would contribute to solution of the problem of cash flow as well as providing high quality literature for personal range reference libraries.

The Denver Office: Our Executive Secretary, David Smith, has now completed his first full year on the job. He has been a busy man, as he has reorganized the office and increased the visability of the Society through his travels and contacts throughout western United States, Canada, and Mexico. There are a lot of new faces in the Denver office, and as always it is the center of Society activity. The staff is there to serve the needs of the membership and I believe is so doing in an outstanding manner. A computer has been purchased that, when fully programmed and operational, will add a measure of efficiency to processing membership lists, routine mailings, and accounting and bookkeeping procedures.

A major function of the Denver office is service to the Sections and the membership. Constructive inputs that will contribute to better service by the Denver office are welcome—in fact solicited.

Needs

Awareness: This is a two-pronged need. First, the Society for Range Management needs to, in fact must, increase its awareness of its responsibilities in all matters which impinge upon development, use, and management of rangelands and related resources. As a Society and as individual members we must be ready to state our case in terms of scientific fact and application of both ecological and economic principles to sound resource management. We must be aware of, and integrate into our thinking, the social implications of resource management and use.

Secondly, we must find a way to increase the awareness of the general public, of legislators and decision makers at all levels of the importance of and the contributions of rangeland resources to the economic and social welfare of the world. This awareness has increased in recent years, especially on the international scale. We must somehow exploit this increasing awareness and crystalize it into meaningful action programs that will benefit mankind as a result of more intelligent use of rangelands and related resources.

Issues: The Society for Range Management needs to respond more aggressively to issues concerning rangeland resources. Each issue must be analyzed on the basis of its merits. Responses must be timely and consistent with technical and social aspects of the issues.

Unequalled technical and professional resources are represented by our membership. This intellectual resource must be more fully exploited to provide informed guidance, both to the membership and to the public, regarding issues of our concern. We must stand up and be counted. But we must present an informed, learned, professional, and objective stance. It is not imperative that we take sides on a given issue, but we must present pertinent facts and the best professional judgments upon which decisions can be based.

Financial: The society is sound financially. We are paying our bills and providing a reasonable level of service to the membership. But like any alert and aggressive organization, we see things undone. There are additional services that would benefit both Society members and society at large. New programs that have been undertaken with the Old West Regional Commission are paying their own way. Other such programs, if developed, will do the same. I full well recognize that more money is not necessarily the answer to all problems. It is men not money that get things done. But we have an excellent staff in the Denver office, whose capabilities exceed the resources with which they have to work.

A new Financial Committee has been established. Under the leadership of Bob Williamson the committee is actively seeking new sources of funds and exploring fiscal management alternatives that will enable the Society to better serve the membership from a sound financial base.

Permanent Headquarters Building: It is sometimes necessary though difficult to distinguish between needs and desires. In some cases, such as our own, economic reality may be a predominant factor in reaching a final decision. As you know, we are leasing adequate but limited space at the present location. Expanding programs and activities will increase space requirements. It seems prudent that during the remaining period of the present lease that we fully analyze space needs and explore viable alternatives for meeting these needs in the Denver vicinity. A new Permanent Headquarters Committee under the leadership of Dr. Bob Hyde is studying the area and evaluating various building options. This committee of necessity maintains a close liaison with the Financial Committee. We are looking to them to meet our space needs in the Denver area at a price we can afford.

Liaison Office, Washington, D.C.: There is a growing feeling that the Society for Range Management, like many other professional societies, needs representation in the Washington, D.C. area. Without question, decisions are made in Washington that impact rangeland resources and all who are interested in them or derive their livelihood from them. The Society, which is the only organization dedicated to rangeland resources, could and probably should pay a strong information and advisory role in decisions involving areas of our concern. This can only be accomplished by having a man on the scene in Washington. There are many problems that must be solved, many questions that must be answered before a decision can be reached in this matter. Unquestionably, the Society for Range Management could make constructive inputs into legislation and decisions affecting rangeland resources. Decisions will continue to be made and legislation passed whether we have inputs or not. I believe both the decisions and the legislation would benefit from our involvement. Despite these needs there are logistical and financial problems that must be solved before this matter can be resolved.

Problems

Membership: the need continues for the Society to increase its membership. Additional membership is needed to enable the Society to expand programs and services to members and society at large. While the Society needs additional members, there are many non-members who need the Society. It is regrettable to note the large number of technicians and resource managers who derive their livelihood from endeavors related to rangelands who are not members. Somehow as a Society we have failed to articulate our objectives and our programs in terms that stimulate these non-members to satisfy their needs by joining with us. We must continue to try, for they need us and we need them.

Membership turnover is another problem that continues to plague the Society. We do have a solid and expanding core of members fully committed to the objectives and goals of the Society. But in addition, we have too large a portion of the membership that is transitory, that is with us a few years then fails to renew its membership. There is a continuing problem in trying to provide the incentive or stimulate the imagination of this uncommitted segment.

Visability: As the Society matures it has come to be recognized by those who know it as a first-rate professional and scientific organization. The problem is that too few know of us. Despite the fact that the Society for Range Management is preeminently qualified to speak out on matters concerning rangeland resources, it too often appears reluctant to do so. We appear timid and unsure, if we appear at all. It is very disconcerting to pick up a newspaper and read what the Society of American Foresters, the Agronomy Society, the Wildlife Federation, the Sierra Club, or the Natural Resources Defense Council has to say about a current issue involving rangeland resources, with no mention of the position of the Society for Range Management. It can only be concluded that we have no position or that we are too shy or too bashful to make ourselves heard.

Yes, we have a problem, a problem of visability. But, there must be a solution. I am requesting the Board of Directors to direct the Public Affairs Committee or some other duly appointed body to continuously be alert for an opportunity to analyze issues relating to rangeland resources and feed this information to the Denver office. This information will be screened and evaluated by a small (not more than three) News Release Committee appointed by the President. News releases will be prepared and circulated on a timely basis. In cases where urgency demands, it may be necessary to utilize the telephone rather than the mail service in order to develop a meaningful news release in a timely manner. This News Release Committee will shoulder a heavy and demanding burden. For while increasing our visability, we must not jeopardize our credibility.

Opportunities

International: The growing realization of the contributions of rangelands to the food and fiber needs of a hungry and energy-scarce world is providing new opportunities to the Society for Range Management. The trend toward production of food grains for direct human consumption will strengthen and continue. At the same time, demands for animal protein will increase. The rangelands of the world produce virtually limitless amounts of plant products that can be converted to sustained yields of animal protein by integrating and applying sound ecological principles of rangeland management and animal husbandry.

The opportunities to increase productivity of rangelands is accompanied by responsibilities. Management programs to assure sustained resources must be designed, implemented, and monitored. In the broad sense this will call for management of rangeland ecosystems that vary from the arid and semiarid regions of the sub-Sahara to the lush forage-producing regions of the humid tropics. In addition, management schemes to function effectively must be adapted to meet a virtually unlimited and complex arrays of cultural, political, and economic patterns.

There are vast rangeland areas of the world where ecological principles of resource management are unknown or ignored. We cannot and probably should not hope to superimpose twentieth century technology and management practices onto cultures that have changed little in the last 1,000 years. But we have an opportunity to begin. In a world-wide context we must start where we are now. Each rangeland resource management problem must be analyzed and evaluated on its own merits. Biological, ecological, social, and economic factors must all be given full consideration. From this virtually overwhelming complex, management schemes must emerge that will begin to change the direction away from those facets of traditional or archaic management programs that are inconsistent with ecological management principles.

Skill, patience, dedication, and understanding will be required to capitalize on this opportunity. The Society for Range Management must move ahead, develop and strengthen linkages with international organizations and agencies concerned with development, management, and use of rangelands and related resources. The professional skills and experience embraced by the membership of this Society, properly applied, could make significant contributions to mankind by helping to assure that rangeland resources are making optimum contributions to the food and fiber needs of the world.

The International Rangeland Congress, which was mentioned earlier, will significantly expand our international exposure. We will be under close scrutiny. But if we carry it off, and we will, our opportunities to serve the world-wide range community will be greatly enhanced.

Domestic: Opportunities for accelerated programs in rangeland resource management are not limited to those areas that are located outside the North American continent. Challenging opportunities exist on this continent, where the vast majority of the membership resides, for the Society for Range Management to make real input into virtually all aspects of rangeland resource development, management, conservation, and use. These opportunities vary from planning and implementation of management schemes out on the ground to legislation and administrative decision at the Federal, State, Provincial, or Regional levels. We have a history of rangeland resource management on this continent. While we have certainly not solved all of our problems or even identified them, we are in a position to formulate and implement resource management programs of a more sophisticated nature, starting from a higher plane of knowledge and understanding than is the case of some of the instances referred to earlier. However, the same set of principles is applicable. Each problem must be analyzed on its own merits and solutions developed consistent with the existing social, political, and economic environment. There are no black box answers, and each member is challenged to recognize the uniqueness of each problem and to approach it with professional objectivity.

Both on this continent and abroad, the Society for Range Management has opportunities to influence curriculum in universities and Civil Service standards by itself setting high standards of professionalism. The continued opportunities for service will, in the long run, be related to our credibility, which in turn is related to the professional acumen of our membership and how this storehouse of experience and knowledge is mobilized into Society action.

Summary

In summary, I believe that the Society for Range Management has moved ahead this year. In an instance or two we have deviated a bit from traditional programs and have explored new ground. I hope the Society will proceed with a philosophy of cautious adventurism. We must take some risks if we are to advance. The accomplishments, needs, problems, and opportunities of the Society are interrelated to such a degree that it is difficult to discuss them separately. No accomplishment has been made without solving problems. No problem has been identied without its presenting a challenge and an opportunity. Our needs to a large degree are a function of our desires to meet the opportunites that have been presented to us.

Viewed from the holistic standpoint, I see rough spots, but no unsolvable problems. I see opportunities for growth and expansion of services. And most importantly, I see a membership of skilled, dedicated, and sincere men and women who are anxious to get on with the job of advancing the causes of the Society for Range Management.

I want to thank you once more for the honor you have accorded me by allowing me to serve the past year as President of this great Society. It has been an interesting, challenging, and sometimes frustrating year. Over all I have enjoyed it tremendously.

Thank you all very much.

THESIS: UNIVERSITY OF IDAHO

An Evaluation of Larkspur Poisoning in Cattle and the Trampling Damage that Occurs during Grazing on a Summer Range in Eastern Idaho, by Kenneth Knowles, MS, Range Management. 1974.

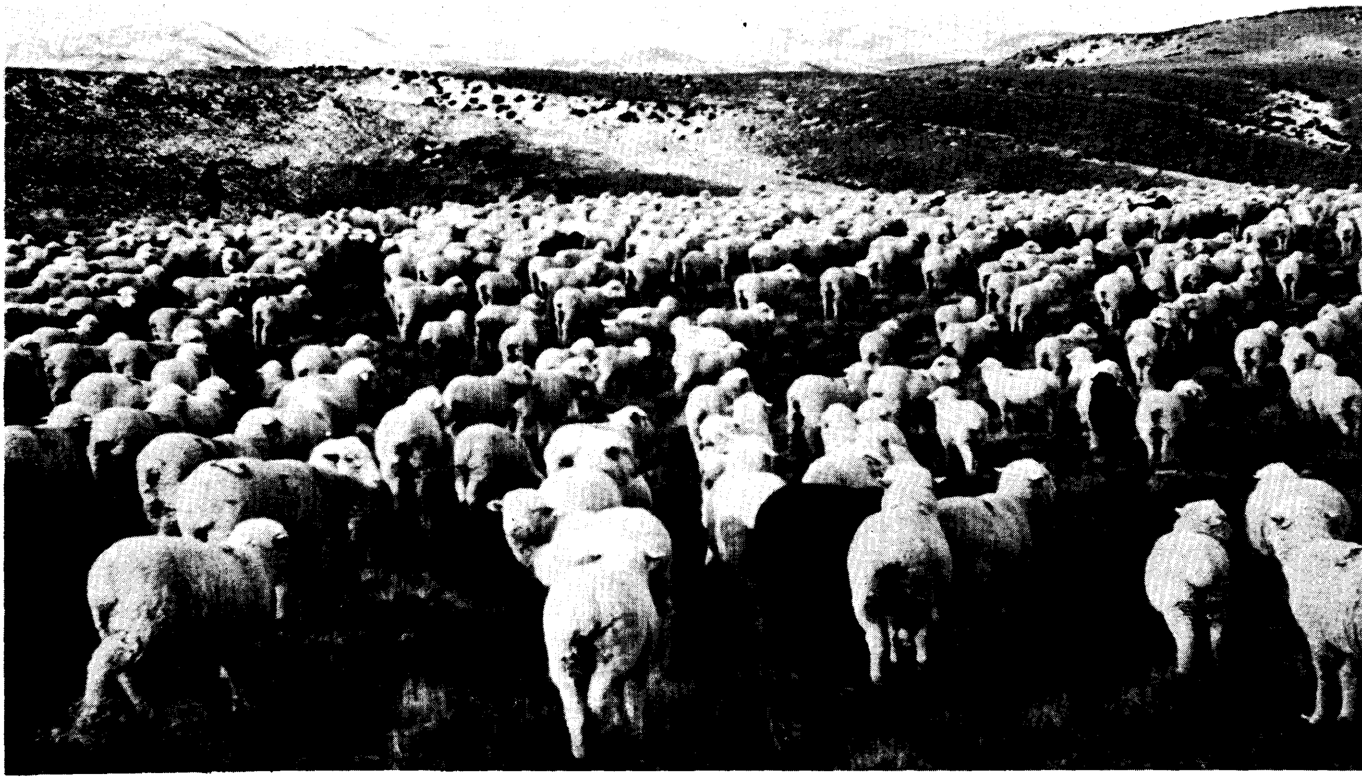
In 1972 a study was initiated to evaluate the prevention of larkspur poisoning in cattle by feeding two specifically formulated mineral supplements. Larkspur plants were collected during the two summers to determine their weekly alkaloid content. Trampling damage of the vegetation due to grazing was also ascertained during the 2 years.

During this study ten cattle died in the experimental pastures. In 1972 three deaths occurred in the control pastures while two died in the pastures containing a mineral supplement with bentonite clay. In 1973 two cows died in the control pastures while two cows and a calf died in the pastures containing the mineral supplement with bentonite clay. No deaths occurred in the pastures receiving mineral supplement without bentonite during the 2 years.

The two mineral supplements may have delayed larkspur utilization early in the grazing season when the plants were most poisonous. In the control pastures the cattle utilized more larkspur in early summer than they did in late summer. By the end of the summer, however, there was no significant difference in the amount of larkspur utilized in any of the experimental pastures.

The total alkaloid content of larkspur plants was highest early in the year, but gradually decreased to a low level. The leaves and flowers of the plants had a higher concentration of total alkaloids than the stems.

During 1972 cattle trampling resulted in the loss of 71% and 45% of the grasses and forbs, respectively. In 1973 trampling accounted for 54% and 44% of the grasses and forbs being lost to the grazing animals. The effects of trampling did not, however, significantly increase soil bulk density, and in some cases may have actually decreased it due to the pulverizing effect it had on the soil.



Predation on Domestic Sheep in Northeastern Nevada

DONALD A. KLEBENOW AND KENT McADOO

Highlight: *A northern Nevada range band of sheep was studied in order to verify the extent of losses to predation and to other causes. Daily searches were made for losses and carcasses were autopsied. During lambing, predator losses varied on the two operations studied, 1 loss per 14 days in one case and 1 loss per day in the other. Losses from other causes were high at that time. Predation increased in late summer and continued to be high into the fall. Predation was the major cause of loss at that time. Winter losses were variable. In one short period, 38 head of sheep were lost to halogeton (*Halogeton glomeratus*). In one annual production cycle 9% of the band was the total verified loss. The verified predator loss was 4% of the band. The coyote (*Canis latrans*) accounted for 91% of the total predation.*

A Society for Range Management (1971) statement on predator control noted that although range sheep operations undoubtedly suffer economic loss from predation, "there is no hard evidence to substantiate the actual loss or how it may fluctuate through time or from area to area." Cain et al. (1972) recommended that field studies are needed to "determine with all possible accuracy the actual livestock losses caused by each major predator," as well as those losses due to other causes.

Authors are associate professor and graduate fellow, Division of Renewable Natural Resources, University of Nevada, Reno.

Manuscript received October 14, 1975.

Our research was a field study to determine the extent of loss due to predators in relation to total loss suffered by a typical Nevada sheep band.

This study covered the annual production cycle for one band of sheep from lambing on May 5, 1973, through the end of spring trail on April 20, 1974, plus an additional lambing period with a band from another rancher.

Study Areas

The sheep chosen for initial study were owned and managed by Jess and Elias Goicoechea. They were a band herded on rangelands for the entire year. Lambing occurred in Elko County. The area was between 6,200 and 7,000 ft in elevation, and comprised primarily of northern desert shrub type vegetation, with scattered wet meadows near springs (Fig. 1a). The dominant shrubs were big sagebrush (*Artemisia tridentata*), often as much as 6 ft high, and low sagebrush (*Artemisia arbuscula*). The principal grasses were primarily bluegrass (*Poa* spp.) and cheatgrass brome (*Bromus tectorum*).

Summer range was in northern Elko County. Elevation ranged between 6,500 and 8,800 ft, and the area was dominated by mountain brush and northern desert shrub type vegetation (Fig. 1b and 1c). Big sagebrush, bitterbrush (*Purshia tridentata*), and snowberry (*Symphoricarpos* spp.) were the common shrubs in the area. Grasses and forbs included bluebunch wheatgrass (*Agropyron spicatum*), cheatgrass brome, bluegrass, arrowleaf balsamroot (*Balsamorhiza sagittata*), and Indian paintbrush (*Castilleja* spp.). In addition, groves of willow (*Salix* spp.) and aspen (*Populus tremuloides*) were common along stream bottoms. Small stands of white fir (*Abies concolor*) and aspen occurred at higher elevations, particularly on concave north slopes.

The sheep were trailed from summer ranges to winter ranges in White Pine and northeastern Nye counties. Winter ranges were located on valley floors, about 6,000 ft elevation, composed primarily of northern desert shrub and salt desert shrub type vegetation (Fig. 1d). Big sagebrush, low sagebrush, rabbitbrush (*Chrysothamnus* spp.), cheatgrass, and other grasses were common in the area. Shadscale (*Atriplex confertifolia*), and winterfat (*Eurotia lanata*) occurred in alkaline flats. Halogeton (*Halogeton glomeratus*) also occurred on much of the winter range. On those allotments which bordered foothills, Utah juniper (*Juniperus osteosperma*) was common.

During the 1974 lambing season, the study band was one owned by Paris Brothers Livestock Company, located in Butte Valley, White Pine County, Nev. The elevation and vegetation was similar to the winter ranges occupied by the Goicoechea operation (Fig. 1d). Rabbitbrush and stands of winterfat were common on the valley floor.

Methods

At lambing, each band was similar in size, 1,113 ewes in the Goicoechea band and 1,134 in the one owned by Paris Brothers. At docking and through the remainder of the year the number of sheep in the Goicoechea band, including lambs, ranged from 2,466 at docking down to 2,221 on the spring trail. Reorganization of the band occurred several times during the year resulting in some variation in band size. The average size was 2,405 sheep.

The sheep were checked daily throughout the year. An investigator accompanied the herder each morning as the sheep were being moved off bedding areas. The bedding grounds and surrounding vicinities were checked thoroughly for losses afoot or on horseback, and by glassing all open areas. Dogs were used occasionally.

Strays, sheep that were wounded, crippled, diseased or otherwise incapacitated and left back, were located by making trips into areas previously occupied or trailed through by the sheep. The periphery of the band was checked daily for sick, slower-moving animals.

When a carcass was located, the cause of death was verified when possible. The objective was to differentiate between predator losses, death losses due to causes other than predation, carrion feeding, and sheep losses where death had not yet occurred. The techniques for verifying cause of death have been described by Rowley (1969, 1970), Wiley and Bolen (1971), and Bowns et al. (1973).

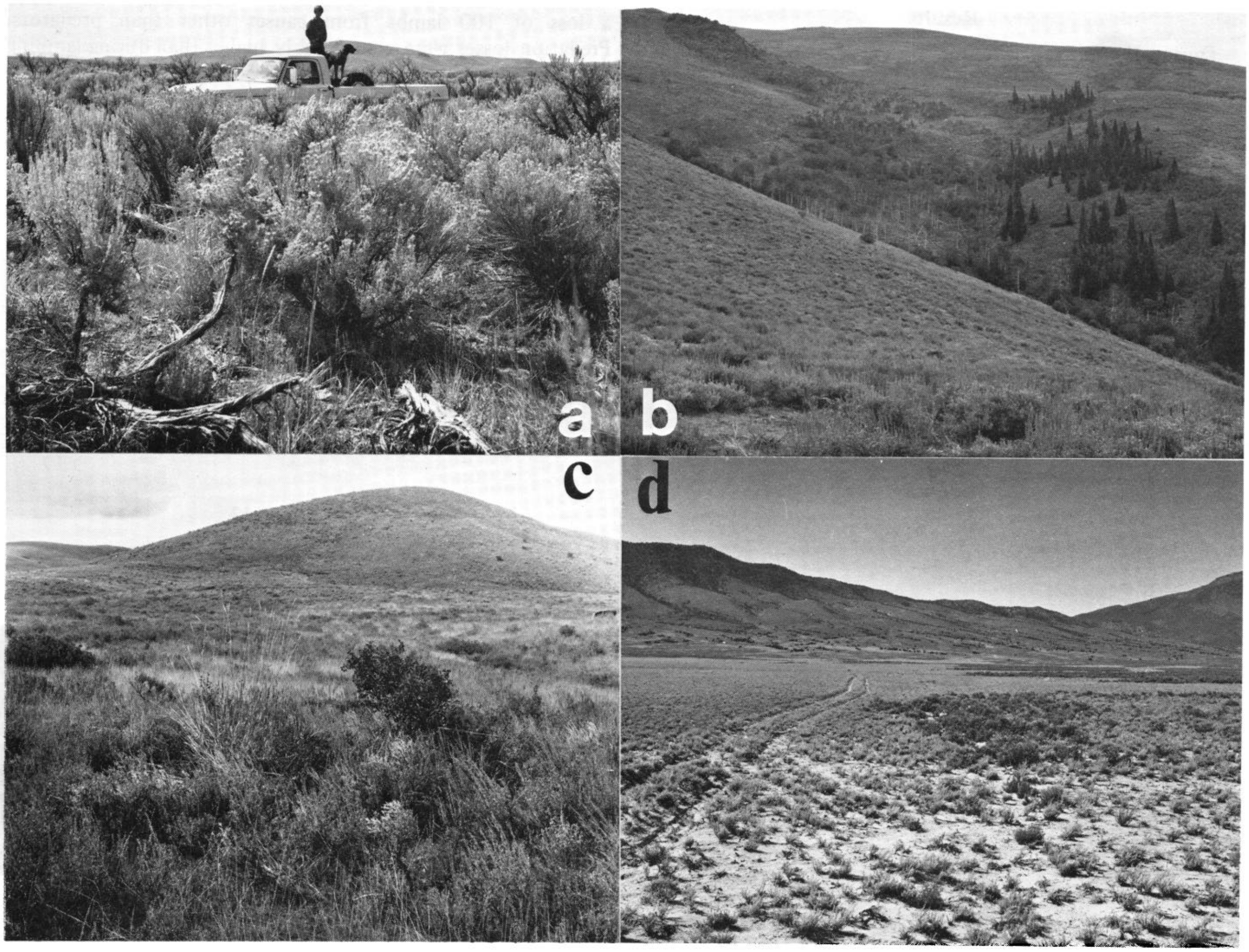


Fig. 1. *Study areas in Elko and White Pine counties, Nevada: (a) Big sagebrush on lambing range; (b) Summer range with white fir, aspen, snowberry, and big sagebrush; (c) Summer range dominated by big sagebrush, antelope bitterbrush, bluebunch wheatgrass with scattered serviceberry; (d) Valley floors where winterfat and big sagebrush were interspersed provided winter range.*

Counts of the number of sheep in the band permitted a comparison between verified and actual losses. The six counts made of the Goicoechea band during the year were made when ranch management permitted or required a census. No counts were made of ewes and new-born lambs at the beginning of either lambing season. Typically, the count at docking is the first one in a range-lambing operation.

The predator species involved in each attack were identified by wounds and types of consumption damage. Other aids were evidence at kill site, such as tracks and droppings, and observations of predators in the area. Major references on predator identification include Rosko (1948), Gier (1957), Rowley (1970), Wiley and Bolen (1971), and Bowns et al. (1973).

To determine the physical condition of predator losses, victims were examined for any external abnormalities (swollen joints, broken bones, general emaciation, etc.). Lacking any external evidences of a weak condition, a lamb was judged to be either healthy or unhealthy by its relative size compared to the other lambs at that time.

For purposes of this study, sheep were divided into two age classes:

1. lambs—sheep under 12 months old (all sheep born during the study).
2. ewes (adults)—all sheep more than one year old.

Results

During the early part of the study, from the beginning of the lambing period until the sheep arrived on their summer range, predation was low (Table 1). During those periods, losses related to the birth of lambs were common. There were stillborn lambs, orphaned and abandoned lambs, and ewes lost to birth complications. Others died of diseases or from poisonous plants. Accidental deaths were caused by faulty castration, drowning, and trampling in corrals. Just three lambs were verified losses to predators, a loss of one lamb per 14 days.

Following arrival on the summer range, predation intensity increased and predators were the major cause of losses. A high intensity of predation, one loss per day, was reached in late summer and the intensity remained high until shipping time was reached in mid-October. Fifty-five sheep were lost to predators during that late summer and fall period and 53 were lambs. Following shipping, the intensity of predation dropped and continued to drop through mid-winter. Only one lamb was killed during the 42-day mid-winter period. Then the rate increased, and during the 12-day period on the spring trail, five sheep were lost to predators. The Goicoechea band incurred an average predation intensity of one loss every 4 days during the complete production cycle. Ninety-two percent of all the Goicoechea predator losses were lambs.

Losses other than predation were particularly high during the mid-winter period. Of the 46 losses that occurred, 38 were sheep killed during a 3-day period in February from poisoning by halogeton.

The Paris band, studied the second lambing season, suffered a loss of 100 lambs from causes other than predators. Predation losses were considerably higher than during lambing on the Goicoechea range the year before. Twenty-five losses were verified for a predator intensity of one loss per day.

When actual losses based on census were compared with the verified losses (Table 2), we found we could explain 180 of

Table 1. Domestic sheep losses and predation intensity verified from one Nevada range band during the 1973–74 production cycle and from another band during lambing, 1974.

		Verified losses						
		Predation		Other		Total		
Time period	Length of period (days)	Ewes	Lambs	Ewes	Lambs	Predation	Other	Predation intensity (1 loss/no. days)
Goicoechea band								
Lambing 5/5–6/15/73	42	–	3	15	22	3	37	1/14
Trail to summer range 6/16–6/30/73	15	–	–	–	12	–	12	–
Early summer 7/1–8/15/73	46	–	11	1	7	11	8	1/4
Late summer 8/16–9/15/73	31	–	35	2	5	35	7	1/1
Trail to shipping 9/16–10/12/73	27	2	18	–	5	20	5	1/1
Fall trail 10/13–11/28/73	47	–	5	2	1	5	3	1/9
Early winter 11/29/73–1/17/74	50	1	4	4	1	5	5	1/10
Mid-winter 1/18–2/28/74	42	–	1	24	22	1	46	1/42
Late winter 3/1–4/8/74	39	4	7	4	2	11	6	1/4
Spring trail 4/9–4/20/74	12	1	4	–	1	5	1	1/2
Total period 5/5/73–4/20/74	351	8	88	52	78	96	130	
Paris band								
Lambing 5/1–5/25/74	25	0	25	12	88	25	100	1/1

Table 2. Verification success and percent predation losses from a range band of sheep during one annual production cycle.

Measurement	Number	Percent of band
Actual losses based on census 6/15/73–4/8/74	210	9
Verified losses during period covered by census 6/15/73–4/8/74	180	7
Total verified losses- lambing 5/5/73–end of spring trail 4/20/74	226	9
Predator losses verified 5/5/73–4/20/74	96	4

210 losses or 86% of the losses that occurred. The period covered by census did not include the entire production cycle. The sheep were not censused prior to lambing, the number of lambs born were not counted at birth, and the sheep were not counted at the end of the spring trail. The total verified losses for the entire production period were 226, 9% of the band. Predator losses for the entire production cycle totaled 96. Four percent of the band was the verified loss to predators.

Coyotes were the major predator (Table 3). The losses caused by dog, bobcat, and golden eagle were insignificant in comparison. No instances of predation by mountain lion were verified.

The physical condition of 81% of all predator losses was good when attacked (Table 4). Seven sheep were in poor condition. Three were orphaned lambs observed during lambing season, three were small lambs attacked during the summer period and one was an old, sick, ewe left back as the sheep were moved off a bedding area in March. Physical condition was considered nonassessable for 16 hseep. These animals had been consumed to such a degree by predators and/or scavengers that accurate assessment was impossible.

Discussion

It was virtually impossible to census the number of lambs born under open-range lambing conditions. In the Goicoechea operation the study band of ewes at lambing was scattered throughout an area approaching 6 square miles in size. The vegetation prevented close observation (Fig. 1a). Therefore, the number of actual losses between the start of lambing and until docking could not be determined. The 25 verified lamb losses for the Goicoechea band prior to docking (Table 1) were probably a relatively small percentage of actual losses incurred during this period.

Venkatachalam et al. (1949) and Safford and Hoversland (1960) reported that lamb mortality during the first few weeks after birth represents a considerable loss to sheepmen. Rambouillets (the basic breed of sheep in the Goicoechea and Paris bands) showed an average lamb loss of 15% to 120 days of age in an Illinois study (Vetter et al., 1960). Early et al. (1974a and b) reported more lamb deaths occurred during the lambing period than during any other time, despite this being the shortest time interval. In his study, 36% of the total lamb deaths were found to occur during the lambing period. The accuracy of our data during the lambing periods is speculative and we consider our results to be only a minimal estimate of losses during that time. This is true even during the second lambing period with the Paris band when more losses were discovered. During that time, the vegetation permitted more visibility on the lambing grounds (Fig. 1d), the ewes were more closely herded and not scattered as widely as the year before, and project personnel had more experience in locating losses. Still we are certain losses occurred that were not verified. A coyote den with at least three pups was discovered on the lambing grounds. A lamb's ear within 5 yards of the den was all that remained of a lamb that had been carried off and nearly all consumed. We suspect others were fully consumed by coyotes.

Predators accounted for 22% of the total verified losses in Paris' band during lambing compared with 12% for the Goicoechea band during lambing. Therefore, relative to other losses during lambing, predator losses appear to have been more significant for the Paris band than for the Goicoechea band. Predator losses were very much exceeded by natural losses among new-born lambs in both operations.

During summer, predation was a major cause of losses. During the early and late summer periods, 75% of our verified losses were due to predation. In a Utah study, 74% of total summer losses were verified as predator caused (Bowns et al., 1973). Apparently, natural losses are typically lower during this time of year.

In late summer, during a 31-day period, a loss of 35 lambs was verified. Apparently this critical period occurs annually. Rosko (1948) verified more losses in August than during either June or July for sheep in Utah, and he noted that losses remained high until mid-September. A similar late summer increase in predation on sheep occurred in Saskatchewan, Canada.[1] The increased predation during late summer in the study area was forecast by the government trapper, herders, and the operator.

As the Goicoechea sheep were trailed from summer range to winter range, the occurrence of predator losses became less frequent. A similar pattern has been reported for Utah herds in general (Bowns et al., 1973).

Between docking and the end of the production cycle of the Goicoechea band, eight predator losses and four other losses were reported by the herder but not verified by us. These instances in which verification did not occur were due largely to one or more of the following circumstances: (1) heavy cover in the vicinity of a reported loss; (2) inclement weather (particularly heavy fog); or (3) trailing conditions (no time to drop back for verification). In no instance did the herder ever report on a loss to predation that was later verified to be due to other causes, or vice versa. These additional losses were probably truthful, but were not included in Table 1. Incidentally, were it not for our study, we estimate the herders would have discovered only a third to one-half of the losses that occurred. The attention that the living sheep require does not permit time for a herder to account for dead animals.

Table 3. The type of predators preying on domestic sheep during the entire production cycle of one band, plus the lambing period of another.

Predator	Losses Number	Percent of total
Coyote	110	91
Dog	2	2
Bobcat	3	2
Golden eagle	1	1
Undetermined	5	4

Table 4. Physical condition of sheep preyed upon by predators.

Condition of sheep	Losses Number	Percent of total
Good	98	81
Poor	7	6
Unknown	16	13

[1] Personal communication with T. Rock, Wildlife Branch, Department of Natural Resources, Saskatoon, Sask.

The predator losses we verified, 4% (Table 2), fall within the range reported by several studies. Herd loss to predators based on rancher surveys reported from 3% in Utah during 1968-1969 (Nielson and Curle, 1970), to 3.4% in Idaho during both 1970-1971 (Early et al., 1974a) and 1972-1973 (Early et al., 1974b), and from 3.6 to 7.9% in various years between 1966-1969 for four western states (Reynolds and Gustad, 1971). According to the Morris estimates, as reported by Cain et al. (1972), losses in Utah between the late 1940's and 1965 ranged from 2 to 4% in most years.

Presnall (1948) estimated losses of 1.5 to 2% for all the western ranges and Evanson (1967) estimated an annual loss of 1% of the flocks in the 17 western states. In a California verification/questionnaire study involving seven ranches, Nesse (1973) calculated an annual predation rate of 1.17% in 1972, and 0.50% in 1973. The loss of 4% of the Goicoechea band to predators is considerably higher than the predation rates reported in these studies.

During the critical summer season (docking through shipping), 5% of the Goicoechea lambs counted at docking (and 3% of the entire band) was lost to predation. Compared to the results of two other verification studies, these percentages seem relatively high. Rosko (1948) reported that Utah herds in his study suffered an average herd loss of 0.29% during the summer. The highest loss recorded for one herd was 1.75%. In another Utah study (Bowns et al., 1973), the average summer lamb loss to predators for 10 flocks was 1.1%, with one band suffering a 4.1% loss.

Several studies (Rosko, 1948; Nielson and Curie, 1970; Bowns et al., 1973; Nesse, 1973) have shown that predator losses vary considerably from one operation to another. Variations in predator abundance, natural prey availability, management of sheep, terrain, and intensity of predator control are no doubt largely responsible for the predator loss fluctuations from one herd to another and from one year to the next.

Coyotes were responsible for 91% of all predator losses verified during this study. Nesse (1973) attributed 97% of the predator losses in Glenn County, California during the 1973 production period to coyotes. Coyotes were also found to be by far the major predators on domestic sheep in two Idaho studies (Early et al., 1974a and b), and three Utah studies (Rosko, 1948; Nielson and Curle, 1970; Bowns et al., 1973). The statement by Presnall (1948) that coyotes are the major predator on sheep in the West seems well based.

Data collected during this study do not show evidence that predators select for weak, sick, or otherwise physically disabled domestic sheep (Table 4). The reverse may be true for wild ungulates (Cowan, 1974; Crisler, 1956; Mech, 1966). However, domestic species such as sheep are probably much more susceptible to predators due to thousands of years of domestication which has bred out natural defense and/or escape mechanisms (Kupper, 1945; Howard, 1974). There is no logical reason to believe that coyotes are forced to select for unfit individuals among an introduced species which, even when healthy, are susceptible as prey.

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Morpa Weeping Lovegrass Produces More Beef

MARVIN SHOOP, E. H. McILVAIN, AND P. W. VOIGT

Highlight: *Morpa, a new variety of weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees), increased yearly gain per steer 33 lb, or 12%, in a 3-year grazing comparison with Common weeping lovegrass at Woodward, Oklahoma. Because steer gains were greater, Morpa produced \$12.00, or 170%, more profit per acre. Also, Morpa had the same high carrying capacity as Common; was equally adapted to withstand drouth; and required the same high level of cultural and grazing management. Morpa was slightly less winterhardy than Common.*

Weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees) produces about three to five times more usable forage at Woodward, Okla., than does native range. Weeping lovegrass (lovegrass) also is well adapted to the climate and to the sandy soils of the Southern Great Plains. Lovegrass establishes easily, persists well under grazing, and responds to such improvement practices as nitrogen fertilization, rotational grazing, and mowing of overmature forage. However, lovegrass declines rapidly in palatability as it matures, and special management is required to maintain good cattle gains.

In palatability trials at Woodward, steers preferred one strain of lovegrass, P. I. 208994 (Voigt et al., 1970). This strain was named 'Morpa' to indicate that it was *more* *pa*latable.

Morpa and Common (Soil Conservation Service strain A-67) belong to the "curvula" type of *Eragrostis* (Leigh, 1961) and reproduce by apomixis. Morpa was released in 1970 (Voigt, 1971), and seed is now commercially available. In the past, Common constituted most of the unnamed lovegrass grown in the United States.

Although Morpa was more palatable, the question remained: Would cattle pastured on it produce more beef than those on Common? Our experimental objective was to compare the beef-producing value, adaptation to the area, and management requirements of Morpa and Common.

Experimental Procedure

We compared Morpa and Common lovegrass in two studies made on the Southern Plains Experimental Range in northwestern Oklahoma: a grazing study and a hay feeding study. The two studies were conducted independently, except that the hay in the feeding study was from opportunity harvests from the pastures used in the grazing study.

The experimental area was located on Pratt-loamy-fine-sand soil (Nance, 1960). The 85-year average yearly precipitation is 23 inches. Sixteen inches of this falls during the growing season, April through September. During the experiment, 1968 and 1969 were abnormally dry in midsummer. A 50-day drouth occurred in 1968 when precipitation was only 52% of the average for the period. In 1969, a 75-day drouth occurred when rainfall was only 38% of the average. The mean temperature is about 36°F in January-February and 80°F in July-August.

Four 6-acre pastures of Morpa and four of Common lovegrass were planted on May 14–18, 1965. The pastures were laid out so as to create four replications of a randomized-complete-block design for vegetation studies. For grazing, two pastures of each grass were combined to give two replications.

A uniform herd of Hereford steer calves weighing about 465 lb/head was obtained each October from the same ranch. The calves were allotted to treatments at random within weight classes. They were individually weighed at the start and end of each year's trial and at the end of each month. Each calf was fed 1.5 lb/day of 41% protein cottonseed pellets during the winter. Salt was the only other supplement fed.

Grazing Study

The grazing trials started on an average date of November 19 and ended on August 24 during the three grazing years 1967–69. Winter grazing continued until the grass was eaten or spring growth started, about March 15; then the steers were fed hay that had been harvested from surplus forage in the experimental pastures. Summer grazing started when the new grass was about 6 inches tall, about May 10.

By the start of spring grazing, nearly all forage produced the previous year had been removed by winter grazing, spring mowing, or spring burning (McIlvain and Shoop, 1970). The pastures were fertilized each year with an average of 50 lb/acre of nitrogen (N) from urea. The N was applied in a single application in 1967 and in two applications per year in 1968 and 1969.

The original 6-acre pastures were subdivided, and each replication of steers was rotated among its assigned subdivisions during the growing season. A pasture subdivision was grazed for about 14 days during each rotation cycle the first 2 years and for 6 days the last year. The stocking density with which each subdivision was grazed was 1.3, 2.7, and 8.0 steers/acre during 1967, 1968, and 1969, respectively.

Pastures were usually rested for 30–40 days between grazings so the new growth could reach 12–16 inches in height. However, sometimes the grass was more mature when grazing started.

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In most cases, each pasture subdivision was mowed once each summer. The mowing was done to remove excess grass as hay or to remove overly coarse grass left after a subdivision was grazed. The grass was grazed or mowed to a stubble height of about 4 inches in most instances.

Hay Feeding Study

Morpa hay was fed in direct comparison with Common lovegrass hay during each of the three winters, 1967-69. The hay was "opportunity-hay" harvested from subdivisions of the pastures used in the otherwise independent grazing study. As opportunity-hay, it was coarser and more mature than normal hay.

The three trials lasted an average of 104 days each. Duplicate five-head lots of steers were fed each variety of hay. Before each trial, the steers were pastured together on native range for 6-10 weeks and then preconditioned to lovegrass hay for 2 weeks. All hay was fed in mangers covered by a shed, and the orts were weighed back.

Results and Discussion

Grazing Study

Steers pastured on Morpa gained 305 lb/head/year, whereas those pastured on Common gained 272 lb (Table 1). Thus, Morpa increased the gain per steer an average of 12% during both winter and summer as compared with Common lovegrass.

Table 1. Gain per steer (lb) on 'Morpa' and 'Common' weeping lovegrass, 1967-69.

Trial	Morpa	Common	LSD 0.05
Pasture trials			
Winter	117	102	11
Summer	188	170	14
Total	305	272	8
Hay trials			
Dec.-Mar.	75	70	N.S.

The increase in gain per steer produced by Morpa became larger in each of the 3 succeeding years. During 1967-69, respectively, steers on Morpa gained 18, 36, and 44 lb/head, or 6, 13, and 19% more than steers on Common. However, this interaction of strains with years was not statistically significant.

As a 3-year average, Morpa produced greater steer gains than Common during each of the five grazing periods of the year (Fig. 1). Statistically, the greater gains on Morpa were significant only for the periods May 13 to June 30 (0.05 level) and June 30 to August 24 (0.01 level).

Gains of steers on both strains of lovegrass compared favorably with gains of steers on native range during those periods when the lovegrass was not over 40 days of age and when ample forage was available. However, gains on both strains of lovegrass fell rapidly as forage maturity increased beyond 40 days. Because we were learning as we proceeded, the gains obtained in this experiment were lower than those that could be obtained by using management methods now known (McIlvain and Shoop, 1970). For example, in a later study during 1971, steers that grazed lovegrass whenever it was available (about half of the grazing year) and native range the balance of the time gained 397 lb/head—the same as steers grazed continuously on native range.

The carrying capacities of Morpa and Common were equal. Both were stocked identically at a 3-year average of 1.7 acres/steer during a 278-day grazing year. Also, the amount of

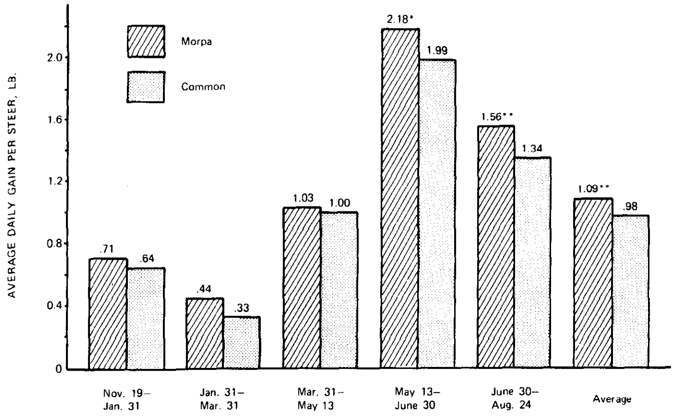

Fig. 1. *Average daily gain of steers pastured on 'Morpa' and 'Common' weeping lovegrass, 1966-67 to 1968-69.*

hay harvested was the same for both strains, an average of 1,400 lb/acre annually. The potential stocking rate was reduced by drouth during 1968 and 1969 and by understocking because we did not know how to manage lovegrass as intensive pasture. As evidence, the average stocking rate was 0.75 acres/steer during the last year of this study.

Morpa lovegrass increased annual profits from grazing \$12/acre over those of Common lovegrass. Returns above costs were \$19/acre from Morpa and \$7/acre from Common. Thus, Morpa increased profit 170%. All of the increased profit was due to the 33-lb greater gain per head produced by Morpa (Table 2).

Table 2. Net returns from steers on 'Morpa' and 'Common' weeping lovegrass.

Item	Morpa	Common
Purchase weight, lb/steer	465	465
Purchase cost, \$/steer	149	149
Yearlong gain, lb/steer	305	272
Sales weight, lb/steer	770	737
Sales value, \$/steer	215	206
Total costs, \$/steer[1]	201	201
Net returns, \$/steer	14	5
Net returns, \$/acre[2]	19	7

[1] Costs, in addition to steer purchase, were death and veterinary; buying; hauling; selling; tax on steer; cottonseed cake; salt; pickup, horse, and miscellaneous costs; interests on steer and other costs; fertilizer; and labor.

[2] Based on the optimum stocking rate, as determined during the last year of the study and a later 3-year experiment on the pastures.

Hay Feeding Study

Steers fed the Morpa opportunity hay consumed 9.6 lb/head daily and gained 75 lb/head during 104 days. In comparison, those fed the Common hay consumed 9.2 lb and gained 70 lb (Table 1). These differences are not statistically significant. However, these data are highly similar to those obtained during the three hay-feeding periods (March 15-May 10) of the grazing study. Thus, the steers ate slightly more Morpa hay and gained slightly more weight.

The average intake of lovegrass hay, 9.4 lb by 520-lb steers, compared relatively favorably with the amount of hay of medium quality that cattle have been observed to consume, about 2% of body weight (Crampton and Harris, 1969). Average daily consumption of hay per steer and daily gain per steer during each trial were 11.6 and 1.0 lb in 1967, 8.1 and 0.4 in 1968, and 8.9 and 0.8 in 1969.

The larger quantities of hay eaten and the satisfactory steer gains during 1967 resulted from first-growth lovegrass cut on June 9, when the seed was in the dough. The lower consumption and lower gains during the next 2 years resulted from more mature hay cut during August 1967 and July 1968 from pastures that had been grazed once or twice earlier in the season without subsequent mowing.

Other Comparisons

Adaptation

Frequent close examination of Morpa and Common lovegrass revealed no differences in establishment or in reaction to grazing, burning, nitrogen, or drouth. Morpa was slightly less winterhardy than Common at Woodward. However, during the 16 years that Morpa was studied intensively at Woodward, this lesser winterhardiness was important only twice when the grass was defoliated in September, October, or November.

About 20% of the plants and tillers of both Morpa and Common were killed during the summer of 1968 by a combination of (1) application of over 40 lb/acre of N in mid-May, (2) drouth, and (3) overmaturity of the grass. Permitting the grass to become overmature when fertilized with over 40 lb of N apparently caused excessive transpiration that led to exhaustion of soil moisture. Mowed and unmowed grass fertilized with rates of N from 0 to 30 lb/acre did not die.

Management

Morpa and Common lovegrass both required the same intensive management practices. However, along the northern and western edges of the area of lovegrass adaptation, Morpa especially must not be defoliated in September, October, or November. Defoliation by fall armyworms, [*Spodoptera frugiperda* (J. E. Smith)] in the fall of 1969 killed 25% of the tillers of Morpa and 15% of the tillers of Common. Observations during the fall suggested that Morpa was preferentially eaten by the armyworms. Thus, the greater loss may have been due to greater fall defoliation of Morpa, rather than to an appreciable difference in winterhardiness.

Appearance

Morpa was readily distinguishable from Common lovegrass when the seedheads of both strains were present. Morpa matured 7 to 10 days later and its seedheads were dark brownish-gray, whereas those of Common were light tan. Morpa was about 3 inches taller and had slightly wider leaves than Common. Both strains started growth at the same time in the spring and quit growth at the same time in the fall.

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THESIS: WASHINGTON STATE UNIVERSITY

Some Soil Properties Affected by Trampling on Forested Summer Range in Central Washington, by Dale Edward Wondercheck, MS, Range Management. 1972.

The objectives of this study conducted in the summer of 1971 on forested summer rangelands on the Colockum Multiple Use Research Unit near Wenatchee, Washington, were: (1) to determine the occurrence of soil compaction, and (2) to determine whether trampling of livestock caused soil compaction.

Five sites were selected, three on Colockum silt loam and two on Stemilt stony loam soils. Plots were established using vegetation and soil types for selecting similar areas. No exclosures were available; therefore, vegetation, species composition, and the presence or absence of a layer of mosses and lichens on the soil surface were used to determine past grazing intensity. The current year's use of range forage varied from 0% to 50%.

Bulk densities, infiltration rates, soil structure, wetting patterns, organic matter content, and soil texture were studied. Variation in bulk densities within plots was minute. Bulk density was not significantly correlated with current year's use, but was inversely related (1% level) to organic matter content. An increase from 2.3% to 3.7% in organic matter content decreased bulk density 0.17 g/cc. No significant relationship between organic matter content and current year's use was found. Infiltration rate was not significantly correlated with organic matter content, clay content, current year's use, or bulk density. An increase in clay content decreased the infiltration rate. Platy structure was predominant at all sites and is apparently related to current year's use. The platy structure was found closer to the surface on grazed areas but did not extend as deep into the profile as on ungrazed areas.

The following conclusions were derived from this study: (1) Evidently, past over-grazing has resulted in the replacement of some perennial vegetation by annuals which are capable of maintaining the organic matter content in the upper portion of the soil profile even under heavy grazing, but whether this condition will continue over a longer period of time is not known; (2) Any effect of clay on infiltration rate was probably caused by a surface crust formation; and (3) Increased vegetal cover may prevent the formation of a surface crust on the soil and increase infiltration rates.

Deer Forage and Overstory Dynamics in a Loblolly Pine Plantation

ROBERT M. BLAIR AND HANS G. ENGHARDT

Highlight: *In a loblolly pine plantation in central Louisiana, forage growth was basically governed by the development of pine crowns and the corresponding reduction of light in the understory. In young stands ready for initial thinning at age 20 years, growth of herbaceous and woody vegetation was virtually precluded by the dense pine canopy. Hardwood trees, shrubs, and woody vines increased as stands were thinned every 5 years. By plantation age 30 years, a multilayered midstory was developing as hardwoods and some shrubs grew beyond the deer feeding zone. Midstory density increased directly with the intensity of pine removal, and by stand age 35 it was the principal deterrent to growth of deer forage. Herbage was not abundant.*

Loblolly pine (*Pinus taeda*) plantations grown on a long-term rotation can provide sustained habitat for deer in the Gulf Coastal Plain, but only if they are intentionally managed for wildlife forage in the understory. Forage growth is largely governed by the forest manager's ability to adjust the overstory so as to provide sufficient light for understory plants.

This paper evaluates composition and growth of deer forage as influenced by pine thinning and development of a hardwood midstory in a loblolly pine plantation. Forage and tree dynamics were evaluated over a 13-year period from stand age 30 to 42.

