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THE TRAIL BOSS

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Volunteer Paper Solicitation

1981 SRM-Tulsa, Oklahoma
February 8-13, 1981

Papers for the 1981 SRM meeting will be solicited in ten general categories for synthesis into program units. You are encouraged to plan your participation; a formal call for titles and abstracts will be issued at a later date.

General program categories with topical annotations are:

1. **Range Animals**—production; diets and nutrition; wildlife; insects; other animals
2. **Range Plants**—collection; selection and breeding; germination and establishment; physiology; morphology; taxonomy
3. **Soil and Water**—range watershed management; rangeland hydrology; grazing and water management; soil fertility and management
4. **Range Ecology and Rangeland Ecosystems**—succession; fire nutrient cycling; drought; ecosystem classification
5. **Range Management Systems**—grazing systems; forest grazing; complementary forage; grazing impact
6. **Range Inventory and Evaluation**—range inventory; survey methods; condition and trend; land capability
7. **Range Improvement and Land Reclamation**—renovation; seeding; brush and weed control; fertilization; reclamation and stabilization of disturbed lands
8. **Sociological and Political Concerns**—history; education; communications; technology transfer; international programs
9. **Range Economics and Management**—production costs and returns; modeling; computer utilization
10. **Ranching Practices**—ranching experiences; enterprise concerns; technology integration

The following policies will apply to volunteer papers:

1. A single individual shall not be author or senior author of more than one title per session.

2. Finished titles and abstracts will be due o/a *September 15, 1980.* These abstracts will be printed without further editing and will furnish the basis for selection; freshness, clarity, and discreteness of topic will carry considerable weight in the selection process.

3. Individual program segments will be 15 minutes in length. We anticipate scheduled discussion periods at strategic times; program participants are expected to attend as a condition of paper acceptance.

4. Titles and abstracts received after the due date will be considered as alternates.

5. Notification of acceptance/rejection will be in your hands by November 1, 1980.

6. Undergraduate students may submit papers to the student conclave or the technical sessions.

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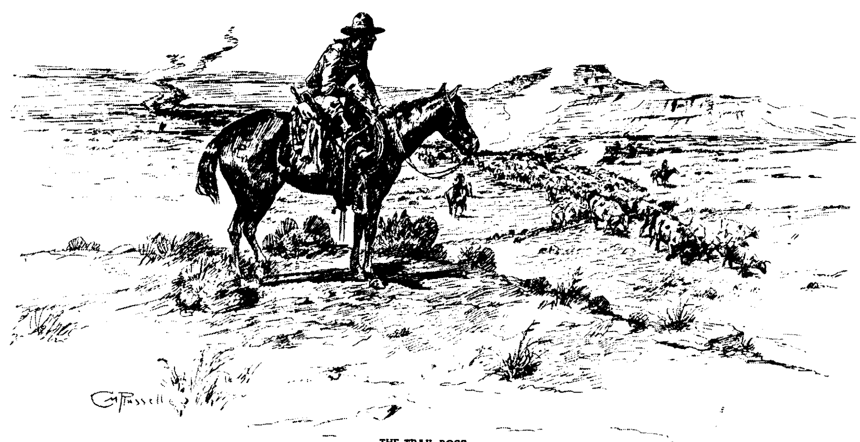

THE TRAIL BOSS

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

The objectives for which the corporation is established are:

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

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

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

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

—*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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TABLE OF CONTENTS: Vol. 32, No. 2, March 1980

ARTICLES

83 **President's Address: SRM's Future—Dreams or Opportunities** by Daniel Merkel

85 **Long-term Effects of Fire on Cactus in the Southern Mixed Prairie of Texas** by Stephen C. Bunting, Henry A. Wright, and Leon F. Neuenschwander

89 **New Collections of Range Plants from the Soviet Union** by D.R. Dewey and A.P. Plummer

95 **Brush Control and Rio Grande Turkeys in North-Central Texas** by Dee A. Quinton, Alan Kent Montei, and Jerran T. Flinders

99 **Organic Solvent-Soluble Organic Matter from Soils Underlying Native Range and and Crested Wheatgrass in Southeastern Alberta, Canada** by J.F. Dormaar, A. Johnston, and S. Smoliak

101 **Root Distribution in 1- to 48-Year-Old Stripmine Spoils in Southeastern Montana** by John W. Wyatt, Douglas J. Dollhopf, and William M. Schafer

104 **Responses of Falsemesquite, Native Grasses and Forbs, and Lehmann Lovegrass after Spraying with Picloram** by S. Clark Martin and Howard L. Morton

107 **Contributions of White Clover to the N,P, and Ca Concentration of Perennial Grasses** by James W. Dobson and E.R. Beaty

111 **Perennial Grasses and Their Response to a Wildfire in South-central Washington** by D.W. Uresk, W.H. Rickard, and J.F. Cline

115 **Chemical Scarification, Moist Prechilling, and Thiourea Effects on Germination of 18 Shrub Species** N.D. Stidham, R.M. Ahring, J. Powell and P.L. Claypool

119 **Nitrogen Fertilization of Range: Yield, Protein Content, and Cattle Behavior** by M.J. Samuel, F. Rauzi, and R.H. Hart

122 **The Response of Native Vertebrate Populations to Crested Wheatgrass Planting and Grazing by Sheep** by Timothy D. Reynolds and Charles H. Trost

126 **Fall and Winter Diets of Feral Pigs in South Texas** by J.H. Everitt and M.A. Alaniz

129 **Food Habits of the Plains Pocket Gopher on Western Nebraska Rangeland** by Dale G. Luce, Ronald M. Case, and J. Stubbendieck

132 **Factors Influencing the Feed Intake and Liveweight Change of Beef Cattle on a Mixed Tree Savanna in the Transvaal** by Ibo Zimmermann

136 **Habitat and Dietary Relationships of the Pygmy Rabbit** by Jeffrey S. Green and Jerran T. Flinders

143 **Range Grasses and Their Small Grain Equivalents for Wind Erosion Control** by Leon Lyles and Bruce E. Allison

146 **Bite-count vs Fecal Analysis for Range Animal Diets** by Kenneth D. Sanders, Bill E. Dahl, and Gretchen Scott

150 **Microhabitat Relationships of Six Major Shrubs in Navajo National Monument, Arizona** by John A. Fairchild and Jack D. Brotherson

TECHNICAL NOTES

157 **Seasonal Concentration and Toxicity of Saponins in Alfombrilla** by M. Coburn Williams and Luis C. Fierro

BOOK REVIEWS

158 *Common Texas Grasses—An Illustrated Guide* by Dr. Frank W. Gould; *Handbook of Tropical Forage Grasses* by B. Ira Judd; *Plant Strategies and Vegetation Process* by J.P. Grime.

SRM's Future—Dreams or Opportunities

Daniel L. Merkel

It has truly been an honor and privilege to serve you as president during the past year. I sincerely appreciated this opportunity to work for you and the profession of range management. I hope I have given as much to improving the world's rangelands as I have gained from the experience you provided me.

The president's address has been used by many of your presidents in the past as a State of the Society message. They have informed the membership of the important SRM programs and notable accomplishments of the last year; recognized the dedicated work of members, chapters, sections, committees, advisory council and board; and looked to the future.

These are important and topics that I would like to discuss. You have, however, had the opportunity during the year to become familiar with many of the current and recent range activities. Executive Secretary Floyd Kinsinger has outlined the current administrative situation. And like other presidents, I have been blessed with the services of many active members to whom the accomplishments of the past year belong. Anything I could say here would be inadequate to properly express my appreciation for their assistance.

Therefore, I want to use this opportunity to look to the future—to share my dreams for the Society for Range Management, with you. I want you to put aside those ideas that "it can't be done," "It's been tried," "That's not the real world," and "What's happened to him?" I want you to evaluate the possibilities if we are willing to dedicate ourselves to becoming the best of societies. Then I will let you separate the dreams from the opportunities in SRM's future.

You must first recognize that we are small in number, about 5,700 today, but our mission is to improve the management of the world's rangelands, which influence the lives of millions of individuals and almost every nation. We are young as an organized Society and recognized profession, but we are mature and experienced among the groups concerned with the environment. We are poor financially, but we are rich in knowledge and dedication to our goals. We are inexperienced in the political arena; but we are recognized for our honesty and desire to do the right thing. We have determined that SRM should be the leader in rangeland issues; but we are uncomfortable when called on to act rather than react. We have said that we should exercise self-evaluation and flexibility to change the Society, when necessary, to better serve the members and public, but we resist change or breaking tradition. We provide assistance to many; but we are a pawn to no one.

To look to SRM's future, we must evaluate the past and present. You are aware that for most of civilization, rangelands have been the "forgotten resource," that area that was left over, or, "land unsuitable for cultivation," or as one of our members often says, "The bastard child at the family reunion." It was not until people became concerned about their supply of high quality low cost food, water, recreation, and energy that they recognized the value of those "wastelands."

Then the instant experts and interested groups sprouted like cheatgrass after a fall rain. They quickly recognized, with our help, that less than desirable conditions existed on much of the world's rangelands. They did not study the early history of range use and the progress that had been made by SRM members and others to improve rangelands that had been damaged throughout history. In place of recognizing the long, silent battle to conserve and improve our range resources, they often searched for the bad guys to wear the "black hat." The livestock industry and range managers won the booby prize. The rancher was given credit for learning and using the three R's—Rape, Ruin, and Run. The range manager was pictured as being on a sagebrush picnic without his marbles.

Fortunately, we have passed the stage of people trying to establish blame, and most are seeking constructive methods to speed up rangeland improvement. This almost universal support for increased authority and resources for range improvement has resulted in unprecedented response by legislative bodies and managementment, research, and technical assistance agencies. This has resulted in a more involved, better informed public to work with and respond to both through the Society and in our regular employment.

With this background, please let me outline the role I believe the Society must assume if we are to emerge as the international leader in directing this new interest in a productive and constructive manner. We must:

1. *Be the source of and provide technical assistance* on the development of rangeland policy. We should build an identity and reputation that would inspire any person responsible for legislation or policy to seek our advice and assistance. The help should then be provided by any level of the Society to any level of authority.

2. *Do an even better job of improving the public's awareness,* internationally, of the function rangelands perform in the production of food and fiber; in the protection of the environment; and in meeting human needs. Although there is a growing interest in range improvement, those that are supportive and concerned represent a small percentage of the population. Many of those that seek better range conditions are not aware that improvement can result from proper management for production; and, the resource need not be excluded from use. We need to develop more innovative methods of telling people tthat when rangeland is managed properly, we can have our cake and eat it too.

3. *Further the understanding of and appreciation for* the role range performs in meeting the social, cultural, and political needs of people. More than any other thing, failure to recognize these factors in our work and to identify their importance to others has limited application of available technology. In this area, we have a great deal to learn before we are effective in spreading the message.

Presented at the 33rd annual meeting of the Society for Range Management, San Diego, California, February 13, 1980.

4. *Provide the base to increase and improve the professional level* of the individuals and institutions associated with the science and management of rangelands. Although the Society has established a certification program for consultants and an accredition procedure for educational institutions; provides access to the most recent technology through SRM publications and meetings; and is working to improve U.S. Civil Service employment standards we recognize there are unqualified and substandard individuals and institutions involved in range management.

5. *Through programs, provide the media* for technology transfer for all those interested in the science and applications of range science information. Although this was one of the major objectives of the Society's formation, we must greatly improve the rate of field application of range research results. We must improve the way we package new technology and seek better methods of directing it to the correct audiences.

6. *Develop SRM as a recognized body* serving a lead role in management of the world's rangelands. With the growing interest in and demand on the range resource, the Society must provide the leadership to improve the management of rangelands around the globe or by default allow other groups without needed range knowledge and experience to assume our role. We must explore new, more innovative methods of working on an international level.

7. *Take leadership in providing a forum* for the dissemination and exchange of range science information. The Society's annual meetings have long provided an excellent forum for the exchange of information among members. The Society must extend this role beyond its standard meetings and membership. There is a need for SRM to expand its role of hosting, sponsoring, or co-sponsoring important meetings addressing range topics for more non-members.

8. *Encourage a sound basic and applied research program* aimed at the expansion of rangeland management knowledge. One cannot overstate the progress that has been made by the SRM Research Committee since it was formed at the 1977 summer meeting. There is more support for and interest in range research than has existed in recent history. This new attention to range research, however, has not resulted in major increases in resources for research. The Society must, therefore, continue to push for quality rangeland research.

Are these eight items dreams or opportunities? Your Board of Directors considered them reasonable and achievable responsibilities of the Society in 1978 when they were identified as the long-range SRM goals. The 1979 and 1980 Society's Programs of work described initial steps to accomplish each of these. I am proud, as you should be, of the progress SRM has made in changing these goals into accomplishments. This progress has been made by dedicated committee members, Board of Directors, executive secretaries and Headquarter's office staff under trying conditions.

In spite of this first step, we have many miles to go before we can honestly say we have assumed a leadership position that will establish SRM as the best of professional societies. This journey will require greater efforts by more of our members, an increased membership; a sound and expanded financial base, increased staff; more visible representation in the centers of government; more professional and higher standards in all range activities; improved communications within and outside the Society; more cooperative efforts with other natural resourse, interest and user groups and agencies; and, a greatly expanded international program.

Yes, we must do all this and more if we are going to capitalize and the current interest in and attention to natural resourses.

It would be easy to withdraw from our professional responsibilities at this time of major SRM financial crisis. The profession, Society, and world's rangelands cannot afford for us to take the easy way out. We need to continue to move aggressively forward in accomplishing the Society's goals, while solving our current budget problems and building a solid future financial program.

SRM's members are the masters of the Society's future. Dreams may pass, opportunities be missed, goals go unachieved, and future generations suffer if we fail to respond to the range management challenge of the 1980's.

Call for Papers

The XIV International Grassland Congress will be held on the campus of the University of Kentucky, Lexington, June 15-24, 1981. It will include seven pre- or post-Congress tours to leading forage-producing areas of the United States and Canada. The formal program will include ten plenary papers and about 300 volunteer papers. Plenary and volunteer papers will be published. Paper titles and 500-word summary statements must be submitted by **May 1, 1980,** to Congress headquarters in Lexington on a form included in the brochure. Write for your copy of the brochure and send your title and summary to XIV International Grassland Congress, Agricultural Sciences Center, University of Kentucky, Lexington, Ky. 40546.

Long-term Effects of Fire on Cactus in the Southern Mixed Prairie of Texas

STEPHEN C. BUNTING, HENRY A. WRIGHT, AND LEON F. NEUENSCHWANDER

Abstract

Few brownspine pricklypear were immediately killed by the direct effects of fire. Most plants resprouted after burning in the spring, but mortality averaged 70% by the end of the fourth year after burning. Interactions of fire with insects and rodents caused most of the brownspine pricklypear mortality. Walkingstick cholla and tasajillo were more directly affected by fire than brownspine pricklypear. First-year mortality was 40 to 65%, respectively; and fourth year mortality was 57 to 80%. Mortalities of other minor species of cactus varied from 49 to 100%.

The increase of cactus on grassland ranges, particularly in the Southwest, has been a problem for many years. During a 17-year period (1932-1949) in southern Arizona, jumping cholla (*Opuntia fulgida*) increased from 5 to 368 plants/ha, cane cholla (*O. spinosior*) increased from 14 to 785 plants/ha, and Engelmann pricklypear (*O. engelmannii*) increased from 0 to 74 plants/ha in a grazed area (Glendening 1952). On an ungrazed area, percentage increase for cane cholla and Engelmann pricklypear were similar to the increases on a grazed area over the same period of time (Glendening 1952). These data indicate that neither reduced grazing pressure nor increasd grass competition will prevent the increase of cacti density.

However, Cook (1942), working in the Central Great Plains with pricklypear (*O. humifusa*), observed that ranges with dense stands of grass also supported high populations of *Melitera dentata,* a cactus feeding moth, during years with above-average precipitation. The cactus feeding moth was a major factor in reducing cactus density. Ranges in poor condition did not have high enough populations of moths to cause cactus mortality. Thus, reduced grazing pressure in combination with above-normal moisture can reduce the density of cacti, at least on the eastern edge of cacti ranges. Drouths favor cacti throughout their range (Cook 1942; Houston 1963), and fire and animal use are left as the primary factors to control their density (Humphrey 1958).

High densities of cactus plants can reduce forage production and utilization. Rea and Pieper (1973) found that controlling walkingstick cholla (*O. imbricata*) on blue grama (*Bouteloua gracilis*) range increased herbage production by 20% and utilization by 9%. Bement (1968), however, was unable to show an increase in herbage production after control of plains pricklypear (*O. polyacantha*).

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Manuscript received February 16, 1978.

Cactus plants vary in their response to fire, depending on species, size, and how soon they are observed after a fire. In Arizona, Humphrey and Everson (1951) found that 1 year after a fire the densities of Englemann pricklypear, jumping cholla, and cane cholla had decreased 9, 29, and 7%, respectively. However, Reynolds and Bohning (1956) reported that a prescribed fire reduced densities of barrel cactus (*Ferocactus wislizeni*) 67%, jumping cholla 44%, cane cholla 45% and Engelmann pricklypear 28% after 2 years. Similarly, Cable (1967) found that fire reduced densities of jumping cholla 63%, cane cholla 45%, and Engelmann pricklypear 32% by the second year after a fire. In Texas, mortality of brownspine pricklypear (*O. phaeacantha*) was 20% the year after burning and 68% after the second year (Heirman and Wright 1973). Thus, first year mortality is not an adequate indication of the effect of fire on cacti mortality.

Small cacti are more susceptible to fire damage than the taller plants (Dwyer and Pieper 1967; Heirman and Wright 1973). Density of walkingstick cholla less than 0.3 m tall was reduced 50%, but larger plants were not severely damaged by fire (Dwyer and Pieper 1967). Hierman and Wright (1973) found that the mortality of walkingstick cholla less than 0.3 m tall was 81%, and for those greater than 0.3 m tall, mortality was 45%. They observed little difference in the mortality of large (≥10 pads) and small (<10 pads) brownspine pricklypear.

The purpose of this study was to measure the long-term effect of fire and drought on three major cactus species—brownspine pricklypear, walkingstick cholla, and tasajillo (*O. leptocaulis*)—and several less common species in West Texas.

Study Area and Methods

This study was conducted in Callahan, Garza, and Mitchell counties, Texas, which lie within the Southern Mixed Prairie. Topography of the Beckham Ranch, in Callahan County, is level to undulating with some areas dissected by steep canyons. The average precipitation is 66 cm. The soil is a limestone-derived stony loam. The area is dominated by little bluestem (*Schizachyrium scoparium*), buffalograss (*Buchloe dactyloides*), sideoats grama (*Bouteloua curtipendula*), and Texas wintergrass (*Stipa leucotricha*). Several species of oak (*Quercus* sp.) and ashe juniper (*Juniperus ashei*) are interspersed with the grasses. The large juniper had been dozed before burning.

Study sites on the Dalby Ranch, in Garza County, were located on a level area dominated by tobosagrass (*Hilaria mutica*) and alkali sacaton (*Sporobolus airoides*) with an overstory of walkingstick cholla and honey mesquite (*Prosopis glandulosa* var. *glandulosa*) less than 1.2 m tall. The average annual precipitation is 48 cm and the soil is a heavy clay vertisol.

Study sites on the Renderbrook-Spade Ranch in Mitchell County were located on a level to undulating tobosagrass-mesquite community. Untreated mesquite are medium-sized trees (3 to 4 m), but had been sprayed with 2,4,5-T[2,4,5,-trichlorophenoxy) acetic acid] 6 years before the first prescribed fire. The average annual precipitation is 50 cm and the soil is a clay vertisol.

Brownspine pricklypear were permanently marked with iron stakes on prescribed spring burns on the Beckham Ranch in 1971, and on the Renderbrook-Spade and Dalby Ranches in 1972 and 1974. Additional pricklypear plants had been marked on a wildfire that occurred on the Dalby Ranch in July, 1970. Tasajillo were permanently marked on the Renderbrook-Spade Ranch in 1973 and 1974. Walkingstick cholla were marked on two prescribed fires on the Dalby Ranch in the spring of 1973. Smaller numbers of less common cacti, devil's pincushion (*Echinocactus texensis*), *Mammillaria gummifera*, star cactus (*Coryphantha vivipara*), *Echinocereus reichenbachii* and Engelmann pricklypear were also marked. Mortality was based on a total of 600 brownspine pricklypear, 200 walkingstick cholla, 175 tasajillo, 79 devil's pincushion, 66 *mammillaria gummifera*, 10 star cactus, and 18 *Echinocereus reichenbachii*.

Brownspine pricklypear was divided into size classes by pad counts (1–10, 11–25, and >25) and cholla and tasajillo by height (≤0.6 m and >0.6 m tall). Mortality was recorded during July and December each year until December, 1976. Mortality was determined by the absence of living tissue above ground on permanently marked plants on each sampling date. Subsequent mortalities were accumulative for every species on each prescribed burn. An individual cactus plant might be recorded as "dead" on one date and then resprout and be recorded as "living" on a following date. This resulted in a decline in mortality for tasajillo during some years. Chi-square analysis was used to test for differences in mortality between burned and unburned treatments and between size classes of cacti plants.

Results and Discussion

Brownspine Pricklypear

Fire caused little immediate mortality of brownspine pricklypear. The plants were usually top-killed, but within a few weeks after the burn all had resprouted. Average mortality was only 20% at 6 months after the fire. By the end of the third year, however, mortality exceeded 70% (Fig. 1). After the third year, mortality of pricklypear increased about the same rate as it did for the unburned plants.

Mortality during the first 3 years apparently was caused primarily by fire weakening the plant and making it more susceptible to damage by insects, rodents, and rabbits. Insects entered the plant through fire-scarred tissue and spread to the young living pads, opening the plant to bacterial and fungal infections. Pads sprouting from burned plant tissue often lost their vascular connection to the root system because of insect damage and decay. Plants sprouting from the root crown survived for a longer period but many of these also died. Most of the plants that survived after 3 years, however, had sprouted from the root crown.

Young pads require several weeks before the spines are fully developed. During this time they are frequently browsed by lagomorphs and rodents. This is particularly important during the winter and dry summers when other green material is scarce. The mortality of both burned and control (unburned) plants increased during years when precipitation was below average. Over 50% of one set of control pricklypear plants located on a shortgrass site died during one drought year, probably because they were easily visible and eaten by lagomorphs and rodents. Only 8% of the control plants on tobosagrass sites died during this period. The taller grasses on these sites seem to provide more protection against browsing by small animals. Cactus plants growing in shortgrass (i.e. buffalograss), however, are less susceptible to fire-induced damage. Drought and drought-induced browsing may be major factors in reducing prickly pear densities on shortgrass sites.

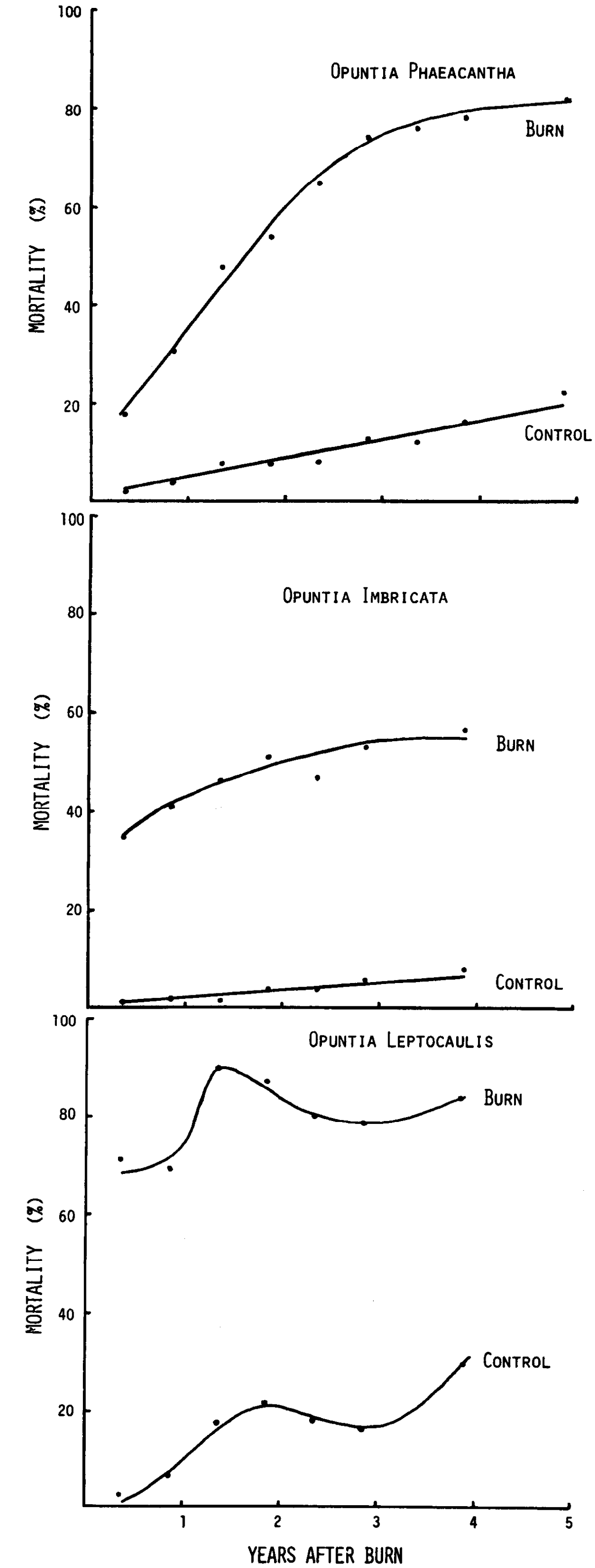

Fig. 1. *Mortality of* Opuntia phaeacantha, O. imbricata *and* O. leptocaulis *after prescribed burning in early spring. Mortality was caused by a combination of damage by fire, insects, and rodents.*

Table 1. Percent mortality of different size classes of *Opuntia phaeacantha* in relation to years after a prescribed burn in tobosagrass (6,000 kg/ha) in West Texas.

Size class (pads/plant)	Years after burn[1]	
	1	3
1–10	27 a	75 a
11–25	20 b	81 a
>25	11 c	68 a

[1] Numbers within a column followed by different letters are significantly different ($P<0.05$).

At the end of the first year the small plants (1 to 10 pads) had a higher mortality than the large plants (>10 pads), but by the end of 3 years there were no significant differences between the size classes of pricklypear (Table 1).