Study Plantation and Methods

The plantation is on the Alexander State Forest in central Louisiana, an area supervised by the Louisiana Forestry Commission. Pine seedlings were planted in 1928 at a square spacing of 2.44 m.

The soil is a Muskogee silt loam with good surface and internal drainage. Terrain is level. The site is considered average for loblolly pine, and predicted heights at age 50 years are about 25 m.

Beginning in early 1948, when pines were 20 years old, a series of light, medium, and heavy pine thinnings was initiated on a layout of 0.16-ha plots. Pine basal areas after thinning averaged 23.0, 19.5, and 16.1 m^2 per ha. Plots were rethinned every 5 years to these same basal areas. Each thinning level was replicated four times in a completely randomized design. Except for an occasional hardwood tree cut for pulpwood, only pines were removed. Pine crop trees are managed for high-quality sawtimber or veneer bolts.

Fire was excluded until December 1962, when a backfire was prescribed for hazard reduction. A second controlled burn was made in December 1966.

Tree strata and understory flora for the study of deer forage were first sampled in the late summer of 1957. Sampling immediately preceded a pine thinning. Measurements were taken in 1962 and 1967 prior to scheduled thinnings and again in 1969, 2 years after the fifth pine cut. All pines, hardwoods, and shrub stems larger than 3.81 cm in diameter at breast height (dbh) were inventoried by 2.54-cm diameter classes on the central 0.04 ha of each thinning plot.

To appraise forage responses to overstory dynamics, the current season's growth of leaf and stem tissue on understory vegetation was clipped from the ground to a height of 1.52 m on nine 2-m quadrats located in a grid pattern within each of the central 0.04-ha plots. Samples were taken in late summer, after growth was completed. Growth of herbaceous species was sampled separately by grasses, grass-like plants, composites, legumes, and miscellaneous forbs. Browse, consisting of current twig and leaf tissues of shrubs, small hardwoods, and woody vines, was sampled by species or species groups. A new set of sampling quadrats was selected each measurement year. Clipped plant tissue was dried to constant weight in a forced-draft oven at 65°C.

The relations between both herbaceous and browse forage and the overstory were evaluated by correlation and multivariate regression analyses (Grosenbaugh, 1967) when pines were 30, 35, 40, and 42 years old.

Dependent variables for testing herbage relations were dry-matter yields in kg/ha (Y_1) and their logarithmic transforamtions (Y_2). Independent variables were the per-hectare density (X_1) and basal area (X_2) of pines, the density (X_3) and basal area (X_4) of midstory hardwoods and large shrubs, the dry-matter yields of browse in kg/ha (X_5), and the logarithmic transformations of these variables (X_6 to X_{10}). The relationships of browse yields (Y_3) and their logarithmic transformations (Y_4) were tested with four independent variables expressing the density and basal area of pine and midstory stems and their logarithmic values.

The objective was not to develop precise mathematical expressions for predicting forage yields but to clarify the ecological relationships. The relations between overstory density or basal area and forage production were generally curvilinear. Changes in production of forage dry matter as the plantation developed were tested by analyses of variance. In addition, mean forage yields were compared by Duncan's (1955) multiple range test, with Harter's (1960) tables. All statistical tests were at the 0.05 probability level.

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Overstory Dynamics

Pine stocking was reduced appreciably by the initial thinnings in 1948. For example, stocking decreased from 1,137 to 776 stems per ha in lightly thinned stands and from 1,151 to 583 stems per ha with heavy thinning. Thinnings in 1948 and again in 1953 increased the light reaching the understory and thereby stimulated growth of suppressed hardwoods and favored the invasion of additional stems. Compositional and structural trends in the tree strata were consistent with Chapman's (1948) conclusion that thinning will inevitably allow hardwoods to develop under pure stands of loblolly pine.

By 1957 all plots had a multilayered but discontinuous midstory of hardwood trees and large shrubs (hereafter referred to collectively as hardwoods) beneath a dominant pine canopy (Blair, 1967). Hardwood stocking was directly related to pine cutting intensity (Fig. 1). Pines ranged from 593 stems per ha with light thinning to 420 stems under heavy thinning, while hardwoods ranged from 432 to 672 stems per ha. Over the next 5 years hardwoods continued to increase in all stands, and their density continued to be highest with heavy thinning.

Hardwood stocking declined appreciably in all stands after the 1962 and 1966 prescribed burns, which killed many small stems. Before the burns, the 5.08- and 7.62-cm diameter classes comprised more than 71% of the stocking. By 1967 only 49% of the hardwoods were less than 9.02 cm dbh. During the 12 years from 1957 to 1969, average hardwood dbh increased from 7.11 to 11.18 cm. Large trees were more numerous in stands receiving medium and heavy thinnings than in those thinned lightly.

Pine basal area in 1957 ranged from 27.55 m^2 per ha with light thinning to 21.16 m^2 with heavy cutting. Hardwood basal area varied directly with pine thinning intensity from 1.29 to 3.19 m^2 for light and heavy cutting, respectively. While pines were cut back to prescribed levels each 5 years, hardwood basal area continued to increase unabated except for losses caused by prescribed burning and an occasional tree cut for pulpwood.

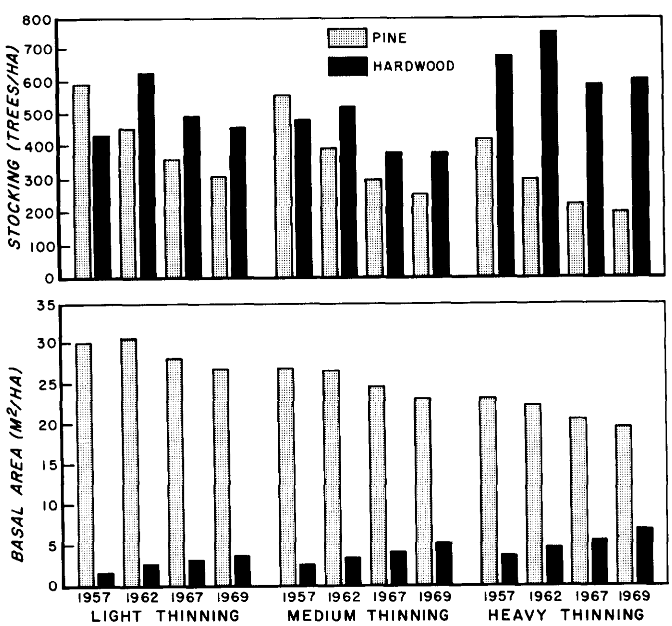

Fig. 1. *Stand characteristics of pine and hardwood trees > 3.81 cm dbh under three levels of pine thinning.*

The successively narrowing basal-area ratio of pine to hardwood at all thinning levels from 1957 to 1969 further illustrates the progressive alteration in the mixed tree strata. With light thinning the ratio narrowed from 21.4:1 in 1957 to 7.7:1 in 1969. In heavily thinned stands where hardwood growth was greater the ratio narrowed from 6.6:1 to 2.9:1. Negative linear relations between pine and hardwood basal areas were significant in 1957 (**r** = −0.67), 1962 (**r** = −0.55), and 1969 (**r** = −0.56). The nonsignificant association in 1967 (**r** = −0.39) probably was attributable to the loss of hardwood stems from the burns in 1962 and 1966.

Number of species comprising the midstory increased with pine thinning intensity. Sweetgum (*Liquidambar styraciflua*) was the principal midstory component under all pine thinning regimes, varying little in relative ranking from 1957 to 1969. Thus, it averaged 84% or more of the hardwood stocking with light pine thinning, 52% with medium thinning, and 71% with heavy thinning. Blackgum (*Nyssa sylvatica*) ranked second in prominence in association with such species as southern red oak (*Quercus falcata*), water oak (*Quercus nigra*), flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), and tree sparkleberry (*Vaccinium arboreum*). As midstory density increased from 1957 to 1962 several less abundant species succumbed—among them were white ash (*Fraxinus americana*), rusty blackhaw (*Viburnum rufidulum*), Elliott's blueberry (*Vaccinium elliottii*), and sassafras (*Sassafras albidum*). The controlled burn in the winter of 1962 eliminated American holly (*Ilex opaca*) and southern bayberry (*Myrica cerifera*) from the midstory.

Thinning levels also influenced pine growth. Heavier cuts resulted in the fastest diameter growth but the least cubic-meter or board-foot volume growth by stand age 40 (Enghardt, 1970). From 1957 to 1969 average pine diameter increased from 24.6 to 33.0 cm.

Understory Vegetation

Herbage

Herbaceous vegetation, especially grass-like plants and forbs, was sparse in 1957 (Table 1). Average dry-matter yields tended to vary inversely with pine basal area and directly with hardwood basal area, though differences between thinning regimes were not large. By 1962, when stands were scheduled for the fourth thinning, yields had not increased significantly and varied little by cutting intensity. The change in pine-herbage relations appeared to be the product of invading hardwoods and the subsequent increase in midstory density. Under light thinning where hardwood basal area was least, herbage increased 23% from 1957 to 1962. With moderate thinning it declined 25%, and with heavy thinning and the greatest hardwood basal area it was down 29%.

The prescribed winter burns in 1962 and 1966 favored herbaceous vegetation not only by reducing the density of competitive woody stems but also by destroying litter and thus improving seedbeds. By 1967 herbage had increased 208, 285, and 293% under light, medium, and heavy thinning (Fig. 2). The greater increases under medium and heavy thinning probably resulted from a proportionately greater fire kill of small hardwoods and shrubs. Dry-matter production did not change significantly from 1967 to 1969 in response to the fifth thinning.

Grasses comprised 62% or more of the herbage dry matter over all thinning regimes and years.

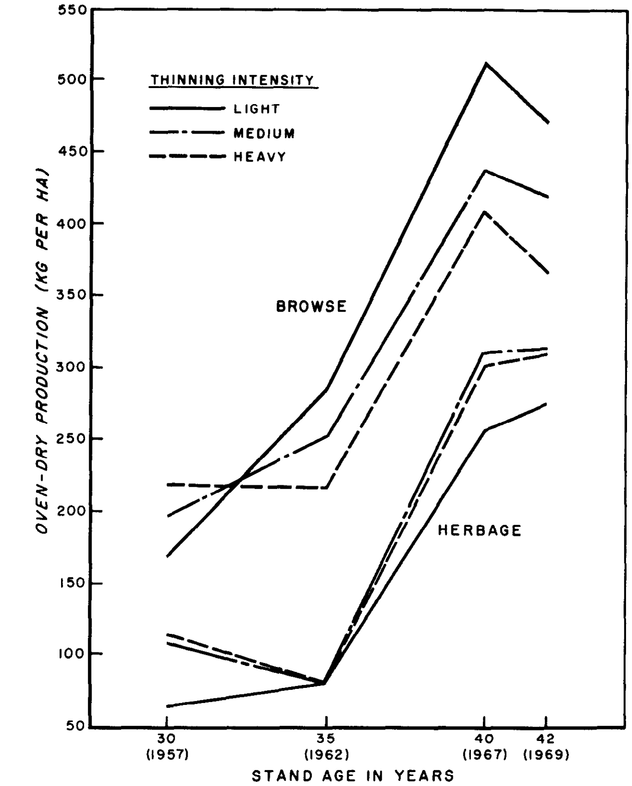

Fig. 2. *Variation in the production of forage dry matter per ha as the stands aged.*

Shade-tolerant longleaf uniola (*Uniola sessiliflora*) and spike uniola (*Uniola laxa*) contributed around 60% of the dry-matter yield of grasses in 1957 and 1962. Pinehill bluestem (*Andropogon divergens*), broomsedge bluestem (*Andropogon virginicus*), and several species of panicum (*Panicum* spp.) were common associates of uniola at this stage of plantation development. By 1967, when the hardwood midstory was extensively developed, the two species of uniola yielded over 90% of the grass dry matter. Competition had eliminated the more intolerant bluestems and drastically reduced the panicums. Sedges and rushes in the genera *Carex* and *Rhynchospora* had virtually disappeared, while nutrushes (*Scleria* spp.) increased.

Though forbs are a highly desirable food for deer, most species are intolerant of low light levels. Except for legumes, the comparatively low forb yields tended to increase after the controlled burn. Dry-matter yields of legumes varied little. Prominent composites such as bonesets (*Eupatorium* spp.), grassleaf goldaster (*Chrysopsis graminifolia*), and ironweed (*Vernonia texana*) declined appreciably after 1962, while the occurrence of bushy aster (*Aster dumosus*), elephantfoot (*Elephantopus tomentosus*), and goldenrods (*Solidago* spp.) changed little with increasing midstory density. Tickclovers (*Desmodium* spp.) and partridgepea (*Cassia fasciculata*) were the principal legumes. Of the remaining common forbs, copperleaf (*Acalypha gracilens*) and poor-joe (*Diodia teres*) declined as the plantation aged, while narrowleaf mountainmint (*Pycnanthemum flexuosum*), skullcap (*Scutellaria* spp.), lobelia (*Lobelia puberula*), and the highly tolerant partridgeberry (*Mitchella repens*) increased. Bracken-fern (*Pteridium aquilinum*) was the only fern observed.

Because of the low herbage production, plantations generally afford only limited grazing for livestock. Cattle should be excluded where deer are desirable, since both eat the leaves and tender twigs of browse.

Browse

Current leaves and stems of woody plants dominated understory forage growth (Table 1). In 1957 browse yields varied inversely with the basal area of pine and directly with that of hardwoods. Over the ensuing 5 years this relationship reversed and remained so through 1969 as the hardwood midstory progressively increased with pine removal (Fig. 2). From 1957 to 1962 browse dry matter increased 66% with light pine thinning and 27% with moderate thinning. With a heavy cut there was no significant increase.

Following the prescribed burns in 1962 and 1966, browse yields rose by an average of 81% throughout all stands. The increase was significant under all thinning regimes. By killing above-ground fractions of many single woody stems, fire stimulated multiple-stem sprouting, greatly increasing growth per plant. Production did not change significantly from 1967 to 1969.

The tree-browse relationships for the composite of species regarded as palatable deer food generally followed the same pattern as that for total browse (Table 2). The ratio of palatable to total browse dry matter varied little as the stands aged and as the composition and structure of the overstory changed. It ranged from a high of 0.70 in 1962 to a low of 0.61 in 1969.

Table 1. Forage dry matter (kg/ha) in late summer under pine stands thinned every 5 years (means of 36 2-m sampling quadrats per year and thinning intensity).

	Light thinning				Medium thinning				Heavy thinning			
Vegetation class	1957	1962	1967	1969	1957	1962	1967	1969	1957	1962	1967	1969
Herbage												
Grasses	42.6	65.1	226.6	238.9	78.5	57.2	264.7	280.4	78.5	55.0	242.3	267.0
Grass-like plants	3.4	2.2	5.6	3.4	7.9	4.5	24.7	11.2	5.6	4.5	9.0	6.7
Forbs												
Composites	7.9	3.4	10.1	10.1	11.2	3.4	12.3	13.5	11.2	3.4	16.8	19.1
Legumes	2.2	2.2	2.2	5.6	2.2	4.5	2.2	4.5	3.4	4.5	2.2	6.7
Miscellaneous	5.6	1.1	3.4	6.7	9.0	7.9	11.2	7.9	10.1	4.5	14.6	11.2
Ferns	6.7	10.1	11.2	14.6	T[1]	4.5	T	1.1	3.4	7.9	20.2	4.5
Total herbage	68.4 a[2]	84.1 a	259.1 b	279.3 b	108.8 a	82.0 a	315.1 b	318.6 b	112.2 a	79.8 a	305.1 b	315.2 b
Browse	172.8 a[2]	286.1 b	518.3 c	476.8 c	200.8 a	255.8 b	444.2 c	422.9 c	223.2 a	218.8 a	415.1 b	374.7 b
Total forage	241.2	370.2	777.4	756.1	309.6	337.8	759.3	741.5	335.4	298.6	720.2	689.9

[1] < 0.051 kg per ha.

[2] Yield values within a thinning regime and vegetation class followed by a common letter are not significantly different.

Table 2. Leaf and stem tissue produced (kg/ha, ovendry) by palatable[a] and nonpalatable browse species.

Palatability class & year	Light thinning Leaves	Light thinning Stems	Medium thinning Leaves	Medium thinning Stems	Heavy thinning Leaves	Heavy thinning Stems
Palatable species						
1957	55.3	43.4	73.5	50.1	88.5	61.7
1962	103.4	89.2	88.7	88.5	91.4	68.9
1967	169.0	154.7	143.6	137.3	140.6	124.6
1969	156.1	131.8	138.7	116.1	132.8	105.1
Nonpalatable species						
1957	61.0	13.1	59.6	17.6	58.3	14.7
1962	75.5	18.0	56.6	22.0	45.2	13.3
1967	149.0	45.6	98.8	64.5	100.4	49.5
1969	121.8	67.1	94.4	73.7	102.5	34.3

[a]Species generally ranked as palatable deer forage within the western region of the loblolly-shortleaf pine-hardwood forest association.

Over all years and levels of pine thinning, woody vines contributed more than 55% of the palatable browse. Principal species were Carolina jessamine (*Gelsemium sempervirens*), Alabama supplejack (*Berchemia scandens*), common greenbrier (*Smilax rotundifolia*), and cat greenbrier (*Smilax glauca*). Shrubs and trees included American beautyberry (*Callicarpa americana*), flowering dogwood, blackgum, blackberries and dewberries (*Rubus* spp.), water oak, and Elliott's blueberry. With the exception of blackgum, occurrence and growth of these species generally increased.

Principal nonpalatable species were muscadine grape (*Vitis rotundifolia*), sweetgum, southern bayberry, southern red oak, post oak (*Quercus stellata*), common deerberry (*Vaccinium stamineum*), and rabbiteye blueberry (*Vaccinium virgatum*).

Under all thinning regimes, dry-matter yield of leaf tissue exceeded that of stems each year (Table 2), but the leaf:stem ratio was considerably higher for nonpalatable than for palatable species. The abundance of large-leaved species in the nonpalatable category accounted for the differences. Carolina jessamine, a small-leaved evergreen, consistently yielded a third or more of the total leaf dry matter in the palatable group.

The leaf:stem ratios of the palatable and nonpalatable categories did not vary appreciably with intensity of pine removal, controlled burning, or subsequent invasion of hardwoods.

Timber Stand-Herbage Relationships

In 1957, when pines were 30 years old and ready for the third thinning, analyses indicated that growth of herbaceous plants was governed primarily by the influence of pine stocking and basal area in conjunction with browse growth. When pine overstory and browse growth were combined into a multivariate expression, they accounted for 73% of the variation in herbage production. Pine overstory alone accounted for 66% of the variation.

After the third pine thinning, hardwoods and shrubs continued invading. By 1962 the midstory was so dense that the growth of herbaceous forage now appeared to be governed primarily (**r** = −0.50, significant) by hardwood stocking.

By 1967, midstory had become a progressively greater herbage deterrent, even though prescribed burns in the winter of 1962 and 1966 reduced the number of stems. Collectively, midstory stocking and basal area accounted for 74% of the variation in herbage yield. Pine or browse attributes, individually or in combination, were exerting little influence on herbaceous vegetation.

A number of hardwoods were cut or broken over during pine harvest in the winter of 1967–68. This disturbance appeared to temper the effect of the midstory. Sufficient time had not elapsed by 1969 for hardwoods and shrubs to invade and shade out herbage, primarily grasses, that seeded into openings created by the reduction of both pines and hardwoods. Herbage yields were significantly correlated with hardwood stocking (**r** = −0.62), pine stocking (**r** = −0.86), and pine basal area (**r** = −0.53). In combination, these overstory attributes accounted for 94% of the variation in herbage.

Timber Stand-Browse Relationships

In 1957 the combined influence of hardwood stocking and basal area and pine basal area inversely governed browse yields and accounted for 73% of the variation in production. Individually, these stand attributes were not significantly correlated with browse yields.

From 1962 to 1969 the low, dense hardwood canopy appeared to be the principal deterrent to browse growth. Both midstory stocking and basal area were significantly related to browse dry matter, the correlations ranging from a low of **r** = −0.58 for hardwood stocking in 1962 to a high of **r** = −0.85 for hardwood basal area in 1969. Collectively, the midstory attributes accounted for 67% of the browse variability in 1962, and for 76% in 1967 and 1969.

The canopy of dominant pines was sufficiently high and thin by 1962 to permit the transmission of considerable light. Hence pine offered little competition to browse in the understory by plantation age 35.

Discussion and Conclusions

Even though some timber growth may be sacrificed (Grano, 1970a), quality deer habitat in a loblolly pine plantation requires an interspersion of the herb and shrub stages of plant succession beneath the dominant pine canopy.

A loblolly plantation on a pulpwood rotation of 20 to 25 years generally provides forage, especially herbage, for deer only from the time of planting to crown closure. This is a period of 8 to 10 years, depending on pine spacing and site quality. Thereafter, herbaceous and woody forage is sparse in the understory until trees are harvested. In stands managed for sawtimber and veneer stock, the understory begins increasing again after the initial pine thinning at about pine age 20 (Blair, 1969). Suppressed woody plants respond to the increased light, and additional browse and herbage plants become established. When left uncontrolled, many plants soon grow beyond the deer feeding zone (Blair, 1967; Schuster and Halls, 1963).

The development of a hardwood midstory should be prevented. When the preponderance of leaf material on shrubs and hardwoods grows beyond about 1.5 m aboveground, individual stems can be felled when the pines are thinned. Species that will produce fruit or mast in the reduced light should be retained.

In the absence of a broadleaved midstory, forage growth is generally inversely proportional to pine basal area. For deer habitat, therefore, stands should be managed at a minimum level of pine basal area. A loblolly plantation thinned to about 16 m^2 per ha every 5 years after age 20 can provide adequate forage for deer when the midstory is limited to desirable fruiting trees and shrubs.

Though woody vines are generally a major source of palatable browse in loblolly plantations, they often form dense entaglements that impede tree marking and harvest, and may kill or deform young pines. Vines that interfere with pine culture have generally grown beyond the deer feeding zone and should be cut back.

Green leaves of browse plants are an important part of the deer forage. Foliage of broad-leaved evergreens is particularly important in late fall and winter, when nutritious foods are scarce. Nutrient quality and dry-matter digestibility of current woody stems are generally at an acceptable level only during a brief period in spring (Blair and Epps, 1969; Short et al., 1973). Thereafter the ingestion of fibrous stems declines appreciably. Harlow and Hooper (1972) concluded from investigations in the southeastern Coastal Plain that deer eat more green leaves than twigs at all seasons.

Judicious prescribed burning can also control the density of midstory hardwoods (Grano, 1970b) and subsequently improve the forage (Lay, 1957). Winter backfires at about 5-year intervals will kill the aboveground portions of many smaller stems of hardwoods, shrubs, and woody vines—including many that have grown beyond the deer feeding zone. Multiple-stem sprouting the following spring increases the productivity and nutrient quality of forage. But frequent burning, as at 2- to 3-year intervals, eradicates the understory browse community (Grano, 1970b) and eliminates food and cover for deer and other wildlife.

The size, shape, and distribution of plantations greatly influence desirability for deer habitation. Where a large block of forest land is scheduled for regeneration, only a portion should be clearcut and planted yearly. Then if the planting sites are small and well distributed they will provide deer with a diversity of food and cover. Long, narrow plantations of 10 to 20 ha are usually the most desirable (McGinnes, 1969), since they have more edge than units that tend toward a square or circular form.

Guidelines for sustaining deer habitat in plantations are generally applicable also to the vast acreage of natural loblolly-shortleaf pine (*Pinus echinata* Mill) stands. The thinning cycle in natural stands can be extended to 7 or 8 years. These stands should be maintained as a pine-hardwood association, but overstory and midstory hardwoods with no commercial potential or of no value to wildlife should be deadened.

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Water Quality Implications of Cattle Grazing on a Semiarid Watershed in Southeastern Utah

JOHN C. BUCKHOUSE AND GERALD F. GIFFORD

Highlight: *During 1973 and 1974 wildland water quality analyses were performed on a semiarid, chained and seeded, pinyon-juniper site in southeastern Utah. The area was treated in 1967 and protected from grazing until 1974. In 1974 livestock grazing was introduced and investigations continued to determine if any deleterious land use effects were present from fecal contamination by cattle. No significant changes were noted in fecal and total coliform production (fecal pollution bacterial indicators) from grazing use. There is an element of risk involved whenever data generated from a small area are projected to larger land areas. However, it appears that this level of livestock grazing (2 ha/AUM) did not constitute a public health hazard in terms of fecal pollution indicators on the semiarid watershed.*

Pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) vegetative type conversions have been made on millions of acres of semiarid rangeland. Chaining, which involves mechanically uprooting the trees with a large anchor chain suspended between two crawler tractors, is a frequently employed technique. In Arizona alone, almost a million acres of woodland have received some vegetation treatment between 1950 and 1960 (Dortignac, 1960). Yet many of the hydrological aspects of such vegetation conversion are poorly understood. The secondary treatment effects of grazing these treated areas are even less well understood.

Our population is continuing to grow. Recreational demands on public lands are accelerating. Arid land use planning and zoning ordinances may well be on the horizon. Natural resource managers are faced with decisions of extreme importance, and in many cases they are hampered by an incomplete knowledge of the physical factors which are taking place on the lands under their control. For instance, should cattle be allowed on public lands? Are there public health implications that need to be considered in conjunction with grazing?

With such problems in mind, a study designed to answer some questions about secondary treatment of pinyon-juniper chainings was undertaken. The objective was to determine the impact of grazing by domestic livestock on fecal pollution indicator bacteria from a pinyon-juniper site which had been chained with debris windrowed.

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Literature Review

Wildland water quality studies are rare, or only peripherally associated with true wildland situations, and studies of this nature dealing with semiarid, ephemeral watersheds are nonexistent.

Wildlands may be defined as those remote areas which are not developed for agriculture, other than forestry, and are usually public lands in the western states (Darling, 1973, p. 14).

According to the Public Land Law Review Commission (1970) nearly one-half of the 273 million acres of public rangeland in the eleven western states is grazed at one time or another by domestic livestock. Recreational use of many of these same lands is rapidly increasing as leisure time, increased affluence, greater mobility, and urban pressures grow (Outdoor Recreation Resources Review Commission, 1962). The Public Land Law Review Commission (1970) further notes that grazing is permitted on nearly one-quarter of the land areas which have been withdrawn for recreation. Apparently, therefore, a potential for domestic animal fecal pollution and ensuing health hazards exists on high density recreational wildland which is grazed.

Diesch (1970) has reported that numerous diseases can be transmitted from one warm blooded organism to another via water. Commonly observed diseases related to contamination of water supplies from cattle feedlots are salmonellosis and leptospirosis. A leptospirosis outbreak among several young people in Iowa was traced to their swimming hole on the Cedar River. Leptospirosis-infected cattle had access to the river upstream from the swimming hole (Willrich, 1967). Bryon (undated) has also reported a leptospirosis outbreak associated with a swimming hole near Columbus, Georgia. Cattle, swine, and dogs found to have a *Leptospirosis canicola* infection all had access to the stream which fed the swimming hole.

Geldreich (1970) has concluded that the frequent occurrence of pathogens in domestic animals and wildlife supports concern about fecal contamination from all warm blooded animal sources.

Kunkle (1970) related bacterial densities to patterns of land use in Vermont. He found an increase in fecal coliform counts when cattle were adjacent to the stream as opposed to further away. However, he determined that only a "minor fraction of the total available live bovine fecal material ever washed into the stream." He concluded, therefore, that only the area immediately adjacent to the stream, rather than the entire watershed, is of major importance in terms of introducing this sort of pollution into the stream.

Working with a wildland stream in Colorado, Morrison and Fair (1966) attempted to determine several environmental effects on microbial dynamics. They did note, as a peripheral observation, that cattle grazing adjacent to the stream caused an increase in coliform counts.

Kunkle and Meiman (1967) studied the Little South Fork of the Cache la Poudre River in Colorado in order to assess several water quality characteristics. They found that fecal coliforms proved to be a better indicator of watershed impact than turbidity and suspended sediment.

The same team also investigated the water quality impact of grazing on a mountain meadow. They found that the indicator bacteria produced evidence of more pollution in a grazed watershed than in a natural ungrazed catchment (Meiman and Kunkle, 1967).

Slawson and Everett (1973) found that the water quality of the main stream Colorado River was relatively constant in terms of chemical and biological parameters. However, the tributary streams showed extreme temporal variability in these parameters as a result of summer rain and flood patterns. They concluded that the side streams pose a definite health hazard to unwary travelers.

Kunkle and Meiman (1968) also investigated the variation in bacterial numbers with time. They noted a daily variation with afternoon lows and evening highs. This cycle followed the cyclic diurnal stream stage, with the high bacterial counts correlating to high streamflow. They also noted an extreme bacterial die-off contributed to the low bacterial counts observed during the late afternoons.

Mack (1974) demonstrated, however, that coliform bacteria can persist and even multiply in natural waters. He also noted that multiplication was greater at 35°C than at lower temperatures. Hendricks and Morrison (1967) have also reported the enteric bacteria's ability to multiply and grow in cold mountain streams. They suggest that the river's self-purification mechanism plays a role in suppressing the unrestrained growth of these organisms, however.

Walter and Bottman (1967) studied a pair of watersheds near Bozeman, Montana. They noted that one of the watersheds which had been protected from public use for over 40 years consistently showed higher bacterial counts than the adjacent watershed, which was open to the public. Stuart et al. (1971) observed the same watershed and theorized that the higher bacterial counts could be attributed to higher wildlife numbers. Apparently the wildlife favored this watershed due to its protected or "refuge" status. Bissonette et al. (1970) employing a serological technique attempted to isolate the source of bacterial contamination on the same closed or refuge watershed. They concluded that the sources of contamination were indeed wild animals.

Skinner et al. (1972) observing a mountain watershed in Wyoming noted a seasonal fluctuation in bacterial numbers. The authors found increasing concentrations of bacteria as the snowmelt hydrograph advanced toward its peak. They further speculated that increased bacterial numbers were correlated with grazing periods of domestic livestock and wildlife numbers.

In a recent wildland study in northern Utah, Darling and Coltharp (1973) found significant increases in bacterial counts during periods of cattle and sheep grazing at stream locations immediately downstream from the grazing activity. Bacterial counts in streams draining the grazed watersheds reached seasonal maximum values during the grazing period, while counts from a nearby ungrazed watershed remained relatively low and constant. In evaluating the health hazard implications of livestock grazing on public wildlands they recommended that direct access of livestock to important water supply streams be prevented (Coltharp and Darling, 1973). Fencing of stream channels would provide a buffer zone between the stream and the livestock. Livestock watering places should be developed away from the live stream. They further recommend that rather than suggesting a curtailment of livestock grazing on public lands, the recreating public be advised of the possible dangers involved in drinking untreated stream water.

Study Area and Treatments

The study site is located near Coyote Flat, approximately 1 km west of Utah Highway 261, between Natural Bridges National Monument and Mexican Hat, Utah, and approximately 70 kg west of Blanding, Utah. It is at an elevation of 2,150 m and within the confines of the Colorado Plateau.

The soil at this location is derived from a sandstone parent material and extends to a depth of approximately 1.5 m. The pH of the soil is slightly basic, averaging about 8.0. Organic matter content is low, slightly less than 2.0%. Soil texture is a sandy loam, with few rocks present (Gifford, 1973).

Primary treatment was applied to the site in the fall of 1967, namely chaining and windrowing of debris. The windrowed treatment was drill seeded to crested wheatgrass (*Agropyron cristatum*) at 9.1 kg/ha (8 lb/acre). The study area was then fenced to exclude livestock.

During June, 1974, secondary treatment was established. Six head of 2-year-old bulls and four mature cows (three with nursing calves) were allowed to graze the chained-with-debris-windrowed location for 2 weeks. The cattle were stocked at the rate of 2 ha/AUM. This is comparable to stocking rates which local Bureau of Land Management officials attempt to attain on well-established crested wheatgrass seedings near the study site (Assistant Area Manager Ken Moore, 1974, personal communication).

Under undisturbed conditions mature juniper trees (*Juniperus osteosperma*) made up 24% of canopy cover (500 trees/ha) while pinyon pine (*Pinus edulis*) composed about 8% (200 trees/ha). Shrub cover, consisting primarily of big sagebrush (*Artemisia tridentata*) was less than 1%. Bare ground, including some cryptogam species, and litter composed the balance (Gifford, 1973).

The chained-with-debris-windrowed treatment had from 13–73% ($\bar{x}$ = 40.94%) total cover of which 4–45% ($\bar{x}$ = 23.09%) was litter and 1–35% ($\bar{x}$ = 17.25%) was crested wheatgrass cover. These cover measurements are based on small plot percentage cover values. Each of the .23-m^2 runoff plots was evaluated for total cover using 100 systematically located points per plot.

After the cattle were removed the area was composed of 5–55% ($\bar{x}$ = 31.78%) total cover, of which 4–39% ($\bar{x}$ = 21.22%) was litter, and 0–26% ($\bar{x}$ = 10.56%) was crested wheatgrass cover. This represents a vegetative production of approximately 319 kg/ha and a subsequent consumptive use of 177 kg/ha or 55.5% utilization.

Methods

Field Procedure

A Rocky Mountain infiltrometer (Dortignac, 1951) was used to generate runoff from small, moveable plots, each plot being 0.23 m^2 in size.

All plots were pre-wet prior to application of simulated rainfall in order to eliminate confounding effects of antecedent moisture. Artificial rainfall was then applied to the plots at a rate of approximately 7 cm per hour for 28 minutes. Both runoff and rainfall were collected initially, after 3 minutes, and subsequntly at 5-minute intervals during the rainfall period.

Six samples per treatment area per treatment date were run. Two randomly located clusters of three plots were located within the observed areas (undisturbed woodland and chained with debris windrowed). Each of the six observations were considered independent samples and were treated as such in all data manipulations.

Parameters Analyzed

Each sample of the runoff water was tested for indicator bacteria (fecal and total coliform) using the multiple tube and evaluated temperature tests as outlined in *Standard Methods* (American Public Health Association, 1971) and *A Laboratory Manual for Aquatic Microbiology* (Post, 1971).

Since it was difficult to use distilled water as the artificial rainfall source, local water from Natural Bridges National Monument was used. This water was drawn from one of the two deep wells located at the Monument and stored in a large 50,000 gallon metal tank. The artificial rainfall water was transported from the Natural Bridges storage tank to the plots in three 55-gallon metal drums and a 300-gallon trailer mounted water tank. Runoff water samples were collected for analysis after they had passed over the soil surface and into containers at the base of the plot.

Samples of "rainfall" were collected concurrently by placing a 1000-ml beaker on an elevated stand and catching drops of water as they fell. This "rainfall" water was then analyzed in the same fashion as the runoff water.

Bacterial analyses were performed using a Most Probable Number (MPN) (American Public Health Association, 1971). The principle involved in this technique is that coliform bacteria will produce gas from the fermentation of lactose in a broth medium within a given time at a specific incubation temperature. Presumptive and confirmed tests for coliform were performed routinely at the field laboratory.

The multiple tube (MPN) technique was chosen over the membrane filter technique due to the heavy sediment load present in the water samples, which interfered with filtration and suppressed bacterial growth on the filters. Pre-filtration to remove the sediment was unacceptable since that would also remove any bacteria adhering to the sediment particles (Post, 1973, personal communication). Kitrell and Furfari (1963) noted a similar situation when they observed that bacteria may be effectively removed from water if they are absorbed on soil particles which subsequently settle out of suspension.

Results and Discussion

There were no significant differences for fecal indicator bacteria averages between grazed and ungrazed treatments, time, or years; and only the year/time interaction of the related interactions showed significance at the .05 level.

Both the total and fecal coliform counts per 100 ml are relatively low in the runoff water produced by simulated rainstorm from the Rocky Mountain infiltrometer. However, the low numbers do not necessarily meet the Public Health Service standard of <1 coliform/100 ml for drinking water (Public Health Service, 1962). An increased variability in bacteria numbers was noted in 1974, when the debris-windrowed area was grazed by cattle, however.

Why is an area subjected to cattle grazing registering such low coliform counts? Do the bacteria die rapidly after being deposited on hot soil surfaces and subjected to intense sunlight?

Apparently coliform bacteria are able to survive intense sunlight and heat for at least one summer. A bacterial longevity experiment was conducted concurrently with the other research to determine if the bacteria would remain viable under local conditions throughout the entire grazing season. A fresh "cow pie" (fecal material) was marked and periodic samples were taken from it over an 18-week period to determine bacterial viability. Each sample (approximately 16 cc volume) was suspended in 100 ml of distilled water for 1 hour. At the end of the hour the supernatant was withdrawn and processed according to the standard method for the MPN bacteria test. The results of this experiment are delineated in Table 1. The coliforms within this slurry were able to persist in numbers in excess of 1,100/ml of slurry for at least 7 weeks. At approximately 9 weeks under ambient conditions, some variation in bacterial die-off was noticed. Fecal coliforms, which are present in lower numbers than total coliforms, began to show a decline in population several weeks earlier than the total coliforms. The atypical pattern expressed during the eleventh week is attributed to natural variation in bacteria numbers within the feces itself as the bacteria numbers begin to decline.

Table 1. Total and fecal coliform bacteria (no./ml) found in bovine feces exposed to ambient weather conditions from 0 to 18 weeks in southeastern Utah.

Week	Total coliform	Fecal coliform	Date of sample
0	>1,100	>1,100	June 19, 1974
1	>1,100	>1,100	June 25, 1974
3	>1,100	>1,100	July 9, 1974
7	>1,100	>1,100	August 4, 1974
9	>1,100	290	August 20, 1974
11	9.3	9.3	September 3, 1974
18	>1,100	53	October 22, 1974

*Based on 16 cc of bovine fecal material suspended in 100 ml of distilled water.

Post (1974, personal communication) has speculated that the bacterial life span under such conditions could be as long as several seasons since the bacteria are able to maintain life for several years if they are desiccated quickly while being held within a protective media. This may have been the case on the study site, since the cow manure containing the bacteria dries within 3 or 4 days under the summer sun and subsequently remains intact for several months or even years.

Apparently then, the low bacterial counts must be associated with a low density of bacterial sources. In this study, 102 plots 9.6 ft^2 were analyzed for percentage of feces coverage on the debris-windrowed watershed. This survey indicated that only 0.2% of the area was covered by manure at this level of grazing per season (2 ha/AUM). If the manure itself is taken as a point source for pollution, then it is apparent that only a very small percentage of any given watershed area is contributing indicator bacteria.

Figure 1 shows the results of another experiment testing the bacterial relationship between 1-month-old manure and increasing distances from it. A series of three infiltrometer plots were located so that one plot was centered around the fecal deposit. The next two were centered 0.5 and 1.0 m away from the feces, respectively. A high intensity simulated storm

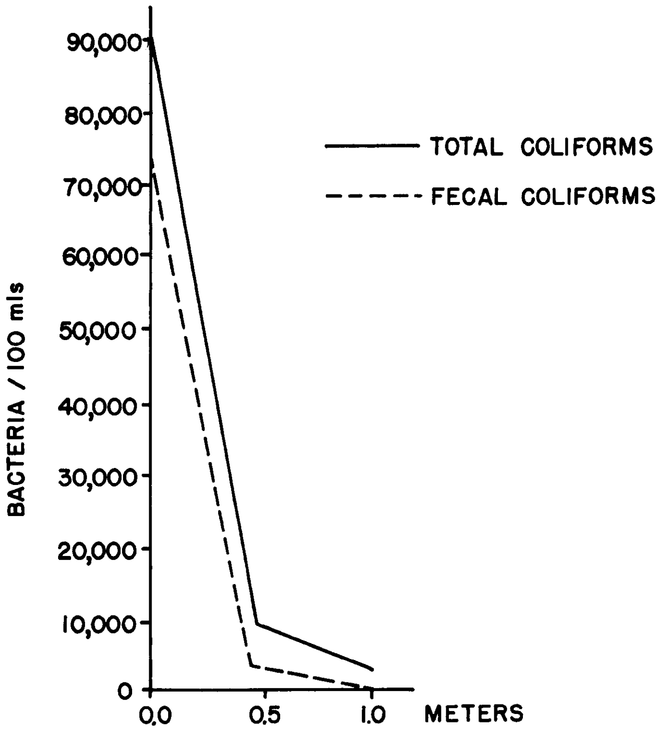

Fig. 1. *Spatial relationship between coliform bacteria and distance from month-old bovine feces.*

was created above the plots with the Rocky Mountain infiltrometer. The resultant runoff was collected and analyzed for total fecal coliform bacteria.

At a distance of 1 m from the feces very few fecal coliforms were present (average of approximately 23 organisms/100 ml) total coliforms were observed. Apparently only the feces themselves and an area within perhaps a meter radius of soil surrounding them are subjected to any degree of fecal bacteria pollution from grazing livestock. Even including the adjacent area associated with pollution sources, only about 4.9% of this particular grazed area could be classified as a source area.

It seems, therefore, that unless the feces are deposited in or adjacent to a streambed there is little danger of significant bacterial contamination resulting from livestock grazing on semiarid watersheds similar to those included in this study. Even those feces deposited in the streambeds and gullies of these dry, ephemeral watersheds may not constitute a problem, since Gifford (1973) has noted that little, if any, water runs off from similar areas during any given year, particularly in debris-in-place chainings. (Gifford's studies have, however, been confined to areas of less than 20% slope and fairly deep soils. His findings do not refer to steep slopes, shallow soils, or slick rock areas. They are applicable, however, since livestock tend to favor the flatter, better vegetated sites, rather than the steeper, rougher areas.)

Summary and Conclusions

During the summers of 1973 and 1974, a water quality study was conducted in San Juan County, southeastern Utah. The area chosen for the study was a 7-year-old pinyon-juniper chaining project. The site had been chained and the debris bulldozed into windrows. It was seeded to crested wheatgrass in the fall of 1967. An "undisturbed" woodland area situated adjacent to the chaining was maintained and served as a control area.

During the 1973 field season, water quality baseline data were collected from the area. Secondary treatment, consisting of livestock grazing of the chained-with-debris-windrowed location was implemented during the spring of 1974. Water quality information was subsequently collected during 1974 in order to evaluate the changes which occurred on the sites relative to the treatment it had received.

A Rocky Mountain infiltrometer was used to create simulated, high intensity rainstorms on the area. Resultant runoff was analyzed for the several water quality parameters in question.

Results of the study indicate, first of all, that it is indeed possible to record levels of bacteria (which would seemingly have the potential to wash from upland watershed areas into streams) through use of the Rocky Mountain infiltrometer. Secondly, it appears the potential public health hazard of livestock grazing on semiarid open range on gentle slopes is minimal. While the bacteria present in the livestock fecal material remains viable for at least one grazing season, they are apparently confined within the fecal material itself. The actual watershed area which is occupied by fecal material may only be in the order of 0.2% during that year's grazing season, based upon a grazing use rate of 2 ha/AUM, though approximately 4.9% of the area may be within a 1-m radius of the feces.

Under dry rangeland conditions, such as experienced in much of the southwestern United States, permanent flowing streams are rare. More frequently, the area is perennially dry, with an occasional flash flood providing a short-lived, ephemeral water flow. Cattle are maintained in these locations by hauling water to established watering troughs or by developing water catchment ponds at local springs. Therefore, there is little or no effective stream bank area from which the bacteria can be flushed into a water course. Moreover, on most chainings, and in particular on debris-in-place chainings, it is doubtful that runoff water ever flows any distance overland. Due to high water retention and detention storage potentials, very little rainfall coming into these debris-in-place areas ever runs off.

It is difficult to extrapolate from the results observed under small plot measurements to an entire watershed. The reactions of the whole, integrated system may well be different from those observed as components of this system. Nevertheless, with these risks and hazards in mind, one must at least attempt to draw some practical conclusions. In terms of livestock grazing, no apparent negative public health hazards were demonstrated through observation of the small runoff plots established on an area grazed at the rate of 2 ha/AUM. While additional factors may cause significant alteration of this pattern on the watershed as a whole, there is no evidence based on this study to indicate any significant public health problems presented by cattle grazing on open range similar, at least, to the sites and grazing rates included in these observations.

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THESIS: WASHINGTON STATE UNIVERSITY

Emergency Rehabilitation of Watersheds Denuded by Wildfire in the Ponderosa Pine and Douglasfir Zones of North-Central Washington, by William Lemley Stewart, MS, Range Management. 1973.

This study was conducted in the summers of 1970 and 1971 in the ponderosa pine and Douglasfir zone of north-central Washington. The objectives were to develop means of increasing success and reducing costs of wildfire rehabilitation projects by (1) evaluating several perennial grasses and legumes for adapting of use in emergency revegetation of burned-over watersheds, and (2) correlating several selected severity-of-burn criteria with natural recovery of vegetation.

Plots of three burn intensities were seeded and foliage production, root production, density, as well as weed invasion and composition were examined following one growing season.

Burn intensity criteria evaluated included (1) height of char on tree stems, (2) percentage tree leaf mortality, and (3) percentage of leaves consumed by burning on conifers. Lightly burned stands were those in which live trees remained following burning; moderate burns were those in which a maximum portion of the leaves were killed but not consumed; heavily burned stands were those in which a majority of the conifer leaves were consumed by fire. Species composition and percentage coverage as correlated with burn intensity criteria were studied for natural recovery following burning.

Significant differences were obtained for foliage production among seeded species and for species-burn intensity interaction from seeded plot data. All seeded species, in some degree, were found to be successful at all burning intensities.

Height of char and percentage leaf mortality were found to be reliable criteria for predicting natural recovery following burning in the Douglasfir zone. It appeared that natural recovery is limited where char heights were greater than 4 or 5 feet. Due to high ecologic variability, these burn intensity criteria did not prove as useful in the ponderosa pine zone.

A Research Program for and the Process of Building and Testing Grassland Ecosystem Models

G. M. VAN DYNE AND J. C. ANWAY

Highlight: *This paper reports on the organization and operation of the U.S. International Biological Program's Grassland Biome study. The study has involved in the past 8 years a large number of scientists from many disciplines working in an integrated and data-sharing mode. Field studies have been conducted on 11 western grassland sites to obtain data to drive and to validate mathematical simulation models and to provide cross-site comparative information. The models are based upon data from field studies, the literature, and rate process studies, often conducted in the laboratory. A multiple-flow, ecosystem level model called "ELM" which can be adapted to various sites by changing parameters is described. The types and sources of scientific outputs from the program are described.*

Historical Aspects

The work on which we are reporting has been part of the International Biological Program (IBP) of which the United States component was organized through the National Academy of Sciences (U.S. National Committee, 1974). The part of the IBP of main interest to us here was originally called the Analysis of Ecosystems (AOE) study. There are also several other large integrated research programs in the US/IBP. The pertinent global objectives and the specific objectives of the US/IBP and the AOE study are:

- to examine the biological basis of productivity in human welfare
- to study organic matter production on a world-wide basis
- to acquire information to develop and test ecological theory
- to develop a theory of usefulness to man
- to develop a theory of energy flow, nutrient cycling, trophic structure, spatial patterns, interspecies relations, and species diversity
- to further examine the ecosystem processes by which the above observed characteristics are achieved and maintained.

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Comments on the manuscript by Ron Sauer and Bill Hunt are appreciated.

Analysis of Ecosystems Studies

The original plans in this part of the US/IBP were to develop several large-scale, integrated, interdisciplinary research programs called "biome studies." These biomes were to include grasslands, deciduous forests, coniferous forests, tundra, desert, and tropical rain forests. Programs were developed in the first of these five areas. General discussions of examples of the aims, organization, and management of these large-scale programs in the U.S. and Canada are provided by Auerbach (1971), Coupland et al., (1969), Gessel (1972), Goodall (1972), and Van Dyne (1972, 1975).

Support for and Participants in the Grassland Biome Study

Our research has been supported primarily by the National Science Foundation with some inputs from the Atomic Energy Commission. We have also had cooperation from many state and federal experiment stations. The study has been an interdisciplinary, interinstitutional, integrated, basic ecosystem-oriented research program. Scientists from organizations in some 24 states have participated in the Grassland Biome field studies in 10 western states. We also have been cooperating with some 30 nations having IBP grassland projects. This paper is a general overview of progress and results, and we do not present detailed results of the work of the some 200 scientists (see Wright, 1971, and Hendricks, 1973) who have participated in the Grassland Biome study at various times in the last 6 years.

The general organizational structure during the main phases of the program divided the program into main experimental portions of (i) field validation studies, (ii) field and laboratory rate process studies, (iii) synthesis and integration efforts, and (iv) systems analysis and modelling (Fig. 1).

Grassland Biome Focus

Our original objectives included a series of broad questions which called for total-system research. No matter how narrow or detailed a single given subproject was, the relationship to the whole system was our dominant theme. A main mechanism for synthesizing our information into a whole was the use of mathematical models.