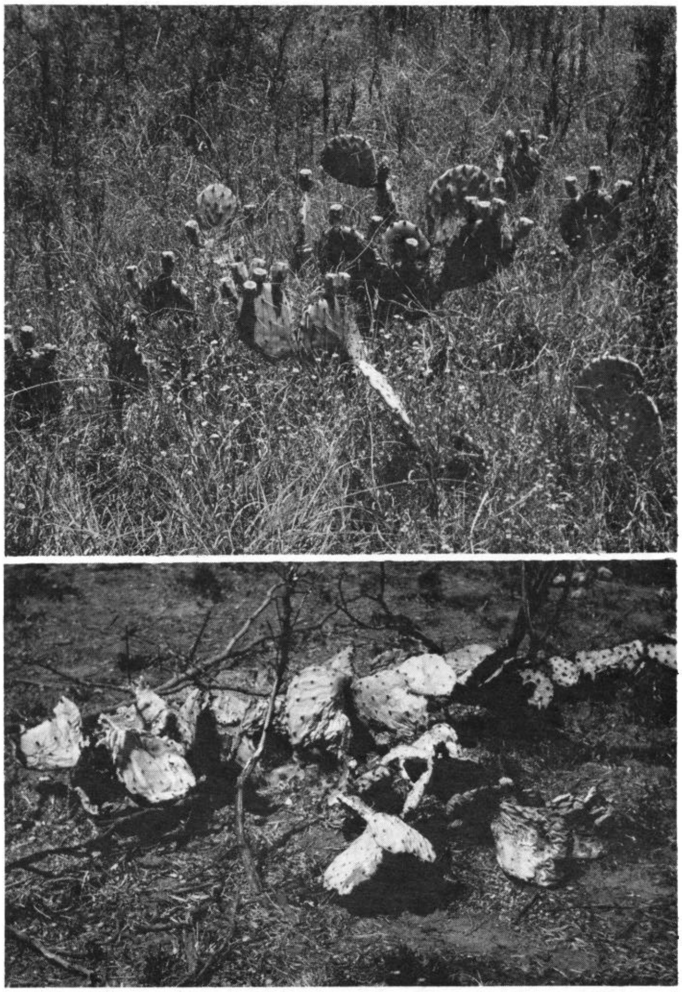

Fig. 2. *Because of the dense fuel within the canopy of the brownspine pricklypear (top), most plants are top-killed by fire (bottom).*

Walkingstick Cholla

Fire had a more direct effect on the mortality of walkingstick cholla than on brownspine pricklypear. At the end of the first year over 40% of the walkingstick cholla plants had died. Most of the plants that died were less than or equal to 0.6 m tall. Over 60% of the shorter plants died, whereas, only 16% of the plants greater than 0.6 m tall died. At the end of 3 years, mortalities were 73 and 27%, respectively, for the short (≤0.6 m) and tall (>0.6 m) plants Table 2); total mortality was 53%. Beginning with the fourth year, mortality of burned and unburned plants

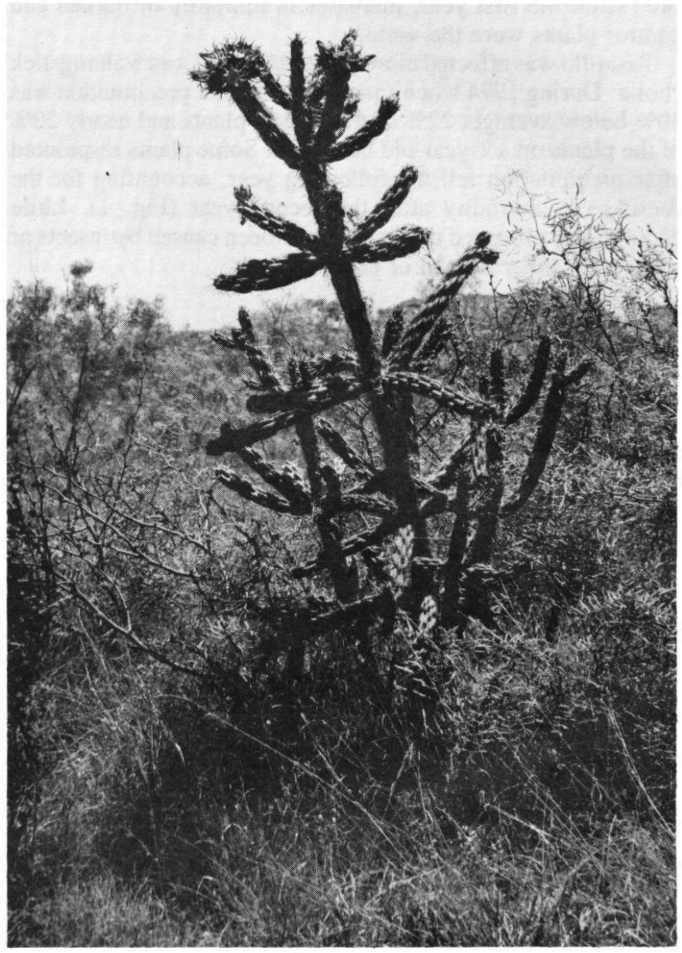

Fig. 3. *Walkingstick cholla greater than 0.6 m tall suffered fire damage to only the lower branches, and mortality of these plants was significantly less than for the shorter plants.*

increased at the same rate. In Arizona, Martin et al. (1974) reported that density of cholla may actually increase after fire as a result of joints falling from the plants and taking root. This was not observed with walkingstick cholla in West Texas.

Table 2. Percent mortality of different size classes of *Opuntia imbricata* in relation to years after a prescribed burn in tobosagrass (6,000 kg/ha) in West Texas.

Size class (cm)	Years after burn[1]	
	1	3
<61	61 a	73 a
>61	16 b	27 b

[1] Numbers within a column followed by different letters are significantly different ($P<0.01$).

Neither drought nor the activity of rodents and insects appears to have as much effect on mortality of cholla as on pricklypear. The bases of some walkingstick cholla plants were stripped of the green epidermal tissue but most plants were able to recover. The woody interior may protect the vascular system of the plant. Mortality of control plants was about 2%/year throughout the study.

Tasajillo

Tasajillo were highly susceptible to direct damage from fire. Many of the plants did not resprout after fire, and 65% of the plants were dead after the first year. Tasajillo, most of which were seldom greater than 0.6 m tall, were usually top-killed by fire. After the first year, increases in mortality of burned and control plants were the same.

Tasajillo was affected more by drought than was walkingstick cholla. During 1974 when spring and summer precipitation was 30% below average, 22% of the control plants and nearly 20% of the plants on a 2-year-old burn died. Some plants resprouted after precipitation fell the following year, accounting for the decrease in mortality after the second year (Fig. 1). Little damage was observed that might have been caused by insects or rodents to either burned or control plants.

Other Cacti Species

The numbers of several other species of cactus studied were small but some inferences on their response to fire are possible. Mortality of devil's pincushion occurred gradually after fire. They were also attacked by rodents and insects after the epidermis was damaged by heat, resulting in the growing center being eaten from many of the plants. After 3 years, mortality of devil's pincushion was over 40% (Table 3).

Table 3. Percent mortality of various cactus species in relation to years after a prescribed burn in tobosagrass (6,000 kg/ha) in West Texas.

Species	Number of plants	Years after burn 1	2	3	4
Echinocactus texensis	79	17	30	44	49
Mammillaria gummifera	66	33	70	73	74
Echinocereus reichenbachii	18	17	89	94	—
Coryphantha vivipara	10	100	100	100	100

Mammillaria gummifera and *Echinocereus reichenbachii* plants were severely damaged by fire. At the end of the first year after burning, mortalities were 33 and 17% respectively. Two years later, mortalities were 71 and 89% and did not change appreciably thereafter. Most surviving plants were in areas with less than 1,000 kg/ha of fine fuel. Star cactus was very susceptible to fire (Table 3). This may partially explain its rare occurrence except on rocky, lightly vegetated sites.

Engelmann pricklypear plants were not seriously injured by most of the grass fires. The center of the plants usually contained light grass cover due to small animal activity. This combined with its upright growth form resulted in only the peripheral pads of Engelmann pricklypear being damaged by fire. The average size of the plants was reduced, but most individuals survived. Plants less than 0.3 m tall and plants in areas with more than 6,000 kg/ha of fine fuel reacted to fire much like brownspine pricklypear.

Conclusions

Prescribed burning effectively controlled the density of several species of cacti in West Texas. Of 8 species studied, all except Engelmann pricklypear suffered mortalities of at least 49% by the fourth year after burning. Mortality of some species was a direct effect of fire while fire-induced interactions with insects, rodents, and disease caused the mortality of other species to increase for several years after fire.

Mortality of brownspine pricklypear was 20% at the end of the first year and increased to 70% by the end of the fourth year. Mortality increased at the same rate as natural mortality after the fourth year. At the end of the first year, percent brownspine pricklypear mortality caused by fire decreased as the size of the plant increased. However, by the end of the third year after the burn, there were no significant differences in the mortality of the different size classes of brownspine pricklypear.

Walkingstick cholla were more directly affected by fire than brownspine pricklypear. Mortality was 40% at the end of the first year and increased to 57% by 4 years after burning. Cholla less than 0.6 m tall were much more severely affected than the taller plants. After 3 years the mortality of short and tall plants was 73 and 27%, respectively.

Mortality of tasajillo was 65% at the end of the first year and increased at the same rate as the control plants after the first year. Many plants were killed directly by fire and failed to resprout. No differences were observed in the mortality of the different size classes of tasajillo, but most were less than 0.6 m tall. Tasajillo was the most drought sensitive of the cactus species studied.

Mortality of *Echinocactus texensis, Mammillaria gumifera,* and *Echinocereus reichenbachii* at the end of 3 years was 44, 73, and 94%, respectively. The interaction of other factors with fire caused mortality of these cacti to increase over this period. Star cactus, however, was killed directly by fire. All plants were dead at the end of the first year after burning.

Engelmann pricklypear was resistant to most grass fires unless there were fine fuel accumulations greater than 6,000 kg/ha. The lack of fuel beneath the canopy and the tall growth form resulted in only the outer pads being damaged. The size of the plant was reduced but most survived the fire.

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New Collections of Range Plants from the Soviet Union

D.R. DEWEY AND A.P. PLUMMER

Abstract

Range revegetation in the temperate arid and semiarid regions of the United States has been accomplished to a considerable extent with species introduced from Asia, particularly the Soviet Union. Only a small part of the Asian range-forage germplasm has been collected and evaluated in the United States. A 45-day plant-collecting expedition was authorized during the summer of 1977 to five locations in the U.S.S.R.—Stavropol, Tselinograd, Alma Ata., Dzhambul, and Chimkent. About 1,100 seed collections were made of 250 species, most of which were grasses and legumes from arid or semiarid sites. Large collections were made of *Agropyron cristatum, A. desertorum, A. intermedium, A. repens, Bromus inermis, Dactylis glomerata, Festuca sulcata, Medicago falcata-romanica, M. sativa,* and *Trifolium ambiguum.* All collections have been established at Logan, Utah. Preliminary observations indicate that certain collections may be useful for forage or conservation purposes on rangeland. All accessions have been entered into the National Plant Germplasm System, and seed will be available for research and evaluation purposes in 1979 or succeeding years.

The United States is a "have-not" nation with respect to native agriculturally important plant species. For example, the small grains (*Triticum, Hordeum, Secale*) come from Eurasia; rice (*Oryza sativa*) and soybeans (*Glycine max*) from the Far East; and tomatoes (*Lycopersicon esculentum*) and potatoes (*Solanum tuberosum*) from South America (Harlan 1976). Even corn (*Zea mays*) is not indigenous to the U.S. but had its origin in Central America. We are equally dependent on other parts of the world for our major forage crops— the alfalfas (*Medicago*), clovers (*Trifolium*), and grasses (*Bromus, Dactylis, Agropyron, Festuca*).

Much of the revegetation of temperate arid and semiarid western rangeland has been accomplished with introduced grasses—viz. crested wheatgrass (*Agropyron cristatum, A. desertorum*), intermediate wheatgrass (*A. intermedium, A. trichophorum*), tall, wheatgrass (*A. elongatum*), and Russian wildrye (*Elymus junceus*). On the upper foothills and higher mountain ranges, restoration depends heavily on other introduced grasses including smooth bromegrass (*Bromus inermis*), meadow foxtail (*Alopecurus pratensis*), orchardgrass (*Dactylis glomerata*), and tall oatgrass (*Arrhenatherum elatius*).

In recent years, more emphasis has been given to the use of native plants in range revegetation (Plummer et al. 1968), and considerable sentiment prevails that native plants should be used to the exclusion of exotics. Plant breeders and range scientists must be committed to the best plant materials regardless of their geographic origin. To do otherwise would unnecessarily hinder range improvement.

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Although millions of acres have been seeded to crested wheatgrass, most of these seedings can be traced back to no more than a dozen introductions (Dillman 1946). The genetic base of the intermediate wheatgrass and Russian wildrye grown in the U.S. is even narrower than that of crested wheatgrass. The recent increased awareness of the genetic hazards of seeding large acreages to a single species with a narrow genetic base has stimulated the search for additional sources of grasses, forbs, and shrubs to be used in mixed plantings on range. Recognizing the need to expand the germplasm base of forage plants commonly seeded on arid rangeland, the U.S. Department of Agriculture sponsored a plant-collecting expedition to the Soviet Union. After lengthy negotiations a 45-day expedition (Fig. 1) July 18-August 31, 1977, was authorized for two plant collectors (D.R. Dewey and A.P., Plummer) and an interpreter (L.E. Law).

Collecting Procedures

The Soviets provided land transportation and local

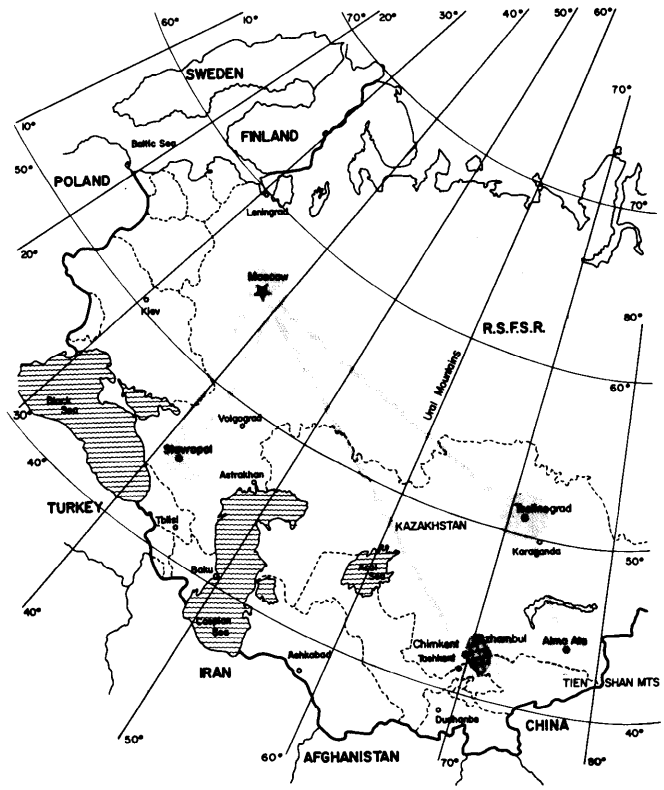

Fig. 1. *Route of plant-collecting team in the Soviet Union in the summer of 1977.*

Fig. *Soviet "jeep" used to traverse rough terrain in the Moyun-Kum Desert Dzhambul.*

escorts. Land transportation usually consisted of durable 4-wheel drive vehicles, which permitted access to rough off-road terrain (Fig. 2).

Most collections were made as seed. The size of individual collections ranged from less than 100 seeds to several thousand, depending on the size of the seed, its availability, and the size and nature of the population being sampled. Vegetative cuttings or seedlings were taken from some of the woody species that did not have seed at the time of our visit. However, all of the vegetative material was subsequently lost in a fire at the U.S. Embassy in Moscow in August 1977. Most collections were made in the wild, although local botanical gardens and agricultural institutes sometimes shared seeds from their collections.

We usually had the services of a local botanist who provided many of the species identifications, some of which are yet in doubt. All seed was inspected by Soviet plant quarantine officers before shipment to Moscow. Upon entering the U.S., the seed was inspected by the Animal and Plant Health Inspection Service. Only one collection, *Aleuropus repens,* was refused admittance; the refusal was because it contained a rust not present in this country

Collecting Areas

Our itinerary called for 2 weeks in the northern foothills of the Caucasus Mountains (Stavropol), 1 week on the plains of northern Kazakhstan (Tselinograd), and 3 weeks in the mountains (Alma Ata) and desert regions (Dzhambul and Chimkent) of southern Kazakhstan (Fig. 1).

The city of Stavropol served as our headquarters while collecting in the northern Caucasus region, and we collected in an area radiating about 150 km from the city. This is a rich agricultural region at 45° N Latitude (comparable to Minneapolis-St. Paul) with elevations between 200 and 800 m and annual precipitation ranging from 20 to 75 cm. The main Caucasus range is about 240 km to the south of Stavropol. The Stavropol Kray (Territory) is a climatic analog of Nebraska (C.I.A. 1974). The native vegetation consists, in part, of a rich and varied mixture of grasses (*Bromus, Festuca, Agropyron, Phleum,* and *Bothriochloa*) and legumes (*Medicago, Astragalus, Trifolium, Lotus,*

Fig. 3. *Soviet botantists and plant collectors at rich collecting site on Mt. Strizhament near Stavropol.*

Onobrychis, Vicia, and *Lathyrus*) (Fig. 3). Stavropol is in a transition zone where cool-season (*Agropyron cristatum*) and warm-season (*Bothriochloa ischaemum*) grasses are sometimes intermixed.

Tselinograd (formerly Akmolinsk) is in the heart of the "New Lands" area, where 60,000,000 ha have been broken out of native prairie and planted largely to wheat (*Triticum aestivum*). Tselinograd is close to 51° N Latitude (comparable to Calgary, Canada) at an elevation of about 300 m. The Tselinograd Oblast (Region) is climatically and topographically similar to the Canadian prairies of Alberta and Saskatchewan (C.I.A., 1974). The native Tselinograd prairies are dominated by grasses (Fig. 4), principally *Festuca sulcata* and *Stipa capillata.* We were primarily interested in collecting *Elymus junceus, E. angustus, Bromus inermis, Agropyron cristatum,* and *Medicago falcata,* none of which were particularly abundant on the native prairie.

The three collecting areas of southern Kazakhstan—Alma Ata, Dzhambul, and Chimkent—are between 42 and 43° N Latitude (comparable to Salt Lake City, Utah) and the areas are climatically similar to much of the Intermountain Region (C.I.A. 1974). Alma Ata, the capital of Kazakh S.S.R., lies at the base of the Tien Shan Mountains, and most of our collecting was done in the nearby mountains at elevations up to 2,000 m. The mountains around Alma Ata support a rich mixture of grasses, forbs, shrubs, and deciduous trees. Some of the more common grasses and legumes around Alma Ata

Fig. 4. *Imported hereford cattle on native prairie near Tselinograd.*

include *Agropyron, Brachypodium, Dactylis, Medicago,* and *Vicia* species.

Dzhambul is on the fringe of a great sand desert, the Moyun-Kum, the elevation of which is around 600 m. Annual precipitation is less than 20 cm. Our most productive collecting was in the sand desert (Fig. 2) where the dominant vegetation consisted of shrubs (*Artemisia* and *Calligonum*), grasses (*Agropyron*), and legumes (*Astragalus*).

Chimkent is situated 200 km southwest of Dzhambul in an arid valley (about 600 m elevation) surrounded by low mountains to 1,600 m. The area was heavily grazed by sheep, and collecting was possible only on nongrazed sites. Most collections were made in a mountainous game preserve where *Agropyron, Dactylis,* and *Bromus* species formed the major grass vegetation.

The Collections

The expedition obtained 1,094 seed collections representing about 251 species from 115 genera. However, not all collections were forage species because we also gathered seeds of trees, ornamentals, and miscellaneous plants whenever the opportunity arose. Main forage collections and their areas of origin are summarized in Table 1. Only those collections that appear to be particularly important or unique are discussed below.

Grasses

The largest collections were made of the crested wheatgrasses—*Agropyron cristatum, A. desertorum,* and *A. sibiricum.* The emphasis on crested wheatgrass reflects the senior author's interest in the plant-breeding potential and cytogenetic characteristics of this species-complex. The 16 collections of *A. sibiricum* from the Moyun-Kum Desert are particularly interesting because of their ability to thrive in almost pure sand. However, when grown under favorable conditions on heavy soils at Logan, those collections did rather poorly in the establishment year when compared with other crested wheatgrasses. The spikes of Moyun-Kum *A. sibiricum* are much narrower than other *A. sibiricum* accessions previously introduced into the U.S. A survey of the USDA Plant Inventories, which give the source of all introductions, indicates that crested wheatgrasses have not been previously introduced from the Moyun-Kum Desert.

The intermediate wheatgrasses (*Agropyron intermedium* and *A. trichophorum*) are widespread in the southern U.S.S.R. and we made many collections of those grasses (Table 1). The need to expand the germplasm base of intermediate wheatgrass is particularly critical because five of the seven bred varieties of intermediate wheatgrasses originate from one plant introduction, PI 98568 (Hanson 1972). This introduction came from the Maikop region, an area close to Stavropol. Hopefully, some of our collections from Stavropol will be as successful as PI 98568.

Some may question the need of bringing more quackgrass (*Agropyron repens*) and its close relative, *A. elongatiforme* (no common name), into the United States. However, these species are extremely diverse, and they may contain strains that are less aggressive than typical North American strains. Furthermore, interspecific hybrids with *A. repens* as one parent are some of our most productive grasses (Dewey 1976). The Soviets are breeding and promoting *A. repens* in the U.S.S.R. An *A. repens* breeding program has recently been initiated at the University of Wisconsin, River Falls (Louis J. Greub personal communication).

The 15 collections of Altai wildrye (*Elymus angustus*) should be of considerable interest to Canadian plant breeders and range scientists because they are conducting the only breeding program on *E. angustus* in North America at Swift Current, Saskatchewan (Lawrence 1970). Since our return, the Soviets have provided us with an additional 110 collections. This grass is a very coarse and robust species with stiff stems up to 2 m tall. It serves well as a winter pasture because the plants extend above the snow, and it is effective in catching and holding blowing snow. Our *E. angustus* collections should be well adapted to the Canadian prairies because they come from a climatically similar region in the Tselinograd Oblast.

Elymus ramosus (no common name) is considered to be a valuable forage grass in the U.S.S.R. (Nevski 1934). It is a low-growing, strongly rhizomatous species, and we encountered it on road cuts where it effectively bound the soil. It has been introduced previously as *Agropyron ramosum* (because it has single spikelets typical of *Agropyron*) but it has never gained importance either as a forage or a conservation species (Weintraub 1953). A major defect of *E. ramosus* is that it rarely produces seed. Its low seed set is probably due to the absence of compatible pollen rather than to sterility *per se*. Inasmuch as it is almost certainly a self-sterile species, an *E. ramosus* plant requires foreign pollen to produce seed. Because the plants are so strongly rhizomatous, a single clone may cover a very large area and would not be exposed to pollen from other *E. ramosus* clones. This hypothesis can be tested very easily now that we have several sources of *E. ramosus* growing in close proximity.

Elymus multicaulis (no common name) has been introduced only once previously, in 1965 as PI 314665 and 314666. The additional nine collections from Dzhambul should provide a better estimate of the adaptation and forage value of *E. multicaulis.* This species is the Asian counterpart of North American beardless wildrye (*E. triticoides*) (Dewey 1972), although *E. multicaulis* is considerably more leafy and may be the better forage grass.

A major disappointment of the expedition was our failure to make appreciable collections of Russian wildrye (*Elymus junceus*). Our itinerary took us only to the fringes of the *E. junceus* distribution. At Shorthandy (near Tselinograd) we were able to make seven small collections. However, the Soviets supplied seed of an improved variety, 'Bozoisky,' which looks impressive at Logan. Since our return to the U.S., they have supplied an additional 25 collections of *E. junceus.*

According to our Soviet escort, a bromegrass specialist, the smooth bromegrass (*Bromus inermis*) from Tselinograd is tetraploid, 2n=28. If so, it can be much more easily manipulated genetically than can typical *B. inermis,* which is octoploid, 2n=56 (Carnahan and Hill 1961).

The 12 collections of chee reedgrass (*Calamogrostis epigeios*) were made with little hope of obtaining seed, because all plants appeared to be totally sterile. Nevertheless, with careful threshing, some viable seeds were obtained from each collection. This grass is strongly rhizomatous and has considerable potential for soil stabilization purposes. The low seed set under natural conditions is probably due to the lack of compatible foreign pollen. Because of its strong spreading habit, an entire colony may be made up of a single

Table 1. Forage collections obtained from the Soviet Union in 1977 by the Dewey-Plummer plant collecting expedition.

Species	Collecting area					Total
	Stav.	Tselin.	Alma A.	Dzham.	Chim.	
Achillea spp.	10	2	—	1	2	15
Agropyron caninum	—	—	4	—	—	4
cristatum	40	9	6	1	11	67
desertorum	73	—	—	—	—	73
elongatiforme	16	—	—	—	1	17
intermedium[1]	64	—	—	12	16	92
repens	21	4	2	5	—	32
sibiricum	—	-	-	16	-	16
Agrostis spp.	3	1	2	—	2	8
Astragalus spp.	8	6	2	7	2	25
Bothriochloa ischaemum	7	—	—	—	—	7
Brachypodium spp.	4	—	5	—	—	9
Bromus inermis	13	10	4	—	5	32
riparius	12	—	—	—	2	14
Calamagrostis epigeios	6	4	—	2		12
Calligonum spp.	—	—	—	10	—	10
Carex spp.	1	1	2	8	2	14
Coronilla varia	7	—	—	—	—	7
Dactylis glomerata	10	—	9	—	7	26
Elymus angustus	—	15	—	—	—	15
junceus	—	5	2	—	—	7
multicaulis	—	—	—	9	—	9
ramosus	—	5	—	—	—	5
Festuca arundinacea	9	1	—	2	2	14
sulcata	17	3	1	1	2	24
spp.	6	1	3	6	—	16
Galium ruthenicum	—	5		—	6	11
Heracleum spp	5	—		—	—	5
Hordeum bogdanii	—	—	—	2	—	2
bulbosum	—	—	—	—	4	4
violaceum	1	2	—	—	—	3
Iris spp.	10	3	—	3	2	18
Koeleria spp.	9	—	—	—	1	10
Lathyrus spp.	7	1	2	—	—	10
Lotus spp.	7	2	—	4	—	13
Medicago cancellata	7	—	—	—	—	7
falcata	1	7	4	—	—	12
romanica	13	2	—			15
sativa	2	3	3	11	9	28
Melilotus alba	1	1	—	2	—	4
dentatus	1	—	—	—	—	1
officinalis	6	1	1	2	2	12
Onobrychis spp.	8	4	—	—	1	13
Phalaris arundinacea	—	2	—	1	2	5
Phleum phleoides	8	2	—	—	1	11
Poa pratensis	2	3	2	1	2	10
compressa	4	—	—	—	—	4
Rosa spp.	2	1	4	2	2	11
Salvia spp.	3	—	—	—	2	5
Sanguisorba spp.	1	2	—	—	1	4
Trifolium agrarium	3	—	—	—	—	3
alpestre	3	—	—	—	—	3
ambiguum	48	—	—	—	—	48
diffusum	3	—	—	—	—	3
fragiferum	2	—	—	3	—	5
medium	4	—		—	—	4
pratense	3	—	4	—	2	9
repens	2	—	—	—	1	3
spp.	7	—	—	—	—	7
Vicia angustifolia	5	—	—	—	—	5
cracca	3	4	5	—	1	13
tenuifolia	5	—	—	—		5
tetrasperma	4	—	—	—	—	4
spp.	4	—	2	—	1	7
			Grand Total			907

[1]Includes *A. trichophorum*

clone. Presumably, seed set in our nurseries will be greatly improved because many different clones are growing in close proximity and can pollinate each other.