Our overall plans aimed at answering broad ecological questions. Analyses of these questions dictated early the need for detailed total system research. At the outset in 1968 it was clear that we would not be able to study all things about all

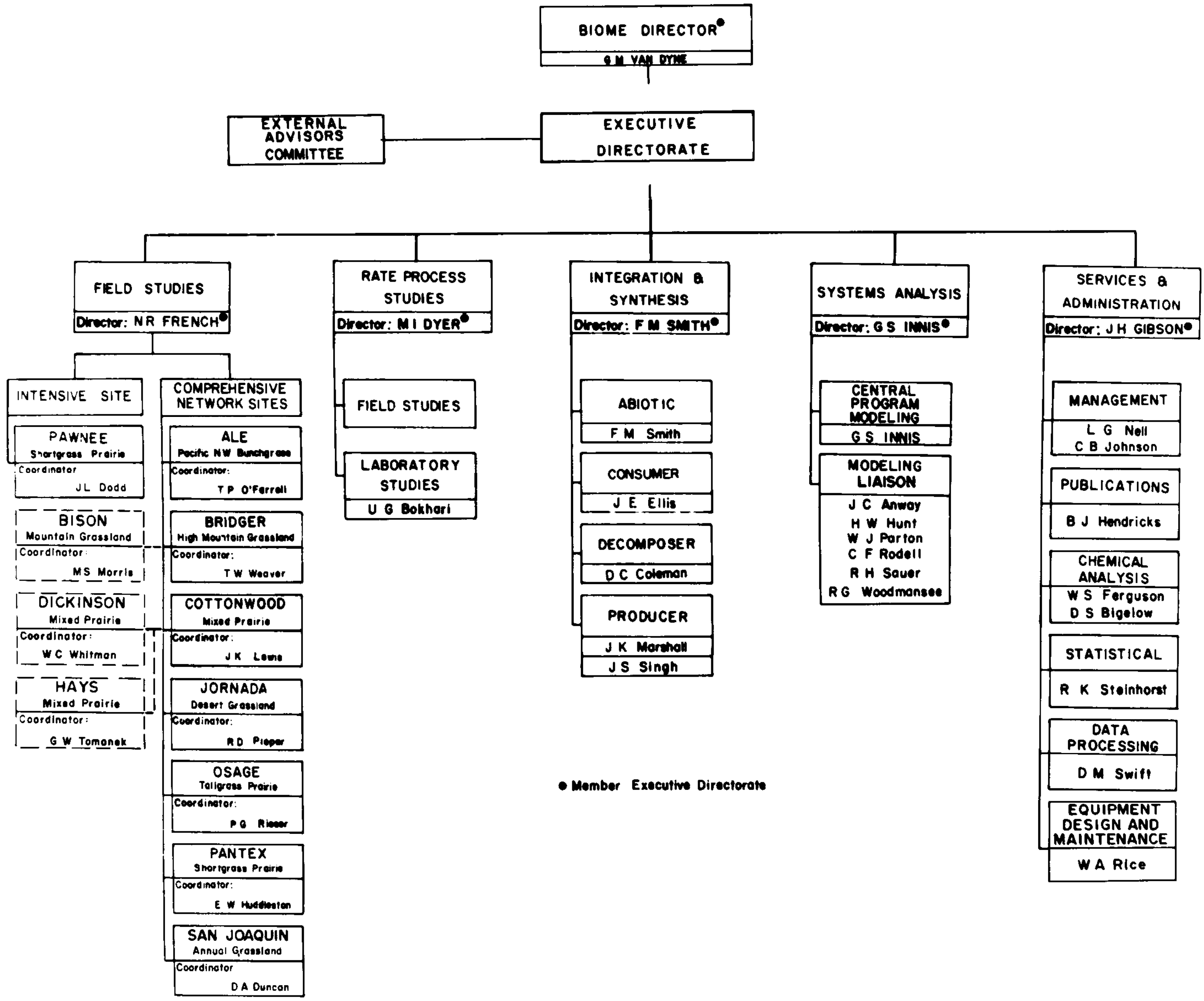

Fig. 1. *Organization chart for the US/IBP Grassland Biome study during its main operational phase. The program had two major data-generation areas (field validation studies and rate process studies) and two major areas of synthesis and analysis (integration and synthesis and systems analysis). There were six types of centralized research support groups under a services and administration area.*

grasslands. Our major effort was to study intraseasonal rather than interseasonal dynamics of grasslands. We put priorities, in order of decreasing importance, on biomass (carbon), energy, nitrogen, phosphorus, sulfur, and eventually other elements that move through the system. Our design has one intensive site (Pawnee) and a network of comprehensive sites (see Fig. 2).

To obtain simultaneous data sets on a comparable basis, we established a number of grassland study sites (Fig. 2). In addition, field data were obtained from other sites in rate process studies. On all sites except Dickinson, Bison, and Hays, we have collected at least 3 years of data. Several scientists have been involved in data collection on each of these sites. Table 1 places the sites into perspective by providing an overview of the grassland type, location, and coordinator.

A Systems View of Grasslands

We use a systems approach as a framework for integrating our knowledge about grasslands into dynamic simulation models of the ecosystem.

To characterize the systems we partitioned them into variables and constants. The variables were further divided into internal or external variables. The external or driving variables were variables "outside" the system which affect performance "inside" the system. Important external or driving variables included precipitation, solar energy input, wind, and temperature above the plant canopy, etc. Driving variables were considered "independent variables," that is independent of the central system under study.

Next we considered a series of internal or system state variables. These are the variables inside the system which change from time to time as a response to alterations in the driving variables or the condition of other internal variables. Examples include soil water levels, herbage biomass, and animal numbers. These are the dependent variables. In a flow diagram of the system the internal or system state variables are denoted as boxes. The boxes are connected with arrows, which represent the flows of matter or energy from part to part

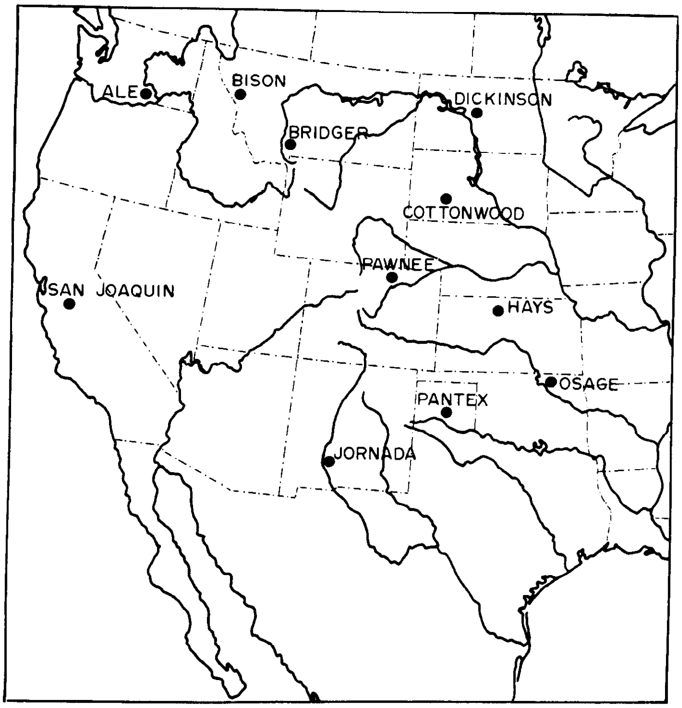

Fig. 2. *Locations of US/IBP Grassland Biome study sites: ALE, shrub-steppe; Bison and Bridger, mountain grasslands; Cottonwood, Dickinson, and Hays, mixed prairie; Jornada, desert grassland; Osage, tallgrass prairie; Pawnee and Pantex, shortgrass prairie; and San Joaquin, annual grassland.*

within the system. Each flow represents one or more rate processes within the natural system.

The items flowing in a flow diagram may be different things. They may be energy or matter; the matter may be water, carbon, nitrogen, numbers, dollars, etc.

The rate processes, i.e., the flows from one state variable to another, may be physically controlled or physiologically controlled. Examples of physical rate processes include infiltration and weathering. Examples of physiological rate processes include photosynthesis and metabolism. The rate processes causing input into a given state variable such as "live aboveground plant biomass," for example, would include photosynthesis and translocation up from the roots. The rate processes causing outputs from this compartment would include herbivory, weathering, trampling, translocation, and death. Each rate process can be affected by several variables. For example, photosynthesis is at various levels of resolution influenced by state variables such as leaf area, soil water, and others, and by driving variables such as solar radiation, temperature, and others.

In a mathematical description of a flow function for a given rate process, we need to use some constants or parameters. These are properties of the system that do not change during the time interval of simulation. One such constant might be the depth of the soil and the texture of the soil which we can measure in the field. Constants may also be applied to those processes whose mechanisms are unknown (e.g., nominal mortality rate) or whose level of resolution is more detailed than a system level model can reasonably encompass (e.g., a single activity factor for mammalian activity).

We also consider man to be a driving variable, or external force, in controlling certain flows to and from the system.

The system model is composed of a series of differential or difference equations which will show the change in the state variables as the functions of flows into and out of each compartment. In general, the equations in this system must each be a function directly or indirectly of the state variables, the driving variables, and time.

The Systems Process

Ecosystem simulation models are constructed largely from the results of process and literature studies and from accumulated experience. Experimental rate process studies provide data for the description of the physiological, physical, and ecological phenomena that account for transferring matter and energy within the ecosystem. These process studies may be conducted in the field or in the laboratory in a growth chamber, greenhouse, or metabolism apparatus. Such studies are designed to give the form of, and parameters values in, equations representing rate processes as the function of other variables.

Simultaneous measurements of the driving variables and state variables must be done in the field, as they cannot be obtained in the laboratory nor usually from the literature (see Table 1). The driving variable records are used as input to run or drive the models developed. The records of state variable response give us initial conditions needed to solve our difference or differential equation systems. State variable records also give results with which to compare model response.

Table 1. Sites, site characteristics, and coordinators for the US/IBP Grassland Biome study (Fig. 2).

Grassland type	Site name	Land ownership	Coordinator	Site description reference
Desert grassland	Jornada	Federal, ARS	R. D. Pieper	Herbel and Pieper 1970
Shortgrass prairie	Pawnee	Federal, ARS	D. A. Jameson J. L. Dodd	Jameson 1969
	Pantex	Federal, ERDA	E. W. Huddleston	Huddleston 1970
Mixed prairie	Cottonwood	State, South Dakota	J. K. Lewis	Lewis 1970
	Dickinson	State, North Dakota	W. C. Whitman	Whitman 1970
	Hays	State, Kansas	G. W. Tomanek G. K. Hulett	Tomanek 1970
Tallgrass prairie	Osage	Private	P. G. Risser	Risser 1970
Mountain grassland	Bridger	Federal, FS	D. D. Collins T. W. Weaver	Collins 1970
	Bison[1]	Federal, BSFW	M. S. Morris	Morris 1970
Shrub-steppe	ALE	Federal, ERDA	T. P. O'Farrell W. H. Rickard	Rickard and O'Farrell 1970
Annual grassland	San Joaquin	Federal, FS	D. A. Duncan	Duncan 1975

[1] Transitional between northwest bunchgrass and mountain grassland.

Models utilizing the data in this way predict the dynamics of the system's state variables. Models can be validated by comparing model output with the measurements made in the field. This comparison leads, in subsequent years, to both model modification and redesign of field and laboratory studies. We will give later some examples of output from our simulation models. We also note here that we use optimization models in our studies, but their description is beyond the scope of this paper (see, for example, Swartzman and Van Dyne, 1972, 1975).

Treatments and Testing Hypotheses

Conducting an intensive survey of an ecosystem even in great detail gains only a limited amount of information about interrelations of structure, function, and utilization. Hypotheses about interrelations of structure, function, and utilization can be developed from intensive surveys, and inclusion of experimental stress treatments allows testing of such hypotheses. In each major field study we included a minimum set of treatments or stresses on the system, and within each treatment we measured a selected set of abiotic, producer, consumer, and decomposer variables and a certain number of processes (Swift and Bokhari, 1972; Swift and French, 1972).

We selected for inclusion in our design what we considered would be the most important stresses in grasslands which we could accomplish within our expected financial and time framework. At each major field study site, we investigated replicated areas where there had been very limited or no grazing by large herbivores for many years (excellent or good condition ranges) vs intensive or heavy grazing by large herbivores (fair or poor condition ranges). Other stress treatments were included on certain sites, especially Pawnee. These included nitrogen fertilization, irrigation, herbicides, insecticides, and other levels of grazing intensity. Our models were developed to predict general responses to these kinds of stresses.

We have two replicates of each of the two treatments on any given site. Thus, data from that site may be analyzed independent of data from other sites. We also make comparisons of all treatments of all sites and all types. Having sites in each of seven types of grasslands provides us the opportunity to make statistically designed comparison of phenomena. We are further interested in fully interrelating or correlating these data with information in the literature.

Some Outputs from the Program

We cannot detail here many of the outputs from the program, but our sequential information flows generally as follows:

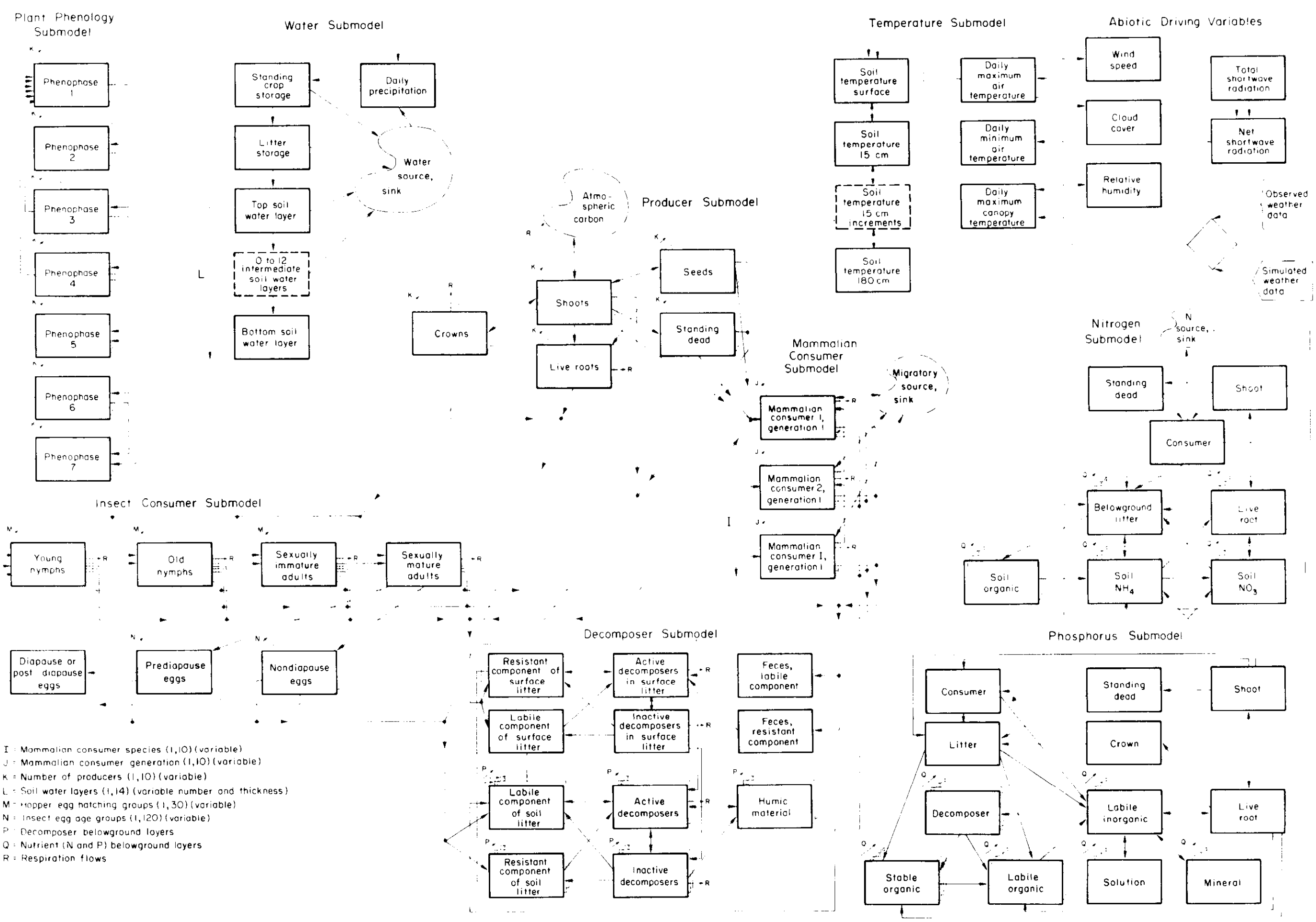

Fig. 3. *Flow diagram of an ecosystem level model for grasslands; controls on flows are omitted for clarity. The third dimension, or layers, in portions of the diagram represents different species or groups of plants and animals or layers in the soil profile. (See further description in the text.)*

(i) A periodic Newsletter listing talks, publications, and reports, and describing major programmatic activities.

(ii) More than 300 technical reports to date, which include the data and brief descriptions from individual subprojects. These reports may be obtained on loan from the library at Colorado State University; the call number is SB197/I5 Tech. Rep. No. , catalogued in the author and serial record as International Biological Programme, Grassland Biome, Technical Reports.

(iii) More than 100 theses and dissertations in the many institutions involved in this study to date.

(iv) More than 160 preprints of selected papers submitted for journal publication, for internal distribution only.

(v) More than 300 publications to date.

(vi) About 10 monographic type papers, across sites or across trophic levels, synthesizing results planned or in development.

(vii) We have also produced three summary volumes to date (Dix and Beidleman, 1969, 1970; Coupland and Van Dyne, 1970; French, 1971), and now we are preparing synthesis volumes on each of the seven grasslands types we have studied. In each of these volumes, we include the condensed data and information we have learned about the driving variables, state variables, rate processes, and models for that particular type of grassland. We also integrate and interrelate this information to that available in the literature. We also plan a synthesis volume on our overall cross-type, total-system comparisons.

(viii) We also produce periodically major progress reports, which include a list of technical reports, preprints, theses and dissertations, talks, and publications from the program. Progress reports and continuation proposals are available on loan from the library at Colorado State University; the call numbers are SB197/V35, SB197/V352, and SB197/V353, catalogued in the author records as George M. Van Dyne and in the title record as "Analysis of Structure, Function, and Utilization of Grassland Ecosystems." A partial listing of publications, investigators, and summary of results is available in U.S. National Committee (1974).

Ecosystem Level Model: ELM

We have developed more than 50 models of grassland systems and major subsystems. But our substantial effort has been toward a multiple-flow, ecosystem-level model which can be adapted to various sites primarily by changing parameter values. An overall diagram of our main ecosystem level model shows some of the complexity of the system (Fig. 3). The model, for all its complexity, is still very much simplified. The model was built to address the effect on net or gross primary production of influences such as type and level of herbivory, soil water, temperature, and added nitrogen and phosphorus. ELM is considered a total system model as the abiotic, producer, consumer, decomposer, and nutrient components are all represented: (i) The abiotic submodel simulates the abiotic variables by a water flow submodel and a heat flow submodel which are stratified through the air, vegetation canopy, and soil profile (upper center, Fig. 3). (ii) The producer submodel considers carbon and phenological dynamics of both aboveground and belowground parts of a variable number of primary producers (center and upper left, Fig. 3). (iii) The decomposer submodel calculates the decomposition rates and microbe biomass in litter and dead material both above and below ground (lower center, Fig. 3). (iv) In the mammalian consumer submodel and the grasshopper submodel we simulate organismal, intrapopulation, and interpopulation dynamics of consumers (center and lower left, (Fig. 3). (v-vi) The nitrogen and phosphorus submodels simulate nutrient flow through the system (lower right, Fig. 3).

Each submodel interacts with the other six submodels to give the total model. An early version of the model has been described in detail (Anway et al., 1972) and simplified descriptions are given by Innis (1972, 1975). A preliminary mammal submodel was reported by Anway (1973) and the producer submodel by Sauer (1973). The model is being adapted for various types of grasslands, but the example graphs of model output that follow all are for shortgrass prairie on the Pawnee Site. This version of the model is described in detail in papers submitted for publication.[1]

Abiotic Submodel

A part of the abiotic submodel which simulates flow of water through the vegetation canopy and the soil layers is structured to include the important feedback mechanism between the biotic and abiotic state variables. The allocation of rainfall and the evaporation of water are the important processes considered. Daily rainfall, relative humidity, cloud cover, wind speed, and maximum and minimum air temperatures are used as driving variables.

Producer Submodel

Carbon and phenological dynamics of the primary producers are simulated for up to 10 species or groups concurrently. The producers can be changed as a model is adapted to different grassland sites. The dynamics of the following state variables are simulated for each species or group: live shoots, standing dead shoots, live roots, seeds, and crowns. In addition, litter and dead root variables are simulated for all producer species combined. The processes simulated are gross photosynthesis, shoot respiration, shoot to crown translocation, shoot to root translocation, shoot death, crown death, root respiration, root death, seed growth, seed germination, and the fall of standing dead to litter.

The phenology submodel simulates qualitative information and is used to regulate seasonal activity of the producer species. Seven phenological stages are considered, from winter dormancy and early vegetative growth through flowering and fruiting and then through senescence. The progression of

[1] Manuscripts submitted to *Ecological Monographs* for consideration for joint publication:

- Anway, J. C. A canonical mammalian model. 82 ms. p.
- Cole, C. V., G. S. Innis, and J. W. B. Stewart. Simulation of phosphorus cycling in semiarid grasslands. 61 ms. p.
- Hunt, H. W. A simulation model for decomposition in grasslands. 62 ms. p.
- Innis, G. S. Behavior and response of ELM: A simulation model for grasslands. 51 ms. p.
- Innis, G. S. Rationale and procedures for building a simulation model for grasslands. 18 ms. p.
- Innis, G. S., and J. D. Gustafson. Compartmental-flow/event-oriented simulation language: SIMCOMP 3.0. 24 ms. p.
- Parton, W. J. Abiotic section of the ELM grassland system model. 51 ms. p.
- Reuss, J. O., and G. S. Innis. A grassland nitrogen flow simulation model. 41 ms. p.
- Rodell, C. F. A grasshopper model for a grassland ecosystem. 73 ms. p.
- Sauer, R. H. A simulation model for grassland primary producer phenology and biomass dynamics. 97 ms. p.
- Steinhorst, R. K., H. W. Hunt, and G. S. Innis. Sensitivity analyses of the ELM model. 44 ms. p.
- Woodmansee, R. G. Critique and analysis of the grassland ecosystem model ELM 73. 52 ms. p.

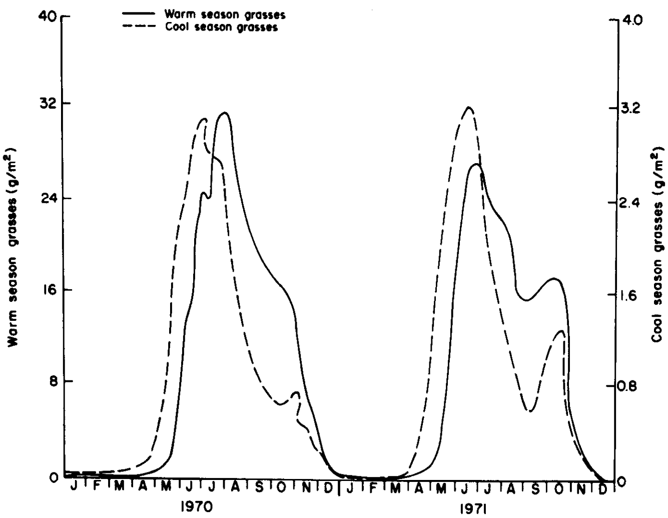

Fig. 4. *Comparison of 2-year dynamics of live aboveground biomass of carbon in warm-season and cool-season grasses. Note that warm-season grasses reach peak standing crops of about 30 $g \cdot m^{-2}$, whereas cool-season grasses reach peak standing crops of about 3 $g \cdot m^{-2}$.*

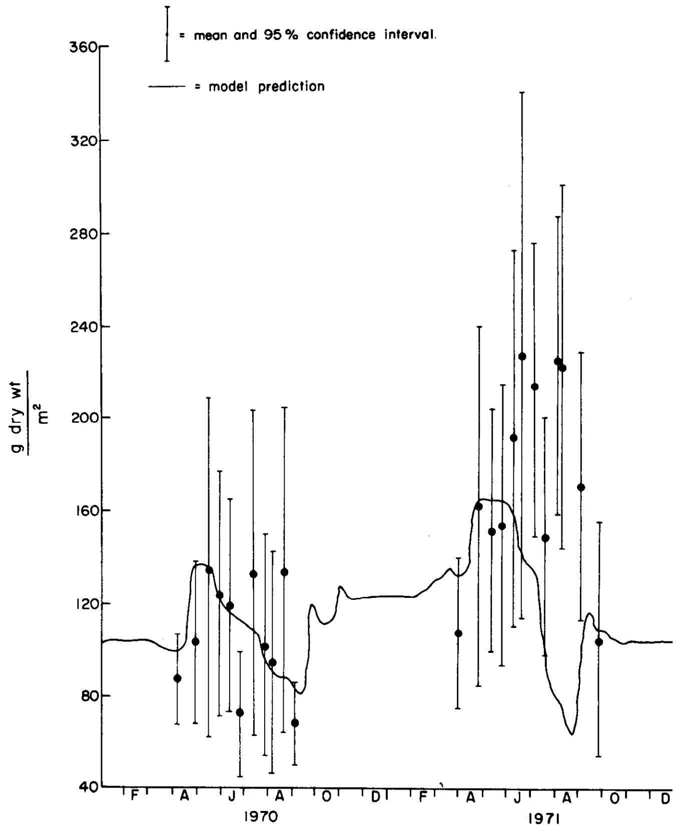

Fig. 5. *Aboveground litter dynamics for a 2-year simulation with mean field values and confidence intervals at each sampling date.*

phenophases is regulated by maximum air temperature, insolation, soil water potential, and soil temperature. The biomass of the model species may be distributed or proportioned through several phenophases simultaneously.

An example of the dynamics of warm-season grass and cool-season grass live aboveground vegetation is shown (Fig. 4). Differences in climatic conditions between years cause the differences in the standing crop dynamics. The cool-season grasses grow earlier in the year and reach their peak standing crop (live + dead) at an earlier date than do the warm-season grasses. The cool-season grasses show relatively more response to favorable growing conditions in the fall of each year.

An example of the dynamics of the litter compartments is shown (Fig. 5) and compared to the 95% confidence limits based on field sampling for the same treatment. Note that biomass of litter greatly exceeds combined biomass of standing live herbage of grasses (compare Figs. 4 and 5) and that there is a high plot-to-plot variability in the litter as denoted by the large confidence intervals on field measurements.

Consumer Submodels

The mammalian submodel considers relationships and functions which are common to all mammalian consumer types. Submodels for mammals, insects, nematodes, and birds have been developed, but as of this writing only mammals and insects are incorporated in ELM. The assumption is mammal consumers affect grasslands primarily through food intake and animal products. The principal control on these processes is metabolism or energy balance, which is influenced in turn by air temperature, animal weight, wastes, activity, reproductive state, population density, animal phenology, hunger, potential intake amount, food availability or accessibility, preference, and digestibility of foods.

Figure 6 shows an example of a prediction of a consumer variable. Cattle weight (not weight gain) expressed in kilograms of carbon per head is shown for a heavy grazing treatment on a shortgrass prairie in 1970.

The objectives of the grasshopper submodel are to consider what effect grasshoppers have on the functioning of the total system and to use the model as a means for estimating the energy flow via grasshoppers through the ecosystem. Daily air temperature and moisture conditions are important factors and have a direct influence on the flows involving forage intake, litter production, and life cycle phenomena (hatching, development, sexual maturation, egg laying, and mortality). The close agreement of model prediction and field data for grasshopper biomass dynamics over time is shown in Figure 7.

Food selection in the various consumer submodels is a function of several factors. The food categories utilized are determined by the characteristics of the consumer being modelled. The quantity chosen from any of 1 to 15 food

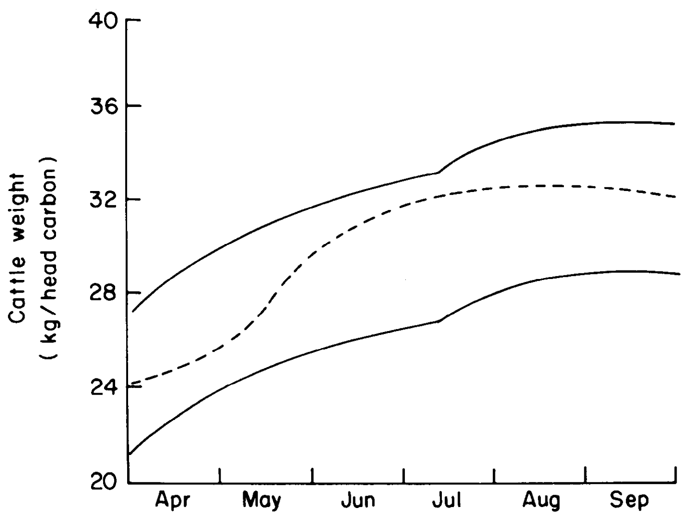

Fig. 6. *Cattle weight dynamics under heavy grazing conditions for 1970. The solid lines represent 95% confidence limits on field data. The dashed line is the model prediction.*

Table 2. Bimonthly averages of percentage intake by food category for the grasshopper mouse, *Onychomys*. D column = May 1969 to April 1970 data (Flake 1973). M column = model results (in italics).

Food categories	Jan.-Feb.		March-April		May-June		July-Aug.		Sept.-Oct.		Nov.-Dec.	
	D	M	D	M	D	M	D	M	D	M	D	M
Warm-season grasses	4	*3*	2	*1*	3	*6*	7	*12*	7	*4*	4	*13*
Cool-season grasses	6	*2*	7	*2*	1	*6*	1	*1*	1	*2*	4	*6*
Forbs	9	*3*	3	*1*	6	*6*	7	*8*	7	*6*	8	*13*
Seeds	25	*24*	15	*15*	3	*0*	4	*7*	12	*12*	16	*45*
Spiders	3	*3*	3	*2*	3	*1*	3	*1*	3	*1*	4	*1*
Leafhoppers	6	*3*	6	*4*	0	*2*	0	*2*	1	*1*	1	*1*
Lepidoptera larvae	4	*5*	14	*16*	18	*15*	1	*9*	2	*6*	1	*1*
Coleoptera	30	*28*	27	*19*	54	*44*	56	*40*	40	*39*	38	*5*
Grasshoppers	12	*29*	23	*40*	12	*20*	21	*20*	27	*29*	23	*15*

categories is influenced by amount of food available, food maturity, consumers' physiological status, and climatic conditions.

Table 2 gives an example of prediction of food intake composition. Data are given there for model and field sampling. There is reasonable agreement between predicted percentage composition and actual composition of the diet in most instances.

Decomposer Submodel

The decomposer submodel is designed to simulate at various soil depths the dynamics of belowground litter, dead roots, and decomposer biomass, which have varying proportions of a rapidly and a slowly decomposing component. Decomposition rates are influenced by temperature, water tension, and the concentration of the inorganic nitrogen. The decomposer biomass states are "active" and "inactive." During periods of activity, substrate is assimilated and the respiration rate is high. Decomposers are susceptible to death by freezing, drying, and starvation.

Decomposer biomass is plotted in Figure 8 for four different depths. Note the lower biomass values at the deepest layer and the lesser seasonal fluctuations in biomass at that depth. Belowground, the decomposers feed on roots and other organic material depicted in the model as belowground litter.

It is not easy to measure microbial biomass directly in the field, but a main byproduct of microbial activity, CO_2, can be measured. Observed and predicted CO_2 evolution for the 1972 growing season are given in Figure 9. In most instances validation data for the model are provided by measuring standing crops of state variables in the field (e.g., see Fig. 5),

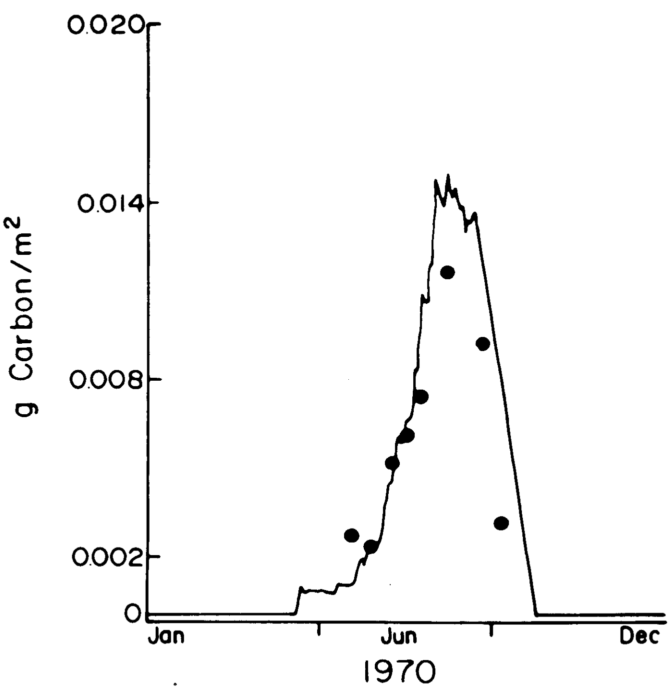

Fig. 7. *Grasshopper biomass dynamics with model prediction (curve) and field data (points).*

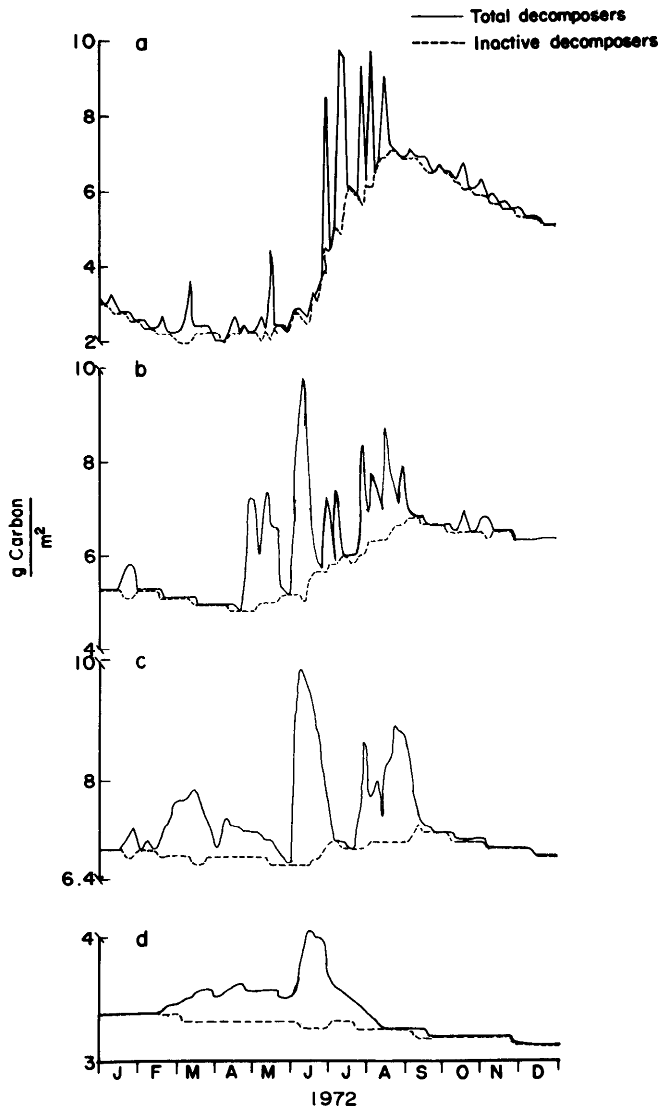

Fig. 8. *Decomposer biomass dynamics predicted by the model for four different soil depths a = surface, b = 0 to 4 cm, c = 4 to 15 cm, and d = 15 to 75 cm.*

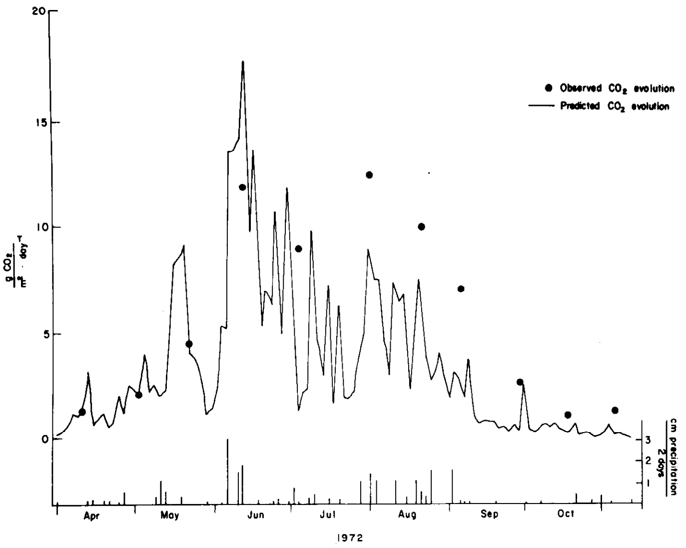

Fig. 9. *Model predictions and field measurements of CO_2 flux from the soil, measured in grams CO_2 per square meter per day, for the 1972 growing season. Precipitation values are also plotted at the bottom of the graph.*

but it is also possible to measure for validation purposes a flux rate (e.g., see Fig. 9).

Nitrogen and Phosphorus Submodels

The nitrogen submodel incorporates eight major kinds of state variables of which five major belowground compartments are further divided into four subcompartments representing four depth layers. The depths represented by these subcompartments may be varied according to the characteristics of the site being considered. All nitrogen flows are described as a function of one or more of the following: time, soil temperature, soil water, daily growth, death or decomposition, and nitrogen or phosphorus content. Nitrogen concentrations for each biotic compartment are internally calculated, and can be used as control parameters by the respective biotic submodel. Example nitrogen model output is shown in Figure 10. Seasonal variability for amounts of nitrogen in shoots is greater than that in roots. Nitrogen in

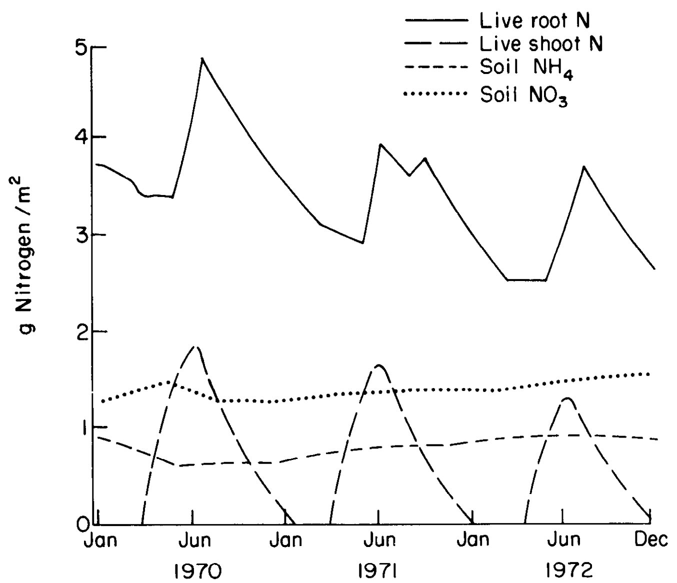

Fig. 10. *Example dynamics of four nitrogen compartments over a 3-year simulation run.*

plants is more variable over time than in soil.

The phosphorus submodel incorporates 12 major state variables. The seven major belowground compartments are divided into three depth layers. The variables in the phosphorus submodel have dynamics similar to the equivalent variables in the nitrogen submodel.

Current Status—Grassland Ecosystem Models

The complexity and size of the ELM model may be illustrated in a number of ways. The flow diagram (Fig. 3) is a simplified picture of the approximately 180 state variables, 400 flows, and 500 parameters actually incorporated in the model. Simulations may be run from 1-day to 5-year time-spans, with a two-year simulation with a 2-day time step requiring approximately 7 minutes of machine time (compiling and running but not input-output time) on a CDC 6400. At the present time the model has about 20 man years of effort in its implementation and reporting. This does not include development of earlier models which provided a starting point.

The utility of ELM will be affected by completion of work in progress and in the future. Work in progress includes adaptations to several grassland sites; results of runs of these adaptations will be incorporated in the synthesis volumes of these grassland types. Contributions to the scientific literature will require considerable time for full evaluation. Considerable guidance to research has already been provided by these modelling efforts within the Grassland Biome study. The modelling process detected many areas of research needed for improving our comprehension of North American grasslands.

Retrospect and Prospect

Our experiments, based on hypotheses derived from ecological theory and resource management experience, result in data which are analyzed by either experimental design models or least squares prediction models. We have used various statistical models to derive parameters and equations to be used subsequently to structure either simulation models or optimization models. These equations may be either individual equations which are part of a total model, or they may be part of a single equation in the total model. Eventually we will need to combine simulation and optimization models into resource system management models. There is feedback to ecological theory and to resource management from the development and running of both systems simulation and optimization models. Large, interdisciplinary research programs, such as the Grassland Biome study, should result in the development of new, improved, or more quantitative ecological theory, and eventually better resource management. Early programmatic synthetic output already is being used in development of environmental impact statements. Overall, this long-term study has had three phases: "feasibility, respectability, and utility." We are convinced we have demonstrated the feasibility of doing this kind of research and producing a large amount of data. We are now in the process of demonstrating the respectability of the data and the models. We have yet to make full utilization of our results. The IBP terminated July 1974 as a formal program, but we hope to have through 1976 to finalize field and laboratory studies and to publish and reflect upon our results.

The final story of the IBP is not written, but in our opinion the overall results are positive. The US/IBP Grassland Biome study, and other national and international programs like it, have produced useful scientific information, perhaps almost too much of it. There is now a major job in condensing it and making it available to the scientific and resource management community. It will take time and a group of unbiased individuals at the national or international levels knowledgeable about these programs to make the final judgments and interpretation of our results.

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Growth and Tillering of Sand Bluestem as Affected by Exogenous Growth Regulators

J. STUBBENDIECK AND WAYNE G. McCULLY

Highlight: *Two plant growth regulators that were reported to inhibit auxin transport were exogenously applied to sand bluestem seedlings. DPX-1840 and Ethrel were shown to change tillering patterns, dry matter production, and plant form. When applied at relatively low concentrations, tillering was accelerated. Larger numbers of tillers developed on plants treated at the three-leaf stage as compared with those treated at the six-leaf stage. Exogenously applied plant growth regulators often reduced tiller length, plant height, and dry matter production. DPX-1840 caused plants to have an open or spreading appearance. In addition, laminas often remained rolled and were chlorotic.*

Establishment is the most critical period in the life cycle of seeded range grasses. Environmental conditions favorable for seedling establishment may be present for only a limited time. If tillering was stimulated during favorable environmental conditions, the total number of established seedlings could be increased. No current agronomic practices exist which will satisfactorily increase tillering of grass seedlings.

In recent years, the chemical control of crop growth and development has been researched and many chemicals have been screened for possible effects on plant growth and development. However, little attention has been given to the physiological effects of these chemicals on growth and tillering of range grasses. Some researchers theorized that auxins directly inhibit the growth of lateral buds, or indirectly inhibit the growth of lateral buds by the production of some inhibitory compound (Thimann and Skoog, 1933; Elliasson, 1961). The inhibitor of lateral bud elongation is considered to be an auxin (Audus, 1963).

It was the authors' opinion that the rate of tillering in range grasses could be increased if the auxin's action was destroyed, or its transport was inhibited. This would reduce the amount of time required for seedling establishment and increase the productivity. A pilot study had shown that DPX-1840 [3,3a-dihydro-2-(pmethoxyphenyl)-8H-pyrazolo-(5,1-a) isoindol-8-one] and Ethrel (technical product consists of 47% 2-chloroethane phosphonic acid, 13% 2-chloroethane phosphonic acid anhydride, and 37% mono-2-chloroethyl ester of 2-chloroethane phosphonic acid) increased the rate of tillering of sand bluestem seedlings. Both DPX-1840 and Ethrel are considered to be auxin transport inhibitors (Anonymous, 1971; Beyer, 1972; Morgan and Durham, 1972; Morgan, 1972). Ethrel has been applied to corn to successfully increase tillering (Earley and Slife, 1969). DPX-1840 is a newer chemical, and its effect on tillering of grasses had not been determined. The purpose of this study was to determine the effects of exogenously applied DPX-1840 and Ethrel on the growth and development of sand bluestem [*Andropogon hallii* (Hack.) Hack. ex Vasey] seedlings.

Materials and Methods

Four hundred and eighty plastic pots 12 cm square were filled with a mixture of Axtell sandy loam and washed sand. Ten caryopses of G-1773[1] sand bluestem were planted at a depth of 1 cm in each pot in a greenhouse. Temperatures varied from 30 to 36°C, and the photoperiod was maintained at 13 hours. After 2 weeks, the seedlings were thinned to three in each pot. Fifteen-day-old seedlings (three-leaf stage) were divided into two groups. Each group of 240 pots was randomly separated into four treatment replications of 60 pots and arranged in a randomized complete block design. The initial group was treated with growth regulators, and a second group was treated at the six-leaf stage, 30 days after planting.

Each chemical was applied at 0.010, 0.025, 0.050, 0.100, and 0.150 M concentrations in a solution of distilled water, with 0.5% Tween 20 (polyoxyethylene sorbitan mondaurate) added as a surfactant. A 0.1-ml volume was applied to each plant using an artist's brush. The control plants received an application of distilled water and 0.5% Tween 20.

Measurements were started 30 days after treatment and were made at 15-day intervals. Measurements included numbers of living plants, plant height, numbers of tillers, and tiller length. The plants were washed from the soil 75 days after planting. Roots and shoots were separated, oven dried, and weighed.

In a separate experiment, different sets of sand bluestem plants were treated at the early heading stage with several concentrations of Ethrel or DPX-1840. These plants were not harvested, but changes in plant form were observed and photographically recorded for 60 days.

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[1] Plant materials collected for potential drought resistance in a cooperative program with New Crops Branch, Crops Research Division, Agricultural Research Service.

Table 1. Average number of tillers per sand bluestem seedling after treatment at the three and six-leaf stages with several concentration of Ethrel or DPX-1840.

Growth regulator	Molar concentration	Days after treatment: Three-leaf stage 30	45	60	Six-leaf stage 30	45
Control	0.000	0.00 d[1]	0.50 bc	2.54 bcd	0.78 d	2.63 ab
Ethrel	0.010	0.03 d	0.30 c	1.26 cde	2.58 a	3.07 ab
Ethrel	0.025	0.25 cd	0.24 c	2.28 bcde	2.28 ab	2.98 ab
Ethrel	0.050	0.28 cd	0.39 c	2.20 bcde	2.23 ab	3.07 ab
Ethrel	0.100	0.36 c	0.22 c	0.94 de	1.55 bc	2.32 b
Ethrel	0.150	0.33 c	0.25 c	0.35 e	1.45 cd	3.24 ab
DPX-1840	0.010	0.80 b	1.08 a	2.70 bcd	2.25 ab	3.40 a
DPX-1840	0.025	1.11 a	1.05 a	5.15 a	1.33 cd	3.79 a
DPX-1840	0.050	0.83 ab	0.85 ab	3.17 b	1.40 cd	3.36 a
DPX-1840	0.100	0.94 ab	0.74 ab	2.79 bcd	1.65 bc	3.38 a
DPX-1840	0.150	0.86 ab	0.77 ab	2.87 bcd	1.60 bc	3.85 a

[1] Means in individual columns followed by different letters are significantly different at the 0.05 level of probability.

Results and Discussion

Numbers of Tillers

Average numbers of tillers per sand bluestem plant treated at the three-leaf stage and evaluated 30 days later were significantly increased by the two highest rates of Ethrel (Table 1). At that time no tillers were present on control plants. Tillers were found on all Ethrel-treated plants. Most concentrations of Ethrel inhibited tillering 45 and 60 days after treatment at the three-leaf stage. The 0.025 and 0.050 concentrations produced the largest numbers of tillers after 60 days from plants treated with Ethrel.

Tillering response to Ethrel differed when plants were treated at the six-leaf stage (Table 1). After 30 days, all except those plants treated with 0.150 M Ethrel produced significantly greater numbers of tillers than the control. However, 45 days following treatment at the six-leaf stage, none of the Ethrel treatments produced greater numbers of tillers than the control.

All concentrations of DPX-1840 significantly increased number of tillers on sand bluestem plants 30 days after treatment at the three-leaf stage (Table 1). Greatest increases in tiller numbers were obtained from the 0.025 M concentration. Forty-five days after treatment at the three-leaf stage, average numbers of tillers were greatest on plants treated with 0.010 and 0.025 M DPX-1840. The 0.050, 0.100, and 0.150 M concentrations of DPX-1840 did not produce higher numbers of tillers than the control, but tiller numbers were greater than those of any Ethrel treatment. Sixty days after treatment at the three-leaf stage, average numbers of tillers on plants treated with 0.025 M DPX-1840 were greater than under other treatments (Table 1 and Fig. 1).

Tillering response to DPX-1840 also differed when plants were treated at the six-leaf stage (Table 1). After 30 days, treatments with 0.025 and 0.050 M DPX-1840 inhibited tiller production. Forty-five days following treatment at the six-leaf stage, no DPX-1840 treatments produced greater numbers of tillers than the control. Numbers of tillers in DPX-1840 treatments were generally higher than in Ethrel treatments. This was the reverse of the relationship existing 15 days earlier.

Tiller Length

Average tiller length of control plants was highest 60 days after treatment at the three-leaf stage. Both growth regulators

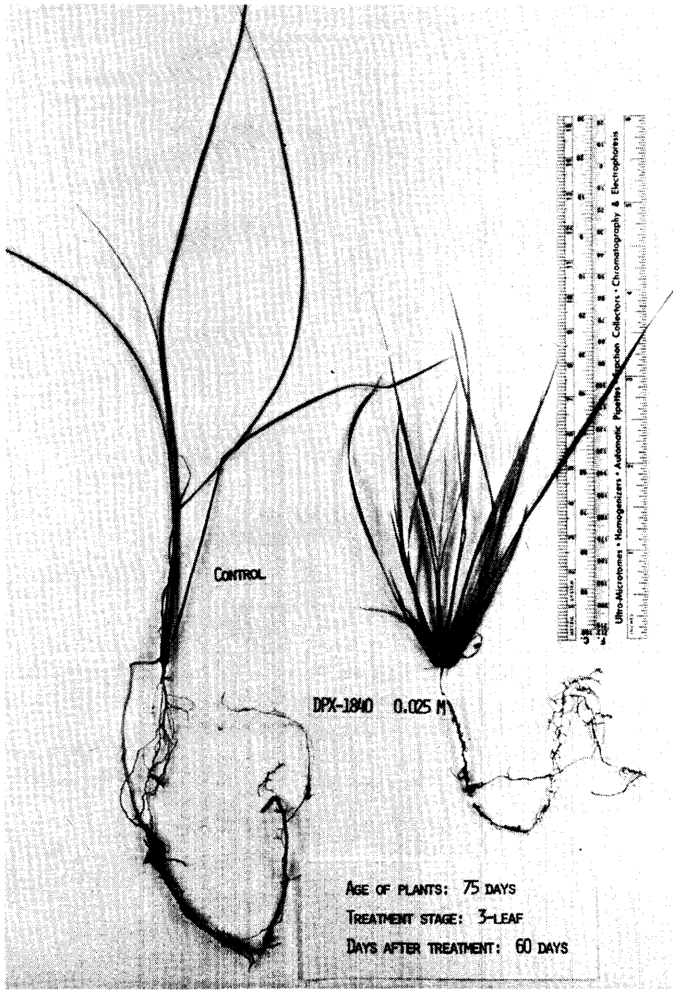

Fig. 1. *Comparison of a G-1773 sand bluestem control plant and one treated with 0.025 M DPX-1840 at the three-leaf stage.*

decreased tiller length (Table 2). Average tiller length on control plants was longest 30 days after treatment at the six-leaf stage. These tillers remained the longest for an additional 15 days, although these lengths were not significantly different from the plants treated with 0.025 and 0.100 M DPX-1840. Shortest tillers occurred on plants treated with highest concentrations of Ethrel.

Table 2. Average length (cm) of tillers per sand bluestem seedling after treatment at the three and six-leaf stages with several concentrations of Ethrel or DPX-1840.

Growth regulator	Molar concentration	Days after treatment: Three-leaf stage 30	45	60	Six-leaf stage 30	45
Control	0.000	0.00 c[1]	8.12 ab	17.83 a	7.85 a	12.30 a
Ethrel	0.010	4.25 abc	9.75 a	13.35 ab	5.68 ab	8.93 b
Ethrel	0.025	7.25 a	4.17 ab	11.05 bc	4.50 b	8.20 bc
Ethrel	0.050	3.38 abc	7.10 ab	8.97 bcd	4.05 b	5.66 c
Ethrel	0.100	2.21 bc	2.42 b	5.91 cd	3.43 b	4.37 c
Ethrel	0.150	1.75 bc	2.34 b	3.28 d	5.65 ab	4.25 c
DPX-1840	0.010	6.30 ab	7.20 ab	11.02 bc	4.55 b	8.63 bc
DPX-1840	0.025	7.27 a	5.72 ab	9.55 bcd	5.18 ab	9.93 ab
DPX-1840	0.050	5.64 ab	3.29 ab	8.21 bcd	4.60 b	7.86 bc
DPX-1840	0.100	5.21 ab	4.26 ab	8.38 bcd	4.33 b	9.62 ab
DPX-1840	0.150	4.65 abc	5.40 ab	7.41 bcd	4.00 b	8.65 bc

[1] Means in individual columns followed by different letters are significantly different at the 0.05 level of probability.

Table 3. Average extended leaf height (cm) of sand bluestem seedlings after treatment at the three and six-leaf stages with several concentrations of Ethrel or DPX-1840.

Growth regulator	Molar concentration	Days after treatment: Three-leaf stage 30	45	60	Six-leaf stage 30	45
Control	0.000	13.48 a[1]	25.33 a	38.34 a	30.40 a	44.74 a
Ethrel	0.010	12.35 a	15.55 b	38.63 a	29.32 a	29.74 c
Ethrel	0.025	7.73 b	10.10 c	27.45 abc	30.88 a	29.00 c
Ethrel	0.050	6.30 bc	7.90 cd	24.40 abcd	27.15 ab	29.50 c
Ethrel	0.100	4.00 c	2.83 e	29.38 ab	23.53 b	29.82 c
Ethrel	0.150	4.18 c	2.85 e	9.50 d	23.88 b	33.41 bc
DPX-1840	0.010	9.15 b	8.93 cd	19.80 bcd	31.18 a	34.42 bc
DPX-1840	0.025	8.73 b	7.73 cd	16.32 bcd	28.40 ab	37.26 b
DPX-1840	0.050	6.98 bc	6.38 d	14.33 bcd	32.43 a	30.79 bc
DPX-1840	0.100	6.85 bc	5.88 de	12.35 cd	30.03 a	31.29 bc
DPX-1840	0.150	6.63 bc	6.23 d	14.08 bcd	28.08 ab	33.48 bc

[1] Means in individual columns followed by different letters are significantly different at the 0.05 level of probability.

Plant Height

Control plants and those treated with the lowest concentration of Ethrel, at the three-leaf stage, were taller than other plants 30 days after treatment (Table 3). Plants treated with 0.100 and 0.150 M Ethrel were shortest, and no differences occurred among other treatments. After 45 days, control plants were taller than plants treated with Ethrel. Sixty days after treatment at the three-leaf stage, no differences in plant height occurred between control plants and those treated with the four lowest rates of Ethrel. Shortest plants were those treated with 0.150 M Ethrel.

Thirty days after treatment at the 6-leaf stage, plants with the two highest concentrations of Ethrel were shorter than the control plants (Table 3). Relatively small increases in plant height were recorded for most Ethrel-treated plants after an additional 15 days; however, the height of control plants continued to increase. The control plants were taller, after 45 days, than plants treated with Ethrel at the six-leaf stage.

Height increases were inhibited in plants treated with DPX-1840 at the three-leaf stage (Table 3 and Fig. 1). After 30, 45, and 60 days, control plants were taller than plants treated with concentrations of DPX-1840. Thirty days after treatment at the six-leaf stage, no differences in plant height occurred between control plants and those treated with DPX-1840. After 45 days, height inhibition among DPX-1840-treated plants was evident.

Stage of development at the time of treatment had an effect on the response of sand bluestem plants. Generally, plants treated with DPX-1840 at the six-leaf stage were taller than those treated with Ethrel (Table 3). This was the reverse of the response obtained by treating plants at the three-leaf stage.

To overcome apical dominance, plant growth regulators must inactivate auxin or interrupt auxin transport (Audus, 1963; Holden, 1969). Inhibition of plant height may result. The quantity of photosynthates produced in young plants is often limiting (Salisbury and Ross, 1969). It may be postulated that photosynthates were being used for production of additional tillers on treated plants rather than for the elongation of existing tillers.

Plant Production

Plants treated at the three-leaf stage were harvested 60 days after treatment, or 75 days after planting. Dry matter production was variable. Root production was significantly higher for plants treated with 0.010 M Ethrel than for any other chemical treatment, although it was not significantly different than the control (Table 4). Plants treated with Ethrel at 0.025 and 0.050 M concentrations produced roots that were heavier than those treated with 0.100 and 0.150 M Ethrel.

Table 4. Average total production (mg/plant) of sand bluestem seedlings 60 days after treatment at the three-leaf stage with the growth regulators Ethrel or DPX-1840.

Growth regulator	Molar concentration	Roots	Shoots	Total
Control	0.000	73 ab[1]	87 a	160 ab
Ethrel	0.010	83 a	110 a	193 a
Ethrel	0.025	52 b	76 ab	128 abc
Ethrel	0.050	52 b	70 ab	122 abc
Ethrel	0.100	18 c	35 bc	53 bc
Ethrel	0.150	9 c	20 c	29 c
DPX-1840	0.010	9 c	65 abc	74 abc
DPX-1840	0.025	15 c	74 ab	89 abc
DPX-1840	0.050	8 c	28 bc	36 c
DPX-1840	0.100	5 c	29 bc	34 c
DPX-1840	0.150	7 c	31 bc	38 c

[1] Means in each column followed by different letters were significantly different at the 0.05 level of probability.

Shoot production was also highest on plants treated with 0.010 M Ethrel at the three-leaf stage (Table 4). No differences in shoot production occurred between control plants and those treated with the three lowest concentrations of Ethrel. The concentration of Ethrel applied was inversely related to shoot production.

Plants treated at the six-leaf stage were harvested 45 days after treatment, which also was 75 days after planting. Not as much variation existed among the six-leaf as in the three-leaf treatments. Root production was higher for the control than for any of the chemical treatments (Table 5). Highest shoot production was from plants treated with 0.010 M Ethrel. Due mainly to greater root production, total production from control plants was highest, although it was not different from plants treated with the two lowest concentrations of Ethrel. The two highest concentrations of Ethrel produced the smallest amounts of total dry matter.

Root production decreased after DPX-1840 was applied at either the three or six-leaf stage (Table 4 and 5). Root production was reduced more than shoot production. The lowest concentrations of DPX-1840 applied at the three-leaf stage did not reduce shoot production. None of the

Table 5. Average total production (mg/plant) of sand bluestem seedlings 45 days after treatment at the six-leaf stage with the growth regulators Ethrel or DPX-1840.

Growth regulator	Molar concentration	Roots	Shoots	Total
Control	0.000	74 a[1]	106 ab	180 a
Ethrel	0.010	35 b	133 a	168 a
Ethrel	0.025	39 b	107 ab	146 abcd
Ethrel	0.050	32 b	98 ab	130 bcde
Ethrel	0.100	23 b	93 ab	116 de
Ethrel	0.150	30 b	78 b	108 e
DPX-1840	0.010	39 b	108 ab	147 abcd
DPX-1840	0.025	42 b	134 a	176 a
DPX-1840	0.050	34 b	121 ab	155 abc
DPX-1840	0.100	25 b	100 ab	125 cde
DPX-1840	0.150	26 b	100 ab	126 cde

[1] Means in each column followed by different letters were significantly different at the 0.05 level of probability.

concentrations reduced shoot production when applied at the six-leaf stage. The lowest concentrations of DPX-1840 applied at the three-leaf stage and the lowest concentrations applied at the six-leaf stage did not significantly reduce total production.

Plant Form

Plant form was affected by treatment with growth regulators. Tillers formed on plants treated with Ethrel grew nearly vertically, much like tillers on control plants. Laminas quickly unrolled upon exposure to light and had a natural green color. Tillers were often uniform in length.

This was contrasted by the form of those plants treated with DPX-1840. Tillers often grew at 45° to 60° angle from the soil surface. This accentuated the opposite leaf arrangement and gave plants an open or spread appearance (Fig. 1). Leaves of tillers on plants treated with DPX-1840 often did not unroll. These tillers were stiff to the touch and generally had a chlorotic appearance. Chlorosis was most evident toward the leaf tips of these tillers.

Plants treated with 0.100 and 0.150 M concentrations of DPX-1840 often exhibited other unusual features. Leaves on the main shoot and on tillers were commonly curled. In some cases, early internode elongation was associated with these two treatments.

In a separate experiment, a few sand bluestem plants were treated at the early heading stage of development. The 0.100 and 0.150 M concentrations of Ethrel caused roots to be formed at nodes of the elongated culm. High concentrations, 0.100 and 0.150 M, of DPX-1840 caused both branching and root initiation at nodes of elongated culms (Fig. 2). It is evident that this chemical is affecting biological processes other than auxin inactivation or transport.

Not only were rates of tillering affected, but also type of tiller produced. Desirability of altered tiller form would have to be determined over one or more complete growing seasons.

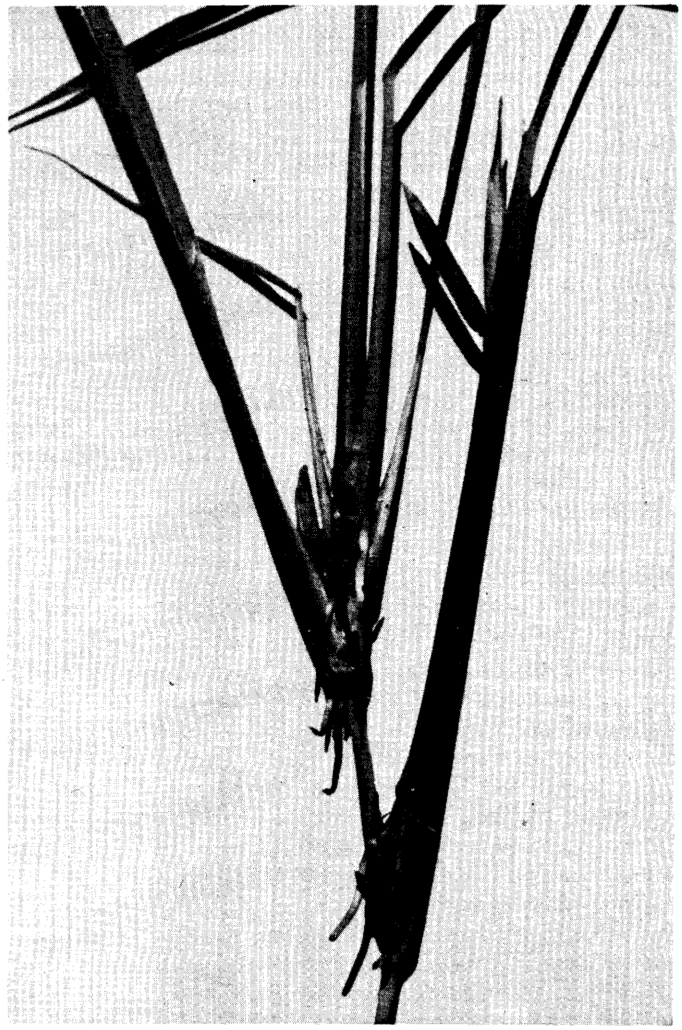

Fig. 2. *Branches and roots formed at the nodes of an elongated culm of a G-1773 sand bluestem plant 60 days after application of 0.100 M DPX-1840 at the early heading stage.*

Conclusions

Range seeding failures are common. The lack of favorable environmental conditions of sufficient length is most frequently cited as the cause of failure of establishment. Many of the agronomic practices, other than proper seedbed preparation, designed to extend the period of favorable environmental conditions are not practical or economically feasible for range seedings.

The data from this experiment show that this problem can be approached from a different angle. Rather than trying to physically extend the period of favorable environmental conditions, grass seedlings could be physiologically stimulated by growth regulators, applied at an early stage of growth, to efficiently use this period of time to maximize establishment. The results from this experiment show that the use of plant growth regulators has the potential to stimulate tillering, which could increase the rate of establishment of range grasses. The effects of DPX-1840, Ethrel, and other growth regulators should be thoroughly tested on other range grass species.

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Influence of Temperatures, Water Stress, and Nitrogen Treatments on Chlorophyll and Dry Matter of Western Wheatgrass

U. G. BOKHARI

Highlight: *Western wheatgrass (*Agropyron smithii *Rydb.) raised from seeds was given four treatments under three temperature regimes in environment controlled growth chambers. Dry matter and chlorophyll (*a + b*) were determined in the shoots of these plants at 20-day intervals for 100 days. Dry matter and chlorophyll production was greater from irrigated and irrigated-plus-fertilized plants under each temperature regime than it was from control or fertilized plants. This response was more pronounced at the intermediate temperature regime (24/13°C) than that at the lower (13/7°C) or the higher temperature regimes (30/18°C). The maximum chlorophyll increase of irrigated and irrigated-plus-fertilized plants was 350% and 395% at 24/13°C while in the control and fertilized plants the increase was 251% and 176%, respectively. A positive linear relationship was found between dry matter and chlorophyll of all the plants under the three temperature regimes.*

Primary production in a grassland ecosystem is dependent, besides other factors, upon the photosynthetic efficiency of the plant species found in the plant community. Photosynthesis provides metabolic energy not only for plant processes, but also for the consumer and decomposer subsystems. Chlorophyll content of plants has been used by many workers as an indicator of productivity in both native and seeded plant communities (Bray, 1960; Braugham, 1960; Aruga and Monsi, 1963; Madison and Anderson, 1963), but the correlation with production under field conditions is usually poor. This is because of the differences in orientation of leaves to incident solar radiation and to the pattern of chlorophyll in leaves at each level of community organizations (Loomis and Williams, 1969). Bray (1960) reported a significant positive correlation between chlorophyll content and herbaceous stand height. Recently Mall et al. (1973) reported a positive relationship between chlorophyll content and both the height and dry matter weight of various dominant species in a diverse herbaceous community. However, Gabrielson (1948) reported that, in plants with foliage leaves, the energy yield was not proportional to the chlorophyll concentrations. Similar results were found by Oelke and Andrews (1966) in sweet corn.

These reports indicate that the relationship between chlorophyll concentration and dry matter production in the field is a species characteristic and is dependent upon community structure and environmental factors.

The study reported here was undertaken to investigate the interrelationship between chlorophyll and dry matter production of western wheatgrass (*Agropyron smithii* Rydb.) under various temperature, water, and nitrogen treatments.

Methods and Materials

Western wheatgrass plants used in this study were raised from seeds.[1] Three plants were transplanted in each of 144 plastic pots (12.7 cm high, 12.7 cm diameter) containing soil potting mixture consisting of native grassland soil, peat moss, and sand (4:1:1). Four treatments: control, irrigated, fertilized, and irrigated-plus-fertilized were each replicated twice at each of three temperature regimes. Growth chambers were maintained at 13/7°C, 24/13°C, and 30/18°C day/night temperature alternating with 12-hour photoperiod at 90 watts/m^2 light intensity. The temperature regimes selected for this study were those normally operative in the native shortgrass prairie ecosystem.

A set of 48 pots (4 treatments × 2 replicates × 6 sampling dates) was placed in each of the three growth chambers consisting of 12 pots per treatment and remained there for 2 weeks before the treatments were applied. At the end of 2 weeks, 12 pots in each chamber received nitrogen fertilizer at the rate of 150 kg N/ha in the form of ammonium nitrate, 12 continued to receive enough water daily to maintain the soil at field capacity (0 to −0.8 bars), 12 received water plus nitrogen fertilizer (at rate noted above), and 12 received no supplemental treatment.

The control and fertilized plants had to be irrigated at 3- to 4-day intervals to prevent them from extreme drought conditions. The water potential in these pots averaged −7 to −10 bars, a condition common in the native shortgrass prairie. Sampling began 1 week following the initiation of treatments. Subsequent samples were taken on 20-, 40-, 60-, 80-, and 100-day intervals. On each sampling date eight pots from each chamber (two from each treatment) were removed and from

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[1] Seeds were obtained from Longmont Seed Company, Longmont, Colorado.

these all the shoots were clipped, chopped into small pieces, mixed thoroughly, and weighed. An aliquot of the mixed sample was frozen immediately for pigment analysis and the remaining shoot material was dried at 100°C for 4 hours and then at 70°C until a constant weight was obtained. Pigment analysis included analysis for chlorophyll *a* and *b* and total chlorophyll. An aliquot of 1 to 5 grams of frozen material was ground in a Waring blender containing 150 ml of 80% acetone. The chlorophyll-containing liquid was filtered through Watman's No. 52 hardened filter paper. The residue was blended in 100 ml acetone twice,and the filtered liquid from the three blending and filtering processes was combined and brought to volume with acetone in a 500-ml flask. Chlorophyll *a* was read at 663 nm, chlorophyll *b* at 645 nm, and total chlorophyll at 652 nm using Gilford micro-sample spectrophotometer, 300 N.

Results

Effects of Various Treatments on Dry Matter (g/pot)

Dry matter of shoots of western wheatgrass increased with time under the four treatments at all the temperature regimes until the 80th day and then began to decline until the final harvest (Fig. 1). A greater amount of dry matter during this period was recorded at the intermediate temperature regime (24/13°C) than at the lower (13/7°C) or at the higher temperature (30/18°C) regimes. At 13/7°C, the increase in dry matter of control, fertilized, irrigated, and irrigated-plus-fertilized plants was 102%, 61%, 181%, and 221%, respectively. During the same period the increase in dry matter of plants under 24/13°C from the above four treatments was 158%, 112%, 284%, and 333%, respectively. At 30/18°C the increase from control and fertilized plants was similar to that under 13/7°C while from irrigated and irrigated-plus-fertilized plants, the increase was of smaller magnitude than that under 24/13°C or 13/7°C.

Following the peak growth, the dry matter of all the plants under the three temperature regimes began to decline at different rates from the four treatments. At 13/7°C, maximum decrease (22%) in dry matter was recorded from control plants and minimum (15%) from irrigated-plus-fertilized plants. Decrease in dry weight at 30/18°C was greater from control plants (32%) as compared to irrigated plants (17%). At 24/13°C the maximum decrease was 24% from irrigated-plus-fertilized plants and minimum of 15% from irrigated plants. Generally, the plants under 24/13°C accumulated greater amounts of dry matter than those under 13/7°C or under 30/18°C.

Effects of Various Treatments on Chlorophyll [$(a + b)$ – mg/pot]

The chlorophyll contents of plants at 13/7°C and 30/18°C peaked on the 60th day while those under 24/13°C peaked on the 80th day, at the same time that dry matter peaked (Fig. 2). Similar to the increases in dry matter of plants under 24/13°C, the increase in chlorophyll content of these plants at this temperature was greater than those at 13/7°C or at 30/18°C. Thus the increase in chlorophyll at 13/7°C from control, fertilized, irrigated, and irrigated-plus-fertilized plants was 250%, 113%, 263%, and 291%, respectively, while at 24/13°C the increase in chlorophyll contents of plants from the same treatments was 251%, 176%, 350%, and 395%, respectively. The increase in chlorophyll contents of plants at 30/18°C from the four treatments was considerably smaller than those at 24/13°C or 13/7°C except for the fertilized

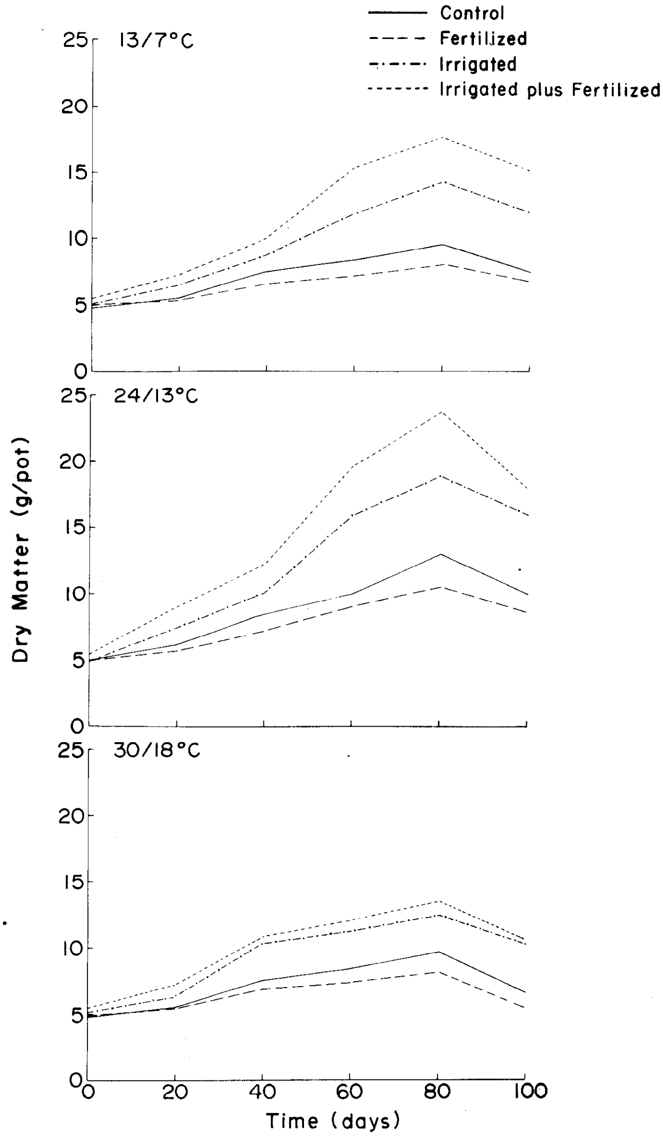

Fig. 1. *Dry matter of western wheatgrass from four treatments at 13/7°C, 24/13°C, and 30/18°C on each of six sampling dates.*

plants, which recorded an identical increase at both 13/7°C and 30/18°C.

Following the maximum production of chlorophyll the percent decreases were relatively greater in plants at 30/18°C than in those at 13/7°C or 24/13°C. Maximum decrease at 30/18°C was 53% from control plants and minimum 31% from irrigated plants at 13/7°C, the maximum was 50% from control and minimum was 28% from irrigated-plus-fertilized plants. At 24/13°C the maximum decrease was 46% from control and the minimum 21% from irrigated plants. Both chlorophyll *a* and *b* increased between 0 and 80 days in all the plants; however, the magnitude of increase from the irrigated and irrigated-plus-fertilized plants was greater than from the control or the fertilized plants at the three temperature regimes. The amounts of chlorophyll *a* and *b* from all the treated and untreated plants at 13/7°C and 24/13°C were greater than from those at 30/18°C. This was also true for total chlorophyll contents ($a + b$). Chlorophyll *a* was always abundant in all the plants as compared to chlorophyll *b*. Similar results for western wheatgrass have been reported by Rauzi and Dobrenz (1970). The percentage increase in dry

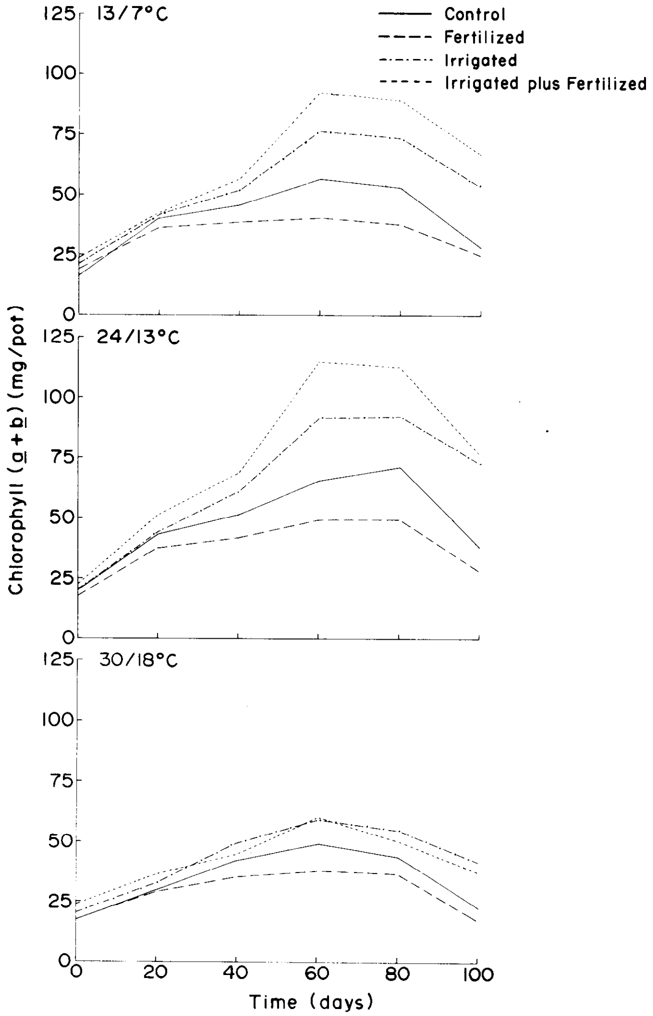

Fig. 2. *Chlorophyll (*a + b*) of western wheatgrass from four treatments at 13/7°C, 24/13°C, and 30/18°C on each of six sampling dates.*

weight and chlorophyll ($a + b$) of western wheatgrass over the control plants from the four treatments under the three temperature regimes is given in Table 1. Greater increases in dry weight and chlorophyll were recorded at 13/7°C; next at 24/13°C; and least at 30/18°C from irrigated and irrigated-plus-fertilized plants. The fertilized plants at each of the three temperature regimes accumulated small amounts of dry matter and chlorophyll. Earlier it was stated that plants at 24/13°C accumulated greater amounts of these constituents as compared to plants at 13/7°C or 30/18°C. This was true between the period from the initiation of the treatments to their respective peak growth. The percentage increase in dry weight and chlorophyll over the control plants at 24/13°C appears to be smaller than that recorded at 13/7°C. This is because of the greater amounts of these constituents from the control plants at 24/13°C. For example, the dry weight and chlorophyll contents of control plants at the time that these increases were recorded were 34% and 36% greater at 24/13°C than those at 13/7°C, respectively.

Discussion

Results indicate that the dry matter and chlorophyll ($a + b$) of western wheatgrass exhibited proportional fluctuations at three different temperature regimes for each of the four treatments.

The irrigated and the irrigated-plus-fertilized plants accumulated significantly greater amounts of dry matter and chlorophyll at each of the three temperature regimes than did the control and the fertilized plants. Additional water, alone or in combination with nitrogen fertilizer, enhanced chlorophyll synthesis as well as photosynthetic efficiency. This confirms that water may be a limiting factor under natural field conditions. Adequate soil water in the presence of adequate plant nutrients in the soil resulted in greater accumulation of carbon-containing compounds at 24/13°C than that at 13/7°C or 30/18°C. The interaction between the intermediate temperature regime (24/13°C) and additional water and nutrients appears to have enhanced the energy harvesting and energy conversion efficiency of western wheatgrass. Increase in dry matter production with nitrogen fertilization and added water have been reported for many other forage plants (Klages and Ryerson, 1965; Baker and Jung, 1968; Power and Alessi, 1971; Hunt, 1973). Cool season grasses like western wheatgrass with the C_3 photosynthetic pathway usually respond better to nitrogen fertilizers (Williams, 1953). The increase in nitrogen content of foliage of western wheatgrass at 24/13°C may be caused by stimulation of N-uptake at this temperature. At the high temperature regime of 24/13°C, respiratory activity seems to increase. This provides additional energy for nitrogen and phosphorus uptake. Watschke et al. (1970) reported similar observations with Kentucky bluegrass (*Poa pratensis* L.). Although the concentration of chlorophyll (mg/g dry wt) during the period between the first sampling date and the peak growth was greater at 13/7°C from irrigated and irrigated-plus-fertilized plants, the total amount of chlorophyll (mg/pot) was greater at 24/13°C from these treatments. For example, at 13/7°C the total chlorophyll ($a + b$) from irrigated plants was 6.26 mg/g dry matter and from irrigated-plus-fertilized plants it was 5.97 mg/g dry matter. From the same two treatments, the chlorophyll production at 24/13°C was 5.82 and 5.72 mg/g dry matter, respectively. The increased production of chlorophyll (mg/pot) at 24/13°C is attributed to greater production of shoot biomass and at 13/7°C to greater concentration of chlorophyll (mg/g dry matter). There seems to be a comparatively faster decline in dry matter and chlorophyll contents of irrigated and irrigated-plus-fertilized plants at 13/7°C and 24/13°C. Western wheatgrass is a cool

Table 1. Increase (%) in dry matter and chlorophyll ($a + b$) of fertilized (F), irrigated (I), and irrigated-plus-fertilized (FI) western wheatgrass over the control plants in 100 days.

	Temperature regimes								
	13/7°C			24/13°C			30/18°C		
Measurement	F	I	FI	F	I	FI	F	I	FI
Dry matter	−11.5	66.2	102.1	−17.4	59.2	79.5	−22.3	56.1	60.5
Chlorophyll	− 1.6	90.2	137.6	−35.6	89.6	100.0	−29.3	82.5	109.5

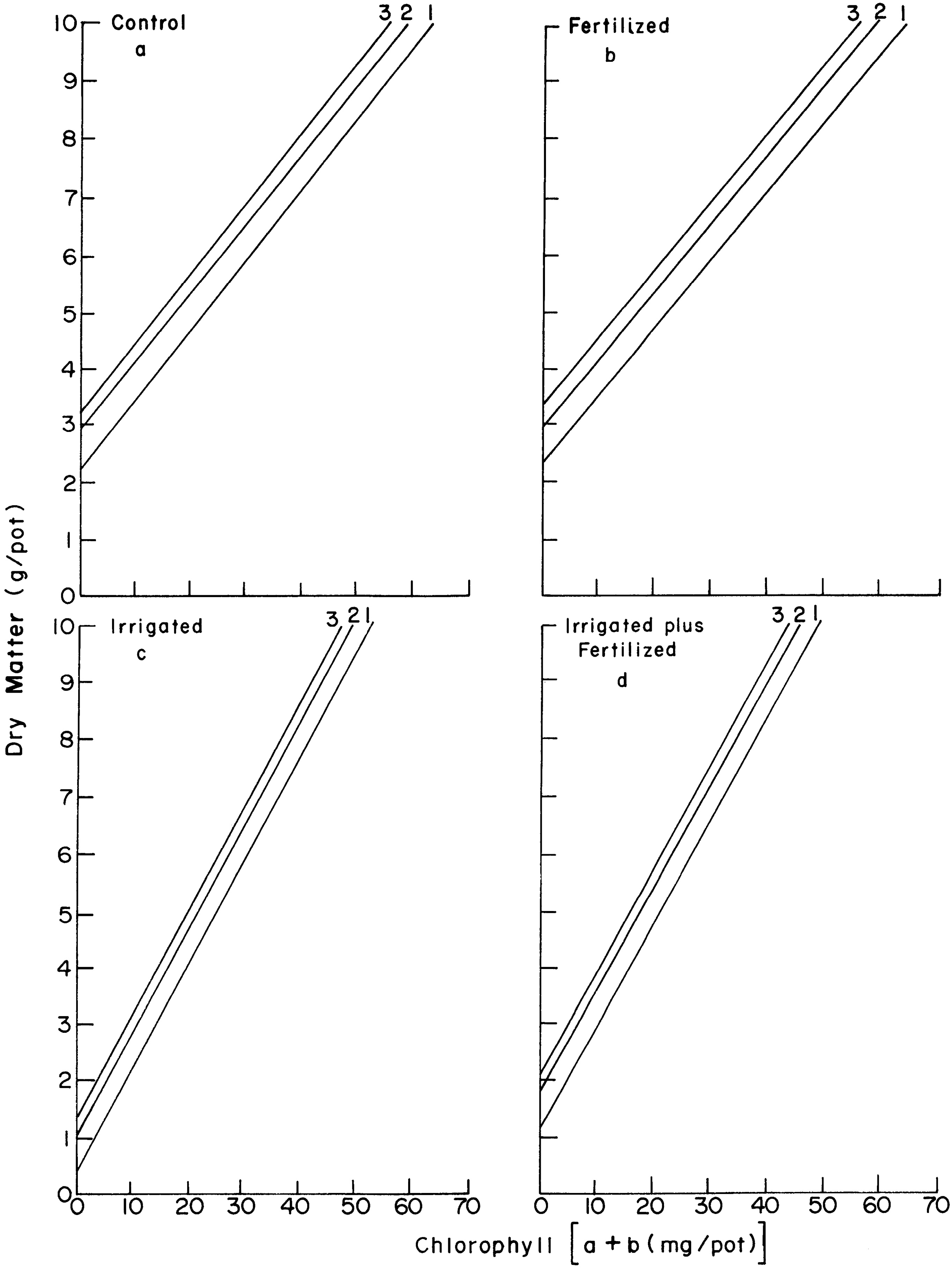

Fig 3. *Interrelationship between dry matter and chlorophyll* (a + b) *of western wheatgrass from four treatments at three temperature regimes (1 = 13/7° C; 2 = 24/13° C; 3 = 30/18° C).*

season grass with C_3 photosynthetic pathway (Williams and Markley, 1973), and thus its temperature optima for maximum growth in relation to dry matter and chlorophyll content are believed to be between 13° to 24°C. At this temperature regime, subsequent to peak dry matter and chlorophyll production, there is perhaps rapid degradation and breakdown of chlorophylls, more so of chlorophyll *a* than chlorophyll *b* (Sanger, 1971). This is followed by reduction in input of new photosynthates to the shoots and perhaps an increase in translocation of previously accumulated photosynthates to the belowground parts of plants (Bokhari et al., 1974; others in a review by White, 1973). Decrease in dry matter production toward the maturity of plants could also be caused by an increase in respiratory activities (Schmidt and Blaser, 1967).

A positive linear relationship, using chlorophyll as a covariate, was found between dry matter production and chlorophyll contents. This relationship holds true when dry matter and chlorophyll production is considered from a given treatment's plants under a given temperature regime (Fig. 3). The treatments and temperature differences were highly significant at 1% level of probability; however, the temperature and treatment interaction effects were not significant. The relationship between dry matter and chlorophyll at different temperatures and treatments is expressed according to the following equation:

$$\hat{Y} = 2.069 + te_i + tr_j + \begin{cases} 0.121X \text{ if control plants} \\ 0.119X \text{ if fertilized plants} \\ 0.179X \text{ if irrigated plants} \\ 0.177X \text{ if irrigated-plus-fertilized plants} \end{cases}$$

where $\hat{\mathbf{Y}}$ is the dry matter (g/pot); $\mathbf{X}$ is the chlorophyll content (mg/pot) at a given temperature and treatment; $\mathbf{te}_1 = -0.527$ if 13/7°C, $\mathbf{te}_2 = 0.097$ if 24/13°C, and $\mathbf{te}_3 = 0.430$ if 30/18°C; and $\mathbf{tr}_1 = 0.723$ if control, $\mathbf{tr}_2 = 0.811$ if fertilized, $\mathbf{tr}_3 = -1.139$ if irrigated, and $\mathbf{tr}_4 = -0.395$ if irrigated-plus-fertilized.

Figure 3 indicates that the relationship between total chlorophyll $(a + b)$ and dry matter production for control plants is identical to the relationship between total chlorophyll $(a + b)$ and dry matter production for fertilized plants. This is clear from the identical slope for the control and fertilized plants at each of the three temperature regimes; however, at each temperature regime the response in terms of the relationship between chlorophyll and dry matter production is different and is evident from the intercepts.

The relationship between the dry matter production and total chlorophyll $(a + b)$ for irrigated and irrigated-plus-fertilized plants (Fig. 3) is also identical in terms of an identical slope, and the difference lies in the intercepts which are different at each of the three temperature regimes.

This means that a positive linear relationship between chlorophyll and dry matter production in western wheatgrass is maintained under diverse environment conditions; however, the absolute amounts of chlorophyll and dry matter production vary depending on the temperature regimes. These results indicate that a fair estimation of dry matter production in western wheatgrass can be made from its chlorophyll contents when some of the abiotic factors such as temperature and soil water tension are known. Whether this estimation of dry matter production based on chlorophyll content will work under field conditions where species competition is involved at community level and where temperature and soil water tension fluctuate during the growing period is a matter of speculation. The results of this study provide encouraging indications that both chlorophyll and dry matter contents can be estimated when some of the abiotic factors under field conditions are known. This hypothesis indeed warrants further investigations on coupling abiotic factors with chlorophyll and dry matter production under field conditions. Also, management strategies such as irrigation or fertilization of western wheatgrass at appropriate times for maximum production can be planned on the basis of information such as temperature regimes during the growing season. Cooler parts of the growing season appear to benefit western wheatgrass from addition of nitrogen fertilizers.

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Response of Switchgrass (*Panicum virgatum* L.) to Clipping Frequency

E. R. BEATY AND JOHN D. POWELL

Highlight: *The native grasses are not widely grown for cultivated pastures in the South but are important forage producers in the United States. Their responses to frequency of clipping are not widely known and appear to be significantly different from that of the introduced cultivars, Bermudagrass (*Cynodon dactylon*) and Bahiagrass (*Paspalum notatum*).*

The introduced species, however, are slow to initiate growth in the spring, and it appears that the forage program in the South could be improved significantly by grazing switchgrass before the summer perennials initiate growth. Haying at flowering and grazing following frost could utilize the switchgrass later in the summer.

*Pangburn switchgrass (*Panicum virgatum *L.), a native species, tolerated one clipping during the season with little or no reduction in forage production, clonal survival, tiller number per clone, or tiller height. However, two or more clippings per season reduced all of the above. Over-utilization of switchgrass at the start of the season decreased the number of tillers and clones per plot and resulted in a serious weed problem.*

Switchgrass (*Panicum virgatum* L.) is a warm-season grass native to North America and is considered as a major species of the tall grass prairies. It grows over wide sections of the southern United States. Forage quality of switchgrass is generally considered to be good and it is generally recognized as excellent for grazing. In addition to its forage value, switchgrass is widely used in areas where soil conserving practices are needed.

In spite of wide interest in switchgrass in other sections of the United States, practically no research has been conducted with it in the South. Most of the forage grown for pastures in the South are introduced and tolerate close grazing, but are slow to start growth in the spring. Switchgrass starts growing some 60 days earlier than Bermudagrass or Bahiagrass, which would reduce the wintering period a third to a half. Regrowth following early grazing could be used for hay or frosted grazing. Therefore, this investigation was designed to achieve three major objectives: (1) to establish the response in yield and tiller production of one switchgrass ecotype, 'Pangburn,' to clipping frequency and degree of defoliation; (2) to establish clipping regimes suitable for sustained yields; and (3) to determine the potential of switchgrass for supplementing the existing forage crops of the lower South, primarily Bahiagrass and Bermudagrass, by extending the grazing season in the early spring and late fall.

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Literature Review

Switchgrass is recognized as a species of rather wide diversity in growth types, and Eberhart and Newell (1959) concluded that endemic strains collected from native grasslands show heritable variation, which should be useful in a program of varietal improvement. They also reported that its fibrous root system is a desirable characteristic in conservation plantings. The probability of different growth types was also established (Newell and Eberhart, 1961), as strains from northern and western Nebraska were semidecumbent, relatively fine-stemmed and usually blue-green in color, while those growing in eastern Nebraska and Kansas tended to be taller, erect, coarse-stemmed, and light green in color.

No extensive studies have been completed on the heritability of response to clipping, but seedling vigor and a number of culms per plant were found to be highly heritable (Newell and Eberhart, 1961).

In a clipping experiment, Baker et al. (1951) reported Nebraska forage yields of 1.03, 1.32, and 1.22 tons per acre annually for early, mid, and late season clippings for a 2-year period. Early cutting reduced stem height and weight of stems as compared to late cutting. The early clipping increased weeds, particularly daisy fleabane (*Erigeron ramosus*) but produced higher beef gains than did later clippings.

Harlan and Ahring (1958) reported clipping 'Caddo' switchgrass two times per year, showing yields for July and October, indicating that multiple harvests were made during

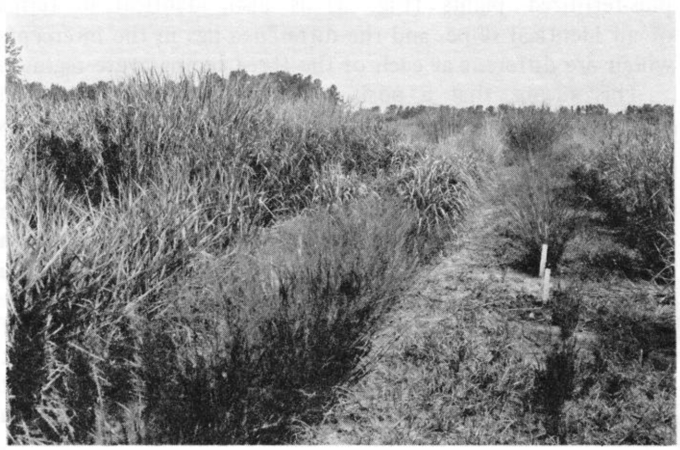

Fig. 1. *Switchgrass ecotypes.*

Fig. 2. *Switchgrass stubble following clipping.*

the season. However, no reference to stand changes were made.

Switchgrasses frequently differ in morphology, with lowland strains such as 'Pangburn' and 'Kanlow' being tall and coarse as compared to upland varieties such as 'Blackwell,' 'Caddo,' and 'Nebraska 28,' which tend to be shorter and smaller stemmed. It is possible that production management suitable for the different types would also be different (Fig. 1).

Procedure

On March 23, 1964, 1.8-by 6.1-meter plots at the Americus Plant Materials Center were sprigged on 46-cm centers to 'Pangburn' switchgrass. The soil was a Red Bay sandy loam fertilized at the rate of 896 kg/ha of a 4-5.3-9.8 N-P-K mixture. Weeds were controlled and the grass was allowed to grow until March 1965, when the 12 frequency of clipping treatments listed in Tables 1 and 2 were established. Annual fertilization was 224-24.6-93 kg/ha of N-P-K and was applied as NH_4NO_3, super phosphate, and muriate of potash. Four replications were included in a randomized complete block design. The forage was hand clipped to a stubble height of 15 cm (6 inches) in 1965 and 20 cm (8 inches) in 1966 and 1967. Tiller height was estimated by averaging the clone and measuring the flag leaf at the whorl. For yield determinations, the two center rows of clones were clipped. After each harvest year, the number of living clones per plot and tillers per clone were determined the following May.

Results and Discussions

Yield, Clone and Tiller Adjustments

For purposes of presentation, forage yields are divided into production harvested during the growing season and total yields, which included forage harvested after frost (Table 1).

Clipping treatment number 1, clipped after frost in November but not clipped during the season, produced an average annual yield of 12,626 kg/ha of dry forage. The material harvested was extremely stemmy and probably had little value as forage. Clones per plot (5.82 m^2) averaged 20 for the 3 years, with a high of 22 after the first harvest year and 18 after the third. (To determine clones per acre, multiply clones per plot by 694.41.) Tillers per clone almost doubled during the experiment, increasing from 60 in 1966 to 114 in 1968. The high yield of dry forage combined with the rapidly increasing number of tillers per unit area indicates that switchgrass has forage potential in the area.

Treatment 2, clipped each time forage reached a height of 61 cm (24 inches), averaged 3,121 kg/ha dry forage for the 3 years, with 2,758 kg harvested during the growing season and 365 kg harvested after frost. Approximately two thirds of the total production was harvested the first experimental season. Clones per plot dropped to 14 in May 1966 and to 9 in 1968. Tillers per clone dropped to 19 in 1966 and increased to 29 in 1968. The drastic drop in tiller number was believed to have resulted from the low clip height. Increasing the clip height from 15 cm in 1966 to 20 cm in 1967 may have increased tiller numbers in later years. Forage reached a height of 61 cm three times the first year, but only two times in each season of later years.

Treatment 3, clipped each time forage reached 91 cm (36 inches), yielded twice as much as treatment 2. Clones per plot were significantly reduced from 19 to 13 and tillers per clone increased from 37 to 61. In general, the grass in this treatment

Table 1. Forage yield (kg/ha) of 'Pangburn' switchgrass (*Panicum virgatum*) by clipping frequencies, 1965–1967, Americus, Ga.

	Dry forage excluding frosted forage[1]				Dry forage including frosted forage[1]			
Clipping treatment	1965	1966	1967	Average	1965	1966	1967	Average
1. After frost only[2]					12,803	9,967	15,108	12,626
2. Each time forage reached 61 cm	5,760	899	1,605	2,758	6,088	1,167	2,107	3,123
3. Each time forage reached 91 cm	4,241	6,371	4,519	5,044	5,201	8,204	5,261	6,222
4. Once when forage reached 61 cm	1,595	5,846	3,623	3,688	11,829	14,096	13,027	12,984
5. Once when forage reached 91 cm	5,316	9,495	11,941	8,917	14,086	16,264	14,022	14,791
6. Two times when forage reached 61 cm	7,420	2,166	4,075	4,554	7,783	3,149	5,181	5,371
7. Two times when forage reached 91 cm	4,742	7,862	5,111	5,905	5,722	9,398	5,729	6,950
8. Three times when forage reached 61 cm	6,904	2,315	3,264	4,161	7,116	3,190	3,936	4,747
9. Three times when forage reached 91 cm	5,060	5,660	2,625	4,448	6,537	7,054	2,867	5,486
10. May 15, June 15, July 15	6,373	1,239	2,834	3,482	6,602	5,419	2,987	5,003
11. May 15, June 15	4,036	3,855	1,951	3,281	5,676	11,693	4,264	7,211
12. Clipped two times to a 61 cm stubble on May 30 and Aug. 1	–	10,928	5,566	–	15,468	18,324	5,926	13,239

[1] LSD ($P = .05$) were: Excluding frosted forage for treatments 123 kg/ha and for years 83 kg/ha; and including frosted forage for treatments 144 kg/ha and for years 98 kg/ha.

[2] Treatments 2 to 12 were also clipped after frost.

was approaching infloresence when clipped and regrowth was rather slow. Two major clips per year were harvested plus a small clip in September.

Treatments 4 and 5, clipped once at 61 or 91 cm, produced as much or more total forage as treatment 1. They also produced considerable forage during the growing season. No significant difference in clone survival was detected between these treatments and treatment 1 with the single clip after frost. Tillers in treatment 5 were comparable in number per clone to those in treatment 1 but in treatment 4 were significantly lower. Apparently switchgrass will tolerate a single clip at almost any time with no year-to-year reduction in vegetative vigor.

Treatments 6 and 7 were similar, except that 6 was clipped twice at 61 cm while 7 was clipped twice at 91 cm. Forage production was greater on treatment 7. Clipping twice per season reduced clone survival and tillers per clone more than a single clipping (Table 2).

Treatments 8 and 9 were clipped three times annually and yields were only slightly less than with the two-clipping treatments (Table 1). Viable clones per plot averaged approximately 15 at the end of the first season and dropped to 12 and 9 at the end of the third season for treatments 8 and 9, respectively. Over the 3-year period, tillers per clone were consistently low, averaging 33 and 36 for treatments 8 and 9, respectively. Higher clonal survival and tillers per clone on the treatment clipped at 61 cm may have been due to a slightly longer period after the last clip, which enables the plant to resupply storage tissues.

Clipping May 15, June 15, and July 15, as in treatment 10, while drastic, is biologically possible. The early clip had a marked detrimental effect on yield, clonal survival, and tiller number. This ecotype, 'Pangburn,' was slow to generate new tillers, and at the second clip many of the growing points of the new tillers were too short to be removed. The second harvest resulted in very little forage. At the third harvest, tillers produced after the first clip were tall enough to be removed, but some tillers initiated after the second clip were not. Consequently, it is possible to utilize switchgrass heavily early in the season if the growing points and regrowth are not removed and later summer growth is allowed to accumulate. Clonal numbers and tillers per clone were significantly reduced by 1968 as compared to treatments 1, 3, or 5.

Treatment 11 was similar to treatment 10 but had consistently more tillers per clone. The major problem associated with early clipping was weed contamination later in the season. Under southern conditions, switchgrass started vegetative growth in March, and when first clipped in early May was usually shading the soil. Because of early clipping and the slow regrowth of tillers, weeds, primarily camphor weed (*Heterotheca subaxillaris*); ragweed (*Ambrosia* spp.); crabgrass (*Digitaria sanguinalis*); guineagrass (*Panicum maximum*); and crotalaria (*Crotalaria spectabalis*) grew vigorously. With the fertilization applied in this investigation, weed growth shaded the switchgrass tillers and prevented normal growth after the last clipping on treatments 2, 10, and 11.

To counter the weed problem, treatment 12, which had been originally included as an expansion treatment, was clipped at a stubble height of 61 cm in late May and early August for the last 2 years. While the 2-year data on treatment 12 are not directly comparable with the 3-year data on the first 11 treatments, the stands had the same duration and have some relevance to the study. Clones per plot and tillers per clone are sufficiently high to indicate vigorous plants, while the forage yields averaged 8,248 kg or slightly more than the highest yield of the other treatments. Weed invasion was also reduced.

Management

Spring tiller height as shown in Table 2 is indicative of physiological effect of clipping on tillers: in treatment 1 with no clipping, tillers averaged 86 cm in height when measured on May 14, 1966, and May 22, 1968; tillers in treatment 2, by comparison, were less than 50% as high. Tillers in other treatments were intermediate between those of treatments 1 and 2. Treatments 2, 10, and 11 were also low in total yield, showing that intense and frequent defoliation will reduce tiller height the following spring.