Legumes

Clovers (*Trifolium* spp) are especially abundant in the Stavropol Kray, and we acquired an extensive collection of kura clover (*Trifolium ambiguum*). Collections were made from accessions growing in the Stavropol Botanical Garden and in the wild. In addition, the botanical garden staff provided 18 seed lots that they had obtained over a wide range of elevations in the Caucasus Mountains. The 48 accessions that we obtained probably represent the largest single accumulation of *T. ambiguum* germplasm at one research location.

We found crown vetch (*Coronilla varia*) only in the Stavropol Kray. No unusual variations were noted at the time of collection. However, after the seedlings had been started in our greenhouse at Logan, Dr. M.D. Rumbaugh (USDA-SEA-AR, Logan, Utah) applied the vanillin-HCl tannin test to the leaves of each collection; two collections, both from the same area, contained some plants that were negative for the tannin test. As far as we know, these are the only tannin-free *C. varia* collections in the United States. Tannins reduce palatability and digestibility, and *C. varia* suffers as a forage crop because of those characteristics. A tannin-free crown vetch might have an advantage over existing varieties, and plant breeders should have particular interest in tannin-free accessions.

Biennial yellow and white sweet clover (*Melilotus officinalis* and *M. alba*) are widespread in the U.S.S.R., and we made a few collections in each area we visited. All collections were more or less typical. One collection of *M. dentatus,* which appeared to be *M. officinalis,* was pointed out to us by Dr. V.G. Tanfielev, a Soviet botanist. We were told that *M. dentatus* is much lower in coumarin than *M. alba* and *M. officinalis.* When grown at Logan, the *M. dentatus* accession was distinctive in that it was much less vigorous than the other sweetclovers. Furthermore, it was much less bitter to our taste, indicating that it is indeed low in coumarin. Low-coumarin lines of sweetclover can probably be developed by hybridizing *M. dentatus* with *M. alba* and *M. officinalis.*

Several alfalfa (*Medicago*) species were collected, and the purple-flowered (*sativa*) and yellow-flowered (*falcata* or *romanica*) types occurred in near-equal frequencies. The most distinctive alfalfa was *M. cancellata,* a yellow-flowered hexaploid with disc-like pods. This species grew in the Stavropol Kray on sandy sites in association with *Agropyron desertorum.* We made a special effect to locate "creeping" alfalfas throughout the expedition, but none was encountered.

More than 800 *Astragalus* species were described in Volume 12 of the Flora of the U.S.S.R. (Goncharov et al. 1946). Although we collected less than 20 *Astragalus* species, they represented a wide variety of plant types. Some have obvious potential as ornamentals; others appear to be good forage species, and some rhizomatous species may be useful as soil-binding plants. Many *Astragalus* species contain toxic compounds, particularly nitrates (Williams and Barneby 1977). Leaf samples of each *Astragalus* collection were analyzed for nitrate compounds by Dr. M.C. Williams (USDA-SEA-AR, Logan, Utah). Only one collection had a dangerous level of nitrate; one had a very low level of nitrate, and 24 had no nitrates (Williams 1978).

Shrubs and Special-use Species

The timing of the expedition (July-August) resulted in very few shrub collections because most range shrubs do not produce seed until later in the season. However, just recently the Soviets sent us cuttings of three sagebrush (*Artemisia*) species. Hopefully, other desert-shrub collections will be forthcoming.

Probably the most interesting shrub collections were those of *Calligonum.* This genus is composed of large desert shrubs with *Ephedra*-like leaves and it forms the dominant vegetation on extreme sandy sites in the Moyun-Kum Desert near Dzhambul. At most collecting sites, *Calligonum* grew in association with *Agropyron sibiricum.* The Soviets consider *Calligonum* species to be valuable for fuel and fixation of sand dunes. Although the plants that we saw showed little evidence of grazing, our escorts assured us that *Calligonum* is valuable as forage for sheep and camels.

Wild marjoram (*Origanum vulgare*) is a fine-stemmed, broad-leafed deciduous woody perennial that may be useful for soil conservation purposes. We collected this species on steep hillsides where it served as the main plant cover and was effective for binding the soil. The plants have decumbent stems, which produce adventitious roots at the lower nodes. This growth habit, coupled with prolific seed production, is conducive to the formation of dense stands. Because these hillsides were ungrazed, we had no means of determining its utilization by livestock, The leaves of *O. vulgare* are highly aromatic, and the shrub probably has limited acceptance by livestock.

Bedstraw (*Galium ruthenicum*), one of the few other woody perennials that we were able to obtain, was collected at widely separated sites in northern Kazakhstan (Tselinograd) and southern Kazakhstan (Chimkent). Nevertheless, all were similar in appearance, except that the southern collections were somewhat larger (stems to 50 cm) than the northern collections (stems to 40 cm). The bedstraws have limited value as forage plants, but they can form an appreciable part of the ground cover. The area around Tselinograd is typically saline, and our collections of *Galium ruthenicum* came from swales that appeared to be quite saline. These collections may have value for providing ground cover on saline-alkaline sites in the western United States.

The 15 yarrow (*Achillea*) collections were identified for us by the Soviets as *A. millefolium, A. micrantha,* or *A. nobilis.* The most notable variations were in foliage color (green and blue), flower color (white and yellow), and rhizome development (completely caespitose to strongly rhizomatous). None of the collections appeared to be particularly palatable to livestock. The rhizomatous collections are good soil binders and may be useful as conservation plants; other collections may find use as ornamentals.

Two cow parsnips, a giant-sized *Heracleum mantegazzianum* and *H. asperum,* were lightly grazed by livestock. These species may find use on some of our mountain ranges.

Four collections of *Thymus marschalianus,* a perennial prostrate species that creeps by adventitious rooting at the nodes were made on sandy, severely grazed sites near Stavropol. This species formed a virtual turf on exposed knolls and should be good stabilizer on raw soils. The leaves are highly aromatic, and the plant may have potential as an ornamental, especially in rock gardens.

A sizeable collection of *Iris,* particularly *I. pumila,* was presented to us by the staff of the Stavropol Botanical Garden. Most of these collections came from the region between the Black Sea and Caspian Sea. In addition, we made a number of collections in the Asian interior near Tselinograd, Dzhambul, and Chimkent. For the most part, the *Iris* species were only lightly grazed and were of secondary importance as forage plants, but they may be useful for soil stabilization.

Disposition of the Collections

In the late fall of 1977, after the seed had been released by quarantine officials, the entire collection—forages, trees, ornamentals, etc.,—was shipped to Logan, Utah, for threshing and cleaning. After threshing, about half of each seed lot was retained at Logan and the remainder was sent to the Regional Plant Introduction Station at Pullman, Washington. Some of the species will be grown and increased at Pullman and others will be increased at other Plant Introduction Stations. In the meantime, plant introduction (PI) numbers were assigned to each collection and they became officially incorporated into the National Plant Germplasm System.

The only location where the entire collection is being grown is Logan. All of the seed lots that could be germinated readily, about 90% of the total, were planted in the spring of 1978 in a 2-hectare planting on the Evans Farm of the Utah Agricultural Experiment Station. Ordinarily, 10 plants were established from each collection.

The collections will be evaluated for general adaptation at Logan. Great care is being exercised to prevent the escape or release of plants that have the potential of becoming weeds. With the aid of Dr. M.C. Williams, plants that contain toxic compounds will be identified.

Seed of those collections that appear to be useful for range and pasture purposes will be increased at Logan. Other collections will be increased at the various Plant Introduction Stations. As seed is increased in 1979 and later years, it will be made available to individuals and institutions for further research and evaluation. Range scientists and all others who might be interested in this collection are encouraged to observe the planting at Logan at any time beyond the spring of 1979.

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Brush Control and Rio Grande Turkeys in North-Central Texas

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Abstract

Rio Grande turkeys used brush-controlled and untreated rangeland equally when suitable roosting and other cover was available but were absent in areas having an adequate food supply with little available cover. Food selection of turkeys was based upon availability of their preferred foods at different seasons. The two most prevalent foods in each of grass, forb, mast and cactus classes were the same from both treated and untreated areas 83% of the time. Similarity indices of diets between brush-controlled versus untreated areas were 60% and 73% for summer and fall, respectively.

The Rio Grande turkey (*Meleagris gallapavo intermedia* Sennett) ranges over much of Texas. In the past, turkey populations decreased to the extent of extinction on much of its former range. However, recent management practices and renewed public interest have restored turkey populations to former habitat areas and have resulted in expansion of wild turkey ranges into areas previously uninhabited by them.

The incidence of brush control is also increasing in Texas where mesquite (*Prosopis* spp) occurs on more than 56 million acres of rangeland; 54 million acres of this could be directly improved for forage production by some practice of brush control (Smith and Rechenthin 1964). While brush control measures undoubtedly affect turkey behaviour, the effects of such measures are not well documented. Glazener (1958) reported that clearing solid blocks of brush reduced or eliminated turkeys by reducing cover and roosting habitat. Conversely, Lehmann (1960) stated that properly applied brush control treatments can increase turkey populations.

This study was undertaken to assess the effects of brush control on turkey diets and use of habitats in north-central Texas.

Study Area

Research, extending from October 1971 to December 1972, was conducted on the Rolling Plains of north-central Texas near the juncture of Haskell, Throckmorton, and Shackelford counties. The study unit, which encompassed 12,000 ha traversed by the Clear Fork of the Brazos River, was located on parts of the Hendrick and River Ranches.

Topography ranges from level ridgetops and rugged slopes to riverbottom with 152 m elevation differences between ridges and the river. Annual precipitation varies between 51 cm and 76 cm with 69 cm being the average (Korschgen 1967). Temperatures range between a winter low of −9.5°C to summer 45.5°C.

The River Ranch had practiced very little brush control in recent years and was considered to represent near natural conditions for this area. This ranch provided areas of untreated riverbottom (8 km long with an average width of 150 m) and untreated upland (1997 ha) adjacent to the river. Riverbottom lands on the Hendrick Ranch had recently been opened by selective grubbing of mesquite (*P. glandulosa*) and undergrowth with a crawler tractor. Upland sites had been treated with 2,4,5-T in 1964 to control mesquite. Thus, the Hendrick Ranch provided areas of treated riverbottom (9 km long with an average width of 150 m) and treated upland (3588 ha) adjacent to the river.

Other upland sites treated for brush control include: 228 ha grubbed with a crawler tractor to remove all brush in 1972, and 1,298 ha treated with chemical followed by chaining in 1957 and an additional chemical treatment in 1970 to control regrowth. These two areas were not adjacent to the river.

Pecan (*Carya illinoensis*), soapberry (*Sapindus saponaria*), ironwood (*Bumelia lanuginosa*), and tasajillo (*Opuntia leptocaulis*) were plentiful along the river. Walnut trees (*Juglans* spp) were present but infrequent in riverbottom habitat. Mesquite was the dominant tree throughout the area. Pricklypear (*Opuntia* spp) was abundant on all sites.

Texas wintergrass (*Stipa leuchotricha*), sideoats grama (*Bouteloua curtipendula*), purple threeawn (*Aristida purpurea*), sand dropseed (*Sporobolus cryptandrus*), and tridens (*Tridens muticus*) were the more abundant grasses present. Prevalent forbs included rock daisy (*Melampodium leucanthum*), ragweed (*Ambrosia* spp), firewheel (*Gaillardia pulchella*), annual broomweed (*Xanthocephalum dracunuloides*), and Arkansas dosedaisy (*Aphanostephus skirrhobasis*).

Methods

Diets were determined by examination of fecal material. A total of 125 fecal samples were collected from roost sites. Each sample contained an average of 25 droppings. Droppings were gathered after turkeys left their roosts in the morning. Results were combined into spring (April to July), summer (July to October) and fall (October to December) diets with each sample size containing an equal number of fecal samples.

Six different habitats, described previously, were sampled. By observing the movements of turkey flocks, their ranges were determined and feces collected at roosts which were known to be from treated or untreated areas. Samples were not collected from turkeys if their range included both ranches.

The microscopic technique of dietary analysis (Baumgartner and Martin 1939) was used to identify dietary items in fecal materials. Microscope slides were prepared as outlined by Hansen and Flinders (1969). Three slides per fecal sample and 10 fields per slide were evaluated at 100 power magnification for a total of 30 fields per individual sample.

Over 250 plant species from the study area were collected. Reference slides of all plant parts were made for verification of the

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histological features of food items identified in fecal samples. Size and shape of epidermal trichomes, presence or absence of trichomes, cell shapes and crystals included in cell walls were the histological features used to identify forb and shrub species. Grasses were identified by occurrence and position of specialized epidermal cells such as corks cells, silica cells, silica suberose crystals, and asperites (Hansen and Flinders 1969).

Food availability was measured on two 183 m transects randomly located in each of the six habitats sampled. Four intensive (15 × 8 m) sampling units (ISU) were located at 35-m intervals along each transect. Shrub and tree frequency, density and cover were recorded along four 2 × 15-m belts in each ISU. Grass and forb frequencies and cover were recorded for 30 × 30cm quadrats placed three to a line along five line transects established in each ISU. Pricklypear data were recorded as for forbs, but analyzed separately. Mast and fruit production was recorded to indicate the beginning and end of availability and relative production. Sampling was conducted during spring (May–June), summer (August), and fall (December).

An adjustment in vegetative sampling was necessary in riverbottom habitats. The first transect was placed parallel to the shoreline. The second transect was parallel to and 32 m distant from the first.

Data on turkey populations, their movements, and roost trees were obtained by searching the various habitats and observing turkey sign, individuals and flocks.

Insect populations were periodically sampled throughout the season by making a double pass with a sweep net along a 60-m transect in each habitat. Turkey diets were compared for the different habitats using Kulczynski's mathematical expression of similarity (Oosting 1956).

Results

Habitat Characteristics

Vegetational differences were apparent among the six habitats and among different sampling dates on the same site. Spring and summer samples had the greatest variation (Table 1). Fall vegetation having slightly fewer forbs and more grass in the understory was not significantly different from summer vegetation thus was not included in the table.

Untreated Sites

Riverbottom habitat had the most dense brush while the other habitats were considerably more open (Table 1). Mesquite was the dominant overstory shrub, accounting for 50% of the total coverage on the riverbottom and 18% coverage on the upland sites. Tasajillo was the most prevalent shrub (75% relative frequency) on the riverbottom, while mesquite was prevalent (41% relative frequency) on the upland.

Treated Sites

Considering only the riverbottom and adjacent upland, mesquite accounted for about 9% of the total yearly cover along the riverbottom and 12% on the upland. Ironwood was most prevalent (28% relative frequency) on the riverbottom and mesquite (38% relative frequency) interspersed with hackberry (*Celtis* spp) was prevalent on the upland.

Mesquite on the two upland sites not adjacent to the river (the grubbed upland and the sprayed-chained-resprayed upland) had relative frequencies of 28% and 34%, respectively. Cover value of mesquite was 1% and 3% on the grubbed upland and the sprayed-chained-resprayed upland, respectively.

Fruit and Insect Production

Ironwood berries and pecan mast were plentiful in the fall of 1971. Pecan mast persisted in limited quantities through February. Ironwood berries were not available after early December, when grain sorghum (scattered by sportsmen) on the River Ranch became a staple winter food of turkeys.

In 1972 ironwood production was poor; few plants produced berries and the berries were not available to turkeys after mid-October. Pecan mast was also limited but was an important fall turkey food.

Other fruit-bearing species that appeared in turkey diets were elbowbush (*Forestiera pubescens*), sumacs (*Rhus* spp), tasajillo, and pricklypear. Elbowbush berries first appeared in early May, lasting through July. Production was heavy during the study period. Moderate amounts of fruit from polecate bush (*Rhus aromatica*) and littleleaf sumac (*Rhus microphylla*) were available in the habitats from April through July. Tasajillo fruits were available through the winter, and pricklypear fruits were available from mid-July through December.

Insect populations, sampled by sweep net, were greatest in sprayed-chained-resprayed habitats and untreated habitats. Orthoptera, Hemiptera, Homoptera, and Araneae were the most prevalent orders of insects present. Insects were abundant on the area until the first hard winter freeze.

Fecal Analysis

Seasonal data indicate that spring diets consisted of 47%

Table 1. Cover and frequency of vegetation on six brush control sites in north-central Texas.

	% cover				% brush freq.	% rel. freq. (30 × 30 cm)		
Site	Brush	Grass	Forb	Pricklypear	(2 × 15 m)	Grass	Forb	Pricklypear
May–Spring								
Untreated upland	21.7	78.9	18.9	6.1	59.4	40.3	48.6	1.7
Untreated riverbottom	79.5	73.1	25.8	1.8	87.5	49.0	38.7	2.0
Grubbed riverbottom	18.8	65.0	26.2	0.0	81.3	52.8	45.2	0.0
Sprayed upland–1964	30.2	78.9	12.4	9.2	84.4	49.3	38.7	3.6
S-C-S upland[1]	3.5	93.8	4.8	7.9	56.3	68.6	28.4	2.3
Grubbed upland–1972	0.0	54.6	9.0	0.7	34.4	45.2	46.5	4.4
August–Summer								
Untreated upland	17.8	92.5	2.6	3.6	62.5	64.7	31.4	3.2
Untreated riverbottom	74.2	76.4	13.4	1.7	90.6	65.3	30.3	1.9
Grubbed riverbottom	19.7	62.3	7.1	0.0	84.4	85.1	12.1	0.0
Sprayed upland–1964	24.8	86.0	7.3	5.6	87.5	63.2	27.8	4.6
S-C-S upland	3.2	97.7	0.2	7.1	53.1	88.5	5.8	2.5
Grubbed upland–1972	0.7	60.2	10.4	0.9	37.5	67.9	23.9	3.5

[1] Sprayed-chained-resprayed upland–1957 and 1972.

insects, 37% grasses (seeds and leaves), 13% brush (seeds and fruits), 2% forbs (seeds, leaves and fruits), and 3% pricklypear tunas. Summer diets contained 31% insects, 23% brush, 23% pricklypear, 16% grasses, and 7% forbs. Fall diets included 36% brush species, 23% grasses, 15% pricklypear, 13% insects, and 12% forbs. Since observations revealed turkeys on the study area readily accepted grain sorghum spread by sportsmen, no data were collected from January through March. Thus winter feeds are not included in this paper.

Insects were important sources of food for turkeys in all habitats during spring, summer and fall (Table 2). Early ripening bristle panicum (*Panicum ramisetum*) and Texas cupgrass (*Eriochloa sericea*) seeds combined with mast from brush contributed greatly to the spring diet.

Ripened pricklypear fruits were of considerable importance as summer foods of turkeys. Turkeys switched to tridens grass seeds as bristle panicum and Texas cupgrass seeds became scarce. Brush species became more important in late summer diets as tasajillo fruits and ironwood berries ripened. Turkeys consumed available mast in fall, with pecan making up 32% of the diet at this time. Pricklypear tunas and insects still remained important turkey foods during fall. Tridens grass seeds (20%) and wild onions (*Allium drummondii*) (12%) became valuable food sources during fall.

Treated versus Untreated Areas

Differences between turkey diets on brush control versus nontreated areas were not as great as had been anticipated. Summer diets from both categories had a similarity index of 60%. Greater usage of insects and less usage of shrubs on treated areas accounted for much of the variation (Table 2). A similarity index of 73% was noted for fall diets between treated and untreated areas. As variety of food decreased in fall, pecan mast became the dominant food in turkey diets and helped account for the higher index of similarity.

Although amounts of grasses, forbs, and brush in turkey diets varied between brush-controlled and untreated areas, the two most prevalent foods in each food class from each area were the same 83% of the time. These important foods from both treated and untreated areas were: bristle panicum, tridens, wild onion, pricklypear, pecan, ironwood, and tasajillo. Turkeys were apparently demonstrating a selectivity of preferred foods throughout the range.

Availability of food items compared to occurrence in turkey diets showed that wild onion, pricklypear tunas, bristle panicum seeds, and pecan mast were preferred foods (Table 3). The occurrence of bristle panicum and Texas cupgrass in turkey diets from the untreated areas appeared low, but these samples were obtained during summer when many of these seeds were no longer available.

There was no evidence of turkeys frequenting the grubbed upland or sprayed-chained-resprayed areas. These sites had undergone brush control treatments aimed at total brush removal but still had ample amounts of the more important grasses, forbs, succulents, and insects frequently ingested by turkeys. In fact, of all six habitat types, insect numbers were greatest on the sprayed-chained-resprayed upland and fifth greatest on the grubbed upland. The insignificant use by turkeys of a readily available food source such as insects agrees with Glazener's (1958) observation that a relationship exists between the amount of escape cover present and turkey use of an area.

Table 2. Important species in diets of turkeys from untreated and treated brush control areas in north-central Texas.

	Spring % rel. freq.		Summer % rel. freq.		Fall % rel. freq.	
Species[1]	Untrt.	Trt.[2]	Untrt.	Trt.	Untrt.	Trt.
Grass						
Bristle grass seeds	14		6	4	3	3
Texas cupgrass seeds	11		2	–	–	–
Sorghum (grain)	7		–	–	–	–
Tridens seeds	2		11	5	11	23
Grama grasses	2		–	1	–	–
Squirrel-tail barley	1		–	–	–	–
Sand dropseed seeds	–		1	–	–	–
Pricklypear tunas	3		20	26	7	19
Forb						
Silverleaf nightshade	2		–	5	–	–
Wild mercury seeds	–		1	–	–	–
Pelotazo leaves	–		–	1	–	–
Pigeonberry berries	–		1	–	–	–
Giant ragweed seeds	–		–	1	–	–
Wild onion leaves	–		–	–	19	9
Brush						
Ironwood berries	6		9	4	3	–
Polecat bush berries	6		5	–	–	–
Mesquite	–		2	2	–	–
Tasajillo tunas	–		13	4	–	–
Pecan (mast)	–		1	–	35	30
Walnut (mast)	–		1	–	–	–
Littleleaf sumas berries	–		3	–	–	–
Insect	47		20	43	17	10

[1] Those species which had a relative frequency greater than 1.0%.
[2] Data not taken because roosts were not located in time.

Table 3. Relative frequency and preference indices (PI) of most important plants found in turkey diets from treated and untreated brush control areas in north-central Texas.

	Treated[1]			Untreated[1]		
Species	% rel. freq. in habitat	% rel. freq.[2] in diet	PI[3]	% rel. freq. in habitat	% rel. freq. in diets	PI
Pecan	8.5	30.3	3.6	8.5	34.6	4.1
Ironwood	20.9	3.9	0.2	11.0	8.9	0.8
Tasajillo	6.4	4.3	0.7	24.0	13.4	0.6
Sumac	–	–	–	–	8.6	–
Pricklypear	2.7	26.3	9.7	2.7	20.4	7.6
Wild onion	0.7	8.9	12.7	1.7	18.5	10.9
Silverleaf nightshade	1.1	5.1	4.6	1.3	2.5	1.9
Bristle panicum	0.5	3.6	7.2	1.5	13.9	9.3
Texas cupgrass	4.6	0.9	0.2	–	10.7	–
Tridens	7.3	22.9	3.1	10.5	10.7	1.0

[1] Riverbottom and adjacent upland habitats combined.
[2] Data are those found during the period of greatest use.
[3] Preference Index-determined by $\frac{\%\text{ relative frequency in diets}}{\%\text{ relative frequency habitats}}$

Populations and Movements

Sightings of 119 flocks of turkeys involving 1,202 birds were recorded during 149 different observations. Most sightings occurred within 0.8 km of the river, all but four (nesting hens) sightings within 1.6 km. Males and females were seldom seen commingling. Average flock size for hens with juveniles was 19 birds (±4.5 SD) from October through March and 6.8 birds (±1.9SD) from April through September. Conversely, toms tended to be less gregarious, averaging 4.2 birds (±3.1 SD) per flock during winter and 3.7 birds (±1.4 SD) per flock during summer.

A survey to determine the density of suitable roost trees over 6.1 m in height was taken within 30 m of the riverbank. Pecan was most abundant with 81 trees per 1.6 km of shoreline. Soapberry, hackberry, walnut, and elm (*Ulnus americana*) had stem counts of 49, 24, 2, and 1 trees per 1.6 km of riverbank, respectively.

Of 68 roost trees observed, pecan was selected by turkeys 93% of the time. Soapberry, elm, and willow (*Salix nigra*) served as roost 4%, 2% and 1% of the time, respectively. The average size of roost trees was 14.7 m in height with a dbh of 0.68 m. Males preferred trees that extended over water or the upper portions of the tallest trees on land. An average of 2.2 turkeys was observed on each roost.

Rio Grande turkeys remained on the roosts longer after sunrise and returned to the roosts earlier during summer than in fall and winter. Turkeys were still on roosts 1 hour after sunrise and returned before sunset during summer. Turkeys left their roosts at sunrise and returned shortly after sunset during winter. Rio Grande turkeys in this locality thus differ from Merriams turkeys, which reportedly leave their roosts before sunrise (Hoffman 1968).