This investigation was concerned with only one ecotype of a very widespread and variable species. Different clonal material could differ widely from 'Pangburn' in response to clipping; and the vegetative sensitivity to clipping frequency shown in yield, tillering, and regrowth obtained with 'Pangburn' switchgrass is far different from that recommended for Bermudagrass and Bahiagrass (Ethredge et al., 1973; Stanley et al., 1967), where weekly clipping to 0 cm at

Table 2. Clones per plot, tillers per clone, and average tiller height (cm) of switchgrass by treatments and years, Americus, Georgia, 1965–1967.

	Clones per plot				Tillers per clone				Tiller height		
Clipping treatment	1966	1967	1968	Avg	1966	1967	1968	Avg	1966	1968	Avg
1. After frost only*	22	21	18	20	59	89	114	87	86	86	86
2. Each time forage reached 61 cm	14	12	9	12	18	20	29	22	36	38	37
3. Each time forage reached 91 cm	19	18	13	17	37	32	61	43	48	48	48
4. Once when forage reached 61 cm	23	22	17	21	65	75	104	81	76	69	73
5. Once when forage reached 91 cm	22	21	17	20	80	75	58	71	74	64	69
6. Two times when forage reached 61 cm	19	16	12	14	27	36	43	35	38	46	42
7. Two times when forage reached 91 cm	16	15	12	14	31	39	57	42	48	48	48
8. Three times when forage reached 61 cm	15	14	12	14	25	36	37	33	41	46	44
9. Three times when forage reached 91 cm	15	11	9	12	45	30	38	36	51	41	46
10. May 15, June 15, July 15	14	14	11	13	22	25	27	25	31	33	32
11. May 15, June 15	16	14	11	14	27	35	41	34	56	46	51
12. Clipped two times to a 61 cm stubble	21	20	19	20	81	73	81	78	79	66	73

	Clones per plot	Tillers per clone	Tiller height (cm)
LSD	05	05	05
Years	2.9	22.3	10.6
Clip treatments	5.0	21.8	5.3

*Treatments 2 to 12 were also clipped after frost.

frequencies of 3 weeks or less had little influence on stands.

Yield data obtained in this investigation in general show that 'Pangburn' switchgrass is productive under southern conditions. It will tolerate one clipping per year and maintain yield and stands, but continuous clipping at heights of 61 or 91 cm will reduce yields and stands. It appears that switchgrass could be grazed or cut for hay early in the spring provided the regrowth is allowed to mature seed. After frost the forage present can be grazed without injuring yields the following year.

Clipping during the spring or summer will allow weeds to invade switchgrass, but grazing to 61 cm (24 inches) will prevent weed development. Under southern conditions, grazing switchgrass until Bermudagrass or Bahiagrass gets big enough to graze and cutting for hay after flowering and grazing following frost would appear to have economic possibilities.

Slow tiller growth, when combined with low tiller numbers, allows enough light penetration for dense weed production. Weeds were effective in reducing summer growth of switchgrass, and in the South weed control is essential before weak stands of switchgrass can be regenerated by resting from grazing. Therefore, it appears probable that once a field of switchgrass has been overutilized the most satisfactory solution for renovation is reestablishment.

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Responses of *Andropogon pumilus* Roxb. to Various Heights and Intervals of Clipping

V. P. SINGH AND L. P. MALL

Highlight: Andropogon pumilus *Roxb. produced most dry matter (above ground and underground) when it was clipped at an interval of 45 days and at height of 15 cm. The average seed output at this clipping was maximum.*

A knowledge and appreciation of the morphology and growth habits of the species used and their responses to defoliation is very helpful in maintaining the desired proportion of grass and legumes in a forage stand. In an actively growing plant, all of the energy captured from sunlight is not utilized in the production of new plant tissue, but part of it is used in respiration and part of it is stored mainly in basal portions of the plant so that new leaves can be produced after defoliation. Thus a knowledge of the effect of defoliation at different stages of growth and at different frequency is essential in foreseeing the possible effect of grazing or cutting practices.

Many studies have sought to evaluate the influence of grazing by clipping herbage artificially. Although clipping does not simulate grazing precisely, a good appraisal of grazing can be attained by clipping treatment. A number of experiments for the study of the effect of frequency of clipping, and height of clipping on the yield of grass have shown that higher annual yield can be expected from infrequent clipping (Albertson et al., 1953; Aldous, 1930; Baker et al., 1945; Canfield, 1939; McCarty, 1932; and Stoddart, 1946), and that cutting the grasses at different heights and stages of growth is effective (Owensby and Anderson, 1969; Smith et al., 1971; and Robinson et al., 1952).

Andropogon pumilus Roxb., a tufted annual grass with numerous radiating branches growing all directions, reaches 1 meter in height, and is found throughout India. Because of its extensive distribution, abundance, and palatability to livestock (Bor, 1941), the species was selected for study. The investigations were designed to determine its responses to various clipping intervals and height of herbage removal under favorable climatic environment (August to October). The responses were evaluated on the basis of herbage, roots, and seed production.

Methods

This experiment was conducted at the Departmental Botanical Garden in a Malwa clay loam (Singh, 1969), with level topography. Precipitation averages about 1,030 mm, most of which occurs during the rainy season. Seedlings of *A. pumilus* Roxb. were grown in individual containers and transplanted on July 2 to the experimental plot. In all, 39 subplots (size 1 m^2) were made. In each subplot the density and spacing of plants were kept uniform. Three subplots were left unclipped and 3 clipped at each combination of clipping heights (base, and 5, 10, and 15 cm) and 3 intervals (15, 30,

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Table 1. Herbage production (g/m², oven dry) by frequency and height of clipping.

Clipping height[1] (cm)	Clipping frequency	Clipping interval[2] (days)	Date clipping Aug. 20	Aug. 5	Aug. 20	Sept. 5	Sept. 20	Oct. 5	Last date	Total herbage
Unclipped										399.5
Base	6	15	60.4	42.5	36.4	26.4	16.3	10.4	23.9	216.9
5	6	15	53.4	36.4	40.5	45.3	49.4	51.3	39.5	315.7
10	6	15	50.6	51.3	56.3	59.4	63.4	65.4	49.5	395.9
15	6	15	43.9	52.4	57.3	62.4	69.3	70.4	55.2	410.9
Base	3	30	63.7	–	73.5	–	93.5	–	63.5	294.2
5	3	30	59.4	–	103.5	–	111.4	–	73.7	348.0
10	3	30	51.2	–	109.3	–	121.3	–	95.9	377.7
15	3	30	46.4	–	116.4	–	129.4	–	148.5	440.7
Base	2	45	64.3	–	–	169.4	–	–	149.3	383.0
5	2	45	57.4	–	–	189.5	–	–	193.4	440.3
10	2	45	54.3	–	–	193.5	–	–	208.4	456.2
15	2	45	49.3	–	–	206.3	–	–	218.5	474.1

[1] L.S.D. = 71.8.
[2] L.S.D. = 64.1
Significant at 1% level.

and 45 days). The clipping frequencies were 6, 3, and 2 for the clipping intervals of 15, 30, and 45 days, respectively. Herbage production for each treatment was calculated on oven dry weight basis.

Results and Conclusions

Herbage Production in Relation to Clipping

It is clear from the Table 1 that greater herbage was produced when the plants were clipped at a height of 15 cm and at an interval of 45 days, as compared to 10 cm, 5 cm, base heights, and 15-day and 30-day intervals of clipping. Yield is supposed to be a reflection of the clipping height. Daubenmire (1947) argues that basal meristems are likely to be injured in close clipping or grazing. Thus, 15 cm seems to be an optimum height for increased herbage production in *A. pumilus.*

Frequency of herbage removal had pronounced effect upon production of forage. Average production decreased with increased number of clipping. Clipping at 15- and 30-day intervals produced less herbage than clipping at a 45-day interval (Table 1). It may be concluded that biweekly and monthly clipping of the herbage reduced the amount of food materials available for translocation to the roots, so that the capacity to produce new tillers was reduced in *A. pumilus*. Similar results were found by Albertson et al. (1953), Aldous (1930), Baker et al. (1945), Brown (1943), Buckner and Henry (1945), Canfield (1939), and Stoddart (1946).

Root Production in Relation to Clipping

Data on quantity of root production under different treatments are given in Table 2. Plants clipped fewest times (30- and 45-day intervals) produced the greatest herbage yield. Frequent clipping (15 days) apparently leaves little time for herbage replacement; hence food manufacture and downward translocation is limited, causing retardation in root growth. This agrees with finding of Weinmann (1943), Lovvorn (1945), and Cook et al. (1958), who showed that increased frequency of clipping grasses significantly reduced the root yield. In general, treatments that produced the greatest herbage production likewise produced the greatest root yield. Plants in high vigor displayed a well-developed root system. It appears that any herbage removal reduces total root production. Albertson et al. (1953) and Biswell and Weaver (1933) have shown that an increase in frequency of clipping resulted in reduction in yield, depth, and spread of roots. Harrison (1931) clipped grasses at different heights and found that the amount of roots increased with the height to which the grasses were clipped. Stapledon and Beddows (1926) showed that the repeated cutting of *Dactylis glomerata* during the growing season not only decreased the amount of hay and aftermath crop but also reduced the root systems of the plants and retarded their growth early in the following spring.

Height of clipping had a significant effect upon root growth. The average yields for the base and 5 cm height were lower than those for grass clipped at 10 cm and 15 cm height (Table 2). The closer clipping reduces the herbage yield and this, in turn, root production.

Table 2. Root production (g/m²) under various heights of clipping and 3 clipping intervals.

Clipping intervals[2] (days)	Clipping height (cm)[1] Base	5	10	15	Mean
15	27.3	40.3	46.3	49.9	40.0
30	40.3	42.3	45.4	56.3	46.0
45	53.0	59.4	63.6	68.0	61.0
Mean	40.1	47.3	51.7	58.0	

[1] L.S.D. = 6.5.
[2] L.S.D. = 5.5.
Significant at 1% level.

Height, Spread, and Seed Output in Relation to Clipping

The spread of plants increased gradually with decrease of time of clipping interval. Maximum spread of the plant was noted when it was clipped at 5 cm in each set of the experiment. The height of the plant increased gradually with increased intervals of time. Thus, a linear relation was formed in case of height versus interval of clipping time (Table 3).

A count of the number of spikes was made at the time of seed maturity in all the treatments, and the number of filled caryopsis was determined. Evidently, treatments producing high forage yields likewise produced high seed yields. Closer and increased clipping frequency decreased both the number of spikes and the number of caryposis/spikes. Similarly, Whitman and Helgeson (1946), Blaisdell and Pechanec (1949), and Cook et al. (1958) observed that frequent and intense clipping of grasses reduces the number of spikes and the number of viable seed/spike.

Table 3. Height, spread, and tiller formation in relation to clipping.[1]

Clipping height (cm)	Clipping frequency	Clipping interval (days)	Average height of plant[2] (cm)	Average spread of plant[2] (cm)	Average number of tiller per plant[2]
Unclipped control			37.2 ± 1.3	16.4 ± 1.9	29 ± 1.5
Base	6	15	18.3 ± 2.3	30.3 ± 0.3	29 ± 1.1
5	6	15	25.4 ± 1.3	32.3 ± 0.9	36 ± 1.3
10	6	15	27.9 ± 1.5	30.4 ± 1.3	32 ± 1.5
15	6	15	37.9 ± 1.8	29.3 ± 2.6	37 ± 0.7
Base	3	30	16.3 ± 2.7	20.4 ± 1.1	30 ± 2.1
5	3	30	26.3 ± 0.3	25.3 ± 1.9	33 ± 0.9
10	3	30	36.5 ± 1.1	24.9 ± 2.6	37 ± 0.6
15	3	30	43.9 ± 2.3	20.3 ± 0.7	49 ± 1.3
Base	2	45	21.3 ± 1.9	15.3 ± 3.8	32 ± 1.9
5	2	45	29.3 ± 1.3	24.9 ± 1.9	49 ± 2.3
10	2	45	44.3 ± 1.9	23.1 ± 1.5	50 ± 2.9
15	2	45	54.3 ± 1.5	20.7 ± 1.7	59 ± 1.3

[1] Mean ± standard deviation.
[2] Average is based on 25 counts.

Table 4. Seed output per plant under various treatments.

Clipping intervals[2] (days)	Clipping height (cm)[1] Base	5	10	15	Mean
15	216	275	293	353	284
30	319	369	295	465	387
45	383	396	469	593	460
Mean	306	346	385	470	

[1] L.S.D. = 49.6
[2] L.S.D. = 43.0
Significant at 1% level.

In general it is logical to believe that if herbage is removed closely and frequently, the amount of food materials available for translocation to the roots is reduced. This in turn reduces vigor of the plant and its capacity to produce herbage and roots and consequently the number of seed.

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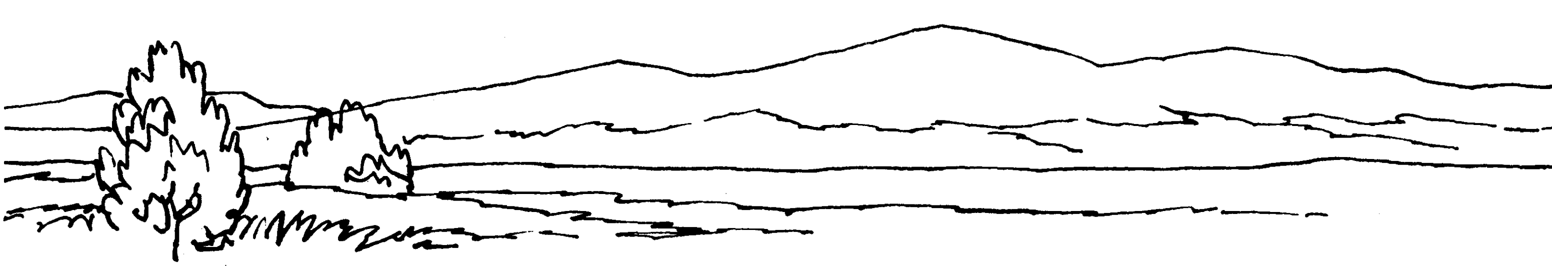

Effects of Water Stress and Temperature on Germination of True Mountainmahogany

J. R. PIATT

Highlight: *The effects of five levels of available water and four constant temperature regimes upon the germination of two ecotypic collections of true mountainmahogany (*Cercocarpus montanus *Raf.) were investigated. Results indicate that moisture stress significantly decreases both the rate and final amount of germination in this species. The amount of moisture stress required to cause these decreases was found to be dependent upon both the seed source and the temperature. Temperature was found to be more important in determining the rate than the amount of germination.*

Of all environmental factors affecting the ecology of terrestrial vegetation, water supply and temperature are probably the most important (Krebs, 1972). Although a substantial number of investigations have been conducted concerning these factors, relatively few of them deal with the germination of forage shrubs (Springfield, 1966, 1968). True mountainmahogany (*Cercocarpus montanus* Raf.) has long been known to be a valuable source of forage for both wildlife and domestic livestock. Although two investigators (Smith, 1971; Heit, 1970) have reported on the effects of temperature on the germination of this species, the interaction of temperature and moisture stress has not been documented; and it is to this question that this report is addressed.

Seeds for this study were collected from two locations in New Mexico and stored in paper bags at room temperature (20–22°C) until the study was conducted in April, 1972. A collection was made in 1969 on Pinabetosa Mesa, an oak-mountainmahogany site (Daubenmire, 1943) at 8,000 ft elevation near the town of Coyote. A second collection was made in 1970 from a group of plants near the northern edge of Santa Fe, at 7,300 ft elevation, in the pinyon-juniper type.

Materials and Methods

Moisture stresses were established through the use of aqueous solutions of mannitol. Sufficient mannitol was added to distilled water to lower the water potential to one of the following osmotic potentials: −0.3, −3.0, −7.0, −11.0 or −15.0 atmospheres. Amount of mannitol required to produce these water potentials were calculated in accordance with the van't Hoff equation (Salisbury and Ross, 1969, p 66-67).

Bulk samples of seeds underwent an initial moist, cold (3°C) pretreatment for 40 days prior to the start of the experiment to overcome dormancy and promote rapid and complete germination (Forest Service, 1948; Heit, 1970). The seeds were germinated in petri dishes atop two layers of standard germination blotters. Fifty seeds were placed in each dish, and the dishes were randomly arranged in factorial design with three replications per treatment. Fifteen milliliters of the appropriate solutions were added at the beginning of the experiment; evaporation over the 28-day-long experiment was minimal.

Temperatures used in this experiment were 10, 20, 25, and 30°C. All tests were conducted in environmental chambers (Lab-Line Mark I) programmed for constant temperatures; fluctuations never exceeded ±2°C. Except when counts of germinated seeds were conducted, the seeds were kept in constant darkness. Preliminary tests have indicated that germination of this species is neither positively or negatively affected by light.

Seeds were considered to have germinated when the radicle had penetrated the seed coats, grown for a minimum of 1.0 cm, and had a meristem which appeared normal (they did not exhibit dark coloration, curvature at the tip, lack of root hairs, etc.). Germinated seeds were removed from the petri dishes.

Counts of germinated seeds were taken daily for the first 2 weeks of the experiment and then at 2- to 3-day intervals.

Germination data underwent arcsin transformation prior to statistical analysis. Such transformations are necessary as the percentage germination data were not normally distributed and would thus violate the assumptions of analysis of variance upon which the statistical procedures used are based (Sokal and Rohlf, 1969).

Results

The overall mean germination of the Santa Fe collection (40.6%) was significantly greater ($p < 0.05$) than that of the Pinabetosa Mesa collection (30.5%). The interactions of a source by temperature and source by osmotic pressure were not significant.

Table 1 illustrates the amount of germination which had occurred at the end of the experiment. The Santa Fe collection proved to be extremely sensitive to moisture stress: each decrease in water potential was found to result in a significant decrease in the final germination percentages. In this ecotype temperature is of comparatively less importance

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Table 1. Effects of moisture stress and temperature on the germination percentage[1] of true mountainmahogany after 28 days.

Temperature (°C)	Osmotic pressure in atmospheres					
	−0.3	−3.0	−7.0	−11.0	−15.0	Mean
Santa Fe collection						
10	78.0 a[2]	42.7 b	34.7 c	1.3 d	1.3 d	31.6 AB[2]
20	86.0 a	73.3 a	62.7 bc	46.0 c	2.7 d	54.1 A
25	81.3 a	78.0 a	58.0 b	22.7 c	6.7 c	49.3 A
30	72.7 a	47.3 b	10.0 c	6.7 c	0.7 c	27.5 B
Mean	79.5 A[2]	60.3 B	41.3 C	19.2 D	2.8 E	
Pinabetosa Mesa collection						
10	65.3 a[2]	30.0 b	8.0 bc	0.7 c	0.0 c	20.8 B[2]
20	78.7 a	75.3 a	28.7 b	10.7 c	1.3 c	38.9 A
25	82.7 a	84.0 a	61.3 b	13.3 c	5.3 c	49.3 A
30	42.7 a	20.0 b	1.3 c	0.7 c	0.0 c	12.9 B
Mean	67.4 A[2]	52.3 A	24.8 B	6.4 BC	1.6 C	

[1] Data underwent an arcsin transformation prior to analysis by Duncan's new multiple range test.
[2] Values within a row or means not followed by the same letter are significantly different at the 0.05 level.

Table 2. Comparisons of the rate[1] of germination of true mountainmahogany under different moisture stresses and temperatures.

Temperature (°C)	Osmotic pressure in atmospheres		
	−0.3	−3.0	−7.0
Santa Fe collection			
10	1.67 a C[2]	0.40 b C	0.31 b B
20	13.09 a A	11.64 a A	6.50 b A
25	12.29 a A	12.24 a A	5.41 b A
30	8.74 a B	5.27 b B	[3]
Pinabetosa Mesa collection			
10	3.10 a B[2]	1.22 b C	[3]
20	13.46 a A	7.32 b B	0.91 c B
25	12.02 a A	11.12 a A	6.13 b A
30	5.52 a B	2.60 b C	[3]

[1] Values are the regression coefficients of linear regressions from the first 7 days of the experiment.
[2] In a collection, values within a row or column not followed by the same letter are significantly different at the 0.05 level. Lower case letters refer to values within a row.
[3] Insufficient germination to fit significant regression lines.

in determining the amount of germination which will occur. Thirty degrees was clearly inhibitory, although statistically equivalent to 10°C. The "optimum" temperature for germination of this collection appears to be approximately 20°C.

The Pinabetosa Mesa collection proved to be more sensitive to temperature extremes, with both the 10° and the 30° temperatures significantly inhibiting the amount of germination. The "optimum" temperature for germination of this collection is approximately 25°C. This collection was not as sensitive to moisture stress as was the Santa Fe collection since a significant decrease in germination did not occur until the water potential decreased to −7.0 atmospheres.

Detailed analysis of the data was required when it was found that the interaction of temperature X osmotic pressure was highly significant ($p < 0.01$). It appears that a moisture stress is less deleterious at "optimum" temperatures. Thus, in both ecotypes an osmotic pressure of −3.0 atm is inhibitory at 10° and 30° but not at 20° or 25°C.

Several authors have presented graphical evidence that moisture stress not only decreases the amount of germination, but also decreases the rate of germination (McGinnies, 1960; Springfield, 1966, 1968; Tapia and Schmutz, 1971). To more accurately describe this phenomenon, a series of simple linear regressions was calculated (Table 2), and the regression coefficients statistically compared by use of the technique of Sokal and Rohlf (1969, p. 451). Although data presented in Table 1 was that found at the conclusion of the 28-day-long experiment, regressions were calculated for the first 7 days of the experiment. Justification for using this shorter time period lies in the fact that over this period coefficients of determination (R^2) values were at a maximum (range of 0.81 to 0.98) and F-values were all highly significant ($p<0.01$). Thus the regression equations explain the observed trends more adequately than do regressions calculated for either longer or shorter time intervals. In addition, a more realistic approximation of field conditions could be presented: constant temperature and/or constant moisture stresses are not found over 28-day periods in the field.

Germination at −11.0 and −15.0 atm of moisture stress was insufficient to fit significant regressions.

The overall pattern found in Table 2 is quite similar to that first noted in Table 1. In general, moisture stresses at favorable temperatures are less inhibitory than at extreme temperatures. The most predominant trend is a decrease in the rate of germination as moisture stress becomes greater. In contrast to the germination data, temperature *per se* is of greater importance when the rate of germination is considered. Extreme temperatures significantly decrease the rate of germination, but the amount of the decrease is dependent upon the seed collection. Here, the Santa Fe collection shows a larger decrease in the rate of germination at 10° than does the Pinabetosa Mesa collection.

Discussion

Woodmansee (1969) found that germination of this species *in situ* was very erratic. He noted that successful establishment of seedlings in central New Mexico occurred only when seeds germinated in areas which were shaded throughout most of the day. He hypothesizes that this differential survival is related to the more favorable moisture conditions of such microhabitats. Results presented herein suggest that his observations may be the result of differences in the amount of germination in different microhabitats in addition to differential patterns of mortality.

Results presented are of importance to management personnel who wish to re-establish this species on depleted ranges. It is now apparent that the germination of this species is strongly affected by both moisture stress and temperature individually and by the rather complex interaction of these factors. It should also be noted that different sources of seeds respond differently to these conditions. These source differences may represent ecotypic adaptations to the environmental conditions associated with the sites they inhabit.

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Effect of Weed Control on Forage Production in the Nebraska Sandhills

L. A. MORROW AND M. K. McCARTY

Highlight: *Plots for the control of broadleaf weeds and for the determination of forage loss due to broadleaf weeds were established in the Nebraska sandhills. Herbicides were applied in the first year, the first and second years, the first, second and third years, and the first and third years in a four-year study. Forty lb/acre of N (40-N) were applied the fourth year. Herbicide treatments included 2,4-D amine, 2,4-D ester, 2,4,5-T, and silvex at 1 and 3 lb/acre; dicamba at 1/8 or 1/4 lb/acre in combination with 2 or 1 lb/acre 2,4-D amine, respectively; and picloram at 1/16 or 1/8 lb/acre in combination with 2 or 1 lb/acre 2,4-D amine, respectively. Control of broadleaf weeds with herbicide increased forage production up to 330 lb/acre when used without N. N applied following applications of dicamba at 1/4 lb/acre combined with 1 lb/acre 2,4-D amine increased forage production up to 660 lb/acre. Total herbage production increased when N was applied, but broadleaf weed production increased when weeds were not controlled. Herbicides and fertilizer can be effectively utilized to increase forage production, but they will not correct the mismanagement that results in weedy grazing lands.*

Weed infestations in grazing lands inhibit forage production and alter livestock grazing patterns (Barrons, 1969; Morrison, 1972). The production of 1 lb of weeds will reduce production of more desirable plants by an equal amount (Klingman, 1956). Weeds are also influenced markedly by the weather and their production fluctuates widely (McCarty et al., 1974).

Many grazing lands have a great potential for increased production by using intensive management practices (Rogler and Lorenz, 1956). Agricultural chemicals can be important in increasing the production on these lands (Barrons, 1969). Elwell and McMurphy (1963) found in Oklahoma that a single application of 2,4-D at rates of 0.5 and 1.0 lb/acre increased grass yields. Corns and Schraa (1965) found that although there was no definite improvement in forage yield associated with silverberry (*Elaeagnus commutata* Bernh.) control, the availability of forage was improved.

Weeds in grazing lands are considered to be a symptom of mismanagement (Dalrymple et al., 1964; Klingman, 1953). Although herbicides can help return weedy grazing lands to a more productive state, if benefits are to be realized over a long period of time, the use of herbicides must be accompanied by good grazing management. To be beneficial, herbicides must reflect an increase in the amount of forage available to the grazing animal.

The objective of this study was to determine the influence of green sagewort (*Artemisia campestris* L.) and other broadleaf weeds on forage production in the grazing lands of the Nebraska sandhills. Weed control treatments and 40-N were evaluated for their effect on forage production.

Methods and Materials

The sandhills of Nebraska receive about 20 inches annual precipitation, 70% of which occurs during the growing season. The soil type is Valentine fine sand.

The major warm-season forage grasses are sand bluestem (*Andropogon hallii* Hack.), prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn.), and blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex. Steud.), which are found on the upland sites, and switchgrass (*Panicum virgatum* L.), which is found on the finer-textured

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Table 1. Comparison between broadleaf weed control and forage production from plots receiving two consecutive annual herbicide applications.[1]

Treatment		Weed control	Forage production	
Herbicide	Rate (lb/acre)	(%)	Amount (lb/acre)	Increase (%)
Check	0	0 d	740 a	0
2,4-D amine	1	19 cd	710 a	0
2,4-D amine	3	85 ab	900 a	20
2,4-D ester	1	42 bcd	980 a	32
2,4-D ester	3	97 a	1,060 a	42
2,4,5-T	1	76 ab	990 a	32
2,4,5-T	3	62 ab	750 a	0
Silvex	1	51 bc	1,040 a	39
Silvex	3	90 ab	810 a	9
Dicamba +	1/8			
2,4-D	2	84 ab	1,020 a	37
Dicamba +	1/4			
2,4-D amine	1	37 bcd	990 a	32
Picloram +	1/16			
2,4-D amine	2	69 ab	1,040 a	39
Picloram +	1/8			
2,4-D amine	1	89 ab	970 a	29

[1] Means in the same column followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.

soils. Prairie Junegrass (*Koeleria cristata* (L.) Pers.) and needleandthread (*Stipa comata* Trin. and Rupr.) are the main cool-season forage grasses. Broadleaf weeds that are present include green sagewort, western ragweed (*Ambrosia psilostachya* D.C.), and annuals such as sunflower (*Helianthus annuus* L.) and spurge (*Euphorbia* L.). Green sagewort comprises about 80% of the broadleaf weedy vegetation.

Plots 20 ft by 300 ft were arranged in a randomized complete block design with four replications to evaluate forage production in relation to broadleaf weed control. In the first year of a 4-year study, the entire plot was sprayed for broadleaf weed control. In the second year, the plots were divided into four equal size sections, of which two were sprayed. In the third year, two sections were also sprayed. This sequence resulted in herbicide treatments that had been applied the first year; the first and second years; the first, second, and third years; and the first and third years of the study. In the fourth year, 40 lb N/acre (40-N) was applied to a 20-ft strip of all subplots perpendicularly to the direction of herbicide applications.

Herbicides were applied in late May of each year when green sagewort plants were 2 to 4 inches tall. Fertilizer was also applied in late May, to compliment the warm-season grasses that constitute the bulk of the forage in the sandhills.

Herbicides included 2,4-D amine [(2,4-dichlorophenoxy) acetic acid], 2,4-D ester, 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] and silvex [2-(2,4,5-trichlorophenoxy) propionic acid] at 1 and 3 lb/acre; dicamba [3,6-dichloro-*o*-anisic acid] at 1/8 or 1/4 lb/acre with 2 or 1 lb/acre 2,4-D amine, respectively; and picloram (4-amino-3,5,6-trichloropicolinic acid) at 1/16 or 1/8 lb/acre with 2 or 1 lb/acre 2,4-D amine, respectively. All herbicides were applied in 20 gallons per acre solution with a tractor-mounted sprayer. The surfactant X-77[1] was added to all herbicides at the rate of 0.5%.

Forage and weed yields were determined in August of each year by clipping at ground level two 2 x 4 ft quadrats located at random in each subplot. Forage and broadleaf weed components were separated and dried at 77°C for 72 hours.

Table 2. Forage production (lb/acre) from plots receiving herbicide applications in the first year (D); the first and second years (A); the first, second, and third years (C); and the first and third years (B).[1]

Treatment		Oven dry forage weights				
Herbicide	Rate (lb/acre)	A	B	C	D	Average
Check	0	840 a	940 a	1,010 a	750 a	890 s
2,4-D amine	1	1,240 a	1,450 a	1,240 a	880 a	1,200 rs
2,4-D amine	3	1,140 a	1,370 a	1,140 a	1,070 a	1,180 rs
2,4-D ester	1	1,090 a	1,240 a	1,170 a	990 a	1,120 rs
2,4-D ester	3	1,470 a	1,310 a	1,240 a	990 a	1,250 r
2,4,5-T	1	1,390 a	1,190 a	1,090 a	860 a	1,130 rs
2,4,5-T	3	900 a	1,080 a	1,070 a	690 a	940 rs
Silvex	1	1,080 a	1,230 a	1,100 a	680 a	1,020 rs
Silvex	3	1,210 a	1,160 a	1,170 a	1,030 a	1,140 rs
Dicamba +	1/8					
2,4-D amine	2	1,230 a	1,260 a	1,200 a	930 a	1,160 rs
Dicamba +	1/4					
2,4-D amine	1	1,380 a	1,300 a	1,130 a	920 a	1,180 rs
Picloram +	1/16					
2,4-D amine	2	1,220 a	1,330 a	1,250 a	1,030 a	1,210 rs
Picloram +	1/8					
2,4-D amine	1	1,320 a	1,360 a	1,090 a	1,190 a	1,240 r
Average		1,190 y	1,250 y	1,150 y	920 z	

[1] Means in columns or rows followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.

Results and Discussion

Forage yields were harvested the second year of the study. No harvests were made at this time if herbicides had been applied only once. Forage yields averaged 740 lb/acre when no herbicides were applied (Table 1). When herbicides were applied in 2 consecutive years, forage yields were not significantly increased. However, the trend was toward increased forage production when broadleaf weeds were controlled. Forage production was increased about 300 lb/acre when 3 lb/acre of 2,4-D ester, 1 lb/acre of silvex, 1/8 lb/acre dicamba combined with 2 lb/acre 2,4-D amine, or 1/16 lb/acre picloram combined with 2 lb/acre 2,4-D amine were applied in 2 consecutive years. Although these forage yields are not statistically significant, the trend indicates that forage production may be increased with broadleaf weed control. Although the increases in forage yields are large, they are not statistically significant because of the great amount of variability. Inadequate sampling may have contributed to the lack of statistical significance.

The third year, forage yields were harvested from all treatments (Table

[1] Trade names are included for the benefit of the reader and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.

Table 3. Average control (%) of broadleaf weeds and forage production (lb/acre, oven dry) from plots receiving herbicide treatments in the first year; the first and second years; the first, second, and third years; and the first and third years.[1]

Treatment		Weed	Forage production	
Herbicide	Rate (lb/acre)	control (%)	Amount (lb/acre)	Increase (%)
Check	0	0 c	890 b	0
2,4-D amine	1	15 bc	1,200 ab	35
2,4-D amine	3	27 ab	1,180 ab	32
2,4-D ester	1	28 ab	1,120 ab	26
2,4-D ester	3	34 ab	1,250 a	40
2,4,5-T	1	30 ab	1,130 ab	27
2,4,5-T	3	33 ab	940 ab	6
Silvex	1	16 bc	1,120 ab	26
Silvex	3	32 ab	1,140 ab	28
Dicamba +	1/8			
2,4-D amine	2	33 ab	1,160 ab	30
Dicamba +	1/4			
2,4-D amine	1	27 ab	1,180 ab	32
Picloram +	1/16			
2,4-D amine	2	36 ab	1,210 ab	36
Picloram +	1/8			
2,4-D amine	1	45 a	1,240 a	39

[1] Means in the same column followed by the same letter do not differ significantly at the 5% level by Duncan's multiple-range test.

2). Three lb/acre of 2,4-D ester or 1/8 lb/acre picloram in combination with 1 lb/acre 2,4-D amine significantly increased forage production over that of untreated check when all treatment years are averaged. Forage production was also increased when herbicides were applied in more than one year. No difference existed between treatments (averaged over all herbicides) that had been applied in the first and second years (A); the first, second, and third years (B); and the first and third years (C) of the study; but all were greater than when herbicides were applied in 1 year only (D).

Control of broadleaf weeds had decreased by the third year of the study (Table 3 compared to Table 1); but in general, broadleaf weed control increased forage production. Picloram at 1/8 lb/acre combined with 1 lb/acre 2,4-D amine resulted in 45% control of broadleaf weeds and increased forage production by 350 lb/acre. The 3 lb/acre rate of 2,4-D ester resulted in 34% control of broadleaf weeds and increased forage production by 360 lb/acre or 40% over the untreated check. Although these two herbicide treatments are the only ones that have increased forage production statistically, the trend is toward increased forage production where some degree of broadleaf weed control has been attained.

The fourth year of the study (Table 4), 1 year after the final herbicide application, forage production was greatest where 3 lb/acre 2,4-D amine, 1 lb/acre 2,4,5-T, the dicamba-2,4-D amine combinations, and the picloram-2,4-D amine combinations had been applied, (averaged over all treatment sequences). The untreated check averaged 820 lb/acre forage, whereas the most successful herbicide treatments produced more than 1,110 lb/acre forage. When herbicides were applied in more than 1 year, forage production, averaged over all herbicides was increased. Herbicides applied in 2 consecutive years increased forage production by 140 lb/acre, compared to a single herbicide application. No difference existed between herbicides that were applied in 3 consecutive years (B) or in alternate years (C). These treatments increased forage production by about 270 lb/acre when compared to a single herbicide application (D).

The best production resulted from herbicide applications in the first and third years or in the first, second, and third years. Forage produced from these repeated applications was nearly 300 lb/acre more than that of the untreated check. About 170 lb/acre more forage was produced from areas that had been treated in the first and second years. However, it had been 2 years since these treatments had been applied. This indicates the reestablishment of the weedy vegetation in the treated areas.

During the fourth year, forage yields were increased 330 lb/acre when 3 lb/acre 2,4-D amine or 1 lb/acre 2,4,5-T had been applied (Table 5). When 40-N was applied, forage yields were increased 200 lb/acre when all herbicide treatments are averaged. Forage production was increased about 520 lb/acre over that of the unsprayed, fertilized check when the application of 1/4 lb/acre dicamba in combination with 1 lb/acre 2,4-D amine was followed by 40-N. The 3 lb/acre rate of 2,4-D amine, dicamba

Table 4. Forage production (lb/acre, oven dry) harvested the fourth year from plots receiving herbicide applications in the first year (D); the first and second years (A); the first, second, and third years (B); and the first and third years (C).[1]

Treatment		Forage production				
Herbicide	Rate (lb/acre)	A	B	C	D	Average
Check	0	660 j	920 b-j	870 c-j	820 d-j	820 t
2,4-D amine	1	730 g-j	1,280 a-d	1,120 a-j	850 c-j	1,000 rst
2,4-D amine	3	1,000 a-j	1,190 a-g	1,310 abc	1,070 a-j	1,140 r
2,4-D ester	1	1,040 a-j	1,000 a-j	970 a-j	840 d-j	960 rst
2,4-D ester	3	1,130 a-i	920 b-j	1,150 a-i	850 c-j	1,010 rst
2,4,5-T	1	1,220 a-f	1,360 ab	1,110 a-j	750 f-j	1,110 r
2,4,5-T	3	730 hij	910 b-j	1,090 a-j	680 ij	850 st
Silvex	1	950 a-j	1,360 ab	920 b-j	730 g-j	990 rst
Silvex	3	1,070 a-j	1,010 a-j	1,030 a-j	990 a-j	1,020 rst
Dicamba +	1/8					
2,4-D amine	2	960 a-j	1,150 a-h	1,140 a-i	860 c-j	1,030 rs
Dicamba +	1/4					
2,4-D amine	1	1,110 a-j	1,400 a	1,250 a-e	780 e-j	1,130 r
Picloram +	1/16					
2,4-D amine	2	1,160 a-h	1,030 a-j	1,280 a-d	780 e-j	1,060 rs
Picloram +	1/8					
2,4-D amine	1	1,050 a-j	1,190 a-g	1,230 a-e	1,000 a-j	1,120 r
Average		990 y	1,130 x	1,110 x	850 z	

[1] Means in columns or rows followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.

Table 5. Forage production (lb/acre, oven dry) the fourth year as affected by herbicide applications in the first year (D); the first and second years (A); the first, second, and third years (B); and the first and third years (C) and 40-N.[1]

Treatments		Forage production									
		A		B		C		D		Average	
Herbicide	Rate (lb/acre)	NF[2]	F	NF	F	NF	F	NF	F	NF	F
Check	0	680	650	810	1,030	940	800	560	1,080	750 p	890 p-s
2,4-D amine	1	760	700	1,110	1,460	1,060	1,180	790	900	930 p-t	1,060 q-u
2,4-D amine	3	1,070	930	1,000	1,390	1,420	1,200	830	1,300	1,080 r-u	1,210 tuv
2,4-D ester	1	870	1,220	830	1,160	930	1,010	710	970	830 pqr	1,090 r-u
2,4-D ester	3	1,070	1,200	790	1,050	1,100	1,190	690	1,010	910 p-t	1,120 r-u
2,4,5-T	1	1,190	1,250	1,310	1,410	1,100	1,130	710	800	1,080 r-u	1,150 r-v
2,4,5-T	3	610	840	770	1,050	1,050	1,150	610	750	760 p	940 p-t
Silvex	1	970	930	1,090	1,630	1,070	760	830	630	990 p-u	990 p-u
Silvex	3	1,210	940	970	1,040	920	1,130	790	1,180	970 p-u	1,010 q-u
Dicamba + 2,4-D amine	1/8 + 2	1,020	900	1,070	1,230	1,030	1,250	610	1,110	930 p-t	1,120 r-u
Dicamba + 2,4-D amine	1/4 + 1	800	1,430*	970	1,820*	930	1,560*	710	850	850 pqr	1,410 v
Picloram + 2,4-D amine	1/16 + 2	1,040	1,290*	1,040	1,020	1,070	1,500*	630	930	940 p-t	1,180 s-v
Piclorma + 2,4-D amine	1/8 + 1	760	1,330*	1,150	1,240	1,010	1,440*	940	1,070	970 p-u	1,270 uv
Average		930 x	1,050 xy	990 x	1,270 z	1,050 xy	1,180 yz	720 w	970 x	920 j	1,120 k

[1] Means in columns or rows followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.
[2] NF—No fertilizer was applied; F—40-N.
*Value differs significantly at the 5% level from the check in the same column.

at 1/4 lb/acre combined with 1 lb/acre 2,4-D amine and picloram at 1/8 lb/acre in combination with 1 lb/acre 2,4-D amine increased forage production when they were followed with 40-N. Forage production was increased by 300 lb/acre from herbicide applications in 3 years (B) followed by 40-N when compared to a single herbicide application (D). This combination of treatments increased forage production by 520 lb/acre when compared to the sprayed, unfertilized check. No difference existed between 3 consecutive years (B) of herbicide applications and alternate yearly herbicide applications (C) when all herbicides are averaged.

After applications of 1/4 lb/acre dicamba in combination with 1 lb/acre 2,4-D amine or the picloram-2,4-D amine combinations in the first and third years (C) followed by 40-N, forage production was slightly higher than for these treatments applied in the first and second years (A) but less than the same treatments applied for 3 consecutive years (B).

The data indicate that the control of broadleaf weeds will increase forage production. Additional increases in forage production will result from effective weed control treatments followed by N fertilizer. Application of herbicides in alternate years, in conjunction with N fertilization, appears to have as many benefits as applications in consecutive years for the control of green sagewort and other broadleaf weeds in this study. Applications of weed control treatments in alternate years will control the reestablishing seedlings, while costs of application and material will be reduced by applying them in alternate years.

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Control of Pinyon Saplings with Picloram or Karbutilate

JAMES A. YOUNG AND RAYMOND A. EVANS

Highlight: *The herbicides picloram or karbutilate were used to kill one-leaf pinyon saplings that form dense stands in areas that were previously chained to remove large trees. The granular herbicides were applied to the soil beneath the crown spread of the saplings by pouring the herbicide on top of the trees and allowing it to trickle down through the branches. Both materials were effective at low rates. If desirable shrubs or herbaceous species were not rooted directly beneath the tree canopies, minimum damage resulted from the herbicide application. Herbage production was not significantly increased or decreased by removal of the pinyon saplings with herbicides. Cutting the saplings and shrubs by hand and removing them from the plot increased herbage production.*

Chaining, the uprooting or breaking-off of trees by dragging an anchor-chain between large tractors, has been widely used by land managers in the pinyon (*Pinus monophylla*)/ Utah juniper (*Juniperus osteosperma*) woodlands of the Great Basin. The goal of these mechanical treatments of closed canopy woodlands is to induce a lower stage of succession dominated by grasses, forbs, and browse species that can be harvested by domestic livestock, wildlife, or both. Many chainings have failed to achieve this goal because of the rapid growth and assumption of dominance by sapling pinyon, juniper, or both that were supple enough to bend with the chain and snap back after it passed (Monroe, 1974). The obvious solution to this problem is to chain only areas that support closed canopy, old growth trees, so a minimum number of small trees are present to escape the mechanical treatment.

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Neither karbutilate nor picloram is registered by the Environmental Protection Agency (EPA) for the use on grazing lands described in this paper. Picloram is registered for control of pinyon or juniper on rangelands within some, but not all western states. Before using either of these materials, check with local state departments of agriculture and/or EPA offices.

The pinyon/juniper woodlands of the Great Basin are usually on mountainous topography with a wide variety of topo-edaphic situations in a given area. Extensive disturbance by wood, post, and charcoal cutting with promiscuous burning often has produced a number of different successional stages within a given woodland stand (Beeson, 1974). To chain desired areas, land managers have often been forced to treat a matrix of closed stands dotted with islands of younger successional stages. They did so because of accepted economic concepts that large blocks must be treated and because the implement requires relatively large areas for maneuvering. To make chaining an acceptable range improvement practice, irregular boundaries must be blended aesthetically into the landscape. It is difficult to design this type of mechanical treatment without including low seral communities. Therefore, the problem of management of mixed stands still persists in many areas. Our purpose was to develop methods of controlling saplings of one-leaf pinyon in areas that had previously been mechanically treated to control larger trees.

Methods

The study area was in Churchill Canyon, about 17 km northwest of Yerington, Nevada. The site was located in the upper one-third of the pinyon/juniper zone at an elevation of 1,965 m on the eastern escarpment of the Pine Nut Mountain Range. Annual precipitation (based on a recorder near the site) averages 285 mm, confined almost entirely to cold winter storms.

The area was chained with an anchor chain, aerially seeded to crested wheatgrass (*Agropyron desertorum*) and bitterbrush (*Purshia tridentata*) and rechained in the opposite direction in 1969. Before chaining, the plant communities consisted of a pinyon/juniper woodland with an old growth matrix interspersed with islands of big sagebrush (*Artemisia tridentata*) representing lower seral stages produced by wildfires and/or woodcutting. When the tree canopies in the old growth pinyon areas were virtually closed, all but the most shade, litter, and competition-tolerant species were eliminated from the understory.

The site we selected supported a dense stand of big sagebrush, with pinyon saplings emerging through the one-meter-high shrub canopy (Fig. 1). Besides big sagebrush, the community occasionally supports bitterbrush, green ephedra (*Ephedra viridis*), horsebrush (*Tetradymia canescens*), and desert peach (*Prunus andersonii*). The understory under the dense shrub canopy was virtually bare, with occasional plants of squirreltail (*Sitanion hystrix*), and various forbs. Details of the community are described by Blackburn et al. (1969) and Young and Evans (1973).

Soils at the study site comprised Mollic Haplargids, with a 20- to 35-cm ochric epipedon over a light yellowish-brown, gravelly-clay loam--argillic horizon (Blackburn et al., 1969).

Herbicide Treatments

In October 1971, we established plots, 10 by 10 m, in a randomized block design with four replications. We applied the herbicides to the crown area of each pinyon sapling rooted in a plot by pouring the material on top of the tree crown. Treatments consisted of karbutilate (*tert*-butylcarbamic acid ester with 3-(*m*-hydroxyphenyl)-1,1-dimethylurea) formulated as a 10% active ingredient (a. i.) granular at rates of 0.7 and 1.4 g a. i. per tree;

Fig. 1. *Dense stand of one-leaf pinyon saplings emerging from canopy of big sagebrush. Old growth stand is in background.*

karbutilate formulated as 60% a. i. tablets applied at the same rates; and picloram (4-amino-3,5,6-trichloro-picolinic acid) formulated as 2.3% a. i. on ammonium sulfate beads applied at the same rates of active ingredients as the karbutilate. The rates of herbicides used were based on several years of testing of these materials on one-leaf pinyon at this and other sites in Nevada. Besides the herbicide treatments, we cut and removed from the plots all pinyon saplings (there were no larger trees), and cut and removed all trees and shrubs, except bitterbrush, as additional treatments.

In October, 1972, on an adjacent area, we applied picloram formulated as 10% a. i. granulars on sand cores at rates of 0.35, 0.7, and 1.4 g/tree.

Sampling

We determined the density and height of all trees on each plot and the density and herbage cover of all shrub species in each plot when the experiment was established. The cover of crested wheatgrass was also estimated. Each subsequent year we recorded symptoms of injury, mortality, or both of pinyon trees. Herbage yield and density of crested wheatgrass plants were determined from 4-m^2 plots clipped in each treatment. The herbage yield plots were stratified under and between trees. Shrub cover and density were recorded annually. In 1974, the plots were inadvertently grazed, so cover estimates of crested wheatgrass were substituted for herbage yield.

Results

The spectrum of activity for the two herbicides used is very different. Karbutilate is a soil-active herbicide that is relatively nonselective. Picloram is foliar-active when applied as a spray to leaves, but it is also soil-active when used as a granular material for basal crown area treatment. At the rates used in this study, picloram does not damage established perennial grasses.

Control of One-leaf Pinyon

The herbicides differ in the symptoms they produced on one-leaf pinyon saplings. By the end of the first season after the application of picloram, most trees had partial or total leaf chlorosis (Table 1). Except for a few trees that rapidly dropped their needles, the trees treated with granular formulation of karbutilate were much slower to develop chlorotic needle symptoms. The trees treated with the tablet form of karbutilate were extremely slow to develop injury symptoms. Many trees that eventually died did not develop symptoms until the second season after application of the herbicide tablets.

In most treatments, occasional single trees showed no herbicide injury symptoms, even though all other trees in the treatment area died. We attributed these escapes to misses when the herbicide was applied. We tried spray painting and flagging trees as the herbicide was applied, but in dense patches of trees, occasional trees were missed. Skipping trees will be a problem in applying the technique on a practical basis, but the leaving of an occasional tree may be aesthetically valuable.

Picloram at 0.7 or 1.4 g/tree formulated as 2.3 or 10% granular and karbutilate at 1.4 g/tree as 10% granular material were very effective for control of pinyon saplings with heights of 2 m or less (Fig. 2). Karbutilate at 0.7 g/tree and picloram at 0.35 g/tree were effective on trees 0.5 m or less in height (Table 2).

The tablet formulation of karbutilate was quite ineffective (Table 2). Tablet formulations had been tried because of (a) concentration of active ingredients with reduced shipping cost, (b) ease of application: one aspirin-sized tablet simply tossed under a tree, and (c) reduced damage to the herbaceous understory by concentration of

Table 1. Symptoms of herbicide injury (% of trees treated) on one-leaf pinyon saplings 1 year after application of herbicides.

	Injury				
Herbicide-formulation rate	Needle drop	Total chlorosis	Partial chlorosis	Spot chlorosis	No injury symptom
Karbutilate					
10% gramular					
1.4 g/tree	16	30	53		1
0.7 g/tree		23	45	30	2
60% tablet					
1.4 g/tree			78	22	
0.7 g/tree				22	78
Picloram					
2.3% bead					
1.4 g/tree		86	12		2
0.7 g/tree		68	29	2	1
10% granular					
1.4 g/tree		92	8		
0.7 g/tree		54	44		2
0.35 g/tree		62	38		

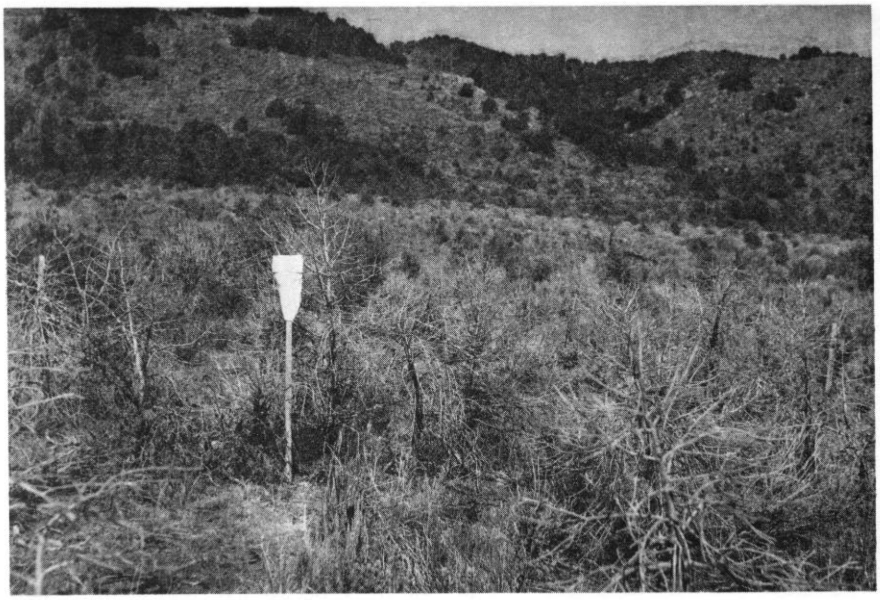

Fig. 2. *Saplings of one-leaf pinyon controlled with 1.4 g/tree of herbicide karbutilate.*

the first application and reliance on lateral diffusion of the herbicide deep in the soil profile to reach enough tree roots.