Discussion

Brush control practices do not necessarily mean a reduction in turkey populations. Good turkey populations can be maintained on properly managed brush control areas. Brush treatments on the Hendricks Ranch opened the brush cover which benefitted their cattle operation; but the treatments, which did not disturb roost and mast trees or berry producers, did not appear to reduce the turkey populations. Food and cover for turkeys could still be found in these moderate brush-controlled areas.

Areas attempting total brush removal retained several of the important food sources but cover was removed. If total brush removal is desired, then the practices should be limited to small patterned areas. This study was not designed to determine how large such cleared areas can be and still be utilized by turkeys, but cleared areas of 228 ha (grubbed upland) and 1,298 ha (sprayed-chained-resprayed upland) apparently were large enough to be avoided by turkeys.

A variety of food items was used by turkeys. Following is a discussion of a few of the more important food items in the turkeys' diets:

1) Pecan mast was the most important natural winter food. Although production was poor during the study period, mast was available through most of the winter months. Brush control measures should not interfere with this species because of its value as food and for roosting.

2) Wild onion was one of the few green forbs present during the winter months. This forb provided a large portion of the turkey's fall diet and was highly preferred. Brush control practices appeared to increase the distribution of this forb.

3) Pricklypear tunas were valuable for food during summer and fall. Maintaining some pricklypear in the habitat would benefit turkey populations.

4) Bristle panicum and Texas cupgrass were turkey favorites in the early growing season but their seeds did not persist into the fall. These grasses were not abundant in any of the habitats studied but were sought by turkeys.

5) Ironwood berries provided food for many forms of wildlife during fall. Berries did not last throughout the winter but were highly preferred when available.

6) Tridens, the most important grass species in turkey diets, retained its seeds well into the winter months and was heavily utilized from middle summer through early winter. This grass decreased following brush control.

7) Tasajillo tunas were another important source of food through winter. This plant, most abundant along the river bottom, is very troublesome to ranchers but does provide turkeys with additional winter food.

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Organic Solvent-Soluble Organic Matter from Soils Underlying Native Range and Crested Wheatgrass in Southeastern Alberta, Canada

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Abstract

Gas chromatographic patterns of organic solvent-soluble constituents present in alkaline hydrolysates of organic matter from soils underlying native range and crested wheatgrass were qualitatively, but not quantitatively similar. The peak at 222°C or with a retention time of about 31 min was identified as bis(2-ethylhexyl) phthalate. Larger quantities of the extracted compounds were obtained from the native range than from the crested wheatgrass soils. Fifty years was not long enough for organic matter of soil cultivated for only 5 years to regain its original quantitative chemical composition under the prevailing climatic conditions.

Crested wheatgrass (*Agropyron cristatum* Gaertn.) is a useful pasture grass for the revegetation of abandoned or marginal cropland, primarily because of increased yield compared to native range (Hull and Klomp 1966; Smoliak et al. 1967). In Western Canada, however, environmentalists are demanding an increasingly greater role in the decision-making processes affecting rangelands. They consider the breaking up of native range and the subsequent seeding of cultivated forage species such as crested wheatgrass to be destructive and irreversible. To counteract these sentiments, an understanding of the long-term effects of crested wheatgrass on soil characteristics is desirable.

About 50 years after seeding, soil under crested wheatgrass stands appeared to be evolving toward an equilibrium somewhat different from that under adjacent native range. Differences were noted in such factors as bulk density, water-stable aggregates, total organic C, extractable organic C, polysaccharides, and moisture retention (Dormaar et al. 1978). Soil organic matter is related to all of these characteristics. Other characteristics of soil organic matter, such as certain solvent-soluble constituents, are responsible for part of the cation exchange capacity of the soil (Schnitzer and Gupta 1965) or are suggested to influence aggregation (Griffiths and Burns 1972).

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The purpose of this study was to compare organic solvent-soluble constituents present in alkaline hydrolysates of soil organic matter developed under native range and adjacent stands of 40- to 49-year-old stands of crested wheatgrass.

Material and Methods

Four pairs of plots, three pairs consisting of abandoned cropland seeded to crested wheatgrass nearly 50 years ago and adjoining range of the Mixed Prairie type (Sites 1, 2, and 4) and one pair where the native range was also on abandoned cropland (Site 3), were selected for the study. These sampling sites were the same as those described in previous studies (Smoliak et al. 1967; Dormaar et al. 1978).

Five 500-g soil samples were collected on October 20, 1976, from the Ah horizon at the four corners and the center of each sampling site, air-dried, ground to pass a 1-mm screen, and mixed to give one composite sample per site.

From each of the eight composite samples, 100 g were extracted in a Soxhlet apparatus for 24 hr with a mixture of ethanol-benzene (1:1) to eliminate fats and waxes (Dormaar et al. 1978). A 40-g subsample of this extracted soil was then hydrolyzed in 1,500 ml of 4% NaOH for 4 hr at 90°C under nitrogen to prevent possible antoxidation reactions (Morita 1965), cooled, acidified with HCl, and fractions presumably containing either phenolic or carboxylic acids, obtained (Burchfield and Storrs 1962; Morita 1965). (The diethyl ether should be of "distilled in glass" grade thereby eliminating the preservative 2,6-di-*tert*-butyl-4-methylphenol.) Aliquots from these two extracts were injected onto a 1 m × 3.1 I.D. mm stainless steel column packed with 5% FFAP on 60–80 mesh GasChrom Q in a Hewlett Packard 5710A gas chromatograph (gc). Controls were run in which the solvents with no soil sample were put through the entire procedure and then gas chromatographed. As the sample emerged, the components were detected by a flame ionization detector and recorded on a Hewlett Packard 3373B integrator with chart speed of 0.64 cm/min. The operating conditions were: N_2-flow rate of 30 ml/min; column temperature program from 100 to 250°C at a rate of 4°C/min; injection port temperature, 200°C; and detector temperature, 300°C.

To deal with the more volatile compounds in the extracts, the samples were not methylated. Materials representing major peaks were eluted from the gc column, collected in capillary tubes, and analyzed by mass spectrometry (Dupont mass spectrometer, model 21-491) and infrared spectrophotometry (Perkin-Elmer infrared spectrophotometer, model 457). The column temperature program was set at a rate of 2°C/min to allow capillary collection of material of peaks between 200 and 250°C. Mass and IR spectra were compared with those of standards of known structure. Known compounds were also co-chromatographed with the original mixtures.

Results

The attempt to separate the extracts into fractions containing either phenols or carboxylic acids was not very successful. The gas chromatographs of both fractions generally showed the same compounds. Since the graphs of Sites 1, 2, and 4 were almost identical, only those of 'carboxyl'-containing compounds of Site 2 and have been presented for comparison with those of Site 3.

Larger quantities of the extracted compounds were found in extracts from the soils covered with native range than from those covered with crested wheatgrass (Fig. 1, a & b vs. c & d). The quantities of the various compounds were generally greater in the extracts from Sites 1, 2, and 4 than from Site 3 (Fig. 1, a & c vs. b & d).

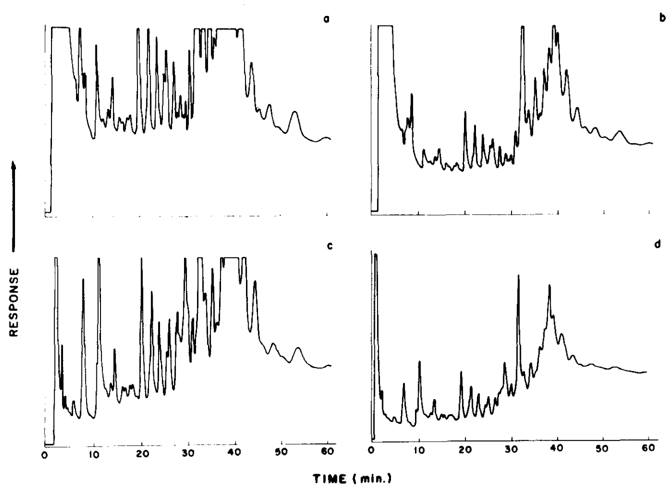

Fig. 1. *Gas chromatographic separation of 'carboxyl'-containing compounds in an alkaline extract of soils under (a) continuous native range (Site 2); (b) native range on eroded abandoned cropland (Site3); (c) crested wheatgrass on abandoned cropland (Site 2); and (d) crested wheatgrass on eroded abandoned cropland (Site 3).*

No major attempts were made to identify the multitude of peaks since we were only interested in patterns. Even so, the peak at 222°C (about 31 min retention time) was identified as bis(2-ethylhexyl) phtalate or dioctyl phthalate (Windholz et al. 1976; listed, incidentally, as two separate compounds in Schnitzer and Khan 1972, p. 181-182). The C content of this compound represented 0.86, 0.32, 0.46, and 0.10% of the total soil C of the native range Sites 2 and 3 and crested wheatgrass Sites 2 and 3, respectively. The C content of the material injected into the gc represented about 4,500, 1,300, 2,300, and 500 kg/ha to a depth of 15 cm respectively.

Discussion

Native range of Sites 1, 2, and 4 had never been broken while that of Site 3 had been cultivated for 5 years, then abandoned about 1928, and the native vegetation allowed to re-establish by secondary succession. By 1977, there was little visible evidence that the site had ever been cultivated. Nevertheless, through a comparison of soils data, it was possible to detect differences between native range of Sites 1, 2, and 4 and that of Site 3 (Fig. 1, a vs. b). Native range soil had greater recuperative power following disturbance than crested wheatgrass soil (Fig. 1, b vs. d), particularly in the light of the comparison of crested wheatgrass vs. undisturbed native range soils (Fig. 1, c vs. a).

The difference between crested wheatgrass sown into abandoned cropland of Sites 1, 2, and 4 with that sown into eroded abandoned cropland of Site 3 (Fig. 1, c vs. d) seems somewhat anomalous. Not only was the recovery of the native range still not quantitative in terms of comparable organic solvent-soluble compounds, but also the soil under the crested wheatgrass of Site 3 showed the same phenomenon in relation to Sites 1, 2, and 4. However, the effect on the soil of the crested wheatgrass of Site 3 probably required longer to express since the plot area was situated within the larger abandoned field, itself slowly reverting to native range. This meant that the plot area was not as well protected from erosion forces as the other crested wheatgrass sites, particularly in the early 1930's on this somewhat exposed location.

Although a good root system is recognized as being essential to the utilization of soil moisture and the uptake of soil nutrients, the range manager is most interested in above-ground vegetation production because it provides forage for his animals and plant litter for ground cover. Crested wheatgrass outyielded native range by 1.08 to 12.42 times in the years for which data were available and produced, on the average, about twice as much forage (Dormaar et al. 1979). Nevertheless, the soil under crested wheatgrass stands had not returned to its original, or climax, condition under the semiarid climate of the study sites. Thus, environmentalists do have some reason for concern. Bulk densities tended to be higher under crested wheatgrass while energy flow was greater under the native range system (Dormaar et al. 1978). The latter seemed to explain the presence of organic matter that was more stable and less extractable and the increased aggregation of soil particles on the native range sites compared with the crested wheatgrass sites. In practical terms, if plans are to renovate land that has been under crested wheatgrass for many years, the range manager would be well advised to exercise caution as such soils are more susceptible to erosion than the native range soils.

Time, the essential parameter of any changing system, is seldom mentioned (Burges 1960). In the study area, it will take at least 50 years to restore the chemical characteristics of an eroded Ah horizon to the dynamic equilibrium that existed before disturbance.

Although the average C contents were only 1.15% for native range soils and 1.08% for crested wheatgrass soils (Dormaar et al. 1978), the organic function of soils of the semiarid regions of the world is known to exert an influence on soil transformations far exceeding its proportion by weight (Wildung et al. 1971). The present study can only be considered a first step toward the elucidation of organic compounds in semiarid soils. Fuller (1974) observed from the literature that the relatively low humus content of semiarid soils is due chiefly to the activity of a highly biogenic soil process, and not, as previously supposed, to a low amount of vegetative remains entering the soil. The role of individual compounds within the soil system may become quite significant under these conditions.

We do not know how widely bis(2-ethylhexyl)phthalate, the compound identified in this study, occurs. It is a hydrophobic compound and has been isolated in small amounts from fulvic acids of other soils (Schnitzer and Khan 1972). Fulvic acid is a water-soluble humic material with relatively low molecular weight that occurs widely in soils and waters. Ogner and Schnitzer (1970) showed that it can combine with lyophobic organic compounds to form stable 'complexes', which are soluble in water. The significance of the presence of such complexes in range soils is difficult to assess. Information regarding the mechanisms and extent of the participation of the soil organic fraction and the soil microflora in terms of exchange capacity, nutrient supply, heat sinks, energy supply, and effect on plant physiological processes is far from complete for semiarid climates (Wildung et al. 1971). In a comprehensive summary of the soil of the drier regions (Dregne 1976), little is said about soil organic matter *per se* or about its quality. Thus, to make the best use of lands in semiarid regions, better understanding of the biochemical processes that occur in such soils would be desirable.

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Root Distribution in 1- to 48-Year-Old Stripmine Spoils in Southeastern Montana

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Abstract

A study was initiated in June 1976 at Colstrip, Montana, to determine root distribution to 1- to 48-year-old stripmine spoils and in undisturbed soils of the area. Root distribution was determined using three methods: (1) soil profile description, (2) root biomass, and (3) radioactive tracer (^{32}P). Results from all three methods showed that old spoils had substantially more roots below 100 cm than new spoils or undisturbed soils. Differences in root abundance were attributed to species composition. Old spoils were dominated by half-shrubs, while new spoils and undisturbed soils were dominated by grasses and forbs. Root biomass in the upper 100 cm of new spoils was 44% less than in undisturbed soils and 43% less than in old spoils. Maximum rooting depths of 15 important plant species were determined using the radioactive tracer method.

Roots are important in soil development (Hole and Nielsen 1970), soil water relations (Hillel and Talpaz 1976), and plant nutrient uptake; however, little attention is given to roots in current studies of stripmined land reclamation. Jones et al. (1975) related the rooting patterns of different forage grasses to organic matter accumulation in Eastern minesoils, but no reference to roots in Western minesoils was found in the literature. Instead, emphasis was usually placed on above-ground portions of plants (DePuit et al. 1978; Ries et al. 1975).

Potential applications of information on root systems in strip-mined lands include: (1) evaluation of reclamation success, (2) determination of the required depth of burial for toxic overburden material based on maximum rooting depth, and (3) identification of critical factors affecting root development. To provide needed information on plant root systems in spoils, a study was initiated in June 1976 at Colstrip, Montana, to determine root distribution in 1- to 48-year-old stripmine spoils and undisturbed soils of the surrounding area.

Methods

Study Area

The study area is located in the unglaciated portion of the Missouri Plateau in southeastern Montana near Colstrip, approximately 150 km east of Billings. Climate in the Colstrip area is semiarid with temperature extremes ranging from −36°C in winter to 42°C in summer. The area has a frost-free period of 120−140 days. Precipitation averages 40 cm, much of which occurs as rain in April, May, and June (NOAA n.d.). The area is characterized by valleys,

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rolling hills, and scattered sandstone and porcelanite outcrops. Soils have developed in sedimentary rocks, residuum, and colluvium consisting of sandstone, siltstone, and shale. Dominant soils in the area include Ustic Torriorthents, Borollic Camborthids, and Aridic Haploborolls. Natural vegetation is of the Eastern Montana Ponderosa Pine Savannah type (Payne 1973). Woodland vegetation is restricted to higher elevation, north-exposed and/or high relief sites, and consists of ponderosa pine (*Pinus ponderosa*) overstory and bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), and little bluestem (*Schizachyrium scoparium*) understory. Grassland vegetation is characteristic of northern mixed prairie, with major species including western wheatgrass (*Agropyron smithii*), thickspike wheatgrass (*Agropyron dasystachyum*), green needlegrass (*Stipa viridula*), prairie Junegrass (*Koeleria cristata*), and needle-and-thread (*Stipa comata*). Degraded sites are dominated by increaser or invader plant species, chiefly big sagebrush (*Artemisia tridentata*), silver sagebrush (*A. cana*), and annual bromegrasses (*Bromus* spp.).

Mine spoils of two age classes are present in the study area: old (44 to 48 years old) and new (1 to 6 years old). Old spoils consist of excess sandy overburden deposited in nearly level platforms. Old spoils have been revegetated through natural succession and are dominated by half-shrubs, primarily false tarragon sagewort (*Artemisia dracunculus*). Other ungraded spoils in the Colstrip area have steeper slopes and higher clay content than the old spoils used in this study. New spoils were regraded, topsoiled, and seeded with introduced and native perennial grasses, biennial and perennial legumes, grains, and shrubs. The research sites on new spoils were dominated by perennial grasses and forbs: crested wheatgrass (*Agropyron cristatum*), smooth brome (*Bromus inermis*), tall wheatgrass (*Agropyron elongatum*), yellow sweetclover (*Melilotus officinalis*), and alfalfa (*Medicago sativa*). Research sites on native range were dominated by perennial grasses and forbs, needle-and-thread, western wheatgrass, purple prairie-clover (*Petalostemon purpureum*), and yellow sweetclover.

Experimental Design

Twelve study sites were selected in the area surrounding Colstrip: four each on old spoils, new spoils, and undisturbed soils. Root distribution was characterized using three methods: (1) standard soil profile descriptions (Soil Survey Staff 1975), (2) root biomass, and (3) radioactive tracer (^{32}P).

Size and abundance of roots were included in standard soil profile descriptions made by experienced soil scientists (Soil Survey Staff 1975) in August 1976. Root biomass was measured using fifteen 1,000 cm^3 soil samples that were collected on September 15, 1976, from each soil profile at three depths: 5–15, 45–55, and 95–105 cm. Samples were hand-washed over a 30 mesh (1 mm) sieve until roots were relatively free of soil. Roots were oven-dried at 60°C to a constant weight, weighed, then oven-dried at 600°C for 24 hours, and reweighed. Root biomass values were reported on an ash-free basis.

Root distribution was estimated *in situ* by injecting plant available ^{32}P into the soil and monitoring radioactivity in above-ground portions of plants during the 1976 and 1977 growing seasons (Fox and Lipps 1964). Radiophosphorus injections were made at six depths (15, 46, 76, 107, 137, and 183 cm) in separate holes at each site on June 11, 1976. Since a few plants had taken up ^{32}P from 183 cm in 1976, a deeper ^{32}P injection depth (214 cm) was added when injections were made the second year on April 6, 1977. Three replicate ^{32}P injections were made in 1977 at each depth on the site from each soil group shown to have the greatest root biomass. The remaining sites received a single ^{32}P injection at each depth as in 1976.

Three aluminum access tubes were installed in each study plot. A neutron probe was used to measure water content at monthly intervals to a depth of 240 cm from June 9, 1976, to July 31, 1977.

Results and Discussion

Profile Description

Most plant roots described were fine (1 to 2 mm) in each soil profile (Soil Survey Staff 1975). Table 1 shows the distribution and abundance of fine roots in old and new spoils, and in undisturbed soils. Fine plant roots were equally abundant in the upper 10 cm of spoils and undisturbed soils. Root abundance decreased between 10 and 50 cm, especially in new spoils. Few fine roots were observed between 50 and 100 cm in new spoils and undisturbed soils, while in old spoils fine roots were common at this depth. Old spoils had more fine roots below 100 cm than did undisturbed soils and new spoils.

The lower quantity in new spoils compared to undisturbed soils, both of which were dominated by grasses and forbs, was probably due to the relatively short time that new spoils had been vegetated. The abundance of roots at lower soil depths in old spoils may have been due to the dominance of deep-rooted half shrubs.

Table 1. Abundance of fine (1-2 mm in diameter) roots in mine soils and native soils of Colstrip study area (Soil Survey Staff, 1975).

Depth (cm)	Native soils	Old spoils	New spoils
0–10	C–M	C–M	C–M
10–50	C	C	F–C
50–100	F	F–C	F
>100	–	F–C	–

M: Many, >100 roots dm^{-2}
C: Common, 10–100 roots dm^{-2}
F: Few, <1-roots $d.^{-2}$

Biomass

Root biomass at three soil depths is shown in Table 2. These data were similar to those obtained from the soil profile descriptions. Root biomass was less in new spoils than in old spoils, particularly at the 45–55 and 95–105 cm depth intervals. Root biomass in the upper 100 cm of new mine soils was 44% less than in undisturbed soils and 43% less than in old mine soils. A gradual increase in root biomass during the first

Table 2. Root biomass (kg/m^3) at three depths in old and new minesoils and native soils near Colstrip, Montana.

Soil group	Site/Age	Depth (cm) 5–15	45–55	95–105
Native soils	Chinook–1	3.59	.56	.04
	Yamac–2	1.57	.00	.00
	Kobar–4	2.01	.29	.17
	Reidel–6	4.29	.06	.00
	Chinook–8	3.35	.48	.19
	Mean	2.96	.28	.08
Old Mine-soils	1928–5	3.36	.74	.63
	1928–7	2.18	.09	.04
	1928–9	1.68	.12	.05
	1929–10	2.94	.61	.17
	1948–3	3.30	.27	.13
	Mean	2.69	.37	.20
New mine-soils	1969–14	1.66	.38	.10
	1970–15	1.74	.11	.13
	1972–13	2.23	.10	.02
	1973–12	1.45	.06	.04
	1975–11	1.23	.01	.00
	Mean	1.66	.13	.06

6 years after reseeding occurred in the new spoils. Root biomass in 4- to 6-year-old spoils is only slightly less than in undisturbed soils.

Root biomass data were fit to a logarithmic function relating root biomass to soil depth:

$$W(Z) = W(O)e^{-\alpha Z}$$

where W(Z) is root weight at depth Z, W(O) is root weight at depth zero, and α is the slope of the line. Slopes (α) for old spoils, new spoils, and undisturbed soils were −.0258, −.0377, and −.0374, respectively. A comparison of these slopes showed that root biomass decreased less with soil depth in old spoils than in new spoils and undisturbed soils. The fact that new spoils and undisturbed soils had nearly identical slopes supported the premise that root distribution was mainly a function of vegetation type.

Root biomass values at 45−55 and 95−105 cm in new spoils and undisturbed soils were highly correlated with water use during the period from April 4 to June 5, 1977, suggesting that grasses and forbs obtained a substantial amount of soil water from these soil depths during that time period. Similar correlations for old spoils were not statistically significant. Correlations of water use with root biomass at 5−15 cm were not significant for old spoils, new spoils or undisturbed soils, indicating that factors other than root biomass such as evaporation, ratio of conducting roots to feeder roots, or other factors influenced water use near the soil surface.

Radioactive Tracer (^{32}P)

The total number of radioactive plants growing within 1 m of ^{32}P injection holes are presented in Table 3. On June 26, radioactivity was detected only in plants growing above ^{32}P injections at 15, 46, and 76 cm in the soil profiles. More plants had taken up ^{32}P from 76 cm in undisturbed soils and new spoils than in old spoils. This trend suggests that grasses and forbs, which dominated new spoils and undisturbed soils, had more active roots deeper in the soil early in the growing season than the dominant vegetation on old spoils (half-shrubs and annual grasses).

The total number of radioactive plants detected on new spoils, undisturbed soils, and old spoils increased from June 26 to July 15 (Table 3). Most of the additional plants on new spoils and undisturbed soils were growing above ^{32}P injections in the upper 76 cm while many of the additional plants on old spoils were taking up ^{32}P from 107 and 137 cm. This pattern of ^{32}P uptake indicated that roots below 76 cm in old spoils became active later in the growing season, while plant roots in new spoils and undisturbed soils did not.

Near the end of the growing season, from July 15 to August 9, the total number of radioactive plants detected on old spoils and undisturbed soils decreased while the number on new spoils increased. In general, plants obtaining ^{32}P from the upper 76 cm decreased, while the number obtaining ^{32}P below 76 cm increased between July 15 and August 9. The decrease in ^{32}P uptake from the upper 76 cm probably resulted from a depletion of water and reduced nutrient availability from these depths. As a result, deep roots, below 76 cm, became more important in supplying water and nutrients for plant growth. Although less than 5% of all roots occurred below 76 cm in these soils, deep roots were apparently extremely important for plant growth late in the growing season.

The total radioactive plants on three soil groups were similar: new spoils had 44, old spoils 46, and undisturbed soils 46. This was unexpected since other measures of root abundance showed new spoils to have less roots than old spoils and undisturbed soils. The relative distribution of roots obtained by the ^{32}P uptake method concurs with data from the other two methods, however. The percentage of radioactive plants which obtained ^{32}P from below 76 cm in old spoils, new spoils, and undisturbed soils was 25.3, 12.8, and 8.7% respectively, indicating that deep roots were most abundant in old spoils.

The results obtained in 1977 concur with those collected during the 1976 growing season. There were no significant differences between the number of radioactive plants or root distribution. However, plants appeared to take up ^{32}P from lower soil depths in 1976 than in 1977. Less precipitation occurred in spring 1977 than in spring 1976; thus, differences in precipitation could have influenced root activity during the 2 years.

Maximum detectable rooting depths were determined for 15 plant species in the Colstrip area during the 2-year ^{32}P investigation (Table 4). Generally, plants found on both undisturbed soils and mine soils had greater rooting depths in undisturbed soils. However, because old spoils were dominated by deep rooting plant species, in particular false tarragon sagewort, there was a greater abundance of roots in the lower depths of old spoils compared to new spoils and undisturbed soils. Of the 180 radioactive plants monitored during this investigation, less than 10% took up ^{32}P from below 107 cm.

Table 3. Total number of radioactive plants detected in 1976 at Colstrip study area.

^{32}P Injection depth (cm)	Native soils 6/26	Native soils 7/15	Native soils 8/9	Old spoils 6/26	Old spoils 7/15	Old spoils 8/9	New spoils 6/26	New spoils 7/15	New spoils 8/9
15	4	5	6	4	6	3	5	6	5
46	4	7	5	4	4	2	2	6	4
76	4	5	2	1	6	4	4	4	3
107					4	2			2
137		1	2		4	3			1
183		1							2

Summary and Conclusions

Three methods were used to characterize root distribution: (1) standard soil profile description, (2) root biomass, and (3) radioactive tracer (^{32}P). Results from all methods indicated that

Table 4. Maximum detectable rooting depths of important species in the Colstrip study area.