Equivalent rates of 10% granular formulated karbutilate were very effective in controlling one-leaf pinyon saplings. Therefore, the solubility of the tablets, poor distribution of the herbicide around the rooting zone of the trees, or both probably accounts for ineffectual control.

Application Techniques

At 0.7 and 1.4 g/tree, we were applying 1.5 to 3.1 kg/ha of herbicide based on a mean density of 2,200 trees/ha. Because the granulars consist of only 10% active ingredients, 15 to 31 kg/ha of actual material must be packed out to the mountainside and distributed. The 2.3% a. i. picloram carried on beads of ammonium sulfate is a very convenient material to handle, in terms of ease of pouring, lack of dust, and conformity. But 65 to 135 kg/ha of material has to be transported.

We used plastic vials, cut down to provide the proper volume, to meter the correct dosage of herbicide to each tree. A 2.25-kg bag of herbicide hung from a shoulder strap provided enough herbicide to treat about 1.4 ha of chaining at the lowest effective rate. Trees can be treated at a fast walk, as long as the applicator can remember which tree has received the herbicide. For a variable-rate base on tree height, we applied 1 vial (0.7 g) for small (less than 1.5 m) and 2 vials (1.4 g) for large saplings.

Shrub Response

The first response of shrubs to the herbicide treatments was rather limited. If the shrubs were rooted under the canopy of the pinyon, they were killed, but if they were rooted between the crowns, no injury resulted. The clonal species, desert peach and currant, usually had only a part of each clump killed, unless the entire clump was under the tree canopies.

We were especially interested in the susceptibility of bitterbrush to the herbicides. At first, we tried to establish a safe distance from treated trees for bitterbrush in relation to one-leaf pinyon control. Experience has shown that the simplest rule of thumb is that as long as bitterbrush or other shrubs are not primarily rooted under the crowns of the pinyon saplings, chances of injury are negligible.

The attempted removal of shrubs by chopping provided a dramatic change. The crown cover of the root-sprouting shrubs, desert peach and currant, increased by 64% on two of the four replications of the hand-chopped plots. On the other two replications, by chance, these shrubs did not occur before cutting. The rapid growth of desert-peach root sprouts after mechanical removal of the aerial parts has been noted before (Young and Evans, 1973).

Herbaceous Response

The crested wheatgrass stand on the treatment area was very stable during the experiment (Table 3). None of the herbicide treatments influenced stand density. Even though stand density was not reduced and crested wheatgrass dominated the understory, yield did not increase when trees were controlled. Yield increased only when the trees or shrubs or both were cut and removed. The increase in production partly resulted from increased production by the perennial grasses, but it largely represented increased downy brome (*Bromus tectorum*) production in the circle of litter where the trees were removed.

Why did production increase on the handcut plots and not on the herbicide treatments? The litter accumulation

Table 2. Control (%) of one-leaf pinyon saplings in relation to height, 3 years after herbicides were applied.[a]

Herbicide-formulation rate	Tree ht (m) 0.25	0.5	1.0	1.5	2.0	Overall controls
Karbutilate						
10% granular						
1.4 g/tree	100	100	98	100	100	98
0.7 g/tree	100	100	98	94	–[a]	88
60% tablet						
1.4 g/tree	84	88	74	64	0	78
0.7 g/tree	64	50	40	23	–	48
Picloram						
2,3% bead						
1.4 g/tree	98	98	100	100	100	98
0.7 g/tree	100	100	98	100	100	98
10% granular						
1.4 g/tree	100	100	100	98	100	98
0.7 g/tree	100	100	100	94	–	98
0.35 g/tree	100	100	94	–	52	78

[a]Dash indicates this height class did not occur in treatments. The height class distribution was carried among treatments, so overall control is not the mean of control by height classes.

Table 3. Total herbage yield (kg/ha) and density/m² of crested wheatgrass.[a]

Herbicide-formulation rate	1972		1973		1974
	Yield	Density	Yield	Density	Density
Control	510	10.1	430 b	9.1	11.1
Karbutilate					
10% granular					
1.4 g/tree	430	8.4	310 b	11.8	9.8
0.7 g/tree	480	7.6	300 b	8.9	10.9
60% tablet					
1.4 g/tree	390	6.7	280 b	7.6	8.1
0.7 g/tree	410	9.1	320 b	10.1	9.4
Picloram					
2.3% bead					
1.4 g/tree	460	8.7	370 b	8.9	9.1
0.7 g/tree	380	7.8	310 b	8.8	8.9
Trees cut and removed	500	9.3	890 a	8.9	10.1
Trees and shrubs cut and removed	480	8.7	980 a	9.3	10.0

[a]Means followed by the same letter are not significant at the 0.01 level of probability, as determined by Duncan's multiple range test. Columns without letters do not significantly differ among means.

beneath the herbicide-treated trees, which was substantial before the herbicides were applied, increased with the needle drop from the dead trees. This blanket of litter failed to support downy brome or other annuals. Not only did the handcut plots not have the needle drop from trees, but also the preexisting litter areas were greatly disturbed by the cutting of the bushy pinyon saplings.

Probably, the shrubs also responded to the removal of the pinyon layer, and this response limited the accelerated production of crested wheatgrass. Where we hand cut the trees and shrubs, herbaceous production increased more than when we cut the trees alone (Table 3). The regrowth of root-sprouting shrubs on two replications of this treatment probably prevented this increase in production from being statistically significant.

Significance to Management

If either of these herbicides is registered for use on rangelands, land managers will have a valuable tool for extending the effective life span of pinyon chaining. Within-state registration for use of picloram for juniper control already exists.[1]

By applying the materials by hand to individual trees, we obtained a level of selectivity that permitted control of pinyon saplings without undue damage to adjacent bitterbrush plants.

An excellent stand of crested wheatgrass was on the study area before the herbicides were applied. In many chainings, areas of dense young pinyon/juniper trees contain no valuable browse or herbaceous species. Under these conditions, broadcast herbicide treatments and revegetation are required.

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THESIS: UNIVERSITY OF IDAHO

Soil Compaction Effects of Livestock Grazing on a Crested Wheatgrass Seeding in Southern Idaho, by Arlin Eugene Colborg, MS, Wildlife and Range Sciences. 1972.

This thesis is the result of a 2-year study to ascertain the effect of livestock trampling on soil compaction of a southern Idaho crested wheatgrass range.

Surface soil bulk density, water infiltration rates, and reliefmeter results were used to measure the effect of livestock trampling on compacting the soil. Total forage production, growth reserves, and growth rates of crested wheatgrass were also obtained to measure relationships with soil bulk density.

Climatic effects, as expressed through raindrop impact, tended to compact soils in both grazed and ungrazed areas. Frost heaving and soil swelling through water intake appeared to loosen compacted soils.

Grazing did not increase surface soil compaction to a great extent; rather the opposite was often the case through the pulverizing action of cattle hooves on the soil surface. Water infiltration rates were reduced a small degree by grazing activity but not enough to warrant corrective measures.

Measurements from reliefmeters, like soil bulk density, reflected the influences of climate and grazing activity.

Total forage production and growth reserves had a small but negative relationship to soil surface bulk density. Growth rates appeared to be more highly related to plant density and past grazing use than soil bulk density.

Control of Aspen Poplar, Balsam Poplar, and Prickly Rose by Picloram Alone and in Mixtures with 2, 4-D

GARRY BOWES

Highlight: *Picloram alone and in combination with 2,4-D was evaluated for the control of aspen poplar (*Populus tremuloides *Michx.), balsam poplar (*Populus balsamifera *L.), and prickly rose (*Rosa acicularis *Lindl.) on rangeland in Saskatchewan which had alfalfa (*Medicago sativa *L.) as an important grazing component. The addition of picloram at 0.5 lb/acre to 2,4-D amine at 2 lb or less per acre did not improve the control of aspen poplar when compared to the presently recommended treatment in Saskatchewan of 2 lb/acre of 2,4-D ester. However, there was some evidence that the addition of 1 lb/acre of picloram to 2 lb/acre of 2,4-D amine may improve control. Picloram applied at 1 lb/acre alone or in combination with 2 lb/acre of 2,4-D amine provided effective control of balsam poplar. There was excellent control of prickly rose for 4 to 5 years following the application of 0.5 lb/acre of picloram with or without the addition of 2,4-D. The herbicide rates that were necessary for the control of any of the woody species, almost completely removed alfalfa from the rangeland. The significance of alfalfa on rangeland and the potential loss of grazing from using or not using herbicides is discussed.*

An important technique used for rangeland improvement in the aspen parkland of Saskatchewan is the removal of mature aspen poplar[1] (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.) trees with bulldozers and the subsequent reseeding of rangeland improvement species. The main problem encountered with this improvement technique is the regrowth of aspen and balsam poplar, which compete with the desirable plant species established on the rangeland. Aerial applications of 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 2.0 lb/acre are used for the control of young trees (Beck. 1968; Friesen et al., 1965). When the shrub prickly rose (*Rosa acicularis* Lindl.) is present, 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] is substituted for a portion of the 2,4-D (i.e., 2 parts 2,4-D to 1 part 2,4,5-T). However, variable control is obtained and retreatment is often necessary.

Picloram (4-amino-3,5,6-trichloropicolinic acid) has shown promise for the control of aspen and balsam poplar (Corns and Dai, 1967). The need for more effective control of woody species in the aspen parkland provided the incentive for evaluating picloram.

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[1]The botanical nomenclature follows that by the Canada Weed Committee (1969).

The objectives of this study were to determine (1) the effectiveness of picloram for the control of aspen poplar, balsam poplar, and prickly rose; (2) the control of all three species by combinations of picloram with other herbicides; and (3) the length of time that control can be expected.

Methods and Materials

The experimental site was located 120 miles northeast of Regina, Saskatchewan, on section 15, township 28, range 9 west of the 2nd meridian. The soil was classed as a Waitville loam (Mitchell et al., 1944). During the winter 1964–65 a solid stand of aspen poplar was bulldozed and piled. In the summer of 1965 the area was disced twice with a heavy duty serrated disc drawn by a crawler-tractor and was seeded with a double disc drill to a mixture of alfalfa (*Medicago sativa* L.) and bromegrass (*Bromus inermis* Leyss.). This resulted in a satisfactory stand of forage; but discing did not kill all of the roots, so aspen poplar, balsam poplar, and prickly rose were rapidly re-establishing in the area at the time of herbicide application.

All experiments were designed as randomized complete blocks replicated four times. Size of plots for Experiment 1 was 6.4 × 9.1 m; for Experiment 2, 13.4 × 30.5 m. Untreated check plots were included in all tests. Evaluation of control was accomplished by counting the number of live shoots in the plots before herbicide treatment and the number surviving after chemical application. The assessment was obtained from three permanent quadrats each 1.5 × 4.0 m on each plot in Experiment 1 and 18 permanent quadrats each 1 × 1 m on each plot in Experiment 2. Results are expressed as percentage reduction in the number of live shoots recorded before herbicide treatment. The density of alfalfa was obtained from the permanent quadrats after herbicide treatment. Final evaluation for both experiments was made in 1972 by estimating the percentage canopy cover on each plot. Cover for each plot was estimated according to the classification system adapted by Trepp and quoted in Brown (1954). The cover scales were as follows: up to 1.0%, 1.0 to 9.9%, 10.0 to 24.9%, 25.0 to 49.9%, 50.0 to 74.9%, and 75.0 to 100.0%. The mid-points of the classes for the replicates were averaged for each treatment. Several extreme values in the data make the standard statistical procedures difficult to apply; and since meaningful conclusions are apparent from the results without resorting to specific tests, statistical procedures are not discussed.

Herbicides were applied as soon as possible after full leaf expansion on June 15, 1967, for Experiment 1 and June 26, 1968, for Experiment 2. In Experiment 1, all treatments were applied with a small back-pack sprayer using compressed air to propel the liquid spray solution to a four nozzle hand held boom. All treatments in Experiment 2 were applied with a sprayer mounted on a truck as described by Meyer et al. (1967).

Herbicides used were the dimethylamine salts of 2,4-D, the butoxy ethanol ester of 2,4-D, a mixture of the *iso*-octyl esters of 2,4-D and 2,4,5-T, the potassium salt of picloram, and mixtures of the triisopropanolamine acid of 2,4-D and picloram. A surfactant containing polysorbate, mono- and diglycerides, butylated hydroxyanisole, butylated hydroxytoluene, and propylene glycol in a water-isopropanol medium (Atlox 210) was added to some treatments (Corns and Dai, 1967).

Results

Experiment 1

The density of aspen poplar in the experimental area varied from 1.0 to 2.2 live shoots/m^2 (Table 1). On the untreated plots there was a natural reduction in the population of aspen poplar from 1968 to 1970. The amine formulation of 2,4-D was ineffective for the control of aspen poplar. When picloram was applied alone, at least 1 lb/acre was required to give a substantial reduction in the plant population. Picloram at 0.5 lb/acre gave good control provided 2.0 lb/acre of 2,4-D amine was added. Similar control was obtained when either 0.5 or 1.0 lb/acre of picloram was applied with 2.0 lb/acre of 2,4-D amine. Five years after any of the herbicide treatments, the cover of aspen poplar was still lower than on the untreated plots. The lowest canopy cover was present on the area treated with 1.0 lb/acre of picloram. However, the canopy cover 5 years after any of the other treatments that included at least 0.5 lb/acre of picloram alone or in a mixture with 2,4-D was similar to 1.0 lb/acre of 2,4-D amine.

Table 1. Pretreatment densities (shoots/m^2), reduction (%) of shoots, and canopy cover (%) of aspen poplar in Experiment 1 following application (lb/acre) of 2,4-D and picloram alone and in mixtures.

Treatment		Density	Reduction of shoots			Cover
Herbicide	Rate	1967	1968	1969	1970	1972
Check		2.2	23	17	37	40
2,4-D amine	1.0	1.4	23	42	42	6
2,4-D amine	2.0	1.9	25	32	47	14
Picloram	0.5	1.0	26	23	57	9
Picloram	1.0	1.7	70	62	75	2
Picloram + 2,4-D	0.25 + 1.0	1.6	5	5	19	26
Picloram + 2,4-D	0.5 + 2.0	1.6	66	70	82	5
Picloram + 2,4-D	0.5 + 1.0	1.2	54	46	51	6
Picloram + 2,4-D	1.0 + 2.0	1.3	67	62	76	6

The density of balsam poplar prior to the application of herbicides varied between 0.9 and 2.1 live shoots/m^2 on the experimental plots (Table 2). For 3 years after the start of the experiment there was a considerable and consistent reduction in the natural population of balsam poplar. The only herbicide treatments that effectively reduced the stand of balsam poplar were picloram at 1.0 lb/acre and a mixture of picloram plus 2,4-D at 1.0 plus 2.0 lb/acre, respectively. The amount of balsam poplar canopy cover 5 years following any of the herbicide treatments was less than on the untreated plots. The lowest canopy cover was recorded on the plots receiving the highest rate of picloram (1.0 lb/acre) and 2,4-D (2.0 lb/acre) applied as a mixture.

Table 2. Pretreatment densities (shoots/m^2), reduction (%) of shoots, and canopy cover (%) of balsam poplar in Experiment 1 following application (lb/acre) of 2,4-D and picloram alone and in mixtures.

Treatment		Density	Reduction of shoots			Cover
Herbicide	Rate	1967	1968	1969	1970	1972
Check		2.0	45	52	62	14
2,4-D amine	1.0	1.9	37	39	50	10
2,4-D amine	2.0	1.4	49	48	67	7
Picloram	0.5	2.1	66	63	72	4
Picloram	1.0	0.9	91	93	90	2
Picloram + 2,4-D	0.25 + 1.0	1.0	33	39	59	3
Picloram + 2,4-D	0.5 + 2.0	1.8	70	67	72	4
Picloram + 2,4-D	0.5 + 1.0	1.6	67	66	73	3
Picloram + 2,4-D	1.0 + 2.0	1.3	89	86	90	0.3

Prickly rose density varied between 2.9 and 6.4 shoots/m^2 prior to herbicide application (Table 3). There was a reduction in the population of prickly rose during a 3-year period after the start of the experiment. The control of prickly rose increased as the rate of picloram increased from 0.25 to 1.0 lb/acre. The addition of 2,4-D to picloram to form a mixture did not appear to have any effect on the control of prickly rose. Five years after the application of at least 0.5 lb/acre of picloram, the canopy cover of prickly rose was 1% or less of the ground surface.

Table 3. Pretreatment densities (shoots/m^2), reduction (%) of shoots, and canopy cover (%) of prickly rose in Experiment 1 following application (lb/acre) of 2,4-D and picloram alone and in mixtures.

Treatment		Density	Reduction of shoots			Cover
Herbicide	Rate	1967	1968	1969	1970	1972
Check		4.3	28	62	33	4
2,4-D amine	1.0	4.4	7	42	35	2
2,4-D amine	2.0	4.1	0	31	23	9
Picloram	0.5	3.7	97	93	90	0
Picloram	1.0	4.4	100	100	100	0
Picloram + 2,4-D	0.25 + 1.0	4.1	78	75	70	5
Picloram + 2,4-D	0.5 + 2.0	4.2	94	93	89	0
Picloram + 2,4-D	0.5 + 1.0	6.4	95	95	91	1
Picloram + 2,4-D	1.0 + 2.0	2.9	100	99	100	0

Experiment 2

Prior to treatment, the density of aspen poplar was relatively uniform and varied between 1.1 and 1.8 shoots/m^2 (Table 4). When picloram was applied alone, 1.0 lb/acre was required to give a high degree of control. The addition of the surfactant Atlox 210 to picloram did not improve the performance of the herbicide sufficiently to cause a satisfactory reduction in the population of aspen poplar. In all cases, the addition of 2,4-D to picloram resulted in a greater reduction in the population of aspen poplar than when picloram was applied alone at a similar rate. Increasing the rate of picloram from 0.5 to 1.0 lb/acre when each was applied with 2,4-D at 2.0 lb/acre improved the control of aspen poplar.

There was an effective reduction in the canopy cover of aspen poplar to less than 1% of the ground surface 4 years after the application of picloram plus 2,4-D at 1.0 plus 2.0 lb/acre; 2,4-D at 2.0 lb/acre; and 2,4-D plus 2,4,5-T at 0.7 plus 1.3 lb/acre (Table 4).

The density of prickly rose varied between 1.7 and 5.0 shoots/m^2 on the plots before treatment (Table 4). The number of prickly rose shoots was reduced as the rate of picloram was increased from 0.25 to 1.0 lb/acre. All treatments containing picloram were also more effective for the control of prickly rose than the presently recommended mixture in Saskatchewan of 2,4-D plus 2,4,5-T at 0.7 plus 1.3 lb/acre. The addition of the surfactant Atlox 210 to picloram did little to improve the performance of the herbicide. The canopy cover of prickly rose 4 years after any treatments that included at least 0.5 lb/acre of picloram was less than 1%.

The herbicide rate necessary to control any of the woody

Table 4. Pretreatment densities (shoots/m²), reduction (%) and canopy cover (%) of aspen poplar and prickly rose shoots in Experiment 2, following application (lb/acre) of 2,4-D and picloram alone and in mixtures.

		Aspen poplar			Prickly rose		
Herbicide	Rate	Density 1968	Shoot reduction 1969	Cover 1972	Density 1968	Shoot reduction 1969	Cover 1972
Check		1.4	21	39	2.3	(4)[1]	6
Picloram	0.25	1.2	21	14	3.0	82	2
Picloram	0.5	1.1	13	10	1.7	95	<1
Picloram	1.0	1.8	83	2	4.2	99	<1
Picloram + 2,4-D	0.25 + 1.0	1.6	31	10	2.7	81	1
Picloram + 2,4-D	0.5 + 2.0	1.2	77	2	2.4	98	<1
Picloram + 2,4-D	1.0 + 2.0	1.1	95	<1	4.6	100	0
Picloram + Atlox	0.25 + 1.0[2]	1.7	18	6	3.6	90	1
Picloram + Atlox	0.5 + 1.0[2]	1.1	32	6	2.5	95	<1
2,4-D ester	2.0	1.6	85	<1	5.0	(1)[1]	18
2,4-D + 2,4,5-T	0.7 + 1.3	1.4	65	<1	2.8	38	1

[1] This represents the increase in the rose population between 1968 and 1969.
[2] Atlox 210 was added at the rate of 1% of the spray volume.

species almost completely removed alfalfa from the rangeland (Table 5). Also, there was a natural reduction in the population of alfalfa in the untreated plots between 1968 and 1970.

Table 5. The density (plants/m²) of alfalfa following application (lb/acre) of 2,4-D and picloram alone and in mixtures.

Treatment		Experiment 1	Experiment 2	
Herbicide	Rate	1970	1968	1970
Check		1.15	0.72	0.28
2,4-D amine	1.0		0.49	0.24
2,4-D amine	2.0		0.11	0.12
2,4-D ester	2.0	0.01		
2,4-D + 2,4,5-T	0.7 + 1.3	0.02		
Picloram	0.25	0.05		
Picloram	0.5	0.0	0.0	0.0
Picloram	1.0	0.0	0.0	0.01
Picloram + 2,4-D	0.25 + 1.0	0.0	0.01	0.03
Picloram + 2,4-D	0.5 + 1.0		0.0	0.05
Picloram + 2,4-D	0.5 + 2.0		0.0	0.05
Picloram + 2,4-D	1.0 + 2.0	0.0	0.0	0.0
Picloram + Atlox	0.25 + 1.0[1]	0.06		
Picloram + Atlox	0.5 + 1.0[1]	0.0		

[1] Atlox 210 was added at the rate of 1% of the spray volume.

Discussion

Mixtures of amines of picloram and 2,4-D with the former component varying between 0.25 and 0.5 lb/acre and the latter component varying between 1.0 and 2.0 lb/acre, did not offer any advantage for the control of aspen poplar when compared to picloram at 1.0 lb/acre or an ester of 2,4-D at 2.0 lb/acre (Tables 1 and 4). However, there was some evidence that the addition of 1.0 lb/acre of picloram to 2.0 lb/acre of 2,4-D amine improved the control of aspen poplar when compared to 2,4-D ester at 2.0 lb/acre (Table 4). Picloram applied at 1.0 lb/acre alone or in a mixture with 2,4-D amine gave effective control of balsam poplar (Table 2). Unfortunately, the presently recommended treatment in Saskatchewan of 2,4-D at 2.0 lb/acre was not included in Experiment 1 so a comparison cannot be made with the treatments that gave effective control of balsam poplar. However, these picloram treatments reduced the balsam poplar population 90% which was the value arbitrarily selected as the acceptable level of control. Picloram at 0.5 lb/acre with or without the addition of 2,4-D gave excellent control of prickly rose (Tables 3 and 4). Therefore, where all three species are present, picloram can be added to 2,4-D for prickly rose control. Control should last 4 to 5 years.

While it has been demonstrated in field and greenhouse experiments that Atlox 210 improved the effectiveness of picloram for control of poplar, (Corns and Dai, 1966; 1967), the addition of the surfactant to picloram at 0.25 and 0.5 lb/acre did not provide satisfactory control of aspen poplar.

All herbicide treatments effective for the control of any of the woody species drastically reduced the population of alfalfa (Table 5). The density of alfalfa was reduced in the check plots on Experiment 2 between 1968 and 1970. During this time period aspen and balsam poplar continued to grow and increase their canopy cover. It was assumed that the increase in the growth of woody plants in the checks was associated with a decrease in the amount of alfalfa. While 1.0 and 2.0 lb/acre of 2,4-D amine did not control aspen and balsam poplar, it retarded the yearly growth of these species, which reduced the competitive effect on alfalfa between 1968 and 1970. The decrease in the density of alfalfa as 2,4-D amine increased from 0 to 2.0 lb/acre was caused by herbicidal injury (Table 5). The presence of alfalfa on any improved rangeland in Saskatchewan could be the deciding factor in determining if 2,4-D and/or picloram should be used to control woody palnts. Additional research is needed on the relationship between the amount of alfalfa and the density of woody plants since the desirable species may be greatly reduced whether herbicides are used or not.

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Controlling Sixweeks Fescue on Shortgrass Range

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Highlight: *Sixweeks fescue is an unpalatable annual grass that, when abundant, may seriously reduce grazing on associated species, limiting livestock gains and causing spot overgrazing. In this study, abundance was affected more by seasonal precipitation patterns than grazing or nitrogen fertilization. Either atrazine and simazine herbicides, applied at 1.1 kg/ha in either fall or spring, effectively controlled sixweeks fescue.*

Sixweeks fescue (*Vulpia octoflora* (Walt.) Rydb.) is a winter annual plant with subspecies distributed throughout the 48 contiguous states (Harrington, 1954). In Colorado, it is found on plains and mountains up to elevations of 2,600 m (8,500 ft). Ranchers on the shortgrass plains listed sixweeks-fescue control as one of their greatest needs in about 1960, following several successive years of serious problems with this weedy grass.

Problems associated with sixweeks fescue on shortgrass plains were investigated at the Central Plains Experimental Range. Hylton and Bement (1961) estimated a loss of $25 per head in liveweight gains of yearling cattle in 1958. The loss was due to overgrazing of bottomland range sites and undergrazing on upland range sites where the sixweeks fescue was abundant. Both avoidance and rejection habits of cattle were reported by Hyder and Bement (1964). Cattle avoided untreated plots infested with sixweeks fescue and preferred those treated with simazine (2-chloro-4,6-bis(ethylamino)-*s* triazine). During the latter part of the summer, the cattle also preferred nitrogen-fertilized plots, even though fertilization increased the stands of sixweeks fescue. However, cattle never grazed the fescue itself even on preferred plots.

Cattle rejected sixweeks fescue in two ways: first, by grazing carefully around the plants, and second, by dropping the plants inadvertently included in a bite. Although it appeared that cattle dropped the plants because they were pulled up with considerable soil attached, the cattle also tended to avoid concentrations of sixweeks fescue even when the plants were too short to be grazed. As a result, the blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) was used poorly and unevenly.

Sixweeks fescue fluctuates greatly in abundance from year to year. Above-average precipitation in the spring appears to promote plant growth and seed production. With abundant seed supply, above-average precipitation in the early fall promotes seed germination, seedling emergence, and thick stands the next year. In 4 of 11 years (1963–73, inclusive), the stands of sixweeks fescue on upland sandy loam soils were thick enough to interfere seriously with grazing (unpublished data). Thus, effective control practices may widely apply on the Central Great Plains. Both simazine (Hyder and Bement, 1964) and atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) (Houston and van der Sluijs, 1973) have effectively controlled sixweeks fescue, but minimum rates and times of application have not been determined.

This paper compares cyanazine (2-(4-chloro-6-ethylamino-*s* triazin-2-ylamino)-2-methylpropionitrile), simazine, atrazine, and potassium hexafluoroarsenate at various rates for effectiveness in controlling sixweeks fescue.

Methods

Two separate studies on shortgrass range in north-central Colorado included responses of sixweeks fescue abundance to triazine herbicides. The first study compared how atrazine, simazine, and cyanazine herbicides combined with nitrogen (N) fertilizer affected species composition of rangeland over 3 years, 1970–72. This study was conducted on Ascalon sandy loam soil on a loamy plains range site. The second study compared the effects of atrazine and potassium hexafluoroarsenate herbicides combined with N fertilizer on ecology and species composition of shortgrass range, 1971–73. This study was conducted on Manter sandy loam and Vona fine sandy loam soils on sandy plains range site.

Both studies were conducted at the U.S. Department of Agriculture, Central Plains Experimental Range, located 20 km northeast of Nunn, Colorado. The long-time average annual precipitation is 31 cm (12.2 inch), with 73% occurring during the growing season of May through September.

The vegetation is dominated by blue grama. Other important species are plains pricklypear (*Opuntia polyacantha* Haw.), scarlet globemallow (*Sphaeralcea coccinea* (Pursh) Rydb.), red threeawn (*Aristida longiseta* Steud.), sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray), woody

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed have been registered.

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Table 1. **Monthly precipitation (cm) for the cropyears (September through August) of 1969–73, cropyear totals, and 35-year mean at Central Plains Experimental Range, Nunn, Colo.**

Cropyear	S	O	N	D	J	F	M	A	M	J	J	A	Cropyear total[1]
1968–69	1.0	2.4	1.7	0.5	0.3	0.7	0.6	4.0	5.7	11.8	4.4	3.5	36.8
1969–70	3.1	7.1	0.3	T	0.1	0.1	3.3	3.4	2.1	2.9	4.0	0.6	27.1
1970–71	3.8	2.9	0.4	0.6	1.1	0.8	2.3	7.2	4.2	3.1	1.5	0.9	28.8
1971–72	5.4	0.4	0.1	T	0.9	T	1.0	1.5	3.1	8.3	4.5	9.7	34.9
1972–73	4.3	1.4	1.6	1.0	0.3	T	1.8	3.5	1.5	2.3	6.8	1.5	27.3
35-year mean, 1939–73	2.9	1.8	0.7	0.4	0.7	0.5	1.5	2.8	5.3	6.1	4.7	3.8	31.2

[1] Totals may not agree with sum of monthly precipitation because of rounding off.

buckwheat (*Eriogonum effusum* Nutt.), and sun sedge (*Carex heliophylla* Mackenz.).

In the first study, atrazine, simazine, and cyanazine were applied at 0, 1.1, and 3.4 kg/ha of active ingredient in factorial combination with 0, 22, and 45 kg N/ha of ammonium nitrate fertilizer. Beginning the spring of 1970, the treatments were applied in four replicates in both spring and fall on the same plots each year. Plot size was 4.6 m by 15.2 m (15 ft × 50 ft). The herbicides were applied as an 80% wettable power in aqueous solution at a rate of 187 liters/ha (20 gallons/acre) with a compressed air sprayer. A nonionic surfactant was added to the spray solutions at a rate of 0.15%. The fertilizer was broadcast on the surface in pellet form. Frequency of sixweeks fescue was recorded in June each year on 25 .41×41 m–(16×16-inch) quadrat frames per plot (Hyder et al., 1965).

In the second study, four plots of 30.5 m × 22.9 m (100 ft × 75 ft) were established for each treatment. Atrazine and potassium hexafluoroarsenate at 0 and 2 kg/ha and N at 0, 22, and 45 kg/ha were applied in all factorial combinations. Atrazine was applied on the same plots each fall in 1970, 1971, and 1972. Potassium hexafluoroarsenate was applied only in the fall of 1970. The herbicides were applied in aqueous solution with a commercial sprayer at 140 liters/ha (15 gallons/acre). The fertilizer was applied by a truck-mounted spreader. Frequency of sixweeks fescue was recorded on 250 quadrat frames on each plot each year in June.

Precipitation was above average during the summer and fall of 1969 before establishment of the first study (Table 1). It was below average during the summers of 1970 and 1971 and continued low from the fall of 1971 through spring of 1972. It was above average during the summer and fall of 1972 and then below average through the summer of 1973 (except for July).

Results

In the first study, both rates of all three triazine herbicides significantly reduced frequency of sixweeks fescue in 1970, except the 1.1-kg rate of atrazine (Table 2). Results from the fall and spring applications of herbicides were essentially the same. Therefore, only the results from the spring applications are shown. During 1971, all herbicides reduced sixweeks fescue while its average frequency on untreated plots increased substantially. During 1972, cyanazine did not reduce sixweeks fescue, but both simazine and atrazine completely controlled it. N fertilizer did not significantly affect its frequency.

In the second study, atrazine reduced frequency of sixweeks fescue 85 to 100% the first year after application (Fig. 1). Control was nearly 100% during the following 2 years. Potassium hexafluoroarsenate reduced frequency of sixweeks fescue about 60% in 1971 and 1973 and about 40% in 1972 (Table 3). It did not effectively control sixweeks fescue, particularly during drought. In this second study N fertilizer had no significant effect on frequency of sixweeks fescue.

The frequency of sixweeks fescue in any one year greatly depended on the amount and distribution of seasonal precipitation (Fig. 2). High precipitation during the second preceding summer prior to June measurement and second preceding winter reduced frequency of sixweeks fescue. High precipitation during the second preceding spring and the preceding fall increased frequency.

Discussion

The unacceptability of sixweeks fescue to cattle in all seasons often

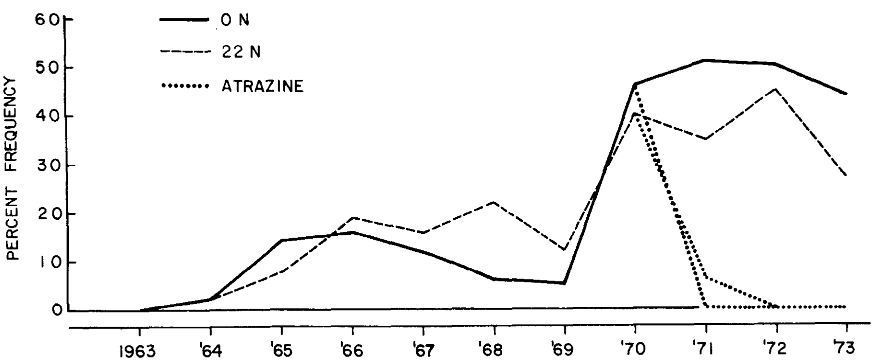

Fig. 1. *Percent frequency of sixweeks fescue, 1963–73, showing effects of N applied annually and atrazine applied at 2 kg/ha in the fall of 1970, 1971, and 1972.*

Table 2. **Percent frequency of sixweeks fescue, 1970, 1971, and 1972. Herbicides were applied in May each year on the same plots.**

Year of sampling	Herbicide[1] and rate (kg/ha)							Average
	Control	C 1.1	S 1.1	A 1.1	C 3.4	S 3.4	A 3.4	
1970	11.7 d[2]	3.0 ef	3.0 ef	5.7 def	3.7 ef	0.3 f	3.0 ef	4.3 b
1971	64.7 a	48.0 b	7.3 de	8.3 de	34.3 c	0.3 f	2.0 ef	23.6 a
1972	7.3 de	5.0 ef	0.0 f	0.0 f	3.7 ef	0.0 f	0.0 f	2.3 b
Average	27.9 a	18.7 b	3.4 de	4.7 d	13.9 c	0.2 e	1.7 de	

[1] C–cyanazine, S–simazine, and A–atrazine.
[2] Interaction means or means in row or column of averages followed by the same letter are not significantly different at the 5% level.

Table 3. Percent frequency of sixweeks fescue 1970, 1971, 1972, and 1973. Atrazine was applied in the fall of 1970, 1971, and 1972 on the same plots. Potassium hexafluoroarsenate was applied only in the fall of 1970.

Year of sampling	Rate of atrazine (kg/ha)	Rate of pot. hex. (kg/ha) 0	2	Average
1970	0	45 a[1]	38 a	41 a
	2	52 a	34 a	43 a
	Avg	48 a	36 a	
1971	0	64 a	24 b	44 a
	2	3 c	T c[2]	2 b
	Avg	34 a	12 b	
1972	0	56 a	34 b	45 a
	2	1 c	T c	T b
	Avg	28 a	17 a	
1973	0	50 a	20 b	35 a
	2	T c	T c	T b
	Avg	25 a	10 b	

[1] Interaction menas or means in row or column of averages in each year followed by the same letter are not significantly different at the 5% level.
[2] T—trace, less than 0.5% frequency.

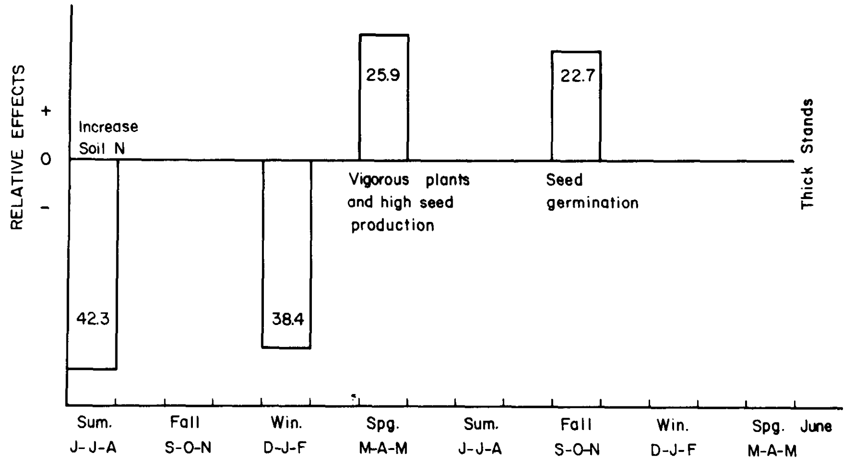

Fig. 2. *Relative effects of quarterly precipitation of two preceding years on percent frequency of sixweeks fescue, measured in June (regression coefficient multiplied by average quarterly precipitation total).*

creates a real problem for ranchers in the Central Great Plains. This annual grass is most abundant on upland range sites, and is present in some degree every year. This species not only contributes nothing to the forage supply, but, in years when abundant, seriously interferes with utilization of palatable forage. Hyder and Bement (1964) pointed out that this species is often abundant even in ungrazed exclosures. Seasonal weather conditions chiefly influence its abundance.

The relationship of seasonal precipitation and frequency of sixweeks fescue is complex. The most important part of the sequence begins with favorable moisture during spring of the preceding year, which produces good plant growth and high seed production. Favorable fall precipitation is then important for seed germination and establishment of a new stand. Low moisture during the second preceding summer is probably important for increasing nitrate N in the soil surface.

Annual applications of herbicides are not needed. Because sixweeks fescue germinates and emerges in the fall, control can be delayed until the need is evident. Both atrazine and simazine at 1.1 kg ai/ha effectively controlled sixweeks fescue. Since cool-season grasses are susceptible to these herbicides, the 1.1-kg rate should not be exceeded. Spring or fall applications were equally effective. Fall application may be preferred if ranges are fertilized in the fall for increased forage production. Cyanazine and potassium hexafluoroarsenate were ineffective herbicides for control of sixweeks fescue.

Cyanazine is highly soluble in water and usually has no residue beyond one growing season. Both atrazine and simazine are less soluble than cyanazine and may have increased in the soil over the three years.

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Site Relations, Regrowth Characteristics, and Control of Lotebush with Herbicides

C. J. SCIFRES AND M. M. KOTHMANN

Highlight: *Regrowth following top removal of lotebush (*Condalia obtusifolia* (Hook.) Weberb.) seedlings and field transplants followed a typical apical dominance pattern. When 2.5 cm of the stem segments were left intact, sprouting occurred from stem tissues. When stems were completely removed, sprouts originated from root tissues. Lotebush densities on the Texas Experimental Ranch were greater on shallow redland than on deep upland, rolling hill, rocky hill or valley range sites. Aerial application of 2,4,5-T at 1.12 kg/ha was ineffective for control of lotebush, regardless of range site. Basal sprays containing 4 or 8 g/liter of 2,4,5-T + picloram in a diesel oil:water emulsion (1:4) effectively controlled lotebush. Basal sprays of dicamba were less effective than 2,4,5-T + picloram; and 2,4,5-T was ineffective in the emulsion carrier. However, 2,4,5-T in diesel oil reduced the canopies by an average 50 to 70% at 2 years after treatment. At rates greater than 5 g (active ingredient)/m of canopy diameter, monuron pellets reduced lotebush canopies by 85 to 100%. At the same rate, dicamba granules completely reduced the brush canopy and resulted in 86% root kill at 2 years after application. Two g/m of canopy diameter of picloram pellets completely controlled the lotebush.*

Five species of *Condalia* (Rhamanaceae) are recognized by Gould (1969) as occurring on Texas rangeland. Three species, lotebush (*C. obtusifolia* (Hook.) Weberb.), bluewood (*C. obovata* Hook.) and knife-leaf condalia (*C. spathulata* Gray), are the primary problem species when considering range improvement programs. Lotebush has recently been reclassified as *Ziziphus obtusifolia* (T. & G.) Gray (Jones, 1975). Lotebush is a highly-branched spinescent shrub which rarely exceeds 2 m in height. The margins of its ovate, almost oblong, leaves are entire to coarsely serrate. The branches are grayish green with alternate formidable spines. The bark is smooth and light gray to bluish except at the base, where it may be cracked and dark brown.

Also known as "lote," "bluebush," and "chaparral," lotebush occurs in every physiographic province of Texas except the Pineywoods (Gould, 1969). It occurs in association with bluewood in the mixed-brush complex of South Texas; and is a common component of honey mesquite (*Prosopis glandulosa* var. *glandulosa* Torr.) savannas and bushlands in the Rolling Plains of northwestern Texas. In the Rolling Plains, lotebush only rarely develops such infestations that control measures are required to maintain productivity of the range. However, lotebush is a persistent species which resists broadcast application of most herbicides used for range improvement; and, in local areas, may become a serious brush problem.

According to Meyer et al. (1969), ground broadcast sprays of picloram (4-amino-3,5,6-trichloropicolinic acid) at 0.56 to 1.12 kg/ha were only slightly toxic to lotebush. However, Bovey et al. (1970) reported effective control from picloram at 2.24 kg/ha and from 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] + picloram at 1.12 kg/ha each aerially applied in the spring. Churchill et al.[1] reported that individual-plant treatments with wetting sprays of 2 to 3 g of 2,3,6-TBA (2,3,6-trichlorobenzoic acid)/ 100 liters of water killed 80 to 100% of the lotebush topgrowth but did not control the roots. Box and White (1969) reported an increase in the abundance in lotebush following burning of South Texas ranges. Presumably, this increase was due to basal sprouting following fire damage to the aerial protions. Neuenschwander and Wright[2] reported that lotebush regrew slowly following prescribed burns for the first 3 years in the Rolling Plains. After the third year, the plants grew rapidly; and regrowth biomass was apparently 70 to 75% of unburned plants by the

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[1] Churchill, F. M., B. R. Ray, and C. King. 1969. Mechanical and chemical control of species of yucca and condalia in Jones and Nolan Counties, Texas. Texas Tech Univ. Noxious Brush and Weed Control Res. Highlights. ICASIS Spec. Rep. 33. p. 58-59.

[2] Neuenschwander, L. F., and H. A. Wright. 1973. Regrowth of lotebush (bluebush) after burning. Texas Tech Univ. Noxious Brush and Weed Control Res. Highlights 4:14.

fifth year. Lotebush was effectively controlled by root plowing followed by raking in South Texas Plains (Dodd, 1968). Lotebush topgrowth was also controlled by roller chopping followed by shredding a year later in the spring followed by burning in late summer (Dodd and Holtz, 1972). Following honey mesquite control, especially in the northern part of Texas, scattered stands of lotebush are occasionally left as the primary brush species. Although it has some value as a food and cover plant for wildlife,[2] most ranchers desire relatively low amounts.

Although lotebush is often mentioned by researchers as an important secondary species in the Texas brush complex, relatively little research has been directed toward the understanding of its regrowth potential, distribution as affected by range site, or methods of controlling scattered plants. Research was conducted from 1969 through 1973 to investigate (a) the regrowth characteristics of lotebush seedlings and sprouts from root section transplanted to the greenhouse; (b) its distribution on several predominant range sites in the Rolling Plains of Texas; and (c) several herbicides, herbicide combinations, and formulations for control of individual plants.

Materials and Methods

Regrowth Characteristics

Greenhouse-grown lotebush seedlings and field transplants of roots and stems were utilized to study origin and development of sprouts following top removal. Seedlings were about 1 year old and 45 cm tall when tops were removed. Two treatments, clipping at 2.5 cm above the cotyledonary nodes and 1.25 cm below ground line (approximately 3.75 cm below the cotyledonary nodes), were each applied to 30 plants. An equal number of plants were not clipped. Two experiments were conducted, one initiated in March and the second in June, 1970. For 90 days after top removal, origin of new branches, number of new branches, branch length, and number of leaves were recorded. Fifty plants were excavated from a rolling hills range site near Guthrie, Texas, in February, 1972. The soil was removed to 15 cm deep and in 16- by 16-cm squares with the lotebush stem in the center. No stem tissue was left intact on 25 of the transplants. Approximately 2.5 cm of the original above-ground stem segments was left intact on the remaining 25 plants. Origin of new branches and branch lengths were recorded for approximately 90 days following transplanting.

Range Site Relationships

In May, 1972, pastures on the Texas Experimental Ranch near Throckmorton were treated with 1.12 kg/ha of 2,4,5-T. The herbicide was aerially applied in 37 liters/ha of a diesel oil:water emulsion (1:4). In August, 1973, reaction of lotebush to the spray was determined on representative deep upland, rolling hill, rocky hill, shallow redland and valley range sites on the ranch. Twenty-five to 40 points, spaced approximately 30 m apart, were established on each range site. At each point, percentage defoliation of the nearest lotebush plant in each quarter was estimated by two workers. Density of lotebush plants within each of the range sites was calculated using distance from the points to the nearest plant in each quarter (Cottam and Curtis, 1956). This method has proven satisfactory for estimating density of other brush species (Beasom and Haucke, 1975; Scifres et al., 1974).

The deep upland site consisted of Abilene, Crawford, Rowena and Tobosa soil series. The soils are dark clays and clay loams, moderate to slowly permeable but well-drained. These soils generally have high fertility levels and high available water capacities, differing mainly in distribution of calcareous material in the soil horizons. The Mereta and Throck soil series were grouped into the rolling hills range site. The dark, grayish brown, highly-calcareous silty clay loam surface ranges in depth from 38 to 50 cm with slopes of 1 to 5%. They are moderately permeable and highly fertile. Rocky hill sites contained primarily Owens-Tarrent complex soils, which are shallow, stoney clays characterized by limestone rocks on the surface. These soils are of generally high fertility with moderate to slow permeability. They occur on deep slopes and rocky ridges where surface runoff is rapid. The shallow redland site consisted of Owens-Vernon soils, which are reddish to olive-brown calcareous clays. Subsoils are underlain by shaley clay, and soil erosion is generally active because of the sparse vegetation and the rapid surface runoff. The valley range site occurred in valleys and depressions adjacent to primary and secondary drainages. Soil depth is greater than 150 cm. Surface soils are dark brown, calcareous clay loams, which are slowly permeable and have a high fertility level.

Control of Individual Plants

Individual-plant herbicide treatments were evaluated from 1969 to 1972 near Guthrie, Texas, approximately 97 km west of the Throckmorton study site. Herbicides, herbicide mixtures, and formulations evaluated as basal sprays for control of individual lotebush plants were 2,4,5-T + picloram (1:1) applied at 4 or 8 g/liter of diesel oil:water emulsion (1:4). Spray solutions were applied to the base of the lotebush plants to runoff using hand sprayers. Dry herbicides evaluated included monuron (3-(*p*-chlorophenyl)-1,1-demethyl urea) pellets, dicamba granules and picloram pellets. Dry herbicides were applied to the soil at the base of lotebush plants. Rates of treatment were determined by size of the canopies at 1 m above ground line. Application rates based on active ingredient were 0.5, 1.25, 2.0, 2.75, 3.5, 4.25, 5.0, and 5.75 g/m of canopy diameter.

Results and Discussion

Regrowth Characteristics

At 30 days after clipping stems 2.5 cm above soil line, 90% of the lotebush plants had sprouted. This regrowth probably coincides with the "first spurt" noted by Neuenschwander and Wright[2] following prescribed burning. The greenhouse seedlings usually developed two branches from stem tissue immediately below the cut. New branches usually formed at 0.5-cm intervals down the stem tissue to soil line. At 90 days after clipping above the cotyledonary node, from two to six branches had formed on each seedling. Branch lengths ranged from 7 to 14 cm and decreased in length from the apical sprout downward. Each resprouted plant produced an average of 46 leaves.

Root tissue sprouted when essentially all stem tissue was removed. From one to four buds, 3 to 5 cm long, formed from root tissue. The potential of lotebush to regrow vegetatively upon disturbance explains its resistance to mechanical top removal. Although rate and extent of regrowth is usually not as great as with species such as honey mesquite (Scifres and Hahn, 1972), lotebush has the capability to sprout from root tissue when total stem removal occurs.

Field transplants of lotebush required about 30 days for the first sprouts to appear. About 40% of the transplants sprouted during the study period. As with the seedlings, branch origin apparently was regulated by apical dominance. If live stem segments remained, growth of lateral buds formed the new branches. Two branches usually formed beneath the original cut on the stem. On those plants from which the majority of the stem tissues had been removed, bud formation occurred from root tissue. However, it appeared that callous tissue formation had to precede branch formation. On plants which had not sprouted, callous tissue formation over the original cut was incomplete and the original root-stem sections deteriorated.

Range Site Relationships

Previous research in the Rolling Plains of Texas (Scifres et al., 1974) has indicated that population density of honey mesquite was influenced by range site and grazing management system. In general, the range site/grazing management system which was apparently the most productive for plant growth supported the more dense, vigorous stands of honey mesquite. Lotebush populations in the same area were aggregated rather than randomly distributed. The density of lotebush was not greatly affected by range site on the Texas Experimental Ranch (Table 1). Of the sites studied, only the shallow redland site differed significantly in lotebush density. The ecological site relationships which contributed to the different stand densities were not clear. However, general observations in the Rolling Plains area indicate that the shallow redland site usually supports denser stands of lotebush.

Table 1. Density (plants/ha) of lotebush by range site on the Texas Experimental Ranch, Throckmorton in July, 1972.

Range site	Density[a]
Deep upland	12.5
Rolling hill	7.2
Rocky hill	11.9
Shallow redland	30.9
Valley	8.1

[a]Difference between densities of any two sites had to exceed 12.2 plants/ha for significance at the 95% confidence level.