Plant species	Depth (cm)
Crested wheatgrass (*Agropyron cristatum*)	76
Thickspike wheatgrass (*Agropyron dasystachyum*)	46
Tall wheatgrass (*Agropyron elongatum*)	183
Western wheatgrass (*Agropyron smithii*)	107
Slender wheatgrass (*Agropyron trachycaulum*)	107
Western ragweed (*Ambrosia psilostachya*)	137
False Tarragon Sagewort (*Artemisia dracunculus*)	137
Blue grama (*Bouteloua gracilis*)	76
Smooth brome (*Bromus inermis*)	76
Prairie sandreed (*Calamovilfa longifolia*)	46
Prairie junegrass (*Koeleria cristata*)	76
Alfalfa (*Medicago sativa*)	76
Yellow sweetclover (*Melilotus officinalis*)	137
Purple prairie-clover (*Petalostemon purpureum*)	76
Needle and thread (*Stipa comata*)	183

old spoils had more roots below approximately 100 cm than new spoils or undisturbed soils. These differences were attributed to differences in species composition. Old spoils were dominated by half-shrubs while new spoils and undisturbed soils were dominated by grasses and forbs. The soil profile description and root biomass methods showed that plant roots were less abundant in new spoils below soil depths of 10 cm than they were in old spoils or undisturbed soils. In addition, root biomass in the upper 100 cm of new spoils was 43% less in undisturbed soils and 40% less than in old spoils. It appears that at least 5 years will be required for root abundance to approach pre-mining levels in the Colstrip area.

Range plants in the Colstrip area commonly have roots deeper than 100 cm while some species have roots as deep as 183 cm. Roots below 76 cm are extremely important in providing water and nutrients for plant growth late in the growing season even though they comprise 5% or less of total root biomass. Reclamation programs and policies should, therefore, be aimed at building soils which provide at least a 2 m root zone free of toxic overburden and compacted layers.

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Responses of Falsemesquite, Native Grasses and Forbs, and Lehmann Lovegrass after Spraying with Picloram

S. CLARK MARTIN AND HOWARD L. MORTON

Abstract

Aqueous sprays of picloram at the rate of 0.56 kg/ha (94 1/ha total volume) were applied to 5 plots each in May 1973 and August 1976 to control falsemesquite (*Calliandra eriophylla*) in southern Arizona. Falsemesquite was effectively controlled on both spraying dates. The greatest vegetation change on sprayed and unsprayed plots alike was the overwhelming natural increase in density and yield of Lehmann lovegrass, an introduced species. Perennial forbs were almost completely eliminated and densities of native perennial grasses were greatly reduced both on treated and untreated plots.

This report presents the results of a 5-year study (1972-1977) to determine the responses of perennial grasses following control of falsemesquite (*Calliandra eriophylla*) with aqueous sprays of picloram. Since falsemesquite is highly regarded as browse plant, why attempt to control it? Our thinking was that, although its leaves are both palatable and nutritious, the value of falsemesquite as emergency forage is relatively low because the leaves drop off in winter and during severe drought. Also, since perennial grass stands often are sparse and of low vigor where falsemesquite is abundant, we suspected that falsemesquite might compete seriously with perennial grasses.

The study was conducted on the Santa Rita Experimental Range, 50 km south of Tucson, Arizona, at 1,160 m elevation, where average annual precipitation is about 380 mm. Sixty percent of the year's moisture falls between June and September. The study area slopes gently downward to the northwest but is otherwise almost flat. Soil is White House gravelly sandy loam stony phase (Youngs et al. 1936). Youngs indicated that erosion was not serious on this soil because of protection by surface rocks and good grass cover. Data collected near the study site from 1968 to 1974 show that perennial grass herbage production was only 14 kg/ha, less than half as much as on another site having comparable rainfall but less falsemesquite and a different soil (Martin and Ward 1976).

The study layout consisted of fifteen 30-m square plots in five 3-plot blocks. Aqueous sprays of picloram at the rate of 0.56 kg/ha acid equivalent in 94 1/ha total volume were

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Table 1. Yearly and long-time average seasonal precipitation (mm) at White House rain gauge, 1 km east of the study site.

Year	Season or period		
	Oct.–May	June–Sept.	Year (Oct.–Sept.)
1972–73	302	109	411
1973–74	73	283	356
1974–75	161	187	348
1975–76	119	299	418
1976–77	141	194	335
5-year average	159	214	373
Average (1922-77)	163	240	403

applied with a tractor mounted boom sprayer. Five plots were sprayed in the spring (May 1973), five in the summer (August 1976), and five were not treated. The summer treatment was delayed until 1976 because summer growth of the false-mesquite was too poor to justify spraying in 1973, 1974, or 1975. Pretreatment measurements, in 1973, included density of herbaceous and woody plants on 100 $0.1 \cdot m^2$ subplots along each of three 10 m long transects located 4.6 m apart near the center of each plot. Remeasurements were made in the fall of 1977. Sample plots clipped in March 1978 provided estimates of herbage production in 1977.

Rainfall from October 1972 through September 1977 was slightly below average for the period but was marked by an unusually wet October–May 1972-73, as well as by the driest 12-month period since 1924 from June 1973 through May 1974 (Table 1). Summer rainfall in 1974 and 1976 was well above average but was slightly below average in 1975 and

Table 2. Density (plants/m^2) of grasses, and (percent of plots [0.1 m^2] without perennial vegetation) forbs and shrubs before treatment (1973) and in 1977.

Species	Picloram spray					
	Spring		Summer		Check	
	1973	1977	1973	1977	1973	1977
Perennial grasses						
Aristida spp.	2.47	0	1.67	0.00	3.20	0.20
Astrebla spp.	0.87	1.47	0	0	0	0
Bouteloua chondrosioides	19.07	6.40	11.27	6.20	12.13	6.80
Bouteloua curtipendula	0.20	0.27	0	0	0	0
Bouteloua filiformis	2.93	1.93	3.67	1.73	3.33	1.73
Bouteloua hirsuta	16.00	6.27	12.60	3.07	21.60	6.47
Eragrostis lehmanniana[1]	5.00	57.53	11.67	92.80	5.00	77.27
Heteropogon contortus	0.33	0.07	0.13	0.73	0.60	0.33
Leptoloma cognatum	0.53	0	0.20	0.20	0.07	0
Lycurus phleoides	0.80	0	0.40	0	0.33	0.13
Trichachne californica	1.33	1.00	1.13	0.40	2.07	0.40
Total perennial grasses	49.53	74.94	42.74	105.13	48.33	93.33
Perennial forbs						
Ambrosia psilostachya	18.47	0	16.00	0	4.13	0
Ayenia pusilla	6.00	0	6.27	0.07	7.00	0.53
Evolvulus arizonicus	2.47	0.33	2.33	0.27	4.20	0.40
Sida procumbens	1.80	0.20	0.47	0.93	0.13	0.80
Solanum eleagnifolium	0	0	0.67	0	0.73	0.20
Total perennial forbs	28.73	0.53	25.73	1.27	16.20	1.93
Shrubs						
Carlowrightia arizonica	1.33	0.13	0	0.27	0.20	0.13
Calliandra eriophylla[1]	48.80	0.73	41.60	0.60	53.87	24.07
Aplopappus tenuisectus	0.07	0	0.80	0	0	0.07
Mimosa dysocarpa	0	0	0	0	0.20	0
Prosopis juliflora var. *velutina*	0	0	0.13	0.07	0	0
Total shrubs	50.20	0.87	42.53	0.94	54.47	24.27

[1] Differences among treatments in 1977 significant at 5% level as determined by analysis of covariance.

1977. Thus, the study period included seasons of high, low, and average precipitation.

Pretreatment differences in vegetation between plots assigned to the different treatments were mostly small or nonsignificant. Perennial grasses were generally low in vigor. Sprucetop grama (*Bouteloua chondrosioides*) and hairy grama (*B. hirsuta*) were the most abundant species, Lehmann lovegrass (*Eragrostis lehmanniana*) was third (second on summer spray plots), and three-awn (*Aristida* spp.) was fourth (Table 2). Western ragweed (*Ambrosia psilostachya*) was the most abundant forb followed by ayenia (*Ayenia pusilla*) and Arizona evolvulus (*Evolvulus arizonicus*). Falsemesquite was the dominant shrub. The fact that Lehmann lovegrass, an exotic perennial, had become a major species by natural spread in 1973 suggested that it might continue to increase at the expense of native species, as reported by Cable (1971 and 1976).

Remeasurement in 1977 showed that the density of falsemesquite on sprayed plots had been reduced by 98%. The spring (1973) and summer (1976) sprays of picloram were almost equally effective.

Fig. 1. *Typical view of the study area. (A.) 1973 before treatment showing relatively sparse grass cover and vigorous stand of false mesquite. (The smal mesquite tree was removed to facilitate spraying). (B.) 1977 showing almost complete dominance of Lehmann lovegrass.*

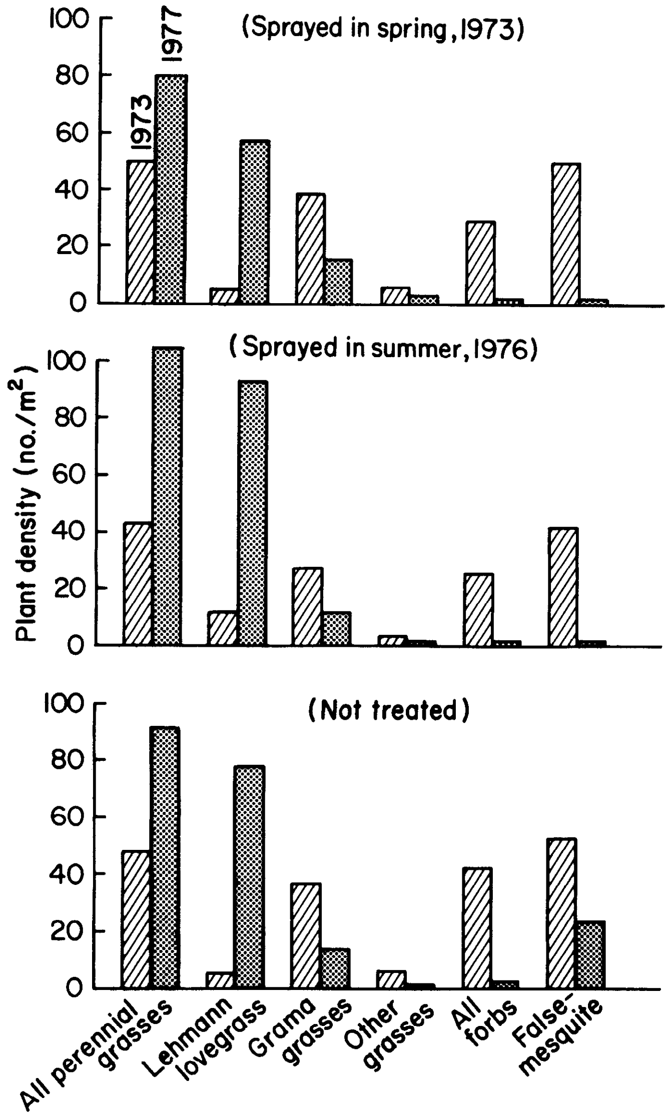

Fig. 2. *Densities (plants/m²) for major species or plant groups in 1973 and 1977.*

The most spectacular vegetation change was the manifold increase in Lehmann lovegrass on all plots (Fig. 1). The increases in lovegrass were accompanied by sharp decreases in most other species, as Cable (1971 and 1976) reported for other areas on the Santa Rita (Table 2). Gains in Lehmann lovegrass more than offset the losses in native perennial grasses, so that total perennial grass densities in 1977 were 1.5 to 2.5 times greater than before treatment. Meanwhile, total forb densities declined from 16 to 29 per m^2 in 1976 to 2 or less in 1977. None of the forbs increased.

The other unexpected vegetation change was that false-mesquite lost 55% of its density on the unsprayed plots. This suggests that Lehmann lovegrass not only thrives in the presence of falsemesquite but that it can compete vigorously with it. Lehmann lovegrass and falsemesquite both draw heavily on cool-season moisture, and the fact that mature lovegrass is about twice as tall as falsemesquite may place the shrub at a disadvantage.

Table 3. Perennial grass standing herbage (kg/ha) March, 1978 (1977 forage crop).

Treatment	Grama grasses	Lehmann[1] lovegrass	Other grasses	Total[1]
Sprayed May 1973	43	2437 ab	134	2614 ab
Sprayed August 1976	74	3012 a	71	3157 a
None	146	1647 b	32	1825 b

[1] Numbers in a column not followed by the same letter differ significantly at the 5% level.

Lehmann lovegrass, which made up only 10 to 27% of the perennial grass density in 1973, made up 77 to 88% in 1977. These increases in density of lovegrass were accompanied by increases in herbage production. Yields of perennial grass in 1977 ranged from 1,825 to 3,157 kg/ha (1,629 lb/acre–2,819 lb/acre) (Table 3) compared to yields of 214 kg/ha (191 lb/acre) reported for a nearby area before Lehmann lovegrass takeover (Martin and Ward 1976). These changes in yield and species composition, though desirable for cattle, may make the range less desirable for wildlife species that prefer forbs and browse to grass.

Any responses of native perennial grasses to control of falsemesquite were obscured by the overwhelming increases in Lehmann lovegrass. The density of Lehmann lovegrass in 1977 was higher on plots sprayed in the summer of 1976 than on those sprayed in the spring of 1973. Initial densities were not significantly different. Standing herbage of lovegrass in March 1978 was greatest on plots sprayed in the summer of 1976 and least on untreated plots (Table 3).

Results of the study suggest that: (1) picloram is effective for controlling falsemesquite, and (2) the 8- to 15-fold increase in grass production due to the natural increase in Lehmann lovegrass suggests that lovegrass can increase herbage yields on areas of White House soil where native perennial grasses now produce very little.

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Contributions of White Clover to the N,P, and Ca Concentration of Perennial Grasses

JAMES W. DOBSON AND E.R. BEATY

Abstract

Southern range forages tend to grow vegetatively for 5 months of the year. During the other 7 months, forage available is low in energy and minerals. Cattle are usually grazed on seeded pastures or fed hay from October until May. Growing of a legume with the grass is currently of major interest as it increases energy, N, and minerals as compared to that of the grasses grown alone. Growing white clover (*Trifolium repens* L.) with any of the five major perennial forage grasses was found to increase the N concentration in the forage produced all season long. Grass forages grown with white clover but without N averaged as high or higher in N concentration than monospecific grass forage fertilized at all N rates up to 336 kg/ha.

Phosphorus concentration of the forage was not appreciably influenced by presence of white clover but averaged 0.37% in the spring and 0.26% in the fall, a 30% reduction with season. Orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) forage had higher P concentrations than did the warm-season perennials Coastal and common bermudagrass (*Cynodon dactylon* L. Pers.) and dallisgrass (*Paspalum dilatatum* Poir.). Ca concentration of the forage was directly related to quantity of clover present. Including white clover with the perennial grasses would significantly increase the N and Ca concentrations of the forage as compared to the grass alone. The increases in concentrations of N and Ca would significantly improve the nutritional quality of the grass forages being grown.

Perennial legumes such as white clover (*Trifolium repens* L.) have not been widely grown on ranges in the Southeast but have been grown on seeded pastures for many years. It is generally believed that legumes improve the energy, N, and mineral composition of seeded grass pastures; and in the South such pastures replace ranges for some 7 of the 12 months of the year. Few data are available to demonstrate the effect that adding white clover to a grass pasture will have on forage chemical concentration.

The amount of white clover grown in pasture mixtures of the southern region has varied widely. In the late 1940's, white clover, as did legumes in general, attracted considerable research attention, but during the 1950's and during most of the 1960's, the application of inorganic N on seeded grass pastures increased and consequently interest in growing white clover decreased. Range grazing has traditionally included native legumes but few were seeded. As the interest in growing cattle in the Southeast inceased, growing white clover in forages, including that produced on range, has increased. By 1970, interest in high rate of N usage on pastures decreased and interest in including white clover in the forage mix was renewed.

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White clover is one of the most versatile legumes and is being grown on 100,000 ha of pastures in Georgia annually. Interest is also increasing to grow white clover on ranges particularly on clear cut and wet areas.

White clover is generally considered to be one of the most nutritious legumes (Gibson and Hollowell 1966; Koger et al. 1961). In contrast to grass forages, variation in chemical concentrations between white clover samples is usually minimal (Wilkins et al. 1958) and probably is caused by the white clover dehiscing dead leaves leaving only green forage. The P, Ca, and K concentrations of white clover have been reported to exceed 0.35, 1.50, and 1.50% respectively (Miller 1958; Stewart and Bear 1951). White clover generally produces low forage yields and growing it with a grass prevents bloat in ruminants, improves forage quality, and increases yields (Daugherty, 1956). The purpose of this experiment was to determine the changes in N, P, and Ca concentration of five perennial forage grasses when grown with and without white clover and at four N rates.

Materials and Methods

Tall fescue, orchardgrass, dallisgrass, and 'Coastal' and common bermudagrass were grown with and without Ladino clover. Nitrogen (N) at rates of 0, 37, 112, and 336 kg/ha was applied as NH_4NO_3 in multiple applications. The first was applied in early April and the second and third after the June 15 and August 1 forage harvest, respectively. Phosphorus (P) and potassium (K) were uniformly applied with surface applications of 560 kg/ha of 0-4.4-16 NPK annually. Calcium (Ca) and magnesium (Mg) were applied as dolomitic limestone the first year of the investigation at the rate of 8 mt/ha. Treatments were replicated five times in split-plot design.

At the first harvest, May 1, plots seeded to tall fescue and orchardgrass with/without white clover were clipped. At the June 15, August 1, and September 15 harvest dates, all grasses with/withou white clover were harvested. In 1952 and 1953, forage samples from the grass/N and grass/white clover treatments were ground through a Wiley Mill in preparation for N determinations. In addition in 1953 forage from grass/N and grass/white clover plots collected on May 1, August 1, and September 20 were analyzed for P and Ca. At each clipping, botanical separations, grass/white clover, and grass/N were made on forage from the tall fescue and Coastal bermudagrass plots.

N was determined by Kjeldahl while P and Ca were determined on aliquots from a solution obtained by wet ashing 1 g of plant material using a mixture of nitric, perchloric, and sulfuric acids. P and Ca was determined by procedures described by Piper (1944).

Results and Discussion

Forage N Concentrations

Increasing the N fertilization rate caused an increase in N concentration of the forage in the presence or absence of white clover (Table 1 and Fig. 1). Applying N as fertilizer increased

Table 1. The effect of N rate and white clover on the N concentration (%) of five forage grasses, Blairsville, Ga, 2 year average.

Forage	N rate 0	37	112	336	Mean
Orchardgrass	2.17	2.27	2.42	2.95	2.45
Orchardgrass/white clover	2.73	2.55	2.62	3.06	2.74
Tall fescue	2.00	2.28	2.27	3.03	2.40
Tall fescue/white clover	2.55	2.56	2.66	3.17	2.74
Coastal bermuda	1.48	1.43	1.59	1.86	1.59
Coastal bermudagrass/ white clover	2.22	2.17	2.18	2.51	2.27
Common bermuda	1.34	1.38	1.49	1.90	1.53
Common bermudagrass/	2.01	2.37	2.36	2.40	2.29
Dallisgrass	1.56	1.58	1.65	1.85	1.66
Dallisgrass/white clover	2.09	1.90	1.98	2.01	2.00
Mean/grass	1.71	1.79	1.88	2.32	
Mean/grass and clover	2.32	2.31	2.36	2.63	

LSD ($P<0.05$) = 0.37%

forage N concentration, but growing grasses with white clover produced a forage with higher amounts of N at all levels of fertilization than grasses grown without white clover. The difference was especially pronounced at 0 N fertilization, where forage with white clover had on the average 2.3% N in contrast to 1.71% N in forage without white clover. The addition of 37 or 112 kg/ha N increased average forage N concentration to 1.79 and 1.88% without white clover and 2.31 and 2.36% with white clover, respectively (Table 1).

Including white clover increased with N concentration of the forage approximately 0.5 percentage point or 27% of the mean as compared to that of the grasses grown alone. With the addition of 336 kg/ha of N, the average forage N concentration of the straight grass was 2.32% and grass/white clover forage that received no N averaged 2.32%. The N content of the orchardgrass and tall fescue without white clover averaged 2.42% N or 0.84% higher than did the warm-season grasses (1.58%). When white clover was added, the average N content of the cool-season grasses was 2.74% or 0.56% higher than that of the bermuda and dallisgrasses, which had an average N

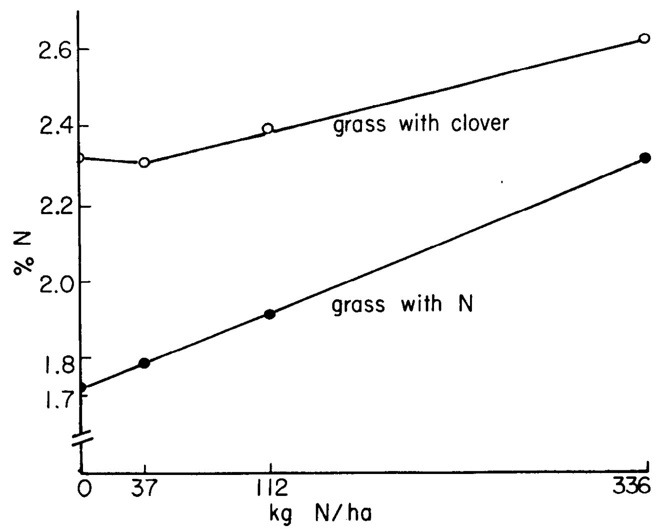

Fig. 1. *Average forage N concentration at four N rates of tall fescue orchardgrass, dallisgrass, Coastal and common bermudagrass grown with N and with white clover. Blairsville, Ga. 1952-1953.*

content of 2.18%. The cool-season growing grasses, tall fescue and orchardgrass, produce forage that is primarily leaf, while the bermudagrass forage is high in stem.

Adequate animal nutrition requires a forage containing 1.76% N and 70% digestibility (NRC 1970). All of the cool-season forages and all forages with white clover had adequate N. However, only when the summer growing grasses without white clover were fertilized with 336 kg/ha of N was N concentration that high.

Nitrogen concentration of the forage composited by N rates and clipping dates with and without white clover is shown in Figure 2. Forage with white clover averaged 0.68% higher in N than forage without white clover. At the first clipping the forage N concentration of grass/white clover was 0.64% and at the second clipping 0.82% higher than grass with N only. By the third clipping the N concentration of the white clover/grass forage was 0.82% higher than the grass plus N. Only at the fourth clipping was there a sizeable decrease in N concentration of forage with white clover. Under Southeastern conditions, fall harvest forage contained very little, less than 10% clover; yet the forage from grass/white clover plots was 0.41% higher in N than was the grass/N forage indicating a residual N input to the grass from the white clover grown earlier.

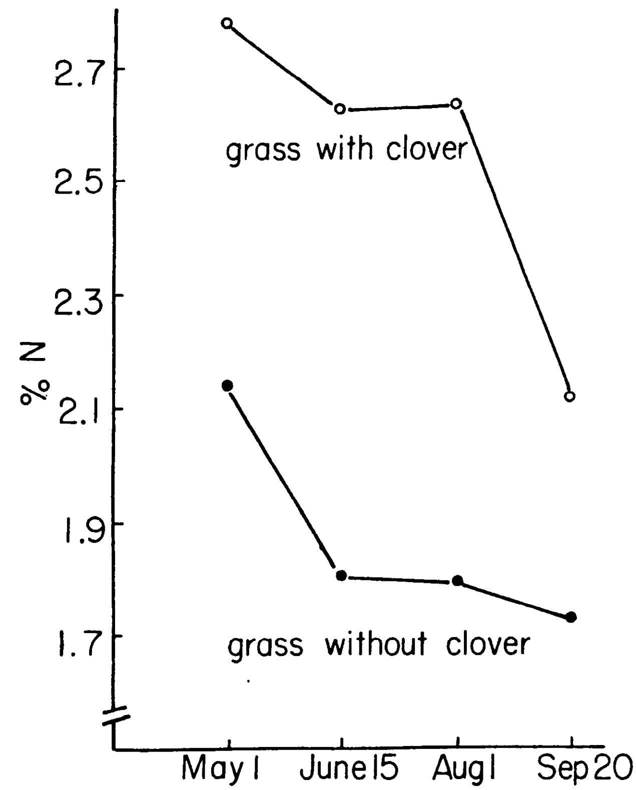

Fig. 2. *Average forage N concentration by harvest dates of tall fescue, orchardgrass, dallisgrass, Coastal and common bermudagrass grown with white clover and with N. On May 1 only plots with tall fescue and orchardgrass harvested. Data average of four N rates. Blairsville, Ga. 1952-1953.*

The effect of growing white clover with a grass on the N concentration of the grass is shown in Figure 3 for Coastal bermudagrass and tall fescue. Grass grown with white clover was consistently higher in N than grass grown with N. The N content of grass growing with but separated from white clover was intermediate between the grass grown with white clover and grass grown with N. These data show that growing white

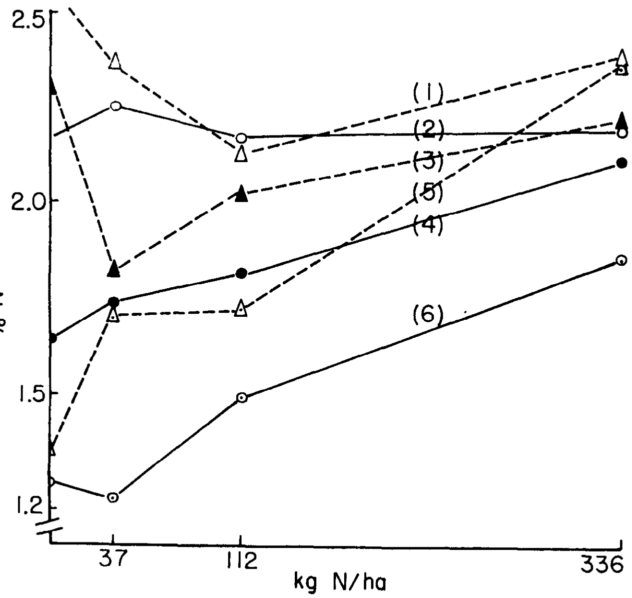

Fig. 3. *Average forage N concentration of tall fescue with (1) white clover, (3) separated from white clover, (5) N only and Coastal bermudagrass with (2) white clover, (4) separated from white clover and (6) N only at four N rates. Blairsville, Ga. 1952-1953.*

clover with a grass will increase the average N content of the forage grass by approximately 0.3% percentage point. Adding white clover to the forage mix increased the N content consistently in addition to a large increase in forage yield (Dobson and Beaty 1977).

Phosphorus Concentration

Phosphorus concentration of the forage including white clover was little different from that of the grass alone (Fig. 4). Forage clipped on May 1 tall fescue and orchardgrass, averaged 0.37% P and decreased to an average of 0.26% by

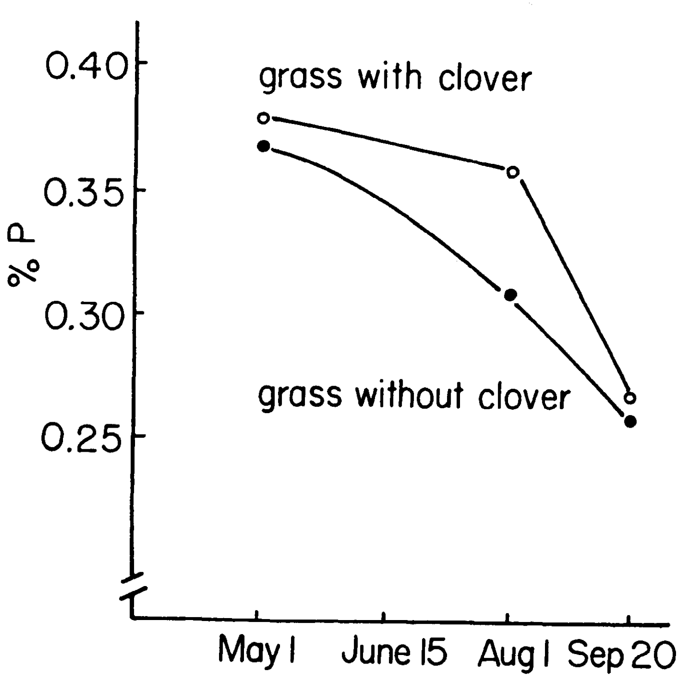

Fig. 4. *Average forage P concentration by harvest dates of tall fescue, orchardgrass, dallisgrass, Coastal and common bermudagrass grown with white clover and with N. On May 1 only plots with tall fescue and orchardgrass harvested. Data average of four N rates. Blairsville, Ga. 1953.*

September 20. Forage containing white clover averaged slightly higher in P than did grass alone, but the difference was not large enough to be of significance. The P concentration of all forages was well above that required by animals (NRC 1970). Nitrogen fertilization did not consistently affect P concentration of the forage, but the P concentration of tall fescue and orchardgrass was approximately 50% higher than that of dallisgrass and bermudagrasses. Tall fescue and orchardgrass forages are largely leaf and should be higher in P than stems. Part of the decrease in average P concentration of the August 1 and September 20 harvested forage reflects the inclusion of the warm-season perennials and their greater stem content.

Forage Ca Concentration

Calcium was significantly higher in the white clover/grass forage than in the grass alone (Fig. 5). At the May 1 harvest, when tall fescue and orchardgrass were harvested, Ca concentration of the white clover/grass forage was almost double that of grass alone. At the August 1 clipping, white

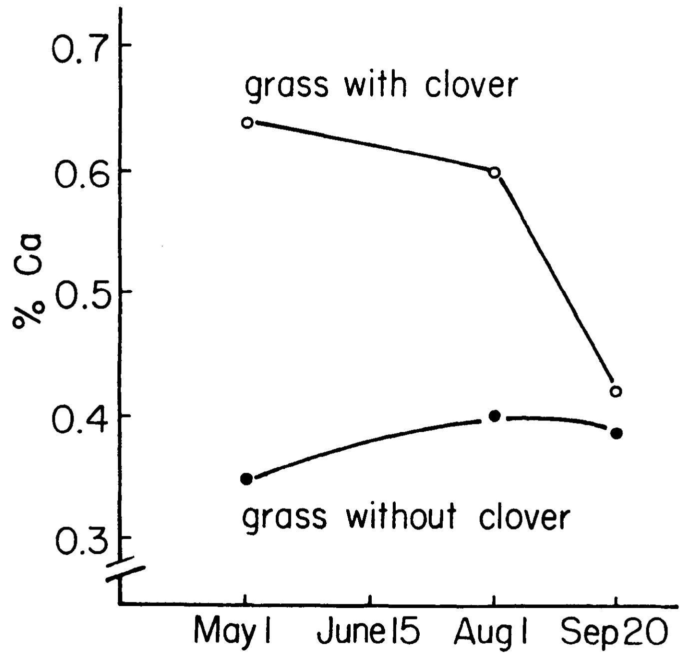

Fig. 5. *Average forage Ca by harvest dates of tall fescue, orchardgrass, dallisgrass Coastal and common bermudagrass grown with white clover and with N. On May 1 only plots with tall fescue and orchardgrass harvested. Data averaged of four N rates. Blairsville, Ga 1953.*

clover/grass forage was still 50% higher in Ca than was grass grown with N. By the September 20 clipping, white clover had largely disappeared (Dobson and Beaty 1977) and the Ca concentration of white clover/grass was comparable to that of the grass plus N. Trends of Ca concentration among grass species are shown in Figure 6. The Ca content of dallisgrass forage is much lower than that of orchardgrass and tall fescue and is similar to that of the bermudagrasses.

Discussion

Adding white clover to five perennial forage grasses significantly increased the N concentration of the forages as did applying 112 and 336 kg/ha of N. The increased N concentration in forage resulting from including white clover would be expected to produce a more nutritious forage (NRC, 1970). Adding white clover to the grasses had little influence

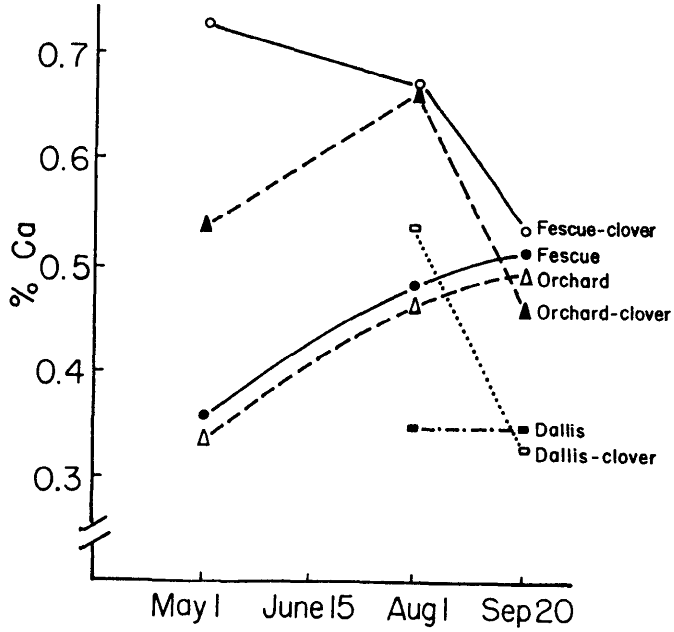

Fig. 6. *Average Ca concentration by harvest dates of tall fescue, orchardgrass and dallisgrass grown with white clover and with N. Data average of four N rates. Blairsville, Ga. 1953.*

on the P concentration of the forage. Phosphorus concentration of all forages appeared to be adequate for beef cattle (NRC 1970). Calcium concentrations of the forages closely followed the percent white clover.

Perhaps the major significance of the data is that nutritionally adding white clover improved the N and Ca concentrations of the warm-season perennial forages more than that of the cool-season perennials. Adding white clover to perennial forages seeded in the lower South would appear to be especially beneficial. Native range forages, like bermudagrass, are probably less nutritious in the fall than the summer; thus when growing bermudagrasses and native grasses, including white clover in mixture would be highly desirable. If white clover cannot be grown, including another summer-growing legume should probably be considered.

Since cattle must be removed from the range for 6 to 7 months each year, alternate sources of forage to complement that range must be provided. In a previous report Dobson and Beaty (1977) showed the forage yield advantage of including white clover with grasses and present research shows that nutritional advantage of adding white clover on increasing the N and Ca concentrations. The advantage of adding a legume to range areas or to seeded pastures used to complement ranges would be highly beneficial in increasing yield and nutritional quality. The concept of growing a legume with range grasses does not appear to be widely appreciated. Biologically, growing a legume such as white clover on ranges probably offers more opportunity to increase forage nutritional yield and quality than any other practice generally available.

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Perennial Grasses and Their Response to a Wildfire in South-central Washington

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Abstract

Three years of past burning responses of three perennial grasses were evaluated by comparing a burned area with an adjacent control (unburned) area. The average leaf length of Cusick bluegrass and Thurber needlegrass was shortened by burning in all 3 years, but leaf shortening was inconsistent for bluebunch wheatgrass. Burning increased the number of flowering culms per clump for Cusick bluegrass during the second year of postburning and for Thurber needlegrass during the third year. The average number of flowering culms per clump in bluebunch wheatgrass was greater in the burned area for all 3 years of postburning. Culm and spike lengths of bluebunch wheatgrass were increased by burning for the first 2 years. Cusick bluegrass and Thurber needlegrass generally responded to burning with shortened culms and spikes. The basal area of Cusick bluegrass and Thurber needlegrass was reduced by burning. Phytomass production of bluebunch wheatgrass showed an increase during the 3 years of postburning, whereas Cusick bluegrass and Thurber needlegrass showed a reduction in phytomass production. No single measurement provided a way to evaluate overall plant responses.

Wildfire is a common event in grasslands which, depending on how, when and where it occurs, may have an important influence on grassland vegetation. Rangemen have often used controlled fire to improve the quantity and quality of livestock forage by eliminating unpalatable but fire sensitive competitive woody species.

Recent literature reviews on fire and its effects on western grasslands are presented by Daubenmire (1968), Vogl (1974), and Vallentine (1974). Daubenmire (1975) reported that burning of bluebunch wheatgrass (*Agropyron spicatum*) only moderately reduced canopy coverage and frequency, but dry-matter production was reduced 50% of the unburned area during the first season, with 16 and 17% reduction during the second and third years of postburning respectively. Mueggler and Blaisdell (1958) reported a 56% reduction in herbage production of bluebunch wheatgrass 3 years after burning.

Pechanec and Stewart (1944) indicated that bluebunch wheatgrass, Cusick bluegrass (*Poa cusickii*) and Thurber needlegrass (*Stipa thurberiana*) were only slightly damaged during the first year after burning, but yield subsequently increased approximately 50%. Wright and Klemmedson (1965) reported that the season of burn was important in determining the extent of damage to Thurber needlegrass, but the size of the bunch determined the amount of fire damage. After a wildfire, as high as 90% of the large plants died but smaller plants survived. Blaisdell (1953) reported that bluebunch wheatgrass was only mildly damaged by burning and within 3 years it had recovered and was producing more herbage on the burned than on unburned areas. Other associated grasses recovered more slowly. Conrad and Poulton (1966) found that crown basal area of bluebunch wheatgrass was reduced 52% following a burn in an ungrazed area. Fire caused a reduction of plant size but not plant density.

This article reports on the 3-year effects of a wildfire upon a sagebrush-bluebunch wheatgrass community, in the semiarid steppe region of south-central Washington.

Study Area and Methods

The study area is located on the east-facing slopes of the Lower Rattlesnake Hills within the Arid Lands Ecology (ALE) Reserve of the Department of Energy's Hanford Reservation. The elevation is approximately 396 m above mean sea level. It receives an average annual precipitation of 23 cm. Rickard et al. (1975) described the study area as a homogenous plant community representative of the *Artemisia/Agropyron* association. The area was fairly uniform in species composition, plant biomass, slope, exposure, elevation, soil type, and soil chemical properties.

Wildfire initiated by a lightning strike in mid-August 1973, burned through a portion of the study area that had been studied as a control site in conjunction with a grazing study performed with the International Biological Program Grasslands Biome Project. A paved roadway separated the study area into two sections and this prevented the fire from burning through the entire community. For the purpose of this report, a 9-ha served as the control (unburned) and an adjacent 9-ha area served as the burned site. Before 1973, the site had not been burned or grazed by livestock for at least 30 years.

Aboveground phytomass was sampled each spring in the years 1974-1976 in eight randomly selected, 15 × 30 m macroplots established in each 9-ha area. Two circular 0.5-m^2 plot frames were than positioned at random within each of the macroplots and all plants were hand-clipped at ground level. All materials were separated by species. Live and dead phytomass were hand-separated, oven dried, and weighed.

Clumps of bluebunch wheatgrass, Cusick bluegrass, and Thurber needlegrass were measured for length of living (green) leaves, flowering culms, and basal area (length × width) when plants were reproductively mature but not dried from summer drought (Uresk et al. 1976). When measuring bluebunch wheatgrass, six clumps were randomly chosen for measurement if more than six clumps were in one circular frame. If fewer than six clumps occurred inside the circular frame, all clumps were measured.

Cusick bluegrass and Thurber needlegrass were only sparsely represented and in this case the first six clumps encountered in a

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search within each 15 × 30 m macroplot were chosen for measurement. All comparisons were subjected to *t*-tests according to the procedures described by Snedecor and Cochran (1967). The three postburning seasons are labeled as first (1974), second (1975), and third (1976).

Results and Discussion

The response of burning upon the three species of grasses is indicated by morphological characteristics and phytomass production. These characteristics give an indication of plant vigor and reproduction as related to the period after burning occurred.

Precipitation

Average monthly precipitation during the three growing seasons after burning is presented in Table 1. The portion of the year considered most influential to plant growth is the period October through May. The first growing season after burning was much wetter than the second and third: 34 cm of precipitation as compared to 24 and 20, which obviously affected the results.

Leaf Length

Burning reduced the average leaf lengths for all three species of grasses (Table 2). Bluebunch wheatgrass responded to burning with shorter average leaf lengths especially in 1974, the first year of postburning. However, during the second year, the burned and control plots had similar leaf lengths. Burning reduced leaf lengths of Cusick bluegrass and Thurber needlegrass in all three years of postburning, but the greatest differences were measured during the first year. Thurber needlegrass showed the greatest sensitivity to burning insofar as indicated by shorter leaves.

Thurber needlegrass also showed the slowest recovery rates over the 3 year perod of postburning (Fig. 1). It will evidently require several more years of recovery before burned plants again produce leaves of normal length. Leaf lengths of bluebunch wheatgrass and Cusick bluegrass were approximately equal to the unburned plants by the second and third years of postburning, respectively.

Culm Length

The flowering culms of bluebunch wheatgrass were substantially taller in the burned plots than in the unburned plots in the first and second years of postburning (Table 2). However, during the third year, the culms were slightly shorter on the burned plots. Cusick bluegrass showed a significant increase in culm length during the second year. Culm length of Thurber needlegrass averaged shorter on the burned area than on the unburned during the 3 years after burning. Figure 1 shows the yearly percent changes in recovery when compared to the unburned plots. Bluebunch wheatgrass and Cusick bluegrass show culm lengths returning to plants on the control during the third year of postburning, while Thurber needlegrass will require several additional years before culm lengths are similar to those in the unburned area.

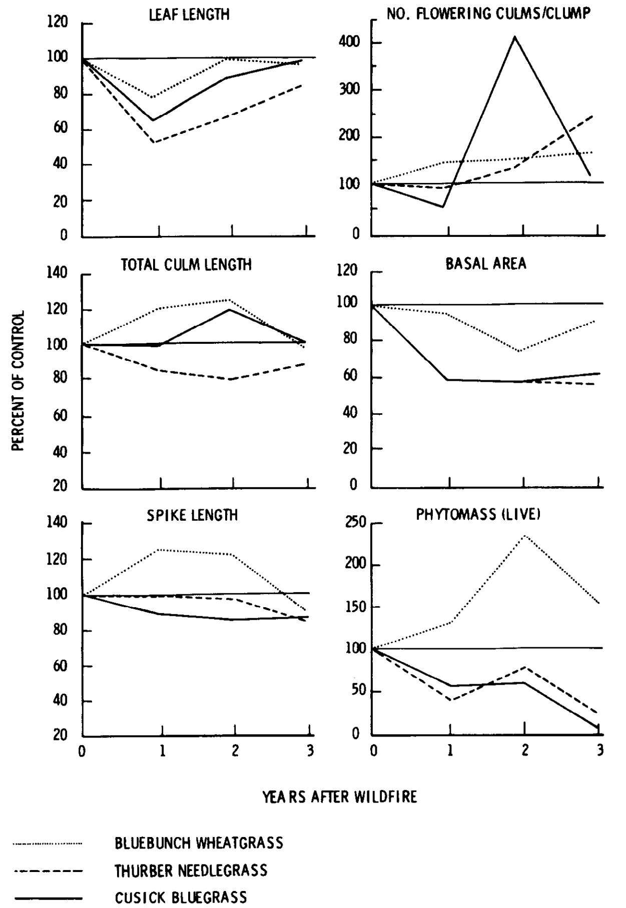

Fig. 1. *Recovery of bluebunch wheatgrass, Thurber needlegrass and Cusick bluegrass for 3 years after a wildfire for leaf length, total culm length spike length, number of flowering culms per clump, basal area, and phytomass (live).*

Spike length

Bluebunch wheatgrass responded to burning by having longer spikes during the first 2 years after burning but showed a significant decrease during the third year (Table 2). Cusick bluegrass showed negative response to burning, spikes were shorter throughout the 3-year postburning period. The spikes of Thurber needlegrass did not respond to burning during the first 2 years, but showed a decrease during the third year of postburning.

The percent change in spikes, when compared to the unburned area, is presented in Figure 1 for all three species. The change in spike length for all three species was shorter during the third year after burning, but was approximately 84–89% of the control.

Number of Flowering Culms Per Clump

Generally, the number of flowering stalks per clump showed an increase for all three species by the second year of

Table 1. Monthly precipitation (cm) during three growing seasons of post-burning.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Sub Total	Jun	Jul	Aug	Sep	Total
1973-74	4.3	8.0	8.4	4.3	4.2	2.8	1.4	0.6	(34.0)	0.2	1.5	0	0	35.7
1974-75	0.4	3.0	3.5	5.5	3.8	4.2	2.5	1.2	(24.1)	1.4	0.3	2.9	<.1	28.7
1975-76	3.1	3.3	3.0	3.0	3.1	1.9	1.8	0.6	(19.8)	0.3	0.9	1.8	<.1	22.8

Table 2. Average leaf length, total culm length, spike length, number of flowering culms per clump, basal area and phytomass measured in burned and adjacent control plots during three years of post-burning. (mean ± standard error)

Year	Bluebunch wheatgrass Burn	Bluebunch wheatgrass Control	Cusicks bluegrass Burn	Cusicks bluegrass Control	Thurber needlegrass Burn	Thurber needlegrass Control
			Total Leaf Length (cm)			
1974	23.9 ± 0.3**	31.1 ± 0.3	14.1 ± 0.2**	21.9 ± 0.2	14.3 ± 0.2**	27.5 ± 0.3
1975	28.7 ± 0.3	29.3 ± 0.2	17.5 ± 0.1**	20.2 ± 0.2	16.8 ± 0.2**	25.8 ± 0.2
1976	26.5 ± 0.3**	28.1 ± 0.3	18.5 ± 0.2**	19.2 ± 0.2	17.1 ± 0.2**	21.1 ± 0.2
			Total Culm Length (cm)			
1974	51.9 ± 0.4**	43.4 ± 1.0	46.6 ± 0.8	46.9 ± 0.6	37.9 ± 0.5**	44.7 ± 0.5
1975	51.3 ± 0.5**	41.7 ± 0.7	43.4 ± 0.5**	36.9 ± 1.4	29.6 ± 0.6**	37.3 ± 1.1
1976	44.0 ± 0.5**	46.3 ± 0.7	41.9 ± 0.5	42.5 ± 0.5	27.0 ± 0.4**	31.5 ± 0.7
			Spike Length (cm)			
1974	8.1 ± 0.1**	6.5 ± 0.2	5.7 ± 0.1**	6.4 ± 0.1	9.9 ± 0.1	9.9 ± 0.2
1975	7.9 ± 0.1**	6.5 ± 0.2	5.8 ± 0.1**	6.8 ± 0.2	9.1 ± 0.2	9.4 ± 0.3
1976	6.5 ± 0.1**	7.3 ± 0.2	5.6 ± 0.1**	6.5 ± 0.1	6.5 ± 0.1**	7.7 ± 0.2
			Number Flowering Culms per Clump			
1974	36.4 ± 7.8	25.7 ± 6.5	6.5 ± 1.2**	13.2 ± 2.5	13.6 ± 1.1	15.4 ± 1.6
1975	37.9 ± 5.5	25.9 ± 5.4	17.5 ± 4.3*	4.3 ± 1.0	6.6 ± 1.1	5.1 ± 1.0
1976	19.8 ± 3.7	12.7 ± 2.7	8.5 ± 1.6	7.8 ± 1.5	9.2 ± 1.3**	4.0 ± 0.5
			Basal Area (l x w)[1] cm²			
1974	244 ± 41	257 ± 47	220 ± 23**	382 ± 35	52 ± 6**	90 ± 8
1975	293 ± 48*	402 ± 52	183 ± 20**	324 ± 29	45 ± 5**	81 ± 8
1976	298 ± 66	337 ± 55	169 ± 16**	285 ± 22	40 ± 4**	75 ± 8
			Phytomass (live) g/m²			
1974	61.1 ± 10.2	46.6 ± 9.6	2.4 ± 1.1	4.3 ± 3.8	0.9 ± 0.5	2.3 ± 2.1
1975	80.7 ± 12.6**	34.3 ± 3.7	1.5 ± 1.4	2.5 ± 2.0	1.1 ± 0.7	1.4 ± 0.6
1976	42.6 ± 3.8**	27.4 ± 3.6	0.3 ± 0.2*	4.1 ± 2.0	0.1 ± 0.1	0.4 ± 0.4
			Phytomass (dead) g/m			
1974	0	58.6 ± 12.5	0	3.8 ± 3.4	0	1.0 ± 1.0
1975	49.8 ± 6.9	46.5 ± 5.7	0	1.0 ± 0.7	0.5 ± 0.5	1.4 ± 0.6
1976	67.3 ± 8.4	48.6 ± 8.0	0.4 ± 0.2*	5.5 ± 2.3	0.1 ± 0.1	0
			Percentage of Clumps with Flowering Culms			
1974	86	74	67	72	100	100
1975	85	90	69**	31	75**	38
1976	67	65	60	65	88	69

* Significantly different from control at .05 level
** Significantly different from control at the .01 level
lXw=length Xwidth; Statisical tests performed on log transformations.

postburning (Table 2). Bluebunch wheatgrass showed an increase in the number of flowering culms per clump throughout the 3 years of restoration. Cusick bluegrass produced the largest number of culms on the burned area during the second year while Thurber needlegrass had the highest number of culms during the third year of postburning. The response rates expressed as a percent of the control are presented in Figure 1 for each species. Bluebunch wheatgrass showed an increase in flowering culms of approximately 50% above the plants in the unburned area during the 3 years after burning. Thurber needlegrass showed a 130% increase by the third year in number of flowering culms per clump. These data suggest that several more years may be required before bluebunch wheatgrass and Thurber needlegrass will be approximately the same for flowering culms as the plants on the unburned area.

Percentage of Clumps with at Least One Flowering Culm

Burning did not reduce the percentage of bluebunch wheatgrass having a flowering culm (Table 2). Yearly differences did occur in the number of clumps with flowering culms, with plants measured in 1976 having the lowest percentage of clumps with culms on both burned and unburned areas. This was also the driest of the 3 years. Cusick bluegrass had an increase of 38 percentage units of clumps occurring with culms during the second year of postburning. However, by the third year no difference occurred. Thurber needlegrass showed that during the first year following the burn, all clumps had flowering culms. During the second and third years, Thurber needlegrass showed a higher percentage of clumps with flowering culms on the burned area.

Basal Area

The basal area of bluebunch wheatgrass showed a significant reduction on the burned area during the second year after burning (Table 2). However, the basal area of Cusick bluegrass and Thurber needlegrass were significantly reduced by burning for all three years of postburning. Fire was more detrimental to basal areas of Cusick bluegrass and Thurber needlegrass than to bluebunch wheatgrass (Fig. 1). It appears that no or very little response has occurred with either Cusick bluegrass or Thurber needlegrass after the first year of postburning.

Phytomass

The production of bluebunch wheatgrass was increased by burning. The burned plots produced more live phytomass than the unburned plots (Table 2). The most pronounced difference occurred during the second year of postburning when 135% more biomass was harvested on the burned area as compared to the unburned area. The average annual biomass production of bluebunch wheatgrass on the burned plots ranged from 43 g/m^2 to 81 g/m^2; on the unburned plot the averages ranged from 27 g/m^2 to 47 g/m^2 over the 3-year postburning period. Production estimates of Cusick bluegrass and Thurber needlegrass were highly variable for these sparsely represented plants in the community. However, general trends indicate that these two species show a negative response to burning (Fig. 1).

This particular fire effectively removed all standing dead bluebunch wheatgrass so there was no residual dead grass on the burned plots at the end of the 1974 season (Table 2). However, most of the 61 g/m^2 production during the first postburning season was still present i.e. 50 g/m^2 at the beginning of the second season. Standing dead grass at the end of the third season averaged 67 g/m^2 indicating that the older portions of standing dead material had been largely transferred to litter. The standing dead phytomass in the control plots ranged between 46 and 59 g/m^2 indicating that about 50 g/m^2 is a reasonable estimate of standing dead material for bluebunch wheatgrass in this area. The average live production amounted to only 36 g/m^2 for the three-year period. This was close to the 42 g/m^2 produced during the years 1971 to 1974 (Rickard et al. 1976).

Other Observations and Relationships to Other Studies

Wildfire is a natural event that usually occurs during late summer months when grasses are mature and dry from summer drought in the steppe region of south-central Washington. The main natural cause of fire is lightning associated with summer storms that typically produce little or no rainfall at the ground surface. The principal persistent change to sagebrush-bluebunch wheatgrass vegetation is the demise of sagebrush. Uresk et al. (1977) estimated the standing crop of sagebrush at 69 ± 16 g/m^2 (±SE). Once sagebrush is burned, the recolonization of the burned land is through seeds. There is no indication that sagebrush was quickly invading the burned area through seed dispersal from the few plants that had escaped burning. However, invasion by sagebrush may occur in later years. Although some clumps of perennial grasses were killed, most survived the burning and were vigorous plants during the spring following the late summer burn. There was also no invasion by weedy species such as *Bromus tectorum*.