The rate of 2,4,5-T (1.12 kg/ha) aerially applied to the lotebush on the Texas Experimental Ranch was twice that normally used for range restoration in the Rolling Plains. However, none of the plants were root killed by the spray. There was no apparent site influence on the level of defoliation of lotebush by 2,4,5-T sprays. Defoliation estimates ranged from 60 to 70% and were highly variable within any site. Root kill of honey mesquite at 2 years after the spray varied from 28 to 46% on the same sites.[3]

Control of Individual Plants

Response of lotebush to the individual-plant treatments did not differ significantly between years, so the data were averaged for discussion. Average canopy diameter of plants in the study area was about 1.35 m. By 30 days after application of picloram pellets, lotebush plants treated with 0.5 g/m of canopy diameter had begun to defoliate. Degree of defoliation increased with increasing rate of herbicide and was almost complete where more than 3.5 g/m of canopy diameter had been applied. At 2 years after treatment, picloram pellets at 2 g/m of canopy diameter had completely controlled the lotebush (Fig. 1). Where 0.5 g/m of canopy diameter was applied, canopy reduction exceeded 60% and foliage of surviving plants was chlorotic.

Dicamba granules were not as effective as picloram pellets. At the highest rate (5.75 g/m of canopy diameter), canopy reduction was less than 50% at 30 days after application. However, by 2 years after herbicide application, rates of at

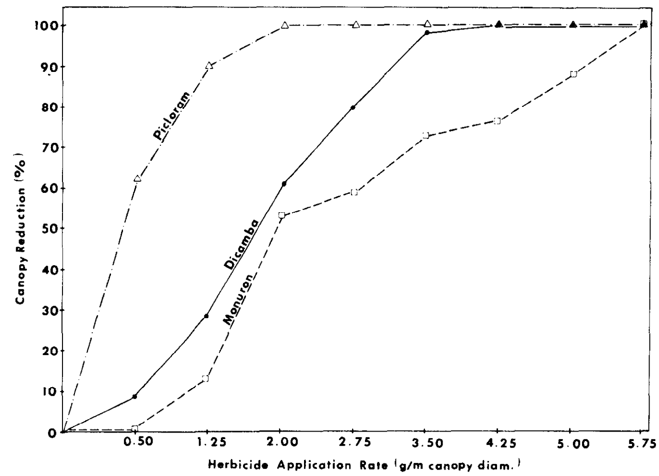

Fig. 1. *Average canopy reduction 2 years after the application of various rates of monuron pellets, dicamba granules, or picloram pellets in the Rolling Plains of Texas.*

least 4.25 g/m of canopy diameter completely reduced the lotebush canopies (Fig. 1) and 86% of the population had not resprouted. After application of at least 5.0 g/m of canopy diameter, there was no resprouting. This high rate, as with picloram, controlled all vegetation within a 0.5 m radius of the treated stem for a year following treatment.

Monuron pellets were less effective than either picloram pellets or dicamba granules. The highest rate of monuron reduced the canopies by only 30% at 1 month after treatment. By 2 years after treatment, the high rate had completely eliminated the lotebush canopies, but about 50% of the population had developed regrowth.

Basal sprays containing 4 or 8 g of 2,4,5-T/liter of the diesel oil:water emulsion did not reduce the lotebush canopies (Table 2). The same rates of 2,4,5-T in diesel oil reduced canopies by 50 to 69% at 2 years after treatment, but all treated plants were resprouting. Dicamba (dimethylamine salt) applied at 4 or 8 g/liter of diesel oil:water emulsion reduced lotebush canopies by about 50%. In a 1:1 combination, 4 g/liter of 2,4,5-T + picloram reduced lotebush canopies by 64% at 2 years after treatment and root killed 20% of the plants. The same herbicide at 8 g/liter reduced the lotebush canopies by 91% and killed 60% of the plants. The 2,4,5-T + picloram combination was the most effective individual plant treatment for control of lotebush.

Conclusions

Lotebush provides excellent habitat for upland game birds

Table 2. Canopy reduction (%) of lotebush 2 years after treatment in May, 1969, or June, 1970, in the Rolling Plains of Texas with basal sprays of various herbicides at two application rates (g/liter).[a]

		Rates[b]	
Herbicide	Carrier	4	8
2,4,5-T	Diesel oil	50 b	69 c
2,4,5-T	Diesel oil:water	0 a	1 a
Dicamba	Diesel oil:water	49 b	50 b
2,4,5-T + picloram (1:1)	Diesel oil:water	64 bc	91 d
None	Diesel oil	8 a	

[a]Means represent averages of the 2 years of treatment.
[b]Means followed by the same letter are not significantly different at the 95% confidence level.

[3]Unpublished data. Kothmann, M. M., and C. J. Scifres.

and other wildlife. It occurs in aggregated stands and, usually, in low densities such that broadscale control efforts may not be justified from an economical or ecological standpoint. However, stands have been noted by the authors which are so dense that management efficiency is substantially reduced. In such cases, thinning of the lotebush population with individual-plant treatments would be desirable.

Lotebush is a proliferic root sprouter capable of rapid regeneration upon top removal. Therefore, mechanical control methods which completely uproot the plants, such as grubbing, apparently offer more promise for control than those which only remove the topgrowth. Although lotebush occurs in scattered stands over most range sites of the Rolling Plains, it was most abundant on shallow redland sites on the Texas Experimental Ranch. Since high application rates of broadcast-applied herbicides have not given effective control and lotebush tends to occur in scattered stands, individual plant treatments may be best for control. Basal applications of 2,4,5-T + picloram, picloram pellets at 2 g/m canopy diameter or dicamba granules at 4.25 g/m canopy diameter applied to the base of the plants may be most effective for its control where deemed desirable by the land manager.

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Seasonal Response of Macartney Rose and Huisache to Herbicides

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Highlight: *Picloram granules and sprays were applied to Macartnev rose (*Rosa bracteata *Wendl.) and huisache (*Acacia farnesiana *(L.) Willd.) in the claypan area of Texas. Monthly granule applications to Macartney rose were generally least effective in the summer. Rates of 1, 2, and 3 lb/acre of picloram as granules reduced the canopy 53, 68, and 86% and killed 14, 32, and 57% of the plants, respectively. Foliar sprays of picloram were about equally effective as granules. Huisache was not as highly responsive to picloram as to either granules or soil sprays at rates up to 4 lb/acre. However, picloram at 2 lb/acre as a foliage spray in May or September killed 90% or more of the plants. A 1 lb/acre foliage spray of picloram combined with a 1 lb/acre spray of 2,4,5-T, dicamba, or picloram in the soil also killed 53% or more of the huisache plants.*

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Contribution from the U.S. Dep. Agr., Agr. Res. Serv. and the Texas Agricultural Experiment Station, College Station 77843. This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation of this product by the U.S. Dep. Agr.

Macartney rose (*Rosa bracteata* Wendl.) is a troublesome woody plant that grows on about 0.5 million acres of potentially productive rangeland in Texas. It is presently controlled by either mowing or spraying with 2,4-D [(2,4-dichlorophenoxy) acetic acid] (Hoffman et al., 1964; Lehman et al., 1966), but many plants sprout and recover a few months after treatment. Haas et al. (1970) found that sprays of picloram (4-amino-3,5,6-trichloropicolinic acid) were more effective in late April and early May than in late May and early June, but the reverse was true for 2,4-D. Mixtures of the two herbicides were effective from April through early June. Lehman et al. (1966) found that spring treatments with picloram and 2,4-D were more effective than fall treatments at Greenlake, Tex. A 2 lb/acre April treatment of picloram reduced the canopy 94% and killed 63% of the plants.

Bovey et al. (1972a) applied sprays of picloram + 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] at 0.25 + 0.25 and 0.5 + 0.5 lb/acre from late June through October on Macartney rose. The September and October treatments were more effective than those applied in June through August. Meyer and Bovey (1973) found that sprays of picloram and picloram + 2,4-D or 2,4,5-T were about equally effective in May, August, and November. Bovey et al. (1972b) found that a spray of picloram alone at 2 lb/acre on Macartney rose was equally effective in June and October. Several formulations of picloram as granules at 2 lb/acre also reduced the plant canopy by 77% or more, whereas almost all plants were killed (99.8% canopy reduction) by 4 lb/acre of picloram as granules. Although picloram is generally effective for spring or fall applications, the variation in control of Macartney rose reported depended on climate, timing of herbicide treatment, size of plants, and stage of growth (Bovey et al., 1972a; Bovey et al., 1972b; Lehman et al., 1966; Meyer and Bovey 1973).

Huisache (*Acacia farnesiana* (L.) Willd.) is an undesirable, thorny woody plant growing on about 1.5 million acres of Texas rangeland. Bovey et al. (1967) showed that huisache was sensitive to picloram as either foliar or soil applications in greenhouse experiments. Meyer and Bovey (1973) at Bryan, Tex., found that June and October applications of picloram at 2 lb/acre as a spray reduced by only 54% the canopy of huisache growing on a heavy clay soil. At Refugio, Tex., on a neutral Papalote fine sandy loam soil, Bovey et al. (1970) found that 2 lb/acre of picloram sprayed on huisache in May, June, July, or October gave good control. In contrast, an application in April before the leaves had fully expanded resulted in poor control. Bovey et al. (1969) applied picloram as granules on huisache at Refugio and Campbellton, Tex. At Refugio, 2 lb/acre of picloram reduced the canopy 75, 55, and 93% when applied in April, May, and November, respectively. At Campbellton, on a calcareous Monteola clay soil, an April application of picloram at 2 lb/acre killed all plants, and a November application reduced the canopy 87% after 1 year. The 4 lb/acre rate killed all plants at Campbellton and caused 92% or more canopy reduction at Refugio.

The main objective of this study was to evaluate the seasonal response of Macartney rose and huisache to monthly applications of picloram granules, particularly on heavy clay soils where sensitive crops are grown nearby. However, picloram sprays were also included as a comparison with granules.

Materials and Methods

Macartney rose was treated on two sites in Texas. From March 1971 through January 1972, treatments were applied to a dense stand of Macartney rose (3 to 6 feet tall) near Montgomery, Tex. The soil type there was a medium soil grading between a Kipling fine sandy loam and a Houston black clay. The study was completed from February 1972 through February 1973 on a similar site near Millican, Tex., on a Wilson clay loam soil. Plots at both sites were established as a factorial design with two replications. Each plot was 20 by 65 feet with 10 to 25 plants. The potassium salt of picloram was applied either as the 2% granule at the rate of 1, 2, and 3 lb/acre or as a spray at the rate of 1 or 2 lb/acre. Granules were distributed by hand. Sprays were applied at 10 gallons per acre with a tractor having a compressed air sprayer attached to a boom 10 feet long. Sprays could not be applied in October because of wind. Control ratings were made May 28, 1974.

An area having almost a complete canopy of huisache 3 to 10 feet tall on a Houston black clay soil was selected near Washington, Tex. Picloram was applied as the potassium salt in 2% granules at the rates of 1, 2, and 4 lb/acre. Two plots 20 by 65 feet, each having 15 to 25 plants, were used for each granule treatment. Granules were applied monthly from March 1971 through February 1973. Control ratings were made October 8, 1973.

Foliar sprays were applied to huisache in May and September 1971. These experiments were not in the same plot layout as those for the granule treatments, but were in the same field at the same time. They serve as a comparison of the two methods of application. On May 27, 1971, seven chemical treatments at 2 lb/acre were applied with a tractor-mounted boom sprayer each to two plots 65 by 200 feet having huisache 6 to 9 feet tall. The treatments included the potassium salt of picloram, the propylene glycol butyl ether ester of 2,4,5-T, and the dimethyl amine salt of dicamba (3,6-dichloro-*o*-anisic acid) alone and in three mixtures. One treatment consisted of the triethylamine salts of 2,4,5-T and picloram. The plants were rated on May 22, 1972.

On September 13, 1971, 10 treatments were applied to huisache 3 to 5 feet tall each on two replicates 20 by 65 feet. The potassium salt of picloram and the propylene glycol butyl ether esters of 2,4-D and 2,4,5-T were applied at a rate of 10 gallons per acre with a tractor sprayer. Some treatments were sprayed on the foliage with a boom 10 feet long; soil treatments were applied in rows at 4 feet intervals, about 6 inches deep, with a nozzle mounted behind a chisel. The plants were rated on September 18, 1973.

Table 1. Control of Macartney rose with three rates of picloram granules applied at monthly intervals from March 1971 through February 1973 at Millican and Montgomery, Tex.[1]

	Rate of granules applied (lb/acre ae)						Mean	
	1		2		3			
Month applied[2]	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)
March	56	22	73	35	96	72	75 ab	43 a
April	57	17	78	42	86	60	74 ab	40 ab
May	51	12	74	38	88	52	71 abc	34 abc
June	38	5	70	38	91	60	66 abc	34 abc
July	36	0	46	5	89	52	57 c	19 c
August	45	12	58	20	76	38	60 bc	23 bc
September	49	11	70	32	82	48	67 abc	30 abc
October	58	24	76	40	88	60	74 ab	41 ab
November	72	28	75	40	91	65	79 a	44 a
December	66	10	66	30	92	68	75 ab	36 abc
January	57	18	72	35	73	50	67 abc	34 abc
February	47	10	60	25	78	60	62 bc	32 abc
Mean	53 p	14 x	68 q	32 y	86 r	57 z		

[1] Values for means in columns or rows for canopy reduction or dead plants followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.
[2] Granules were applied March 1971 through January 1972 at Montgomery and February 1972 through February 1973 at Millican. Treatments were evaluated on May 28, 1974.

Table 2. Control of Macartney rose with two rates of picloram sprays applied at monthly intervals from March 1971 through February 1973 at Millican and Montgomery, Tex.[1]

	1 lb/acre		2 lb/acre		Mean	
Month applied[2]	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)
March	58	32	77	40	68 ab	36 ab
April	69	38	86	52	77 a	45 a
May	64	10	81	45	73 ab	28 ab
June	40	5	64	12	52 cd	9 cd
July	37	2	51	5	44 d	4 d
August	21	0	37	5	29 e	2 d
September	35	2	67	45	51 cd	24 bc
November	46	10	72	42	59 bcd	26 bc
December	53	12	82	55	68 ab	34 ab
January	40	2	86	50	63 abc	26 bc
February	44	0	74	40	59 bcd	20 bcd
Mean	46 x	10 m	71 y	36 n		

[1] Values in columns followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.
[2] Sprays were applied March 1971 through January 1972 at Montgomery and February 1972 through February 1973 at Millican. No treatments were made in October. Treatments were evaluated May 28, 1974.

Control ratings consisted of evaluating 10 plants at random through the middle of the plot for percent canopy reduction. Plants showing no living foliage or sprouts were considered dead.

Results and Discussion

Control of Macartney rose with picloram granules did not significantly differ between years, so the data are combined in Table 1. There also was no significant interaction between month of application and rate of treatment. Increasing rates of picloram granules progressively increased Macartney rose canopy reduction and percentage of plants killed. However, the highest rate (3 lb/acre) did not kill more than 72% of the Macartney rose plants in any one month. Picloram granules controlled Macartney rose about equally well in all months except in July and August. Apparently the high temperatures and hot-dry conditions (photo-degradation) of summer reduced the effectiveness of the herbicide.

Table 4. Control of huisache with seven herbicide formulations sprayed on May 27, 1971, at Washington, Tex.[1]

Herbicide treatment	Rate (lb/acre)	Canopy reduction (%)	Dead plants (%)
Picloram, K salt	2	99 a	90 a
2,4,5-T ester	2	21 c	0 c
Dicamba	2	53 b	3 c
Picloram, K salt + 2,4,5-T ester	1 + 1	92 a	53 b
Picloram + 2,4,5-T amines[2]	1 + 1	97 a	77 a
Picloram, K salt + dicamba	1 + 1	90 a	53 b
Dicamba + 2,4,5-T ester	1 + 1	64 b	0 c
Untreated		0 d	0 c

[1] Values in columns followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test. Treatments were rated on May 22, 1972.
[2] Triethylamine salts.

Sprays of picloram were about as effective as granules (Table 1 and 2). Canopy reductions at the 1 and 2 lb/acre rates were 53 and 68% for granules and 46 and 71% for sprays, respectively. The sprays were generally most effective for reducing the canopy and killing the plants in winter and spring. The sprays were least effective in August. At individual rates by month, sprays killing 32% or more of the plants were statistically more effective than those killing a lower percentage. Consequently, the 1 lb/acre spray killed the most plants in March and April during the period of most rapid new stem elongation.

Control by granules and sprays was less than desired at the sites treated. We desire that a treatment kill at least 70% of the plants. However, this level of control was attained only once with 3 lb/acre in granules. Canopies were reduced 75% or more a number of times with the 2 lb/acre rate either as sprays or granules and at all months with the 3 lb/acre rate as granules. This level of control will open the area of grazing and increased forage production for at least 2 years.

Huisache was more difficult to control than Macartney rose on the heavy clay soil (Table 3). Increasing rates progressively increased the amount of canopy reduction. However, the 4 lb/acre rate reduced the canopy by only 35% and killed only 16% of the plants. Thus, picloram granules were ineffective for killing huisache on this heavy Houston clay soil. Treatments

Table 3. Control of huisache with three rates of picloram granules applied monthly from March 1971 through February 1973 at Washington, Tex.[1]

	Rate of granules applied (lb/acre ae)							
	1		2		4		Mean	
Month applied	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)	Canopy reduction (%)	Dead plants (%)
March	10 bc	5	28 abc	15	24 abc	12	20 ab	11
April	13 abc	0	26 abc	10	24 abc	10	21 ab	7
May	19 abc	8	31 abc	5	38 abc	18	29 ab	10
June	23 abc	5	23 abc	5	35 abc	15	27 ab	8
July	6 c	0	8 bc	0	10 bc	0	8 b	0
August	13 abc	2	19 abc	8	22 abc	5	18 ab	5
September	13 abc	0	16 abc	2	36 abc	12	22 ab	5
October	12 abc	0	29 abc	8	48 ab	20	29 ab	9
November	8 bc	2	14 abc	2	51 a	30	24 ab	11
December	5 c	2	37 abc	15	52 a	28	32 a	15
January	12 abc	5	22 abc	5	43 abc	22	26 ab	11
February	3 c	0	9 bc	0	32 abc	14	14 ab	5
Mean	11 p	2 x	22 q	6 x	35 r	16 y		

[1] Values in columns for treatments, columns for mean, or rows for mean for canopy reduction or dead plants followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test. Treatments were evaluated on October 8, 1973.

Table 5. Control of huisache with nine herbicide treatments sprayed on September 13, 1971, at Washington, Tex.[1]

Chemical	Rate (lb/acre)	Method of application[2]	Canopy reduction (%)	Dead plants (%)
Picloram	2	Foliage	98 a	95 a
Picloram	1 + 1	Foliage + soil	92 a	80 a
Picloram	2	Soil	42 b	10 c
Picloram	4	Soil	60 b	40 b
2,4-D	2	Foliage	43 b	0 c
2,4-D	2	Soil	10 c	0 c
2,4-D	4	Foliage	54 b	10 c
2,4-D	4	Soil	15 c	0 c
2,4,5-T	2	Foliage	50 b	5 c
Untreated			0 c	0 c

[1] Values in columns followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test. Treatments were rated on September 18, 1973.

[2] Foliage sprays were applied with a boom sprayer; soil sprays were applied at 4-foot intervals, 6 inches deep, with a nozzle mounted behind a chisel.

for all months were about equally effective for reducing the canopy, except in July when control was slightly less effective than in December.

On May 27, 1971, huisache was much more susceptible to foliar sprays with at least 1 lb/acre of picloram (Table 4) than to any soil treatment of picloram granules with up to 4 lb/acre (Table 3). A foliar spray of picloram was more effective than either 2,4,5-T or dicamba. The amine salt mixture of picloram + 2,4,5-T killed more plants than the salt + ester formulation in this one test.

In the September 13, 1971, experiment, huisache was highly susceptible to foliage sprays with at least 1 lb/acre of picloram but resistant to subsurface soil sprays (Table 5). Foliage sprays of 2,4-D and 2,4,5-T were ineffective. The soil sprays of 2,4-D reduced the canopy less than foliage sprays. Thus, spring and fall experiments indicated that foliar sprays of picloram either alone or combined with another herbicide were more effective than picloram applied either as a granule or as a soil spray.

In summary, picloram sprays and granules were about equally effective for controlling Macartney rose. April and May were the most effective months for spraying, whereas granules were effective at almost any time other than the summer months. On heavy clay soils such as at Washington, picloram may be applied effectively as foliage sprays to huisache but not as soil treatments. Picloram appears to be less available in clay than sandy soils for root absorption by huisache. Thus, picloram granules can be used at Refugio on a neutral, fine sandy loam soil (Bovey et al., 1970) and at Cambellton on a crumbly, calcareous clay soil (Bovey et al., 1969), but not on a heavy neutral Houston black clay soil such as at Washington. A foliar spray of picloram on huisache was more effective than 2,4-D, 2,4,5-T, or dicamba.

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An Optimum Sampling Strategy for Plant Species Frequencies

CHARLES D. BONHAM

Highlight: *An optimum sampling strategy was developed for predicting frequency values for all plant species occurring in an area. The approach uses both multistage and double-sampling procedures to predict the frequency of occurrence of all species. The application of these procedures to one grassland area resulted in an average saving of 26% in the number of sample quadrats required to determine the frequency of all species.*

Natural vegetation is becoming increasingly more important in detecting, evaluating, and monitoring environmental impacts. Consequently, more quantitative information is needed for vegetation characteristics so that significant vegetation changes can be detected. A number of structural characteristics of vegetation including density, cover, and species composition have been used for many years by plant ecologists in describing plant communities. Rangeland managers have also found many of these characteristics to be valuable for determination and evaluation of trends in range condition.

Frequency of plant species has been

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used as a measure to quantitatively describe vegetation. Frequency continues to be a popular measure since it is easily obtained in spite of disadvantages pointed out by some quantitative ecologists (Greig-Smith, 1964). Frequency is defined as the chance of finding a species in a quadrat (Greig-Smith, 1964). Plant frequencies have also been described as representing a blend of density and dispersion characteristics (Hyder et al., 1965). It has also been noted that frequency characteristics of perennial vegetation are seasonally stable and were useful for the classification of range sites and evaluating plant responses to grazing (Hansen, 1934). The advantages of simplicity, objectivity, and speed should be gained when frequency measurements are substituted for commonly used cover and basal area techniques (Hyder et al., 1965). Although collection of frequency data is rapid, the use of multistage and double-sampling techniques should further increase sampling efficiency.

This paper presents the results of a study of an optimum sampling procedure for estimating frequencies of plant species. The study was conducted on mixed grassland vegetation type at The Research Ranch, Elgin, Arizona. The basic approach was to combine methods for multistage sampling with those for double sampling to obtain an optimum sampling strategy.

Methods

The hypothesis in this study was that a measure of association between two species could be used to predict the frequency value for one of the species. That is, given the quantitative value for association between any two species of a sample area, the frequency of one species could be used to predict the frequency of the second species. Thus, basic assumptions made in the development and testing of the model from which species frequencies were estimated included:

1) The predictor plant species were widely distributed. That is, they had a wide range of environmental tolerances over the sampling area. This did not imply that predictor species had to have large frequency values, but rather that the species were ubiquitous.

2) The precision of the estimated frequencies for a species in the area must be independent of any individual species pattern occurring in the area. Since the species used in the prediction equation had to be widely distributed, any patchiness in the predicted species caused errors in predicting frequencies. The magnitude of these errors was assumed to vary according to the degree of patchiness, intensity of sampling, and size of the area under study.

3) The association index used in the model must have represented the true relationship that existed between the predictor species and the predicted species frequencies for the area sampled.

Like most assumptions underlying theoretical development of ecological models, these were somewhat relaxed in practical applications without invalidating the usefulness of the approach. For example, the importance of assuming that predictor plant species had to be widely distributed was relative in that the exact frequency value of a given species over the sample region is not known. Furthermore, the assumption concerning species patterns which occur throughout a sample area would be difficult to deal with in practice. Individual species have patterns which are peculiar to them under differing environmental conditions, and no single species can be described as to its pattern over an entire area under various environmental conditions. Therefore, any errors which arise as a result of variations in these patterns were assumed to be included in the error for predicting frequencies. The third assumption also includes one of linearity in the relationship that exists between two species. Such linearity seldom exists in nature but can be used for first order approximations to the frequencies of other plants. These assumptions appeared to be adequate for the development and applications of the approach.

In order to test the hypothesis, 25 stands of grassland vegetation with dimensions of 10 m x 10 m were randomly selected from a grid of 100 stands occurring at 200-m intervals in 10 rows and 10 columns. Each stand was relatively homogeneous within in respect to dominant species cover. A subsampling unit (referred to hereafter as a quadrat) 40 cm x 40 cm in size was used to obtain 50 random observations for all species frequencies within each stand. A complete description of the 324 ha (800 acres) has been described previously as to environmental and vegetational characteristics (Bonham, 1974).

The quadrat data were used to compute all possible species association values, taking two species at a time and arranging the data in a 2 x 2 table according to Dice (1945) (Fig. 1). Several other such measures are available, but this one was chosen because of the author's experience with it. Let $\mathbf{A_1}$ be the association of species **B** with species **A**. Then

$$A_1 = \frac{a}{a+b} \qquad (1)$$

where **a** is the number of quadrats containing both species and **(a + b)** is the total number of quadrats containing species **A**. That is, $\mathbf{A_1}$ equals the proportion of quadrats in which species **A** occurred in the presence of species **B**. $\mathbf{A_2}$ is the association of species **A** with species **B**.

$$A_2 = \frac{a}{a+c} \qquad (2)$$

where **a** is previously defined and **(a + c)** is the total number of quadrats containing species **B**. Then $\mathbf{A_2}$ equals the proportion of quadrats containing species **B** in the presence of species **A** (Fig. 1). These two indices were combined and used to predict all species frequencies in the area by the following relationships:

$$A_1 \ (a+b) = a \qquad (3)$$

and

$$A_2 \ (a+c) = a. \qquad (4)$$

Therefore,

$$A_1 \ (a+b) = A_2 \ (a+c) \qquad (5)$$

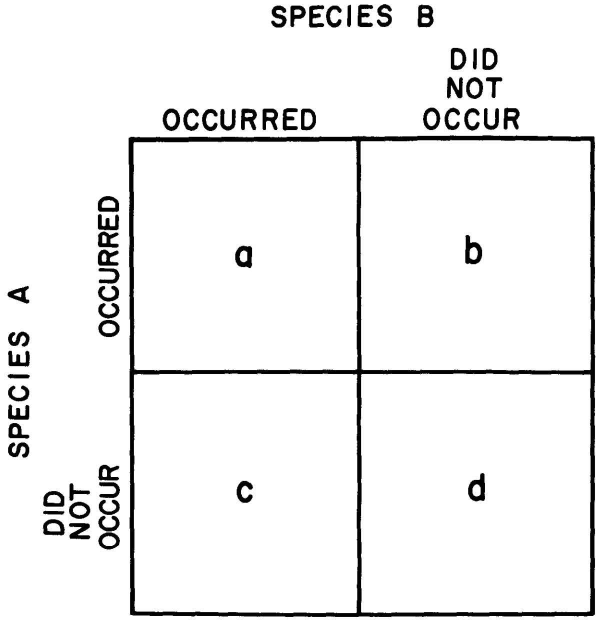
and

$$\frac{A_1}{A_2} \ (a+b) = (a+c) \qquad (6)$$

which is an estimate of the total number of quadrats containing species **B** had all quadrats been examined for its presence.

Thus, the frequency of a species can be estimated by dividing equation (6) through by the total number of quadrats sampled only for the presence of species **A**.

The selection of the species to be used in predicting the frequencies of other species was based on several criteria. A single species could have



a = number of joint occurrences of Species A and Species B
b = number of occurrences of Species A without Species B
c = number of occurrences of Species B without Species A
d = number of times neither species occurred

Fig. 1. *The quadrat data summary method to calculate species association values.*

been selected solely on the basis of its precision in estimating the occurrence of all other species. However, it was obvious that such an individual species did not exist. Furthermore, several species would estimate the occurrence of all remaining species more efficiently than any one species alone. The Central Limit Theorem of statistics was then applied in obtaining an estimate of the number of occurrences of all other species. That is, the precision of an estimate is related to the number of samples used in the estimation of the parameter and is some function of

$$\frac{1}{n_s} \qquad (7)$$

where $\mathbf{n_s}$ was the number of species used to obtain the estimate. Ideally, a set of species which produced a minimum standard error of the estimate should have been selected. While statistically this may be possible, it was not practical since each possible combination of species should have been tested for their combinatorial effect on the standard error of the estimate for all other species frequencies.

A set of species was selected which satisfied the stated assumptions and which gave a minimum variance for occurrences in stands as well as quadrats. Ecologically, these were species which were either dominant or major associates that occurred throughout the area under consideration. In addition to these possible selections, there were also ubiquitous species which were not necessarily abundant but did occur throughout the area. That is, if a species occurs consistently then its variance of occurrence is smaller. It follows that the variance of occurrences for these species in stands would not be as large over the area as for species which were more localized in their occurrence.

Hairy grama (*Bouteloua hirsuta*), Havard threeawn (*Aristida barbata*), spidergrass (*Aristida ternipes*), sprucetop grama (*Bouteloua chondrosioides*), and curly mesquite (*Hilaria belangeri*) were five grasses that occurred throughout the area. These species were not necessarily equally abundant in the area, but all fit the basic assumptions outlined. These five species were used to develop an optimum sampling procedure for estimating the frequency of all other species.

Multistage Sampling Procedures

A cost model for the relationship of sampling stands and quadrats was assumed to be of the form (Cochran, 1953)

$$C = n\,c_s + n\,m\,c_q \qquad (8)$$

where **n** was the number of stands and **m** was the number of quadrats. **C** was the total cost, while $\mathbf{c_s}$ and $\mathbf{c_q}$ were the costs for sampling each stand and quadrat, respectively. Obviously, it was more costly to sample an entire stand than to sample a single quadrat. Therefore, $\mathbf{c_s}$ was much larger than $\mathbf{c_q}$ and a combination of **n** and **m** was used to minimize the variance of the estimate, a+c from equation (6), for a given cost. However, my interest was in obtaining an estimate of the proportion of quadrats occupied, so the estimate was a+c/nm. This proportion was converted to a percentage at the end of the calculations since the development was based on proportions.

The following relation exists between number of quadrats needed and variances and costs for stands and quadrats:

$$m = \sqrt{S_q^2\,C_s \,/\, S_s^2\,C_q} \qquad (9)$$

where $\mathbf{S_s^2}$ and $\mathbf{S_q^2}$ were the variance of a + c/nm from stands and quadrats, respectively. Again, the variable to be estimated by sampling stands and quadrats was the proportion of the total number of quadrats occupied by a species. The value for this variable ranged between 0 and 1, and its variances, $\mathbf{S_q^2}$ was estimated by (Hyder et al., 1965) as

$$S_q^2 = m\,(\Sigma\, p_i q_i) \,/\, n\,(m-1) \qquad \mathbf{(10)}$$

where $\mathbf{p_i}$ was the frequency of a given species in stand **i**, $q_i = (1-p_i)$, **m** equaled number of quadrats per stand and **n** was the number of stands sampled.

The stand variance, $\mathbf{S_s^2}$ was estimated by (Hyder et al., 1965)

$$S_s^2 = \frac{\Sigma p_i^2 - (\Sigma p_i)^2 \,/\, n}{n-1} - \frac{S_q^2}{m} \qquad (11)$$

where i = 1, 2, . . . **n** (the number of stands sampled). The relative cost of observing stands compared to quadrats was estimated to be 625 to 1, since a complete stand contained 625 quadrat-areas and other factors such as location time were about equal for this study. Equation (8) becomes

$$n = 100 / 1 + .16\,(m) \quad \textbf{12)}$$

on a relative basis (Cochran, 1953).

Table 1 provides the variances for the five species selected as predictor species as well as the optimum number of quadrats to be taken within stands. The optimum number of stands needed to sample the occurrences of these species was also included (Table 1). The latter numbers were obtained by using the respective variances to solve equations (9) and (12). An overall average number of quadrats and stands was used to sample for occurrences of the five predictor species. These averages were also used to determine the double-sample size necessary to observe the occurrences of all species in relation to the five predictor species.

Double-Sampling Procedures

Eleven stands were randomly selected from the remaining 75 stands and 50 quadrats were randomly sampled within each of these stands. These 11 stands and 50 quadrats were the average values obtained by solving equations (9) and (12) for the five predictor species (Table 1). These numbers were the optimum multistage sampling numbers to use in further sampling.

Cochran (1953) provided a method for determining the number of quadrats necessary for sampling the occurrences of all other species in a double-sampling fashion by the relationship

$$\frac{k}{\sqrt{V_k c_m}} = \frac{m}{\sqrt{V_m c_k}} \quad (13)$$

where **k** was the number of quadrats to be sampled for the occurrences of all species, **m** was the number of quadrats to be sampled for the occurrences of the five species, $\mathbf{V_k}$ was the variance due to regression between the occurrences of one of the five species and the predicted occurrences of another species, and $\mathbf{V_m}$ was the variance of the deviation from the regression just described. The values of $\mathbf{c_m}$ and $\mathbf{c_k}$ were the estimated costs for obtaining **m** and **k** samples, respectively, and were estimated to be in a ratio of 1:4, respectively. That is, it took four times longer to observe and record the occurrence of all species in a quadrat than to observe and record only the occurrence of the five selected species used as predictors.

Equation (13) becomes

$$\frac{k}{m} = \sqrt{(\Sigma y^2)(r^2)} / \sqrt{(\Sigma y^2)(1-r^2)(4)} \quad \textbf{(14)}$$

where **r** was the measure of linear correlation between the predicted species occurrences and the predictor species occurrences and $\Sigma \mathbf{y^2}$ was the sum of squares of the number of occurrences of the species to be predicted. The ratio of **k/m** was used in the cost equation for **k** and **m** as follows:

$$C = m + k \quad (15)$$
$$= 50.$$

This restriction of relative cost of total sampling within a stand was the result of the optimum number of quadrats needed for obtaining frequencies of the five predictor species. Therefore, this imposed maximum of 50 quadrats was used to determine optimum double-sample numbers. These optimum numbers of quadrats differed for each species frequency to be predicted, as well as for predictor species. Equations (14) and (15) were solved for each species frequency to be predicted using the five predictor species at one time. Average number of stands and quadrats/stands needed for double sampling all species were then obtained for each predictor species (Table 1).

Eleven stands of vegetation were selected as previously described with 50 quadrats being located at random within each of these stands. Observations were made for the occurrences of the five species in the 50 quadrats, while 37 quadrats were observed for the presence of all other species. The 37 quadrats were used to determine the association values of equations (1) and (2). The association ratios were formed and multiplied by the total number of quadrats occupied by the occurrence of one of the predictor species in order to obtain an estimate of the total number occupied by the predicted species [Equation (6)]. That is, the estimate was obtained for the number of quadrats occupied by a predicted species had all 50 quadrats been sampled for its presence.

Determination of Precision

Finally, the precision in estimating the total number of quadrats having an individual species using the model was determined. The variance of this estimate for an individual species occurrence using an individual predictor species was obtained by taking the variance of equation (6) which was

$$V(a+c) = (A_1/A_2)^2 \; V(a+b) \quad \textbf{(16)}$$

where **V(a+b)** was the estimated variance for number of occurrences of an individual predictor species obtained from equation (17). This latter variance was obtained from

$$V(a+b) = \sum_{i=1}^{11} [(a+b)_i - \overline{(a+b)}]^2 / 10 \quad \textbf{(17)}$$

where 50 quadrats in each of 11 stands were used to obtain estimates of $\mathbf{(a+b)_i}$, the number of occurrences of an individual predictor species in the i^{th} stand. The mean occurrences of the predictor species over all 11 stands was $\overline{(a+b)}$. The ratio, $\mathbf{A_1/A_2}$, was considered as a constant over the sample area as stated in the assumptions and was calculated from equations (1) and (2) using the 407 quadrats (11 times 37). This was the total number of quadrats that were double sampled.

The variances for the average predicted number of occurrences of individual species using five predictor species included two sources. One was caused by the variation in the number of occurrences of the five predictor species in the sampling process, while the other involved the association ratios which varied from one predictor species to another. Therefore, the standard error of the estimated total number of occurrences of a species was calculated using five observations since only five species were used as predictors.

Table 1. Variances of species proportions for quadrats and stands and number of sampling units needed for five predictor species. (The numbers in parentheses are double samples needed based on a sample size of 50 for the predictor species.)

Species	Quadrat variance	Stand variance	Number of Quadrats	Number of Stands
Aristida barbata	0.30	0.09	46 (36)	12
Aristida ternipes	0.29	0.05	60 (39)	9
Bouteloua chondrosioides	0.25	0.12	39 (39)	14
Bouteloua hirsuta	0.27	0.12	37 (34)	14
Hilaria belangeri	0.31	0.04	70 (37)	8
Average samples needed			50 (37)	11

Results and Discussion

Estimates for the occurrences of 31 additional species were obtained using the five predictor species and the optimum sampling strategy. Table 2 gives the number of times a species was predicted to occur based on an average value obtained from the five predictor species. The standard error of these estimates is small relative to their respective means. Furthermore, most of the standard errors of the predicted frequencies are zero for practical purposes. This can be verified by multiplying the standard errors of Table 2 by (100/550) which is necessary for conversion to a percentage value.

Species which have a contagious pattern of occurrences were not predicted as precisely as the more ubiquitous species. These patterns for some species restricted their joint occurrence to only one of the predictor species. The average predicted value is very low if all five predictor species are assumed of equal weighted importance. For example, some species may be widespread but locally abundant in at least one of the sample stands. This would present some problems in predicting their average frequency values with a desirable level of precision. Therefore, it becomes a matter of determining the average frequency value of a species in the general area or to be specific to individual stands. If the average species frequency is desirable over the area, then all predictor species should be used to predict the remaining species frequencies. However, if interest centers on the localized frequency of an individual species, then only the predictor species having some joint association with that particular species should be used for predictive purposes.

A wide range in number of quadrats to be double sampled was obtained for the various species to be predicted. Blue grama (*Bouteloua gracilis*), for example, required only 20 plots to be sampled out of 50 when using spidergrass as the predictor species. This was in contrast to black grama (*Bouteloua eriopoda*) where all 50 plots needed to be sampled using spidergrass as the predictor species. However, 38 plots were required to double sample black grama compared to 23 double-sampled quadrats for blue grama when hairy grama was used as the predictor species.

Hairy grama, compared to the other predictor species, required the least number of double samples on the average to estimate all other species occurrences in an optimum way for the area (Table 1). An average of 34 double samples were required using this predictor species, whereas 39 double samples were required when spidergrass and sprucetop grama were used as individual predictor species.

Havard threeawn and curly mesquite were intermediate in their double sampling efficiency. That is, these two species needed between 30 and 37 double samples to predict all remaining species of the area. This was in contrast to spidergrass, which had a large range in double samples required to estimate the occurrences of other species. This latter species required from 20 to 50 samples for an optimum double sample for the occurrence of another species, depending on the individual species. For example, the occurrences of blue grama, common evolvulus (*Evolvulus sericeus*), and bundleflower (*Desmanthus cooleyi*) could be adequately estimated using 20 double samples with spidergrass as a predictor species. On the other hand, at least 49 samples were needed to estimate the occurrences of sida (*Sida procumbens*), leatherweed croton (*Croton corymbulosus*), and wolftail (*Lycurus phleoides*) based on spidergrass occurrence.

Hairy grama, when used as a predictor species, followed about the same pattern as spidergrass in predicting occurrences of certain species. That is, only 19 to 20 double samples were required to predict the occurrences of blue grama, common evolvulus, and bundleflower on the area. This is in contrast to the 35 to 40 quadrats required for sampling the occurrences for most remaining species when these two species were used as predictor species.

The efficiency of double sampling for species frequencies ranged from 22 to 32% savings in number of sample quadrats required. The average saving was 26% when estimating occurrences of all species of an area using the five predictor species.

When emphasis is centered on predicting the occurrences of certain species, then it is not advisable to use the average value of several species for predictive purposes. Instead, an individual species should be selected which has the highest overall association values with the species to be predicted. This would result in an increased precision for predicting occurrences of all other species than would an average of several predictor species. However, in this study it was found that several predictor species served to predict the occurrences of all other species in the area more precisely than did the use of only one or two predictor species. This undoubtedly was the result of at least some heterogenous patterns that existed for a few of the species.

In any case, the use of more than one species to predict the occurrences of other species involves the averaging

Table 2. Average number of predicted occurrences and standard errors of species using five predictor species based on 550 quadrats.

Species	Average	S.E.	Frequency (%)	S.E.*
Asclepias asperula	11	0.1	2.0	–
Aster tanacetifolius	18	0.1	3.3	–
Bailea multiradiata	4	0.0	0.7	–
Bouteloua curtipendula	22	0.2	4.0	–
Bouteloua eriopoda	1	0.0	0.2	–
Bouteloua filiformis	1	0.0	0.2	–
Bouteloua gracilis	151	1.2	27.5	0.2
Brayulinea densa	109	0.8	19.8	0.1
Chloris virgata	6	0.0	1.1	–
Croton corymbulosus	24	0.5	4.4	0.1
Desmanthus cooleyi	60	0.3	10.9	0.1
Eragrostis intermedia	36	0.3	6.5	0.1
Eriogonum wrightii	1	0.0	0.2	–
Evolvulus arizonicus	65	0.5	11.8	0.1
Evolvulus sericeus	158	1.2	28.7	0.2
Haplopappus gracilis	77	0.6	14.0	0.1
Lycurus pheoides	171	1.3	31.1	0.2
Mimosa dysocarpa	23	0.2	4.2	–
Panicum hallii	9	0.1	1.6	–
Panicum obtusum	3	0.0	0.5	–
Penstemon dasyphyllum	15	0.1	2.7	–
Psoralea tenuiflora	3	0.0	0.5	–
Senecio douglasii	3	0.0	0.5	–
Sida procumbens	95	0.7	17.3	0.1
Trichachne californica	69	0.5	12.5	0.1
Zinnia grandiflora	2	0.0	0.4	–

*Only one significant decimal recorded and the dash = < 0.1%.

of phytosociological relationships among species over their differing responses to habitats. If species responded in the same way to environmental conditions, then the accuracy of the predicted occurrences obviously would be greater. This is not usually the case and any differences in environmental responses must be average among several species.

Once the optimum number of stands has been determined, selection of stands to be sampled should probably *not be made on a random* basis. Randomization was used in this study only to determine the statistical precision of the model. However, under normal field sampling conditions, one is usually interested in estimating the occurrence for all species found in the area. Therefore, the optimum number of stands should be allocated in such a way as to include the occurrence of as many species as possible. This procedure does not violate any assumptions of the model, since the purpose is to have all species represented. Moreover, the same approach could be used to study species occurrences or frequencies according to vegetation types. In this case, the procedures developed in this paper should be applied to each of the vegetation types and sampling should be conducted using the optimum strategy for each of the types.

Computer programs were developed for data processing in this study. The ideal application of applying optimum sampling strategies for plant frequencies as developed in this study would include the use of a stepwise computer procedure. That is, a small sample should be obtained initially for processing through the multistage double-sampling model to obtain optimum stand and quadrat numbers. These additional sample numbers could then be collected and processed until sufficient sampling has occurred in a multistage double-sampling fashion.

The procedure developed in this paper might become an important application in field sampling, as more emphasis is placed on determination of quantitative relations among plant species. The optimum sampling strategies developed for estimating species occurrences should greatly reduce the amount of field work necessary to determine frequency values for species in a given area. In turn, such a procedure will permit a collection of objective data for description of vegetation structure in a more efficient manner.

It is believed that much more efficiency can be derived by using this approach than has been shown in this developmental work. The vegetation of the study area, while homogeneous in some respects, also had some habitat diversity. Obviously, more efficiency in sampling for species frequencies is gained by using the model developed in this study as the homogeneity of the vegetation composition increases.

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TECHNICAL NOTES

Poisoning in Sheep from Emory Milkvetch and Nitro Compounds

M. COBURN WILLIAMS AND LYNN F. JAMES

Highlight: *Sheep were fed nitro-containing Emory milkvetch (Astragalus emoryanus) and infused intravenously with 3-nitro-1-propanol and 3-nitropropanoic acid. Emory milkvetch and the nitro compounds produced similar clinical syndromes. Nitro compounds, therefore, appear to be the principal toxic constituent in Emory milkvetch.*

Emory milkvetch (*Astragalus emoryanus* Rydb.) Cory), also called peavine, red-stemmed peavine, or Emory loco, is a poisonous milkvetch found in Texas, New Mexico, and adjacent areas of Mexico (Sperry et al., 1964). This annual or winter annual species is most abundant and troublesome in western Texas and the southern half of New Mexico. The species consists of two varieties, var. *emoryanus,* the most common and widespread, and Big Bend milkvetch, var. *terlinguensis* (Cory) Barneby, which grows locally in Presidio and Brewster counties, Texas.

Mathews (1940) described clinical signs of Emory milkvetch poisoning in sheep, cattle, and goats. The syndrome included momentary collapse of leg muscles, incoordination with knuckling over of fetlocks, especially in the hind quarters, loss of weight, rasping noise due to labored respiration, and paralysis. He further noted that these toxic signs were similar to those reported for *A. tetrapterus* Gray; timber milkvetch (*A. hylophilus*) in Colorado; and timber

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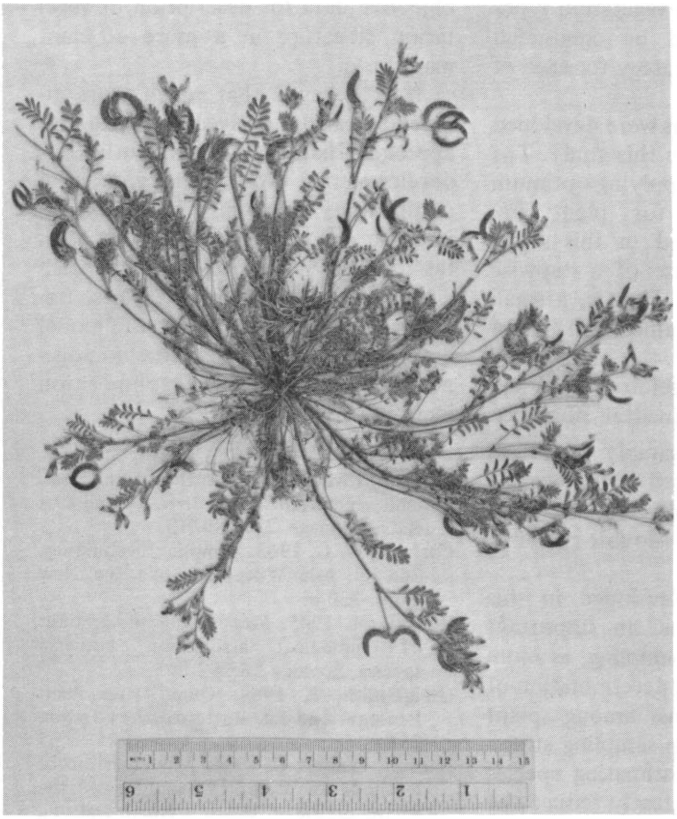

Fig. 1. *Emory milkvetch,* Astragalus emoryanus *var.* emoryanus, *collected near Roswell, New Mexico. This nitro-bearing species is poisonous to cattle and sheep.*

milkvetch (*Astragalus miser* var. *oblongifolius* Rydb.) Cron.) and Columbia milkvetch (*A. miser* var. *serotinus* (Gray) Barneby), respectively. Organic nitro compounds have been identified as the poisonous compounds in Wasatch milkvetch (Stermitz et al., 1969), Columbia milkvetch (Williams and Norris, 1969), and *A. tetrapterus* (Williams and James, 1975).

Stermitz et al. (1969) reported the isolation of the β-glycoside of 3-nitro-1-propanol (3-NPOH) from Wasatch milkvetch. This compound, named miserotoxin, hydrolized to glucose and 3-NPOH in the rumen of cattle and sheep (Williams et al., 1970). The 3-NPOH proved to be the toxic compound. Subsequent investigations revealed that nitro compounds occurred in at least 56 species of North American *Astragalus*, including Emory milkvetch (Williams and Parker, 1974).

Harlow et al. (1975) identified six nitro compounds in *Astragalus flexuosus* (Hook.) Don: miserotoxin, cibarian, karakin, hiptagin, 3-NPOH, and 3-nitropropanoic acid (3-NPA). Upon hydrolysis, cibarian, karakin, and hiptagin yielded 3-NPA. We found 3-NPOH more toxic than 3-NPA to cattle and sheep (Williams and James, 1975). Plants that synthesized primarily miserotoxin or 3-NPOH tended to be more toxic per mg of NO_2 than those in which 3-NPA or the glycosides of 3-NPA predominated.

The clinical signs reported in poisoning from Emory milkvetch were similar to those reported in *Astragalus* in which nitro compounds are known to be the toxic agent. This study was initiated to examine peavine for nitro content and to compare the toxicity and clinical signs of 3-NPOH, 3-NPA, and Emory milkvetch in sheep.

Materials and Methods

Emory milkvetch in the pod stage of growth was collected in June 1972 near Ft. Stanton, Lincoln County, New Mexico, where the plant frequently caused cattle losses. The plants were dried, shipped to the U.S. Department of Agriculture Poisonous Plant Research Laboratory at Logan, Utah, ground to 20-mesh, and stored at 2°C. A nitro analysis in the summer of 1973 yielded 8.0 mg NO_2/g of plant. A second analysis before feeding in September 1974 yielded 5.8 mg NO_2/g.

A 59.6-kg ewe was fed 400 g of the Ft. Stanton Emory milkvetch (38.9 mg NO_2/kg of body weight) for 7 days, excluding Saturday and Sunday. The plant was mixed with water and fed via a stomach pump each morning, after which the animal received alfalfa hay and water free choice for the rest of the day. Blood was drawn from the jugular vein for methemoglobin determination (Evelyn and Malloy, 1938) 3 hours after feeding on the first and third days.

Four ewes were infused intravenously for 1 hour with organic nitro compounds in sterile saline at 20 mg NO_2/kg of body weight. Two sheep received 3-NPOH and two received 3-NPA. After infusion ceased, blood samples were taken hourly for 5 hours for methemoglobin determinations.