Bluebunch wheatgrass is the most abundant grass in the sagebrush-bluebunch wheatgrass association. Although it is not as palatable as Cusick bluegrass (Uresk and Rickard 1976), it is more important in terms of total forage production (Rickard et al. 1975). Because the burning occurred in August, there was little green material other than the crown itself and almost all the photosynthetic and growth activity had been conducted prior to burning. It seems likely that the quick response of recovery following burning was increased by the very favorable moisture regime of the 1973-1974 season and because of the failure of this wildfire to damage crown meristematic tissues. Judging from the reduction of basal area of Cusick bluegrass and Thurber needlegrass these two grasses were more damaged by burning than was bluebunch wheatgrass.

Although burning appeared to have no deleterious impact upon bluebunch wheatgrass as described by Daubenmire (1975) and Mueggler and Blaisdell (1958), it is not certain in our investigation if the results would have been the same if the following growing season had been a drier than average year rather than a wetter than average year.

From the results of this study, it seems clear that different perennial grasses respond to wildfire burning in different ways and that no single measurement we tried appears to provide a way to evaluate overall plant responses.

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Chemical Scarification, Moist Prechilling, and Thiourea Effects on Germination of 18 Shrub Species

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Abstract

Establishment is a major problem of increasing palatable shrubs on rangeland; therefore the objective of this study was to determine the effects of chemical scarification, moist prechilling, and thiourea on seed germination in 18 different shrub species. Scarification for various periods in concentrated sulfuric acid, 10% hydrogen peroxide, and 5.25% sodium hypochlorite (clorox) produced unchanged or reduced germination, except for one hydrogen peroxide treatment of bitterbrush. Moist prechilling prior to germination was conducted on vermiculite moistened with distilled water or 0.2% potassium nitrate for periods up to 16 weeks. In general, prechilling yielded maximum germination, without respect to moistening agent. Seeds treated with thiourea were soaked for periods up to 1 hr in a 0.3% solution. Thiourea treatments were ineffective in increasing germination. On the basis of their germination response to prechilling treatments, bitterbrush, shadscale, big sagebrush, cliffrose, curlleaf mountain mahogany, and golden currant are recommended for fall planting. Apache plume, shrubby cinquefoil and Morman tea could be planted in spring or fall, and winterfat, fourwing saltbush, and Jersey tea should be planted in spring. Constraints other than seed germination, not studied here, must also be considered in planting shrubs for range improvement.

The importance of seasonal availability of palatable range shrubs and their adaptation and establishment on selected range sites has received little attention in other than the western range states. This area of range improvement is recognized in the western states (Cable 1972; Stevens et al. 1977) but direct seeding of desirable native shrubs has met with limited success. Poor stands are often attributed to poor seed germination. Seeds which do not germinate under favorable conditions, but may be induced to germinate, are considered dormant (Mayer and Poljakoff-Mayber 1975). Immature embryos, impermeability of seed coat to water or gases, mechanical causes, light and temperature requirements, or the presence of germination inhibitors are factors which may cause seed dormancy.

Chemical and mechanical scarification, stratification, subjecting seeds to temperature extremes, soaking seeds in various concentrations of thiourea solutions, gibberellic acid, and combinations of one or more treatments have been used to break seed dormancy (Carlson 1974; Everett and Meeuwing 1975; Liacos and Nord 1961; McConnell 1960; McHenry and Jensen 1967; Pearson 1957; Walters 1970).

A hard seed-coat may be impermeable to water, gases, or may constrain the embryo. Scarification (seed coat abrasion/erosion) treatments are used to erode the seed-coat to improve permeability (Amen 1963). Stratification (moist chilling) is believed to limit the effects of inhibitors while promoting growth stimulators such as gibberellic acid. Dilute solutions of potassium nitrate and gibberellic acid are growth stimulators and different concentrations have been used to promote germination of certain species (Mayer and Paljakoff-Mayber 1975; Young et al. 1978). Mirov (1936) observed that stratification treatments increased germination of seeds from plants growing at elevations greater than 1,200 m, while scarification treatments, in some instances, increased germination for species growing at elevations less than 300 m. Considerable difficulty has been encountered by others in establishing palatable shrub species by direct seeding. With this in mind, the objective of our study was to determine the effects of different pre-germination treatments on germination of 18 shrub species, from diverse origins.

Methods

Since seed and availability of palatable shrubs in Oklahoma are limited and the importance of shrubs as livestock browse generally is not recognized, most of the species studied are mountainous or intermountainous in origin. Only *Atriplex* spp., Apache plume (*Fallugia paradoxa*), and mountain-mahogany (*Cercocarpus* spp.) have been evaluated for use in the Southern Plains (Shopmeyer 1974).

Species selected for evalution and study were bitterbrush (*Purshia tridentata*), fourwing saltbush (*Atriplex canescens*), inland Jersey tea (*Ceanothus ovatus*), serviceberry (*Amelanchier alnifolia*), big sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), snowbrush (*Ceanothus velutinus*), winterfat (*Ceratoides lanata*), curl leaf mountain-mahogany (*Cercocarpus ledifolius*), cliffrose (*Cowania mexicana* var. *stansburiana*), Morman tea (*Ephedra viridus*), Apache-plume, prostrate kochia (*Kochia prostrata*), shrubby cinquefoil (*Potentilla fruticosa*), golden currant (*Ribes aureum*), woods rose (*Rosa woodsii*). wedgeleaf ceanothus (*Ceanothus cuneatus*), and chamise (*Adenostoma fasciculatum*). Scientific nomenclature is according to Soil Conservation Service (1971) and USDA Forest Service (1977).

Criteria for selecting those species with potential for Oklahoma rangeland conditions were the availability of seed and reported utilization and winter nutritive value for livestock and big-game. Seeds were obtained from Soil Conservation Service Plant Materials Centers and from commercial seed sources. After processing each seed lot to remove inert appendages (e.g., the winged appendages of fourwing saltbush), heavy, well-filled seeds were separated from the

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light, empty, or immature seeds with a South Dakota seed blower[1]. All seeds utilized in germination studies were counted by hand and considered uniformly well-filled complete seed units. Processing, if any, and storage conditions of seed prior to initiation of study were not known.

Pre-germination treatments (chemical scarification, moist prechilling, and soaking in thiourea ($(NH_2)_2CS$) were replicated 3 times with 25 seeds in each replication. Germination studies were arranged in a randomized complete block design and conducted in a Stultz germinator set for alternating temperatures of 12.5° (night and 20°C (day) for 16 and 8 hr, respectively. Containers used for all germination studies were clear plastic germination boxes 7×7×3 cm containing 70 ml of vermuculite below the seed zone and 30 ml above. A uniform volume of water was added to the vermiculite in each box. Each scarification, moist prechill, and thiourea-soaking treatment involving different treatment durations was terminated simultaneously (i.e., 16-week prechill treatment ended at the same time as the 2-week treatment). Germination counts were made at 7-day intervals for a period of 4 weeks. Seeds were considered germinated when cotyledon or hypocotyl emergence was evident.

Only seeds of bitterbrush, fourwing saltbush, and Jersey tea were used in the scarification experiments, because of a limited supply of seed of other species. Chemical scarification treatments were concentrated sulfuric acid (H_2SO_4), 10% hydrogen peroxide (H_20_2), and 5.25% sodium hypochlorite (NaOC1). The seeds were soaked in each chemical for 0, 3, 6, 9, or 12 hrs. The control consisted of no pretreatment of the seed prior to germination. Seeds removed from each chemical scarification solution were thoroughly washed under running tap-water, and placed in germination boxes in the germinator.

Pregermination chilling treatments consisted of placing the seeds in germination boxes filled with vermiculite, moistening with the appropriate solution of either 0.2% potassium nitrate (KNO_3) or distilled water, and chilling in the dark at 2°C. Bitterbrush, fourwing saltbush, and Jersey tea seeds were subjected to chill durations of 0, 2, 8, and 16 weeks. Because of insufficient seed, the remaining species were prechilled prior to germination for 0, 2, and 10 weeks. The lid of each box was sealed with tape to prevent evaporation loss during prechill.

Thiourea treatments consisted of soaking seeds in a 0.3% solution of thiourea for 0, 20, 40, and 60 min. The control consisted of no pre-soaking of the seed. Following treatment, seeds were washed under running tap-water, transferred to germination boxes, and placed in the germinator.

All data were analyzed on an IBM 370/158 computer using the ANOVA procedure of the Statistical Analysis System (Barr and Goodnight 1972). All differences discussed were statistically significant at the 5% level of probability unless otherwise stated.

Results and Discussion

Scarification

The effects of chemical scarification treatments on seed germination depended upon the chemical and soaking duration. Scarification with hydrogen peroxide produced the highest average seed germination while scarification with sulfuric acid produced the lowest (Fig. 1). With the exception of bitterbrush seeds scarified for 6 hr in hydrogen peroxide, scarification reduced germination below that of the control in all species. Treated bitterbrush and Jersey tea seeds failed to germinate after soaking in concentrated sulfuric acid.

Clorox and concentrated sulfuric acid appear to be too harsh for seed scarification of all three of these shrub species. Soaking the seeds in less concentrated solutions or for shorter durations with all three chemicals studied may have altered the

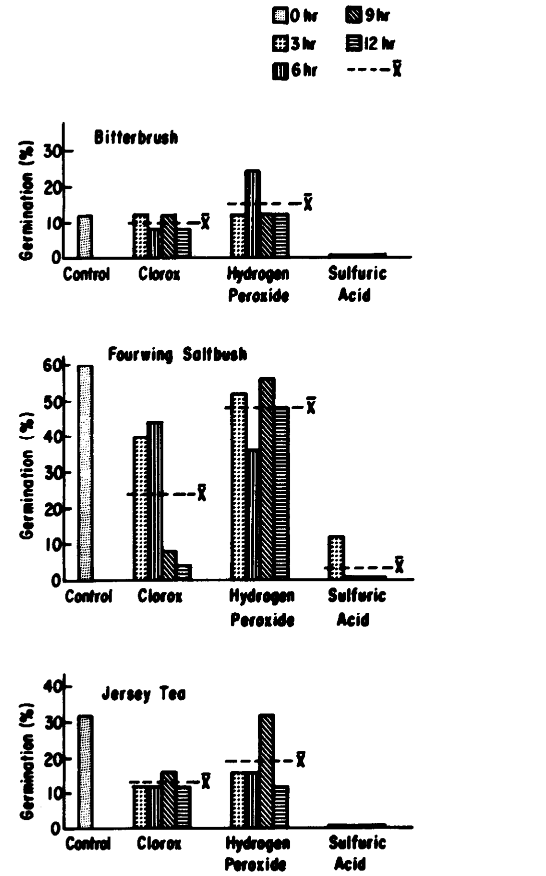

Fig. 1. *Germination of three browse species in response to three chemicals and four soaking time intervals. Time × Treatment $LSD_{0.05}$: bitterbrush, 5.8; fourwing saltbush, 8.0; Jersey tea, 5.5.*

results of this study.

Moist Prechill, Distilled Water and KNO_3

Compared to distilled water as a substrate-moistening agent during prechill, a 0.2% KNO_3 solution did not increase germination of bitterbrush, Jersey tea, or fourwing saltbush seed. Regardless of moistening agent, prechill increased seed germination of all three species (Fig. 2). A direct relationship existed between the mean germination of bitterbrush seeds and length of prechill duration with both moistening agents. Maximum germination of bitterbrush seeds occurred following the 16-week prechill treatment, whereas germination of fourwing saltbush and Jersey tea seeds decreased when subjected to moist prechill durations beyond 2 weeks. Fourwing saltbush and bitterbrush seeds began to germinate while in the prechill environment (2°C) in the 8- and 16-week treatment duration.

Germination averages of Morman tea and shrubby cinquefoil seeds (Fig. 3) were greater when prechilled on substrate moistened with distilled water. Maximum germination of winterfat occurred when seeds received no prechill treatment and were germinated on vermiculite moistened with distilled water. There was an indirect relationship between winterfat seed germination and length of prechill treatments using distilled water as substrate moistening agent.

Big sagebrush, curlleaf mountain-mahogany, cliffrose, and golden currant had greater germination averages when prechilled on substrate moistened with KNO_3 (Fig. 4). Germination of shadscale seeds when prechilled on substrate

[1] Mention of a trade mark of proprietory product does not constitute a guarantee or warranty of the product by Oklahoma State University and does not imply approval to the exclusion of other products that may also be suitable.

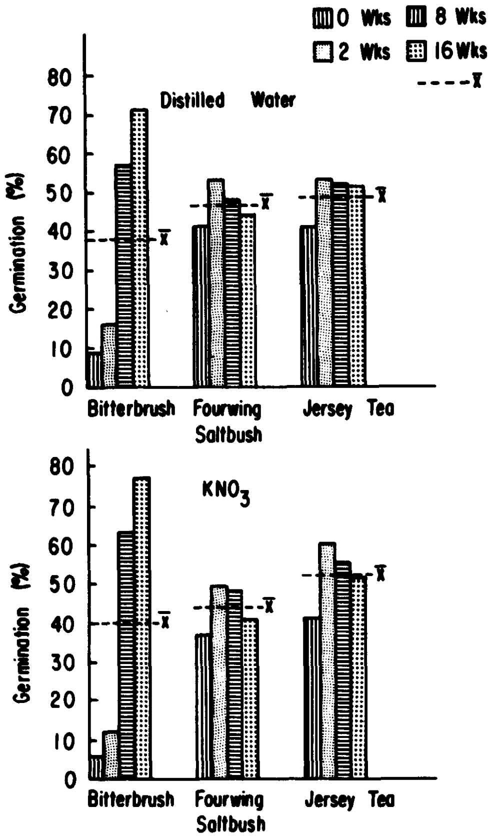

Fig. 2. *Germination of three browse species in response to two moistening agents on seeds prechilled for 0, 2, 8, and 16 weeks. Time × Treatment* $LSD_{0.05}$*: bitterbrush, 4.2; fourwing saltbush, 5.7; Jersey tea, 4.4.*

moistened with 0.2% KNO_3 was sufficiently high to suggest that longer prechill durations may induce a greater number of seeds to germinate. Neither moistening agent nor prechill duration had much effect on germination of Apache-plume.

In general, the use of 0.2% KNO_3 solution as substrate moisture without prechill had no beneficial effect on seed germination over distilled water. However, in combination with prechill the use of KNO_3 on seed germination had (1) a beneficial effect on seeds of big sagebrush, shadscale, curlleaf mountain-mahogany, cliffrose, and golden currant; (2) little or no effect on others such as Apache-plume; and (3) a threshold antagonism to winterfat and shrubby cinquefoil. Regardless of prechill duration, the 0.2% KNO_3 substrate moistening agent had a tendency to delay seed germination during the first 7 to 14 days of incubation. However, this delayed effect disappeared as prechill duration increased.

Potassium nitrate appeared to stimulate early germination of goldent currant. With the exceptions of winterfat, Apache-plume and shrubby cinquefoil, seed germination of all species studied responded to moist prechill. Apache-plume seeds germinated readily regardless of treatment combination.

A direct relationship was observed, for most species, to exist between maximum germination and prechill treatment duration. Maximum germination of big sagebrush, shadscale, curlleaf mountain-mahogany, cliffrose, Morman tea, and golden currant was attained after a 10-week prechill duration. The need for moist prechill durations longer than 10 weeks to attain maximum seed germination of shadscale and curlleaf mountain-mahogany was evident.

Regardless of substrate-moistening agent used during prechill or duration of prechill, serviceberry, snowbrush, prostrate kochia, woods rose, chamise, and wedgeleaf caenothus failed to germinate or germinated less than 5%. Our data suggest that germination of snowbrush and wedgeleaf ceanothus seeds might have been greater if prechill durations with either moistening agent had been longer. Apparently treatments other than moist prechilling are required to germinate seeds of serviceberry prostrate kochia, and woods rose.

Thiourea

Golden currant was the only species for which thiourea promoted germination. Maximum germination of golden currant seeds occurred after seeds were soaked for 40 min in a 0.3% $(NH_2)_2CS$ solution prior to germination.

Bitterbrush, Jersey tea, winterfat, prostrate kochia, and shrubby cinquefoil seed germination results were similar to those obtained by Pearson (1957). He observed an inverse relationship between the concentration of thiourea and length of soaking time required for increased bitterbrush seed germination.

Interactions between light, temperature, and thiourea concentration affect seed germination (Mayer and Poljakoff-Mayber 1975). Apparently the concentration of the thiourea solution used in this study was too low and soaking time

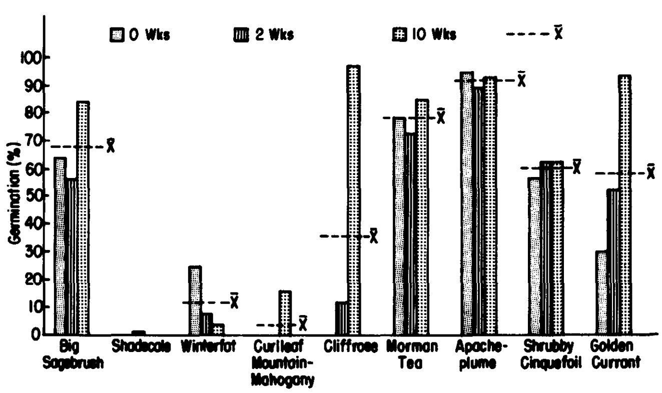

Fig. 3. *Germination effects of distilled water as a moistening agent on seeds of nine browse species prechilled for 0, 2, and 10 weeks. Time × Treatment* $LSD_{0.05}$*: big sagebrush, 30.0; shadscale, 12.0; winterfat, 7.6; curlleaf mountain-mahogany, 9.5; cliffrose, 7.3; Morman tea, 14.6; Apache-plume, 17.4; shrubby cinquefoil, 17.3; golden currant, 18.2*

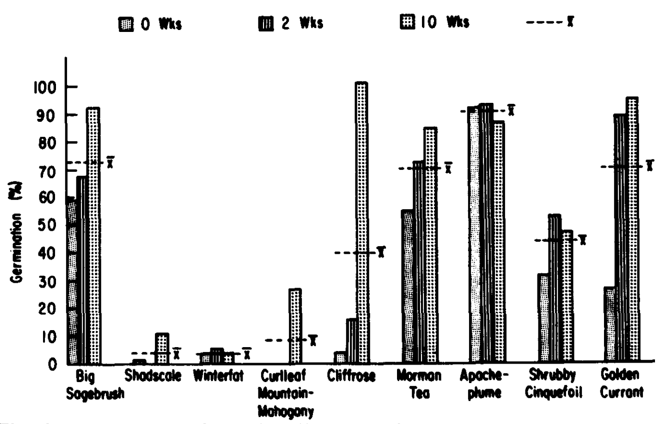

Fig. 4. *Germination effects of 0.2%* KNO_3 *solution as a moistening agent on seeds of nine browse species prechilled for 0, 2, and 10 weeks. Time × Treatment* $LSD_{0.05}$*: big sagebrush, 30.0; shadscale, 12.0' winterfat, 7.6; curlleaf mountain-mahogany, 9.5; cliffrose, 7.3; Morman tea, 14.6; Apache-plume, 17.4; shrubby cinquefoil, 17.3; golden currant, 18.2*

periods too short to effectively promote germination of all species studied except golden currant.

Conclusions

Because many of the shrub species studied are slow to germinate and grow, an understanding of the germination requirements would be advantageous in establishing them on rangelands. It appears highly unlikely that planting seed of bitterbrush, shadscale, big sagebrush, cliffrose, currleaf mountain-mahogany, and golden currant would result in suitable stands if planted in the spring. The prechill requirements for maximum germination suggest that fall planting is required. Other species such as Apache-plume, shrubby cinquefoil, and Morman tea appear to be equally suited to fall and spring establishment. Species, such as winter fat, fourwing saltbrush, and Jersey tea, requiring no prechill or a short prechill duration could be planted in the spring. However, spring seedlings often have a high mortality since drought conditions occur before plants can establish a supportive root system.

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Nitrogen Fertilization of Range: Yield, Protein Content, and Cattle Behavior

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Abstract

Effects of rate and season of nitrogen (N) application on the utilization, crude protein, and yield of mixed prairie in southeastern Wyoming were evaluated. Fertilization increased herbage production, crude protein content and utilization by cattle as measured by both frequency of grazing and forage removal by grazing. Yield and protein content increased linearly with increased amounts of fall applied N, but non-linearly to spring applied N. Forage removal showed a curvilinear response to both spring and fall applied N and was closely correlated with forage yield and frequency of grazing.

Much research on nitrogen (N) fertilization of native rangeland has been conducted in recent years. Forage yields have been increased on native rangeland fertilized with N rates higher than 100 kg/ha (Lorenz and Rogler 1972; Houston and Hyder 1975). Burzlaff et al. (1968) reported increased yield and crude protein content for rangeland fertilized at rates of 34 kg/ha and higher but only higher protein content for forages fertilized at 17 kg/ha. Rauzi et al. (1968), using N rates of 37 and 74 kg/ha reported inceased crude protein but no significant increase in forage yield at a site 19 km east of our study area. Most of the earlier range fertilization studies were conducted for 1 year or if for more than one year then either with spring or fall application.

Forage palatability usually is increased by N fertilization. Burton et al. (1956) applied from 0 to 1,681 kg N/ha to coastal Bermudagrass (*Cynodon dactylon*). The percent of forage consumed by cattle increased with increasing N rate. They found no evidence to indicate that a rate as high as 1,681 kg N/ha reduced palatability. In three different studies, Cook (1965) applied N at rates of 22 and 45, 34 and 67, or 45 and 90 kg/ha to wheatgrass (*Agropyron* spp.) pastures. In each case, utilization increased in proportion to the amount of N applied. Nitrogen fertilization increased palatability of native species in Colorado (Hyder and Bement 1964).

Fertilization also can improve cattle distribution. Smith and Lang (1958) applied 75 kg N/ha to a mountain range site. The utilization on this site was only 15% the year before fertilization. After fertilization, utilization was 73% in the treated area and 55% in the contiguous untreated area. Increased utilization from carry-over effects was significant the next year. Cook and Jefferies (1963) drifted cattle onto plots fertilized with 67 kg N/ha. When these animals revisted the area, they grazed the fertilized areas substantially more than the untreated areas. Hooper et al. (1969) measured the economic value of utilizing fertilized and adjacent unfertilized areas. They showed that, with proper planning and management, fertilization for improved livestock distribution may be profitable.

Our objective was to determine the effect of low rates of N, applied annually either in the spring or fall, on herbage yield, protein content and use of mixed prairie vegetation by cattle.

Study Area and Methods

The High Plains Grasslands Research Station is located in southeastern Wyoming approximately 7 km west of Cheyenne. The topography is rolling hills of mixed grass prairie at an elevation of 1,890 to 1,950 m. The 1941–1977 average annual precipitation reported by the National Weather Service (U.S.D.C. 1941–1977) at the Cheyenne Airport was 365 mm with 70% occurring between April 1 and September 30. The soil on the experimental area is Archerson fine sandy loam, a member of the mixed, mesic family of Aridic Argiustolls. The range site was classed as loamy and consists of deep or moderately deep soils, well drained with a very fine sandy loam or silt loam surface layer. The top 1.2 m of the soil profile will hold 100–180 mm of available water (Rauzi et al. 1976). The vegetation of the experimental area consisted of 40% blue grama (*Bouteloua gracilis*), 20% western wheatgrass (*Agropyron smithii*), 20% needleleaf sedge (*Carex eleocharis*), 10% other grasses, and 10% forbs by weight. Other grasses included needleandthread (*Stipa comata*), prairie junegrass (*Koeleria cristata*) and sandberg bluegrass (*Poa secunda*). The dominant forb was scarlet globemallow (*Sphaeralcea coccinea*).

The experimental design was a randomized block with five treatments and three replications. Nitrogen in the form of ammonium nitrate was applied annually at rates of 0, 22, and 34 kg N/ha to 24 × 30 m plots. Fertilizer was applied to one set of plots in late October of 1974, 1975, and 1976 for the fall treatment and late March of 1975, 1976, and 1977 for the spring treatment to another set of plots. In the spring of each year, five subplots of 0.18 m^2 (1.92 ft^2) in each main plot were randomly located and the previous year's vegetation was removed before plant growth started. Herbage in the subplots was clipped to ground level in August and separated by major species. Crude protein was determined (A.A.O.C., Kjeldahl) for the three major species, blue grama, western wheatgrass, and needleleaf sedge.

In early September yearling heifers were selected from the cow herd to graze all plots free choice. These animals were picked because of their distinctive color pattern, or if they were the same color they were painted differently to make them identifiable. The heifers were allowed 2 days to acquaint themselves with the 4-ha experimental area. Observations of grazing location were made by recording the plot in which each animal was actually grazing. These

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grazing events were recorded every 15 minutes for 3 to 4 hours during the morning and evening intensive grazing periods. In 1975, six heifers grazed for 11 days. In 1976 and 1977, five and six heifers, respectively, grazed for 14 days. Herbage subsamples for each main plot (two per plot in 1975, five per plot in 1976 and 1977) were clipped immediately after grazing.

Results and Discussion

Precipitation for the years 1974–1977 was 251, 272, 279, and 347 mm, respectively, and was lower in all years than the 37-year average of 365 mm (U.S.D.C. 1941–1977). Herbage production was the same for all treatments in 1975 (Table 1). In 1976 herbage yields of all fertilized plots were significantly higher than those of the check. Spring applications of both rates and the 34 kg/ha application in the fall produced higher herbage yields than did the check in 1977. Over 3 years, yield response to fall applied N was linear but response to spring applied N was non-linear (Table 1). Spring applied N gave higher yields than fall applied N at 22 kg/ha, but not at 34 kg/ha.

Table 1. Total herbage production (kg/ha) of mixed prairie range under different rates of N fertilization (kg/ha).

N rate	Season applied	Yield 1975	1976	1977	Mean
0	–	781 a[1]	760 b	761 c	769
22	Spring	872 a	1207 a	1171 a	1083 a
22	Fall	853 a	1050 a	909 bc	937
34	Spring	984 a	1178 a	1029 ab	1064
34	Fall	937 a	1178 a	1039 ab	1051

[1] In this and the next tables, means in the same column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Application of 22 kg N/ha in spring significantly increased crude protein content of all three major species in all years (Table 2). Responses to fall applied N or to 34 kg/ha spring applied N were smaller. The crude protein content of all three species responded in a similar manner, as shown by high inter-species correlations of the 3-year means (r^2-values were as follows: western wheatgrass vs. blue grama, .81; western wheatgrass vs. needleleaf sedge, .96; blue grama vs. needleleaf sedge, .93). Mean crude protein content of three species followed a pattern similar to that of forage yield, with a linear response to fall applied N and a non-linear response to spring applied N, with no differences between season of application at a rate of 34 kg N/ha.