Results and Discussion

The sheep fed Emory milkvetch became weak and unsteady in the hindquarters on the sixth day of feeding. After feeding on the seventh day, the animal rapidly became weaker, and incoordination of the hindquarters was more pronounced. The animal urinated frequently, especially if disturbed. In early afternoon, the animal collapsed and lay with labored and audible respiration. When the sheep was forced to stand, all four fetlocks knuckled over. The sheep became paralyzed and was euthanatized for post-mortem examination when it seemed likely it would die during the night. Methemoglobin was 4.6% of total hemoglobin on the first day of feeding and 4.3% on the third. A significant increase in blood methemoglobin after the animal eats *Astragalus* suggests the absorption of nitro compounds.

This initial feeding exhausted our supply of Ft. Stanton Emory milkvetch and prevented the feeding of a second sheep. No collection of Emory milkvetch was made in 1973 because nitro compounds in the species were discovered after the plants had seeded and died. Because of a severe drought in New Mexico in 1974, Emory milkvetch was virtually non-existent.

Sheep administered 3-NPA intravenously at 20 mg NO_2/kg became depressed and incoordinated in the hindquarters 3 hours after treatment. Twenty-four hours later one sheep was weak and very incoordinated in the hindquarters, and it fell frequently. When it arose, its fetlocks knuckled over. The animal was euthanatized for post-mortem examination. The second sheep was stiff legged and slightly incoordinated at 24 hours, so it was infused a second time with 3-NPA at 20 mg NO_2/kg. The animal died later in the day after showing the same clinical signs observed in the first sheep.

Sheep infused with 3-NPOH became weak and incoordinated in the hindquarters 2 hours after treatment. The animals urinated more frequently than normal. No knuckling of the fetlocks was noted. Respiration was labored and audible; the sound was associated with froth and mucous that collected in the air passages. Both animals collapsed and died about 4 hours after treatment. Methemoglobin in the blood of sheep infused with 3-NPOH and 3-NPA reached only 2.1 to 2.5%. Apparently, little nitrite was split from the 3-carbon side chain to form methemoglobin.

The toxic signs produced in sheep with Emory milkvetch and 3-NPA appear identical. The syndrome produced by 3-NPOH was similar to that produced by 3-NPA except that the time lapse between the onset of toxic signs and collapse and paralysis was very rapid and the knuckled fetlock stage was not evident.

High-pressure liquid chromatography of Emory milkvetch (var. *emoryanus*) produced a distribution of nitro compounds, expressed as NO_2, as follows: miserotoxin, 22%; cibarian, 35%; karakin, 11%; hiptagin, 12%; and 3-NPOH, 20% (Williams et al., 1975). About 58% of the NO_2 was found in nitro compounds that could be expected to yield 3-NPA; the 3-NPA would account for the similarity of toxic signs produced by 3-NPA and Emory milkvetch. Nitro compounds appear, therefore, to be the principal poisonous compound in the milkvetch.

We have observed that the nitro content in dried *Astragalus* species declines during storage. The nitro content of the Emory milkvetch used declined 28% between the summer of 1973 and 1974. We estimate, therefore, that the Emory milkvetch from Ft. Stanton contained over 10 mg NO_2/g when collected in 1972.

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Yearly Variation in Germination in Three Subspecies of Big Sagebrush

R. O. HARNISS AND W. T. McDONOUGH

Highlight: *Yearly variation in germination between individual plants of three subspecies of big sagebrush (*Artemisia tridentata*) was examined. The subspecies* vaseyana *germinated less than* tridentata *or* wyomingensis. *Only* tridentata *showed a significant difference in year-to-year variation. In all years, germination rates of the three subspecies were high enough to exclude seed germination as a limiting factor in sagebrush reinvasion.*

Recognition of subspecies of big sagebrush (*Artemisia tridentata* Nutt.) and of the differing environmental habitats of each has led to interest in the germination and seedling growth requirements among subspecies.

In studies of the temperature required for germination of three big sagebrush subspecies (*tridentata, vaseyana,* and *wyomingensis*) McDonough and Harniss (1974a, b) found that small differences between subspecies were due mostly to the stratification treatment needed by subspecies *vaseyana*. Temperature as a requirement for seed germination was eliminated as a critical factor for successful reestablishment. In a related study (Harniss and McDonough, 1975), seedling growth of the subspecies was reduced under a below average temperature requirement, but there was no difference in growth among subspecies under any one temperature requirement.

Good years for big sagebrush invasion and reestablishment following eradication treatment have been noted by Pechanec (1945); Mueggler (1956); Johnson (1958); and Daubenmire (1970). The study reported here examined the possibility that sagebrush seed has different germination ability in different years.

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Procedures

In 1971, 1972, and 1973, big sagebrush seed collections were made from the same 10 plants of each of three big sagebrush subspecies in the vicinity of the U.S. Sheep Station near Dubois, Idaho.

Seeds were separated from chaff and germinated in 9-cm petri dishes on double layers of filter paper wetted with 3 ml of distilled water. There were 50 seeds per treatment and two dishes per treatment for each of the 30 individual plant collections. Dishes were stacked in metal cans with transparent lids. Cans were placed in temperature cabinets under controlled temperatures of 20/10°C (8/16 hours). An 8-hour photoperiod (1,100 lumens/m^2) coincided with the higher temperature. Germinating seeds were inspected daily for the first 10 days and then every third day until the 30th day, when the experiment was completed.

Germination was considered to have occurred when root growth was visible. Germination percentages were subjected to variance analysis and studentized range tests at the 5% level.

Results and Discussion

There was a significant difference in germination among the subspecies over the 3 years (Table 1). The subspecies *vaseyana* germinated less than the other two. This difference in germination is similar to that noted earlier over different temperature regimens (McDonough and Harniss, 1974a) and is caused by the requirement of the *vaseyana* seed for a stratification treatment (McDonough and Harniss, 1974b). This result corresponds to the topographic location of these

Table 1. Average seed germination (%) for 3 years by three subspecies of big sagebrush.

	Artemisia tridentata var.					
	tridentata		*wyomingensis*		*vaseyana*	
Year	Average	Range	Average	Range	Average	Range
1971	50.2 a[1]	22–75	43.2 a	1–78	17.1 a	1–22
1972	60.5 ab	36–94	50.0 a	22–73	23.0 a	4–50
1973	69.8 b	50–88	70.0 a	27–91	11.0 a	4–19
Average $\bar{x}$	60.2		54.4		17.0	

[1] Average germination values within a subspecies with the same letters do not differ significantly (P=5% level) between years.

subspecies; *vaseyana* is found at a higher elevation than the other subspecies, where there are shorter growing seasons and more snow cover.

Only the subspecies *tridentata* showed a significant difference in year-to-year germination between 1971 and 1973. This difference is likely due to less plant-to-plant variation for *tridentata* than for the other subspecies (Table 1). Between years, there was no difference in germination of seed from the same plant.

None of the results of this study indicate that year-to-year differences in seed germination are the cause of seemingly "good" years for sagebrush reestablishment. In our study, sufficient seed was available for adequate germination each year, even at the lowest germination rates observed.

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Improved Technique for Estimating Milk Production from Range Cows

JAMES S. BLUNTZER AND PHILLIP L. SIMS

Highlight: *Calf weaners, commonly called "blabs," were found to be useful devices to aid in collection of milk consumption data in range animal nutrition research. Inserting a blab in the calf's nostril prevents the calf from nursing when cow and calf are turned out to graze. Calves are then weighed, allowed to nurse, and then reweighed. The difference in the two weighings was considered to be the amount of milk consumed by the calf or produced by the cow for that time interval. This procedure is an improvement over that suggested by other investigators, as both the cow and calf remain together and graze more normally, as opposed to the calves' being penned for 12 hours.*

In the past, milk production in beef cattle has been evaluated indirectly by measuring weight gain of the calf during the preweaning period. Hall (1971), Rutledge et al. (1971), and Knapp and Black (1941), studying factors that influence 205-day weight of beef calves, verify that milk production of the beef cow has greater influence on weaning weight of her calf than any other single factor.

At a recent symposium on the range beef cow, increased milk production and improved fertility of range cows were stressed as two primary areas for increasing efficiency of beef production in the future (Great Plains Agricultural Council, 1973). Therefore, quantifying milk production by different breeds and various crossbreeds seems important in determining the most efficient type of cow-calf unit for utilizing and converting range forage into high protein human foods (Bluntzer, 1974).

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Procedures

Twelve (½ Hereford x ½ Angus) crosbred cows and their calves grazing sandhill range in northeastern Colorado were used in this milk study for seven 3-consecutive day trials. Bluntzer (1974) employed the use of calf weaners commonly called "blabs" in collecting milk records, using similar weigh-suckle-weigh procedures as Drewry et al. (1959). The blabs (Fig. 1) are 10.2 by 20.3 cm metal rectangles with three sharp points and a nose clamp. These devices prevent the calf from nursing during the 12-hour separation interval, but allow the calf to graze somewhat normally. Thus, the need to pen calf and disturb cow's normal grazing habits was avoided.

Actual procedures used are as follows: In mid-afternoon cow and calves were separated 2 to 3 hours. This preliminary separation was to insure that the cow's udders would be depleted of milk just prior to the time blabs were inserted at 6 pm. At 6 am the following day, after the first 12-hour interval, blabs were taken out, calves were weighed, allowed to nurse, and reweighed. Again blabs were placed in calves' nostrils and cow and calf turned out to graze. After another twelve hours the weigh-suckle-weigh procedure was repeated at 6 pm. The sum of the two differences in before-and-after-weights for this 24-hour period has been commonly accepted as an accurate determination of daily milk yield (Totusek and Arnett, 1965).

Table 1. Average milk consumption (kg/day) for seven 3-day calf nursing trials on sandhill rangeland in eastern Colorado during the preweaning period, using blabs to improve the weigh-suckle-weigh procedure.

Calf no.	April 13	May 4	June 1	June 29	July 27	August 24	September 14	Mean	± S.E.[1]
268	–	6.2	8.0	6.1	6.0	5.8	6.0	6.4	.34
271	–	5.2	7.2	7.1	6.5	5.2	4.7	6.0	.44
272	–	4.0	6.9	6.7	6.7	5.9	5.2	5.9	.46
274	–	7.3	7.9	7.6	7.0	5.8	4.6	6.7	.50
275	5.9	6.2	7.6	8.1	7.6	6.6	5.6	6.8	.42
277	6.3	6.8	5.8	6.6	6.4	6.2	4.6	6.1	.28
279	6.3	6.4	8.4	8.0	8.7	4.6	5.0	6.8	.62
280	5.7	5.7	6.7	6.0	4.2	3.1	2.0	4.8	.65
281	8.0	8.4	9.0	9.5	9.5	7.9	5.9	8.3	.30
282	5.7	6.2	5.5	6.8	6.3	6.6	3.8	5.9	.38
283	–	6.5	7.2	8.4	6.0	5.5	4.3	6.3	.56
284	–	5.8	5.7	7.4	5.4	5.3	4.5	5.7	.39
Mean	6.3	6.3	7.2	7.4	6.7	5.7	4.7	6.3	.27
(S.E.)[1]	(.53)	(.43)	(.65)	(.62)	(.67)	(.58)	(.43)		

[1] Standard error based on daily milk consumption.

Precautions

The calf nursing procedure has some room for error in use. Use of improper size blabs may result in their loss and, subsequently, missing data. Different types of blabs can be purchased in at least two different sizes. The authors found the smaller blab of the type illustrated to have the best retention during the separation periods. Care should be taken not to bend the metal flange on the blab that locks the clamp in the nostrils, as this may allow a blab to be lost.

Urination or defecation between the time the calf is first weighed and then reweighed is a source of error that should be considered, as this will reduce the weight difference that should show up as milk consumed by the calf.

Finally, total milk production by the cow may be biased if the calf does not consume all of the milk produced by the cow.

Results

Table 1 shows data obtained at the Eastern Colorado Range Research Center near Akron, Colo., in 1973 on the group of crossbred cattle studied. Average milk production by this group of range cows was 6.3 ± .27 kg/day. The range in milk yield varies from a low of 4.7 kg/day in September to a high of 7.4 kg/day in late June. For comparison, Herefords on similar vegetation had a lower yield of 4.0 ± .28 kg/day, while similar Herefords on a limited ration in total confinement had even a lower yield of 2.4 ± .36 kg/day. The authors found range cows varying in daily milk yield from 1.8 to 9.1 kg (4 to 20 pounds). Hand milking after the calf finished nursing yielded an additional 0.6 ± .04 kg/day of milk during the first month of lactation.

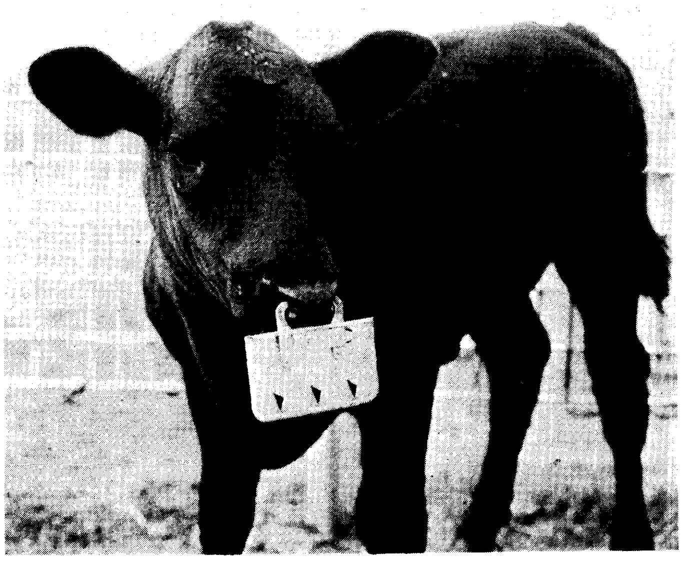

Fig. 1. *Calf blab used in milk study that prevents calf from nursing, yet allows normal grazing activity.*

Conclusions

In summary, the calf nursing technique using blabs is a useful tool in range animal nutrition studies. The authors agree with Neville (1962), who states that calves appear to remove all the milk from the udder at each nursing; however, he further states that this is probably not the case shortly after calving. This technique is useful under range conditions to quantify milk yield of different breeds and crossbreeds. It may also be used to show seasonal variation in milk production and to determine the energy flow to the calf as milk and its efficiency of conversion into pounds of salable beef.

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Three-Dimensional Chlorophyll Concentrations in a High Biomass Blue Grama Canopy

C. J. TUCKER AND M. W. GARRATT

Highlight: *The three-dimensional chlorophyll variation in 50-cm high blue grama canopy was investigated. Statistical analysis revealed significant differences in the vertical dimension and a quadratic relationship between chlorophyll density and height. Maximum canopy chlorophyll concentrations occurred in the 12.5–25.0 cm vertical region with the lowest concentrations occurring in the 0.0–12.5 cm and 37.5–50.0 vertical region.*

The chlorophyll distribution in a grassland canopy directly implies information concerning the photosynthetic activity of that canopy. Little variation in the north-south and east-west concentrations would be expected for a homogeneous canopy. Vertical chlorophyll concentrations in a high biomass grass canopy are related to light penetration and the vertical biomass distribution and would be expected to vary to a large degree. Pursuant to this, a 1-m^2 plot of blue grama (*Bouteloua gracilis*) was selected to study the variation of chlorophyll density within the width, length, and height of the canopy.

Methods

The square meter plot was divided into 64 cells ($4^3 = 64$), having the dimensions of 25 × 25 × 12.5 cm for width, length, and height, respectively. The width and length dimensions corresponded to the east-west and north-south orientation of the plot sampled. The blue grama canopy studied was located in the Environmental Stress Area of the International Biological Program's Grassland Biome Pawnee Site near Nunn, Colorado. The particular location selected for study was in an irrigated and nitrogen-fertilized area and had a biomass of 530 g/m^2. The time of sampling was early August in 1972.

A three-dimensional grid was set up with twine to delineate the compartmentalization of the canopy. Clipping was then initiated, beginning from the uppermost layer and proceeding downward. Clipped vegetation was immediately placed into a plastic bag, sealed, and stored on dry ice in a large styrofoam ice chest. Care was taken to prevent exposure to sunlight or warm air. At the conclusion of the clipping, the clipped vegetation was taken into the IBP laboratory where a representative aliquot was taken from each of the 64 samples.

Two chlorophyll determinations per sample aliquot were made and were expressed as milligrams of chlorophyll per gram dry weight (Horwitz, 1970). The means of each pair of determinations were the data employed in the statistical analysis. The experiment was analyzed as a three-way factorial design with the vertical, north-south, and east-west dimensions as the three factors. Orthogonal polynomials were employed to break the significant sum of squares, the vertical dimension, into its linear, quadratic, and cubic components (Cochran and Cox, 1957) (Table 1).

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Table 1. Analysis of variance of the chlorophyll variation in the blue grama canopy.

Source	Sum of squares	df	M.S.	*F*-value	Prob. greater *F*
Total	15.942	63	–	–	–
East-west (E-W)	0.183	3	0.061	0.679	0.573
North-south (N-S)	0.557	3	0.186	2.065	0.128
Vertical	10.569	3	3.523	39.226	0.000
Linear	2.926	1	2.926	32.523	0.000
Quadratic	7.314	1	7.314	81.306	0.000
Cubic	0.329	1	0.329	3.653	0.067
E-W × N-S	0.443	9	0.049	0.548	0.826
E-W × vertical	1.058	9	0.118	1.307	0.279
N-S × vertical	0.702	9	0.078	0.867	0.565
Error	2.429	27	0.090	–	–

Results

The results show the marked vertical chlorophyll concentration differences that exist in the canopy. The uppermost layer shows the lowest concentration of chlorophyll per unit weight of tissue (0.728 mg/g) because the blue grama seedheads in this vertical zone (37.5–50 cm) are not photosynthetically active. Lower canopy layers show increased chlorophyll concentrations which rise to maximum of 1.851 mg/g in the 12.5–25.0 cm zone. The chlorophyll concentration then begins to decrease with lower canopy depths (i.e., 0.0 to 12.5 cm). A Tukey's test revealed no significant difference at the 0.05 level between the mean chlorophyll concentrations in the 0.0 to 12.5-cm zone and the 25.0 to 37.5-cm zone. All other differences in the mean chlorophyll concentrations were significant at the 0.05 level.

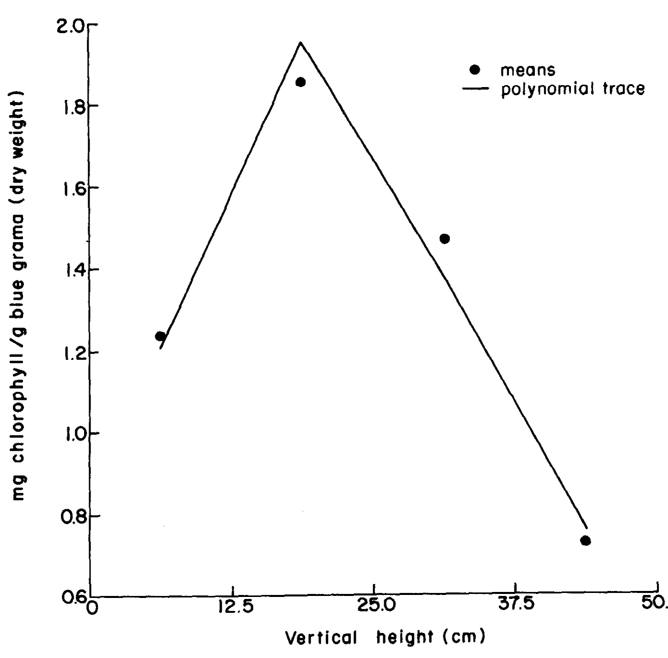

Fig. 1. *Estimated means and polynomial of chlorophyll of blue grama in the vertical dimension.*

The relationship between chlorophyll concentration and vertical height can be approximated by a quadratic function (Fig. 1) of the form:

$$\hat{Y} = 1.321 + 0.096X - 0.338X^2$$

where $\hat{\mathbf{Y}}$ is the estimated chlorophyll concentration and **X** is the height within the canopy.

In addition, the 0.0 to 12.5-cm zone reflects the diminished light penetration but apparently compensates for this in terms of total chlorophyll by having proportionally higher biomass near the base. The results of this experiment support the contention that little variation occurred in the north-south and east-west directions, while significant variations occurred in the vertical dimension. The analysis implies that maximum chlorophyll concentration and hence photosynthetic activity occur *in the* 0.0 *to* 37.5-*cm region of the high biomass blue* grama canopy studied.

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Rainfall Interception by Cool-desert Shrubs

NEIL E. WEST AND GERALD F. GIFFORD

Highlight: *Interception patterns of big sagebrush (*Artemisia tridentata *Nutt.) and shadscale (*Atriplex confertifolia *(Torr.) Wats.) were measured under two simulated rainfall intensities during three different seasons. Mean rainfall interception rate of individual plants of both species was 0.15 cm when averaged over all sampling dates and rainfall intensities. Interception during individual storms of at least 0.15 cm size by entire plant communities, based on measured vegetal cover, was calculated at 0.028 cm or less. On the average, about 4% of the total annual rainfall (not snowfall) would be intercepted by these plant communities.*

Interception of precipitation by plants of the cool deserts or shrub steppes of the Intermountain Region has been little studied. One obvious reason for this is simply that interception rates are assumed to be minor because many of the plant species are small in size and total vegetal cover is often less than 50%. Although Wallace and Romney (1972) indicate the possibility of desert plants channeling rainfall into the soil near the base of their stems, the only studies we could find that report actual interception rates of an American semiarid shrub species is that of Hull (1972) and Hull and Klomp (1974). They studied big sagebrush (*Artemisia tridentata* Nutt.) using small, 10-centimeter diameter gauges in dense (2.2 plants per m^2) stands near Holbrook and Twin Falls, Idaho. A comparison between gauges on heavy brush and in brush-free areas showed that the heavy brush intercepted 31% of the rain which fell between April 1 and October 30 at Holbrook and 30% at Twin Falls. Snow interception averaged 37% on plots at Holbrook. Potential interception per rainfall event as determined by spraying 10 individual plants with water was 0.11 centimeters.

The objective of this study was to examine interception patterns of big sagebrush and shadscale (*Atriplex confertifolia* (Torr.) Wats.) under two simulated rainfall intensities during three different seasons for improved understanding of this phenomenon in hydrologic and mineral nutrient cycling processes.

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Methods

The interception studies were carried out in Curlew Valley near Snowville, in northern Utah, at a study site previously described by Mitchell et al. (1966). A representative sample of mature big sagebrush and shadscale (*Atriplex confertifolia* (Torr.) Wats.) plants was collected during spring (late April), summer (late July), and fall (early October) of 1973 and subjected to simulated rainfall at two intensities, 1 cm/hour and 5 cm/hour using a device designed by Meeuwig (1971). The shadscale plants varied in height from 13 to 35 cm and the big sagebrush plants varied in height from 18 to 44 cm. All plants were cut off at their stem bases, placed in a holding device on a direct reading balance, and weight gains under simulated rainfall recorded at the end of 30, 60, 120, 300, 600, and 900-second intervals. For replications 30 plants were used in the spring, 20 in the summer, and 10 during the fall run. Data on total interception for each brush species, as indicated by total weight gained after 900 seconds, in each season were subjected to analysis of variance.

Canopy coverage of the treated shrubs was determined by taking the east-west and north-south diameters through the center of the fullest part of the crown and calculating the area of a paraboloid.

The average canopy coverage of the community as a whole was determined by placement of a 200-m line intercept tape at crown level through the community in the vicinity where the treated plants were taken. From these data interception per unit area could be calculated.

Results

Mean rainfall interception rates of individual plants used in this study amounted to 0.15 cm for both shadscale and big sagebrush, when averaged over all sampling dates and rainfall intensities. Given a storm of sufficient size to wet each individual plant, actual interception of entire plant communities on this site would amount to approximately 0.025 cm and 0.028 cm, respectively, for shadscale and big sagebrush based on measured vegetal cover of 16.8% for shadscale and 19.1% for big sagebrush.

The analysis of variance indicated a significant species by date by rainfall intensity interaction. Since the species by date interaction was also significant, the implication was that the species by date interaction differs with the level of rainfall intensity. Examination of this two-way interaction indicated the problem was tied to species interception differences during the fall sampling date. Looking then to the species by rainfall intensity interaction for the fall sampling date revealed that there were no significant differences in interception between species at the 1 cm/hour rainfall intensity (0.13 cm vs 0.14 cm); but at the 5 cm/hour intensity the interception for shadscale was 0.13 cm and the interception for big sagebrush was 0.22 cm, the difference being highly significant. This difference is explained by the greater non-growing season retention of leaves by the more evergreen big sagebrush (West and Gunn, 1974).

Interception rates of the two plant species showed no significant differences when averaged over both rainfall intensities for the spring and summer sampling dates.

The average length of time until start of leaf drip and/or stemflow for shadscale and big sagebrush plants was 3.8 minutes under the 5 cm/hour rainfall intensity. Hull and Klomp (1974) mention that they observed leaf drip from big sagebrush in Idaho during heavy storms but stemflow was never observed. A storm of enough intensity (5 cm/hour) to bring leaf drip or stemflow can be expected to recur only about once each 25 years at Snowville, Utah (Richardson, 1971).

We would expect intercepted precipitation to be held above the soil surface in proportion to vegetal cover and be available for evaporative losses of an increased rate over that on soil surfaces. In this respect, about 21 rain storms greater than 0.15 cm are expected between the period April 1 and November 31 of each year at Snowville, based on analysis of U.S. Weather Service records for 1950–1970. Ignoring those storms of less than 0.15 cm, an average of about 0.59 cm of rain is intercepted yearly by the sagebrush and shadscale plant communities. This amounts to about 4% of the total annual precipitation which falls as rain. These results will be utilized in modelling of water and mineral nutrient cycles in these ecosystems.

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VIEWPOINT

Red Meat Production on U.S. Rangelands

JOHN E. MITCHELL

An open letter written by Norman R. French appeared in a recent issue of the Bulletin of the Ecological Society of America.[1] In it Dr. French presented his evaluation of the U.S. Department of Agriculture (USDA) report entitled, "Opportunites to Increase Red Meat Production From Ranges of the United States."[2] In doing so, he raises several interesting and thought-provoking points concerning two subjects those of us in range management hold with no little respect; i.e., improving rangelands and increasing range livestock production.

In brief summary, the USDA report projects an estimated demand for range livestock from approximately 215 million AUM's in 1970 to between 250 and 300 million AUM's by the end of this century. It concludes that the range is fully capable of meeting the highest projected demand by the year 2000, and, moreover, even has a reasonable potential to produce up to 566 million AUM's by that time—a 265% increase! The report at least implies that the principal source of this increase in beef production (the document assumes that little, if any, of the increased production will be provided by the sheep industry under all possible circumstances—a conclusion which I believe to be shortsighted) is expected to be derived from increased stocking rates. Finally, the report states that the expected gain will be achieved, "by applying intensive environmental and livestock management to each acre of the total available range area." In other words, range improvements.

French responds that it seems reasonable, however, to expect range improvements to come at the expense of increased stocking rates for the next quarter century, rather than as a means of increasing it. Consequently, he comes to a basic disagreement with

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[1] Bull. Ecol. Soc. Amer. 56(2):4-5. 1975.

[2] U.S. Dep. Agr. Inter-Agency Work Group. 1974. Opportunities to increase red meat production from ranges of the United States. Phase I (Non-research). 100 p.

conclusions reached by the report and reaches his own decision that, if the projected demand estimates for meat are plausible, the United States will eventually be required to import much of its red meat from other producing countries.

My viewpoint results directly from reading French's letter.

First, I tend to agree with French that magnitudinous increases in the rate of livestock production on our western rangeland, at least, are unlikely. Some areas can show great improvements if the right conditions exist (e.g., closed sagebrush stands that can be opened and seeded to grass or unusable range that becomes usable by introducing water), but, on an overall basis across all of the 11 western range states, a doubling in productivity by the year 2000 cannot be expected if demand only increases gradually.

The above seems even more logical if you consider that rangeland is, by its very nature, land not suited for any single-purpose use of a more intensive nature, and is therefore certain to decrease before the boundaries of such other uses.

On the other hand, I cannot agree with Dr. French's conclusion that the United States will have to rely on imported meat to reach the projected demands that are anticipated. These goals can be reached quite simply if the range livestock industry is developed in the coastal plain and Piedmont plateau regions through our southern tier of states; i.e., North Carolina, South Carolina, Georgia, Alabama, Mississippi, and Florida. The reasons for such a potential are obvious to any person trained in range management who has worked there. For example, consider the following.

Except for inorganic nutrients, the abiotic driving variables for a grassland-livestock ecosystem are in plentiful supply throughout the year. Yearly precipitation is between 45 and 60 inches per year and, compared to western standards, is distributed evenly through each calendar quarter. Moreover, potential evapotranspiration rarely exceeds 45 inches per year, except in southern Florida. Average daily minimum temperatures are above freezing in January, and average daily maximum temperatures do not exceed 90°F in July.

As a result of the optimal abiotic parameters, potential primary production from managed pastures is high, approaching even the productivity of tall grass prairie ecosystems in the eastern Great Plains. However, actual productivity is, in my opinion, at least an order of magnitude below what may be reasonably obtained under present "state of the art" range resource management.

Except for Florida and, to a lesser extent, Mississippi, an adequate program of range research and extension does not exist in the Southeast. Consequently, land owners and livestock operators are not cognizant of the returns they stand to realize from making what a western rancher would consider to be extremely secure investments. The Society for Range Management has not yet reached southern ranchers, either. In 1974, there were fewer than 100 members of the Society in the Southern Section, which includes all of 11 southeastern states.

The majority of livestock operations in the Piedmont Plateau are uneconomically small, and are conducted without regard for accepted management and economic practices. In addition, large tracts of this area capable of supporting intensive range livestock operations are untapped while the landowners make less money raising pulpwood, fruit, or cotton. Therefore, the Piedmont Plateau is especially capable of supporting an increase in red meat production.

The potential which exists in Georgia and its neighboring states does not distract from the continuing responsibilities those of us in the West have in furthering the cause of range resource management and in improving our natural resource base. In fact, most of the real challenges in natural resource management will always remain in the arid West. There are definite gains which can be made in red meat production through improved grazing practices, such as common use grazing, and other means. Factors such as national energy policy and land use planning will continue to present those of us involved in range management with problems and opportunities.

It is likely that many of you do not agree with my viewpoint; it is not data based. No matter what your opinion, I suggest that you read the reports and opinions involved in order that you might reach conclusions of your own. After all, isn't increasing livestock production on a sustained basis the basic objective of our profession?

Herbicide Nomenclature and Related Terminology

C.J. SCIFRES

"A certain degree of standardization (of terminology) is necessary to minimize misunderstanding and to facilitate communication" (Range Term Glossary Committee, 1974).[1] Although the Society for Range Management is not concerned with assignment of common names to pesticides, an increasing number of papers dealing with various aspects of herbicide use for range improvement are being published by the *Journal of Range Management.* In these papers, trade and common names are often mixed, tending to confuse readers without a background in the properties and uses of herbicides. Such mixing of herbicide names (trademark, common, and chemical) should neither be considered by authors nor tolerated by the *Journal* except in cases where no common name has been assigned.

Clear understanding of the naming system for herbicides will help prevent confusion for authors and audience. All herbicides have three names or designations:

1. *Common name.* This is a short name to facilitate referencing of herbicidal compounds (Table 1). Common names of herbicides are assigned by the *Weed Science Society of America* (WSSA) nomenclature committee.

2. *Chemical name.* This is the actual chemical designation of the herbicidal compound. Since many herbicides are rather sophisticated chemicals, chemical names are usually too cumbersome for routine use.

3. *Trademark (trade name).* The name under which the herbicide, as a commercial product, is advertised and sold. Trade names are much like colloquial names of plants in that they vary from company to company for the same basic herbicide (Table 1). In technical communications among scientists, use of trade names should

Author is associate professor, Department of Range Science, Texas A&M University, College Station 77843.

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[1] Range Term Glossary Committee, M. M. Kothmann (Chairman). 1974. A glossary of terms used in range management. 2nd Ed., Society for Range Management, Denver, Colo. 36 p.

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be avoided since their use can be construed to be a proprietary endorsement. When trade names must be used for clarity, a disclaimer statement should be employed unless, of course, the author is an employee of the manufacturer. In that case, the *Journal* should insert a standard disclaimer (see footnote, Table 1).

In written scientific communications, it is proper to mention the common name of the herbicide followed by the chemical designation in parenthesis at first mention. However, for ease of presentation, it is suggested that only common names be used in highlights with chemical name referenced at first mention of common name of the herbicide in the body of the paper, for example; "... 2,4-D ((2,4-dichlorophenoxy) acetic acid) . . ." Thereafter, only the common name is required for adequate reference. In popular articles, use of only the common name will probably suffice for herbicide identification. Other herbicides assigned common names by WSSA are listed with appropriate chemical designation on the back cover of each issue of *Weed Science.*

The same approach should be adopted for referencing herbicide additives such as surfactants and emulsifiers. The formulation of herbicide used should be noted in the materials and methods section of all technical papers, since vital processes such as foliar absorption, tendency to volatilize, and proper carrier for application are strongly affected by formulation. Use of proper nomenclature will not only facilitate communication but will project a more professional image for our Society and its membership.

Table 1. Common names, chemical designations, and examples of trademark names of herbicides used for range improvement or which are showing promise in research.[a]

Common name	Chemical name	Trademark examples[b]
Amitrole	1. 3-amino-*s*-triazole 2. 3-amino-1,2,4-triazole	Amitrol-T (mixture with ammonium thiocyanate); Amizine (mixture with simazine) Amizol; Fenamine (mixture with fenac and atrazine); Kleer-lot (mixture with linuron); Weedazol; Amino Triazole Weed Killer.
AMS	ammonium sulfamate	Ammate X, Ammate X-NI
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine	AAtrex 80W; AAtrex 4L; AAtram 20G (combination with propachlor); Atratol 8P (combination with sodium chlorate and sodium metaborate); Atratol 80W (combination with prometone).
2,4-D	(2,4-dichlorophenoxy) acetic acid	2,4-D; Aqua Kleen; DMA-4 Dacamine; Emulsamine E-3; Esteron-99; Formula 40; Hedronal; Pennamine D; Phenox; Weed-B-Gon; Weedone 638; Weedone LV4; and many others.
Dalapon	2,2-dichloropropionic acid	Dowpon; Dowpon M (mixture with sodium and magnesium salts of dalapon); Dowpon C (mixture with TCA); Radapon liquid.
Dicamba	3,6-dichloro-*o*-anisic acid	Banvel D; Banvel 1 + 3 (mixture with 2,4-D); Banvel 2 + 2 (mixture with 2,4,5-T).
Dichloroprop	2-(2,4-dichlorophenoxy) propionic acid	Weedone 2,4-DP; Weedone 170; Envert 171 (mixture with 2,4-D).
Hexaflurate[c]	potassium hexafluoroarsenate	Nopalmate.
MCPA	1. [(4-chloro-*o*-tolyl) oxy] acetic acid 2. (2-methyl-4 chlorophenoxyacetic)	Chiptox; Rhomeme; Rhonox; Bronate (mixture with bromoxynil); Dow MCP Amine Weed Killer; Weedar Sodium MCPA.
Monuron	1. 3-(*p*-chlorophenyl)-1,1-dimethylurea 2. (*N'*-(4-chlorophenyl)-*N,N*-dimethylurea)	Telvar
Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion [as dichloride salts]	Ortho paraquat; Gramoxone'
Picloram	4-amino-3,5,6-trichloropicolinic acid	Tordon 10K (potassium salt); Tordon 212 (mixture with 2,4-D); Tordon 225 (mixture with 2,4,5-T); Tordon 101 (mixture with 2,4-D); Tordon 155 (mixture with 2,4,5-T as esters).
Silvex	2-(2,4,5-trichlorophenoxy) propionic acid	Kuron; Weedone 2,4,5-TP; Silvex
2,4,5-T	(2,4,5-trichlorophenoxy) acetic acid	Weedar 2,4,5-T; Weedone 2,4,5-T; Amine 4T; Lo-Vol 4T; Veon 2,4,5; Esteron 2,4,5; Brush-Rhap A-4T; Brush Rhap LV-OXY-4T; and others.
Tebuthiuron[c]	*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea	EL-103, Spike.

[a]Source: *WSSA Herbicide Handbook Committee.* 1974. Herbicide Handbook of the Weed Science Society of America, Third Ed. 430 p. (May be purchased from Weed Sci. Soc. Amer., 425 Illinois Bldg., 113 N. Neil St., Champaign, Ill. 61820.)

[b]Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the Texas Agricultural Experiment Station and does not imply its approval to the exclusion of other products that may also be suitable.

[c]Experimental only, not registered by Environmental Protection Agency for use on rangeland.

BOOK REVIEWS

Soils of the Desert Southwest. By Wallace H. Fuller. University of Arizona Press, Tucson, Arizona 85721. 1975. 102 p. $4.95 paperback.

Management of Southwestern Desert Soils. By Wallace H. Fuller. University of Arizona Press, Tucson, Arizona 85721. 1975. 195 p. $7.50 paperback.

These two books are related not only in their authorship but in that the first serves as an introduction to the second, particularly for those readers with no previous exposure to the subject matter.

Soils of the Desert Southwest is a non-technical introduction to the soils of the desert Southwest–how and why they differ among themselves and with soils of humid climates, how they developed, why different soils have the physical and chemical characteristics they have, and how those characteristics may affect or limit the kinds of plants that can be grown on them. The treatment is strictly broadbrush and nontechnical except for the last chapter on soil classification, which identifies and describes the three major orders of desert-occurring soils: Aridisols, Entisols, and Mollisols and their suborders. An appendix includes five figures: the chemical cycles (nitrogen, phosphorus, carbon, and sulfur) and a soil texture chart. This is a clear and concise introduction to desert soils and will be interesting and informative to all who must deal with soils, from the urban dweller with a few flower beds or vegetable garden to the farmer who makes his living from the soil.

Management of Southwestern Desert Soils is described on the back cover as a "practical guide to effective soils use for maximum plant productivity and conservation of the desert environment." This is an accurate description. Although written in largely nontechnical language (technical terms are explained when used), the book presents the technical aspects of soils management clearly and in sufficient detail to enable the average home gardner or urban landscaper to optimize the factors that affect the ability of different soils to produce, and to recognize and deal with problem situations.

The first five chapters: Why Soil Management?, How Plants Grow in a Desert, Soils Have Profiles, Why Organic Matter?, and What Nutrients are Needed, describe the characteristics of desert soils and how those characteristics affect the kind of management needed to obtain optimum production. The next three chapters: How Fertilizers Are Used, Some Soils Need Conditioning, and How Arid Lands Are Managed, deal with the why and how of practices for improving or correcting unfavorable soil conditions. The final two chapters are: Testing Soils, Water, and Plants, and How Soils Act for Waste Disposal. The Appendix contains the same figures that appear in the companion book.

For the layman with little previous exposure to the subject, both books should be purchased. The person with some acquaintance with the subject matter could do without the first. These books are a welcome addition to the nontechnical scientific literature and appear to be reasonably priced for the information they contain.–*Dwight R. Cable,* Tucson, Arizona.

They Saddled the West. By Lee M. Rice and Glen Vernam. Cornell Maritime Press, Inc., Cambridge, Maryland 21613. 1975. $10.00.

This 190-page book, well illustrated with photographs and pen sketches by the co-author Glen Vernam, presents the history and development of the western saddle from the old vaquero rigs to the saddle used today. The authors are old-time cowboys with Westernwide experience. The book shows the great amount of time and research by the authors in attempting to compile the record of the development of the modern western saddle.

The development of the western saddle was a highly individualistic business. Most of the early saddlemakers were skilled leather workers trained in the European apprentice system. This historic system continued in the saddlemaking industry well into the first quarter of this century, with the apprentice training under skilled craftsmen. In many cases, this was a father-to-son relationship. As so often happens with specialized handcraft products, most of the trade secrets lived only in the minds of the artisans. Very few of the developments were protected by copyrights. The mobility of the workers, as they followed the range industry in the settlement of the West, resulted in the more popular and practical innovations to be widely copied through the Western country. The authors give some insight to the popularity of various types of rigs by broad Western regions. Most of these, according to the authors, were associated with the differing methods and needs for handling livestock from the yearlong brush ranges in the Southwest to the winter feeding outfits in the Northern regions. As pointed out by the authors, though, there is really not that much difference between regional areas; the average saddle in any given era ran pretty much to the same pattern, with the basic changes being widely accepted.

The book, in the reviewer's opinion, is a good historical review of the development of the western saddle and an interesting look at the growth and development of the saddlemaking and marketing business.

The famous names in the business and their background and history are well documented. Heiser, Hamley, Porter, Miles City, Frazier, Nelson, Myres, and Connolly are names familiar to *Journal* readers.

My criticism of the book would be in the organization of the material, which made it difficult to follow the major developments. The extraneous detail, such as street locations, does not help the book. The constant repetition of the theme, "poor boy makes good" accompanied by the timeworn cliches to illustrate, detracts from the objectives of the book. The book could have been improved with the inclusion of personal events in the lives of the artisans, some of which were intimated but not developed. I feel sure the authors knew much more about the personal affairs of the saddlemakers than they included in the book.

The book is worthwhile for a western library collection, and in this time when "nostalgia" is so popular, it should be of interest to those who can remember when the saddle catalogues were the most thumb-marked books on the ranch.—*Frank J. Smith,* Albuquerque, New Mexico.

The food in Your Future: Steps to Abundance. By Keith C. Barrons. Van Nostrand Reinhold Co., New York. 1975. 180 p. $7.95.

Here is a well-balanced book that deals with the many diverse aspects of providing food for each of us and for the world. The author has spent his whole career working with various aspects of food production, so is able to deal with the questions and problems of our vital agricultural and food distribution systems as well as give an expert analysis of those things that determine the cost of food at the checkout counter.

The author discusses what it takes to keep our market shelves well stocked, changes in farming methods and their impact, the relation of costs to production, and ecology on the farm. A realistic perspective is given on the divergent views of "far-out environmentalists," "nature lovers," "sportsmen" and other interest groups in relation to farm food production and includes a balanced presentation on the often-discussed problem of forage vs grain and the use of forage and grain for meat production.

In a chapter entitled "The Hunger Mongers," concerns are expressed with those who would discourage food production. This includes using good farming land for other purposes, those groups that would limit livestock grazing on public lands, the organic farming promoters, those who would eliminate pesticides, and the environmentalists, along with others less well known. The central theme is that we will all be much worse off when there is limited food for our tables.

The chapter on "The Great Protein War" discusses the need for increased protein in other parts of the world and includes the status of most of the work being done to try to increase protein for the real poverty areas of the world.

Another chapter deals with the Green Revolution and its hopes and limitations in efforts to feed the world populations. The final three chapters of the book deal with new technology on the horizon, the very direct relationship between energy and the ability to produce food, and finally his crystal ball concerning food supplies in the future.

This book is balanced and comprehensive, well written and easily read, and would give an excellent overall view to anyone interested in understanding the many sides of the food production problems and needs in a world with an ever-expanding population.—*B. S. Reid,* Fort Collins, Colorado.

Readings in Wildlife Conservation. Edited by James A. Bailey, William Elder, and Ted D. McKinney. The Wildlife Society, Washington, D.C. 20016. 1974 722 p. $8.00.

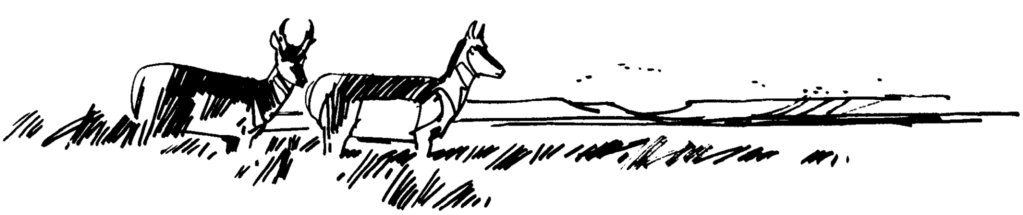
Some years ago there was a popular song entitled "The Impossible Dream." In a way that title summarizes the futility of a publication such as *Readings in Wildlife Conservation.* C. O. Besadny in his foreword summarizes the intent of the book by saying "...while the book is primarily directed at strengthening the interests of undergraduate students, it can also serve as a refresher course for both the seasoned conservationist and layman." Therein lies the impossible dream. No single compendium could simultaneously satisfy the needs of three groups of people with such diverse educational and experiential backgrounds as undergraduate students, seasoned conservationists (whoever they are), and laymen.

If the intent is to stimulate interests of undergraduate students, then a productive approach might be to articulate several alternative hypotheses concerning various components of the art of wildlife conservation. These hypotheses might be evaluated by examining the relevant evidence, pro and con. In this way students might be encouraged to dissect hypotheses analytically, objectively, and critically. This book simply confronts the student with a *few* examples of published literature varying widely in quality. It may be true, as the editors tout in their introduction, that "... papers in this book either present important ideas on philosophies or are good examples of activities in wildlife conservation." Unfortunately, the contributions are not all examples of good activities in wildlife conservation.

On the other hand, the "seasoned conservationist" should already have read and evaluated much of the information presented in *Readings in Wildlife Conservation.* If he has, this book is of little value. If he hasn't, then he isn't likely to read it here either.

The layman presents an entirely different problem. He needs to have a well-digested summary of the state of knowledge in a nontechnical, cohesive, comprehensive review. Such a publication would probably require the combined efforts of competent wildlife scientists and a good journalist. Rarely do you find both characteristics combined in a single individual. *Readings in Wildlife Conservation* does not fill this void.

These criticisms do not mean that *Readings in Wildlife Conservation* has no value. Several excellent articles are included. But the most poignant criticism of "Readings" is not of its contents but rather its omissions. Nearly one-fifth of all the articles included were originally published in the *Transactions of the North American Wildlife and Natural Resources Conference.* If articles from the *Journal of Wildlife Management* are included, these two publications together contribute better than one-third of all the articles. Yet, the vast array of wildlife literature found in foreign journals is significant only by its absence. Why do we hear so little from the Canadians, Europeans, Russians, New Zealanders, Australians, Africans, etc.? Could it be that their contributions to the knowledge of wildlife biology are so meager? I doubt it! In my opinion this silence exemplifies the real failure of "Readings." The task of presenting the significant writings in wildlife conservation was impossible from the outset because the literature on the subject is too immense. So, instead, the editors of "Readings" took a pinch of this, added a pinch of that, and brewed a broth that is decidedly flat, not from what it contains but from the literary spices they had to omit.—*R. B. Gill,* Fort Collins, Colorado.



Information for Authors

The *Journal of Range Management* is an official publication of the Society for Range Management. The editor's objective is to publish in every issue something of interest to each member of the Society and to others interested in range ecosystems and their management. Suitable articles from both nonmembers and members may be published upon approval of the Editorial Board.

Articles suitable for publication in the *Journal of Range Management* include high quality papers concerning technical or practical problems or practices in range management; short articles concerned with research results, experimental equipment, or techniques (which may be published as "Technical Notes"); and short papers dealing with any phase of applied range management or improvement (which may be published as "Management Notes"). Review papers on selected subjects also are acceptable but are usually invited.

All papers should be based on new and adequate information. The introduction should state clearly and concisely the purpose of the article and its relation to other work in the same field. Unsupported hypotheses and rambling discussion should be avoided. Organization of the manuscript may vary to accommodate the content of the article, but the text should point out the application of the results to the range management problem considered.

For suggestions on writing and the preparation of manuscripts, authors are advised to consult *CBE Style Manual* (Third Edition, 1972) published for the Council of Biology Editors by the American Institute of Biological Sciences, 3900 Wisconsin Avenue, NW, Washington, D.C. 20016.

All papers will be critically reviewed by the Editorial Board or other subject matter specialists designated by the editor. Papers returned to authors for revision should be handled promptly. Unsuitable papers will be returned to the authors with an explanatory statement. Prior publication of a manuscript or concurrent submission to another outlet precludes publication in the *Journal of Range Management.*

All manuscripts and correspondence concerning them should be addressed to: **Elbert H. Reid, Editor, Journal of Range Management, 624 South Shields St., Fort Collins, Colorado 80521.**

Preparation of Manuscripts

1. For guidance on matters not specifically covered in the following paragraphs, see *CBE Style Manual,* cited above.
2. Manuscripts must be typewritten, double spaced with ample margins, on good quality white paper, preferably 8½ x 11 with numbered lines. Use only one side of the paper and number all pages. The original and one good carbon copy of the manuscript are to be submitted.
3. The title of the paper and the name, position, and complete address of the author should be typed as distinct, well-spaced entries on a separate page.
4. A "Highlight," typed on a separate page, should accompany each manuscript. The "highlight" should succinctly state the purpose, major findings or conclusions, and their application.
5. Names of plants and animals must be shown in both common and scientific form the first time they are mentioned in the text; further mention should be by common name only. Authorities for scientific names may be included at the discretion of the author.
6. Footnotes should be used very sparingly and numbered consecutively throughout the text. All text footnotes should be typed together (double spaced) on a separate sheet.
7. Good illustrations are desirable but should be held to a minimum. Photographs should be black-and-white glossy unmounted prints (remember that poor photographs will result in poor reproductions), and the graphs should be prepared on white or blue-lined cross section paper with neat lettering of a size suitable for reduction. Illustrations should be no larger than 8½ x 11 inches, and should carry an identification number. *Illustrations should be adequately protected against possible damage in transit.* All figure titles should be typed together (double spaced) on a separate sheet.
8. Tables should be few and as simple as feasible. Each table must be typed, double spaced, on a separate sheet. If table footnotes are necessary, they should be numbered separately for each table and typed on the same sheet as the table.
9. The "Literature Cited" section (when used) should begin on a new page and citations should be listed alphabetically. References to citations in the text are to be by author and date, i.e., Jones (1949) or (Jones, 1949). The "Literature Cited" section should be typed in the style of the following examples:

> **Pechanec, Joseph F., and George Stewart. 1949.** Grazing spring-fall sheep ranges of southern Idaho. U.S. Dep. Agr. Circ. 808. 34 p.
>
> **Sperry, Omer E. 1949.** The control of bitterweed (*Actinea odorata*) on Texas ranges. J. Range Manage. 2:122-127.

Titles of journals should be abbreviated in accordance with instructions given in the *CBE Style Manual* (p. 159-160), cited above. Also, helpful standard abbreviation forms may be found in *Style Manual for Biological Journals* (p. 82-87), Second Edition, 1964, American Institute of Biological Sciences, Washington, D.C. Show the total number of pages for books or bulletins cited.

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