In all 3 years, plots fertilized in the spring with 22 kg N/ha were grazed more often than were the check plots (Table 3). The plots receiving 22 kg N/ha in the fall and either spring or fall applications of 34 kg N/ha were grazed significantly more often then were the checks for 2 of the 3 years. All fertilized

Table 3. Frequency of grazing and forage removal by grazing on mixed prairie range under different rates of N fertilization.

N rate (kg/ha)	Season applied	1975	1976	1977	1975	1976	1977
		Frequency of grazing					
		Events/plot, % of total			Relative number events/t forage		
0	–	3.0 b	3.7 b	3.0 b	3.8 b	4.9 b	3.9 b
22	Spring	8.7 a	8.6 a	8.7 a	10.0 a	7.1 a	7.4 a
22	Fall	7.5 a	5.3 ab	6.9 a	8.8 a	5.1 b	7.6 a
34	Spring	9.4 a	6.8 ab	7.2 a	9.6 a	5.8 ab	7.0 a
34	Fall	6.4 ab	8.9 a	7.6 a	6.8 ab	7.6 a	7.3 a
		Removal by grazing					
		kg/ha			%		
0	–	53 a	−13 b	−21 b	3 a	−2 b	−3 b
22	Spring	117 a	435 a	237 ab	15 a	39 a	21 a
22	Fall	260 a	278 ab	116 ab	33 a	29 a	14 ab
34	Spring	360 a	432 a	208 ab	41 a	39 a	22 a
34	Fall	201 a	305 a	297 a	23 a	29 a	28 a

plots were grazed significantly more often than was the check in 1977. Because it was possible that cattle might have spent more time grazing in plots with more herbage, grazing events also were expressed as the relative frequency of grazing per metric ton of herbage dry matter (events per plot/herbage yield × 1,000). However, grazing frequency per herbage unit followed the same pattern as grazing events per plot. Both showed a non-linear response to N rate, with more grazing on spring fertilized than on fall fertilized plots at 22 kg/ha, but not at 34 kg/ha.

Although a much higher percentage of forage was removed by grazing from fertilized than from unfertilized plots in 1975 (Table 3), the differences were not significant. In 1975 only two subsamples per main plot were clipped after grazing; this small sample produced high variation within treatments that probably accounted for the lack of significance. Five subsamples on each main plot were clipped in 1976 and 1977 both before and after grazing; and the percentage of forage removed from the fertilized treatments was measurably higher than from the check, except from plots receiving 22 kg/ha in the fall in 1977. Forage removal expressed as percent of production followed a non-linear response to N at both application dates. Percent removal from fall fertilized plots appeared to reach a maximum at a lower N rate and to decline more rapidly thereafter than percent removal from spring fertilized plots. However, when removal was expressed in kg/ha, the amount of forage removed increased rapidly from 0 to 22 kg N/ha, then showed little increase to 34 kg N/ha. Removal from spring fertilized range was somewhat higher than that from fall fertilized range. The percentage of the total forage removed by grazing was closely correlated with relative grazing frequency per unit of forage (r^2 = .97). The weight of

Table 2. Crude protein content (%) of major species of mixed prairie range under different rates of N fertilization (kg/ha).

N rate	Season applied	Western wheatgrass 1975	1976	1977	Blue grama 1975	1976	1977	Needleleaf sedge 1975	1976	1977
0	–	7.5 b	12.0 b	11.8 b	9.1 b	10.9 b	9.8 b	9.7 b	12.9 b	11.4 c
22	Spring	10.5 a	15.5 a	14.4 a	12.5 a	13.6 a	11.7 a	12.9 a	16.4 a	13.7 a
22	Fall	9.4 ab	13.3 ab	12.4 ab	11.3 ab	14.0 a	10.5 b	11.5 ab	15.0 a	12.2 bc
34	Spring	9.6 ab	13.7 ab	13.8 ab	12.6 a	13.8 a	11.9 a	12.8 a	15.1 a	13.1 ab
34	Fall	9.5 ab	14.1 ab	14.2 a	11.8 ab	14.1 a	11.9 a	12.5 a	15.7 a	13.6 a

forage removed was more closely correlated with forage yield (r^2 = .90) than with grazing frequency. For the grazing period and type of cattle use in this study, approximately one additional kilogram of forage was grazed for each additional kilogram of forage produced.

Maturity of forage plants can be a factor in determining palatability and degree of utilization by cattle (Marten 1970). However, maturity was unimportant in this study because herbage on all treatments had reached an equally advanced stage of maturity by the time the experimental area was grazed.

Conclusions

Nitrogen fertilization of mixed-grass prairie increased the herbage production; the crude protein content of western wheatgrass, blue grama, and needleleaf sedge; and the utilization of forage by grazing heifers. Spring N application produced higher yields, crude protein content, and grazing frequency than fall N application at 22 kg/ha but not at 34 kg/ha. Application of 34 kg/ha at either season did not result in greater yield, protein content, or utilization than did application of 22 kg/ha in the spring. Because years of below-normal precipitation are certain to occur, although not predictably, our study during a 4-year period of low precipitation showed that the conservative treatment of 22 kg N/ha applied in the spring would be most consistently effective.

Cattle clearly preferred to graze N-fertilized range over unfertilized range when the two were contiguous. If this preference is strong enough, cattle might move considerable distances to graze fertilized range. Thus, fertilization to attract cattle to previously underutilized range should be studied further.

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The Response of Native Vertebrate Populations to Crested Wheatgrass Planting and Grazing by Sheep

TIMOTHY D. REYNOLDS AND CHARLES H. TROST

Abstract

Native vertebrate population levels were examined in grazed and ungrazed habitats dominated by big sagebrush (*Artemisia tridentata*) and crested wheatgrass (*Agropyron cristatum*) in southeast Idaho. Our objective was to determine the species diversity and relative density of birds, mammals, and reptiles in these habitats with and without grazing pressures by sheep. In a habitat dominated by sagebrush, grazing did not significantly alter the species diversity or the density of reptiles or nesting birds. However, both the diversity and the relative density of small mammals were significantly reduced. Crested wheatgrass plantings, regardless of sheep use, supported fewer nesting bird species and a lower density of birds, mammals, and reptiles than did areas dominated by sagebrush. The synergistic effects of planting with crested wheatgrass followed by grazing were most evident in (1) a significant reduction in the relative density of small mammals, and (2) the occurrence of only one nesting bird species: the horned lark (*Eremophila alpestris*).

At one time over 100 million ha of the western rangelands in the United States were covered with sagebrush, mostly big sagebrush (*Artemisia tridentata*) (Beetle 1960). Historically, the primary use of sagebrush rangeland has been for livestock grazing. Many areas formerly dominated by sagebrush have been burned, chained, disced, plowed, or sprayed and reseeded with grasses to improve forage for livestock. Additionally, crested wheatgrass (*Agropyron cristatum*) is being planted in the Intermountain West in an attempt to reclaim strip-mined lands. Braun et al. (1976) estimated that a minimum of 10% of the native sagebrush vegetation in western U.S. has been treated in one way or another. In Idaho alone, 650 thousand ha of public land (BLM document 1974) and 200 thousand ha of private land (L. Sharp, pers. comm.), mostly dominated by sagebrush, have been reseeded with crested wheatgrass. Until recently, little concern was expressed about the potential effects of alteration of sagebrush range on wild animals. The objective of this study was to determine the response of native vertebrate populations (birds, mammals, and reptiles) to different land use practices on the Idaho National Engineering Laboratory (INEL) Site.

Study Areas

The INEL Site, located approximately 48 km west of Idaho Falls, Ida., is a nuclear reactor test facility administered by the U.S. Department of Energy. In 1975 the 2,315-km^2 site was designated as a National Environmental Research Park. As such, stringent controls have been placed on the alteration of habitat and the harassment of wildlife. A notable exception to this is that sheep and cattle are allowed to graze the periphery of the Site, and in those grazed areas predator control is permitted. The climate, topography, and vegetation of the INEL Site are representative of the Upper Great Basin and are characterized by hot summers and cold winters, flat to gently rolling landscape, with big sagebrush as the dominant vegetation.

Four areas of different land treatment were selected for study. Two of these were dominated by big sagebrush, and two were former sagebrush range reseeded with crested wheatgrass. One sagebrush and one crested wheatgrass study area were located just within the southern boundary of the INEL Site. These two areas, each covering over 100 km^2, were contiguous and were a portion of a grazing allotment used by 1,000-1,200 sheep each spring since 1960. The crested wheatgrass here was planted in 1958 or 1959 (INEL Site records vary) after disc removal of the native sagebrush. These areas will be referred to as *Grazed Sage* and *Grazed CWG*. The other two study areas were approximately 12 km northwest of the grazed areas, within that portion of the Site protected from grazing. The sagebrush here (*Ungrazed Sage*) was periodically grazed prior to 1950 but had no domestic livestock on it for over a quarter of a century. This was the control area for the study. The adjacent crested wheatgrass habitat (*Ungrazed CWG*) was planted in the summer of 1960, after winter flooding inundated and killed the native sagebrush (A. Olson, pers. comm.). Livestock have never been permitted in this reseeded area.

Materials and Methods

Detailed descriptions of the materials and methods used in this study can be found in Reynolds (1978). Briefly, the vegetation in each study area was sampled at 160 sampling points with 0.1 m^2 sampling frames. The number of plots in which a species occurred (frequency) and the estimated canopy coverage (Daubenmire 1959) were recorded for each plant species. Data concerning birds and large mammals were gathered via visual observation. This information was the result of equal time spent in a 4-ha grid in each of the study areas. Small mammals were sampled using Museum Special snap traps set in a Type-A trap line (Calhoun 1959). One-hundred and twenty snap traps were set concurrently in all four study areas for three nights each month from January 1976 through February 1977. The traps were moved each sampling period to ensure that population densities, rather than recruitment levels, were being measured. Reptiles were sampled by a series of pitfall traps in a 4-ha grid system with the traps at 50-m intervals. All reptiles collected in the traps, and those captured within the study areas by hand or with a noose, were marked with indelible ink for individual identification. For all taxa, the number of individuals encountered and/or collected in any study was

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considered to be an indication of the relative density of that particular species in that habitat. Differences in the relative densities were tested with the Chi Square test (Sokal and Rohlf 1969). A species diversity index was calculated independently for vegetation, birds, and mammals using the transformation of the Shannon-Weiner function (Zar 1974):

$$H = \frac{n \log n - \Sigma f \log f}{n}$$

where f was the frequency of each species and n was the total frequency of occurrence of all species. Differences in species diversity were compared with the t-test developed by Hutcheson (1970). The level of significance for all statistical tests was $P<0.05$.

Results

Vegetation

The control area (*Ungrazed Sage*) contained 31 plant species (Table 1) and had a species diversity index (H) of 2.85. This was significantly higher than all other study areas. Big sagebrush occurred in 66% of the sampling plots in the control area and accounted for 41% of the total canopy coverage. The *Grazed Sage* contained only 9 species of plants (Table 1). Here sagebrush was found in 71% of the sampling plots and provided 65% of the total canopy cover. Crested wheatgrass was found in all 160 sampling plots in the *Ungrazed CWG* and in 154 plots (96%) in the *Grazed CWG,* providing 98% and 89% of the total canopy coverage respectively.

Table 1. Percent coverage (%) and frequency (f) of plant species in grazed and ungrazed habitats dominated by sagebrush (*Artemisia tridentata*) and by crested wheatgrass (*Agropyron cristatum*) on the INEL Site. Only those species with frequency of 10 or more, or a percent coverage of at least 1% are included.

	Ungrazed				Grazed			
	Sagebrush		Crested Wheatgrass		Sagebrush		Crested Wheatgrass	
	%	f	%	f	%	*f*	f	f
Opuntia polyacantha	1.3	13						
Chenopodium leptophyllum	0.6	17						
Artemisia tridentata	17.00	105			25.00	113	0.5	5
Aster scopulorum	0.7	23						
Chrysothamnus nauseosus	0.2	3			1.6	15	0.4	5
Arabis spersiflora	0.3	11	1.0	15				
Agropyron cristatum	1.9	15	52.0	160			39.4	154
Agropyron spicatum	6.0	35						
Oryzopsis hymenoides	5.2	34	0.2	3				
Poa sanbergii	1.8	16						
Sitanion hystrix	3.0	35			9.2	93		
Astragalis purshii	1.9	16						
Phlox hoodii					1.4	11		
Halogeton glomeratus					1.4	4	3.9	13
Total numbers of species	31		3		9		5	
Total % coverage	41.6		53.2		38.7		44.1	
Species diversity (H)	2.85		0.37		1.17		0.54	

Nesting Birds

A total of 71 bird nests, representing 10 species of bird: was found during the study (Table 2). There were n significant differences in either the density or the diversity c birds nesting in the *Ungrazed* and *Grazed Sage* habitat Conversely, both crested wheatgrass habitats had significantly lower species diversity and relative density c nesting birds than both the control areas and the *Graze Sage.*

Table 2. Number of nests located in grazed and ungrazed habitats dom nated by sagebrush (*Artemisia tridentata*) and by crested wheatgra: (*Agropyron cristatum*) on the INEL SIte, 1976 and 1977.

	Ungrazed		Grazed	
Species	Sagebrush	Crested Wheatgrass	Sagebrush	Crested Wheatgrass
Sage grouse *Centrocercus urophasianus*	0	0	1(1*	0
Mourning dove *Zenaida macroura*	5(2)	0	1(0)	0
Short-eared owl *Asio flammeus*	1(1)	1(1)	0	0
Loggerhead shrike *Lanius ludovicianus*	1(1)	0	1(1)	0
Horned lark *Eremophila alpestris*	0	4(3)	1(0)	4(2)
Western meadowlark *Sturnella neglecta*	1(1)	4(3)	0	0
Sage thrasher *Oreoscoptes montanus*	8(5)	0	14(10)	0
Vesper sparrow *Pooecetes gramineus*	0	1(1)	0	0
Sage sparrow *Amphispiza belli*	7(3)	0	9(6)	0
Brewer's sparrow *Spizella breweri*	4(1)	0	3(0)	0
Area Totals	27(14)	10(8)	30(18)	4(2)
Species diversity index (H)	1.67	1.19	1.40	0.00

* Number of successful nests in parenthesis.

Small Mammals

A total of 548 small mammals, representing 9 species w: collected during 20,160 trap nights (Table 3). The relati' density of small mammals was significantly greater in tl control area than in any other habitat examined. Althou; the *Grazed CWG* area had a relative density of sma mammals significantly below that in all other study area this was the only area that did not have a species diversi' index significantly below that found in the control area.

Large Mammals

Visual sightings, as a sampling technique, are biased favor of large diurnal animals. Thus, to reduce this bia observations of the pronghorn antelope (*Antilocap. americana*) were not included in the relative density a1 species diversity comparisons for large mammals. T number of large mammals sightings are given in Table The relative density of large mammals was essentially t same between the two habitats dominated by sagebrush, b was significantly below the control in both of the crest wheatgrass areas. This same trend was apparent in t species diversity comparisons.

Table 3. Small mammals collected by snap traps in grazed and ungrazed habitats dominated by sagebrush (*Artemisia tridentata*) and be crested wheatgrass (*Agropyron cristatum*) on the INEL Site, 1976-1977.

	Number collected			
	Ungrazed		Grazed	
Species	Sagebrush	Crested Wheatgrass	Sagebrush	Crested Wheatgrass
Peromyscus maniculatus	131	96	130	31
Reithrodontomys megalotis	11	56	8	2
Eutamias minimus	1	1	15	0
Onychomys leucogaster	12	1	4	3
Dipodomys ordii	2	0	2	5
Citellus townsend	4	0	0	2
Perognathus parvus	3	2	0	0
Lagurus curtatus	2	1	0	0
Microtus montanus	1	1	0	1
Total number collected	187	158	159	44
Number of species	9	7	5	6
Species diversity index (H)	1.11	0.85	0.69	1.04

Reptiles

Four species of reptiles were encountered during the study. Two of these were serpentine species: the gopher snake (*Pituophis melanoleucus*) and the Great Basin rattlesnake (*Crotalus viridis*), which were found only in the grazed study areas (Table 5). Linder and Sehman (1977) state that these two species are common and widespread over the INEL Site. Sehman (1978) further states that the maximum dispersal distance recorded on the Site from a winter hibernaculum is less than 2 km. From this, we must assume that the two ungrazed study areas were greater than 2 km from a suitable denning site. This indicated a bias in our sampling technique, and serpentine species were therefore eliminated from further analysis.

The lizard data, however, were comparable. Both the *Grazed* and *Ungrazed CWG* study areas had a relative density of lizards significantly below that found in the control area, although the diversity of lizards was significantly lower only in the *Grazed CWG* habitat. There were no statistical differences in either the density or the diversity of lizards between the two sagebrush habitats.

Table 4. Number of mammals observed in grazed and ungrazed habitats dominated by sagebrush (*Artemisia tridentata*) and be crested wheatgrass (*Agropyron cristatum*) on the INEL Site.

	Number of observations			
	Ungrazed		Grazed	
Species	Sagebrush	Crested Wheatgrass	Sagebrush	Crested Wheatgrass
Mustela frenata	1	0	0	0
Canis latrans	8	9	1	0
Eutamias minimus	18	0	19	5
Neotoma cinerea	1	0	0	0
Citellus townsendi	1	1	1	5
Lepus californicus	1	0	2	0
Sylvilagus nuttalli	1	0	2	0
Sylvilagus idahoensis	0	0	1	0
Total registrations	31	10	26	10
Number of species	7	2	6	2
Species diversity index	1.22	0.33	1.00	0.69

Table 5. Number of reptiles encountered in grazed and ungrazed habitats dominated by sagebrush (*Artemisia tridentata*) and by crested wheatgrass (*Agropyron cristatum*) on the INEL Site.

	Number encountered			
	Ungrazed		Grazed	
Species	Sagebrush	Crested Wheatgrass	Sagebrush	Crested Wheatgrass
Short-horned lizard (*Phyrnosoma douglassi*)	17	4	26	7
Sagebrush lizard (*Scelòporus graciosus*)	37	5	21	0
Gopher snake (*Pituophis melanoleucus*)	0	0	2	0
Great Basin rattlesnake (*Crotalus viridis*)	0	0	3	3

Discussion and Conclusions

Grazing and crested wheatgrass planting significantly reduced the plant species diversity. The *Grazed Sage* had only 1/3 as many plant species as the control area. This paucity of species richness affected the plant species diversity, but the overall physiognomy of the area remained unchanged. Big sagebrush was still abundant and provided the overstory, while grasses and forbs, albeit few species of each, comprised the understory. As such, the relative density and diversity of nesting birds, large mammals, and lizards were essentially unchanged from the control condition. Insects are the major food source for passerine birds on the Snake River Plain during the summer months, while lizards feed extensively on ants (Guyer 1978). Although the distribution of insect species may be altered by changes in vegetation, the availability of insect prey is not necessarily affected. Active ant mounds are ubiquitous on the Snake River Plain and appear to be as common (or even more so) in grazed habitats as they are in ungrazed areas. Additionally, birds as well as large mammals are highly mobile species, able to move large distances in search of food. Thus, any changes in the vegetation caused by grazing in a habitat dominated by sagebrush apparently did not affect either the food base or the use of the habitat by birds, lizards, or large mammals.

Populations of small mammals were, however, significantly reduced in the *Grazed Sage* study area. Small mammals are, for the most part, vegetarians, feeding on seeds or herbaceous material. The decrease in the forbs and grasses suitable for rodent forage was most likely responsible for the reduced diversity and density of small mammals in this area.

Planting a former sagebrush range to crested wheatgrass has a more widespread affect on wildlife populations. Not only is the vegetational diversity reduced to a virtual monoculture, but the entire structure of the habitat is altered. Many species of animals that have evolved in a sagebrush habitat are so tightly tied to that habitat that they apparently are unable to colonize other environments. Notably, the Sage Grouse, Sage Thrasher, Sage Sparrow and Brewer's Sparrow are considered to be sagebrush obligates almost entirely dependent on the sagebrush environment (Braun et al. 1976). Additionally, the two species of lizards encountered in this study may be similarly linked to the sagebrush habitat (Dumas 1964). Thus, it is not surprising that the study areas dominated by crested wheatgrass contained population densities below those found in the control area for all the vertebrate groups examined. It is of interest to note that although the relative densities of small mammals and lizards in the crested wheatgrass areas were below the control, neither the diversity of reptiles in the *Ungrazed CWG,* nor the diversity of small mammals in the *Grazed CWG* were significantly altered. We do not believe that this accurately reflects the response of these groups to different land use practices but demonstrates a shortcoming inherent in all diversity indices: unequal response to unequal sample size. There is an inverse relationship between the number of individuals in a sample and the magnitude of the effect the addition or deletion of a species has on the species diversity index. Thus, with only 9 lizards found in the *Ungrazed CWG,* and only 44 mammals trapped in the *Grazed CWG,* the important aspect is not the quality of the diversity indices, but the actual reduction in the respective populations.

In summary, the alteration of native sagebrush on the INEL Site was accompanied by a differential response of native vertebrate populations to each land management practice. Although small mammal populations were reduced in the *Grazed Sage*, the planting of crested wheatgrass had a more severe effect on wild animal populations than did grazing by sheep. However, the synergistic effect of both grazing and reseeding resulted in the lowest population levels of all the vertebrate classes examined. Birds seemed to receive the brunt of the synergistic effects. The horned lark (*Eremophila alpestris*) was the only species found to nest in the area that was both planted and grazed. And, during both years of the study, even though horned larks were nesting in the *Ungrazed CWG,* they did not begin nesting activities in the *Grazed CWG* until almost 2 weeks after the sheep had been moved to a different range. Thus, physical disturbances, as well as vegetation changes brought about by different land use practices, have an effect on wildlife.

In the Intermountain West we have been fortunate to have a thriving and successful agribusiness without the total loss of good wildlife habitat. However, as the need for more agricultural products increases, and more and more rangeland is altered to meet these needs, we run the risk of seriously reducing, perhaps even losing, the populations of many of our native vertebrate species. We do not advocate that agriculture production be reduced so that a few birds, mammals, and reptiles can survive: but we do feel that with foresight and the proper mitigation measures we can continue to have the best of both worlds. Setting aside portions of the public lands as wilderness or primitive areas would ensure the survival of many species that otherwise may be extirpated by modern agricultural practices. Additionally, these refugia would, like the INEL National Environmental Research Park, serve as a yardstick with which to measure the impacts of land management practices in the future.

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Fall and Winter Diets of Feral Pigs in South Texas

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Abstract

During late fall and winter of 1975-76 and 1976-77, contents of 41 stomachs were analyzed to determine foods of feral pigs in extreme southern Texas. Thirty-six food items were identified, including 32 plant taxa and four types of animal matter. Average volume for food classes were 55.8% forbs, 17.3% grasses, 9.8% sedges, 7.6% woody plants, 4.7% unknown plants, and 4.8% animal matter. Mossrose, an annual forb, was the most important item in the diet, comprising 21.8% of the total volume. Important differences occurred in the diet between years among forbs, grasses, and sedges. The 1975-76 diet was comprised of 41.1% forbs, 24.7% grasses, and 15.4% sedges, as compared to 73.0% forbs, 8.2% grasses, and 3.3% sedges in the 1976-77 diet. Our results indicated that feral pig diets could be competitive with those of livestock and wildlife. The pigs' extensive rooting may result in at least partial removal of many plant species from the range; however, these disturbed areas cause a shift in plant succession which is beneficial to some wildlife.

Feral pigs (*Sus scrofa* L.) are common on many south Texas rangelands. Ranchers, as well as range and wildlife ecologists, are concerned with the ecological effects these animals might have on livestock and wildlife. Of particular concern is the possibility of competition for food among feral pigs, livestock, and wildlife.

Little information is available concerning the food habits of feral pigs. Henry and Conley (1972) investigated the fall food habits of European wild hogs in Tennessee and revealed some competition with other wildlife, mainly for fruits. Springer (1975) studied the year-round food habits of wild hogs at the Aransas National Wildlife Refuge on the Texas Gulf Coast and found they competed, to some degree, with several species of wildlife for seasonal fruits.

The objectives of this study were (1) to determine the overall food habits in late fall and winter of feral pigs and (2) to compare their food habits during the late fall and winter of 1975-76 and 1976-77.

Study Area

We conducted our study on the Yturria Ranch, which is about 13 km north of Raymondville, Texas. The ranch has 7,200 ha of native and improved rangeland. This area is in a transition zone between the Coastal Prairies and the South Texas Plains (Gould 1975).

The climate is mild as average growing season exceeds 325 days (Dallas Morning News 1975). The average rainfall is 70 cm. Rainfall normally is heaviest in May and September.

The topography is flat to gently sloping; elevation ranges from sea level to 30 m (U.S. Geological Survey 7.5-minute topographical maps). Two range sites make up the immediate study area, and a third is adjacent to the area. The major range site is the tight sandy loam site with Delfina fine sandy loam soil (Aquic. Paleustalfs). This site supports a dense cover of mixed woody vegetation. Drawe et al. (1978) classified such sites as "chaparral-mixed grass" communities. Large mesquite (*Prosopis glandulosa* Torr.) trees dominate the overstory and granjeno (*Celtis pallida* Torr.), lime pricklyash (*Zanthoxylum fagara* (L.) Sarg.), and bluewood (*Condalia hookeri* M.C. Johnst.) make up a dense secondary layer. Major grasses are several species of bristlegrass (*Setaria* spp.) and four-flowered trichloris (*Trichloris pluriflora* Fourn.). Abundant forbs are mossrose (*Portulaca mundula* I.M. Johnst.), pigeonberry (*Rivina humilis* L.), and western ragweed (*Ambrosia psilostachya* DC.).

The laguna range site is the second site in the area. It occurs in depressions ranging from 0.5 to 4 ha in size. Although areas of this range site are dispersed throughout the study area, it makes up only 3 to 5% of the total land area. It is associated with Tiocano clay soil (Udic Pellusterts). Water often stands on the surface throughout the year. These depressions catch runoff from surrounding terrain, since there are no streams in the area. Lagunas support a variety of grasses, sedges, and forbs.

The sandy mound range site is adjacent to the study area. It is associated with deep, sandy Falfurrias-Sarita soils (Typic Ustipsamments and Grossarenic Paleustalfs, respectively). This site is moderately brushy with motts of live oak (*Quercus virginiana* Mill.) breaking the landscape. The herbaceous plant community is dominated by a variety of short grasses and forbs.

The major land use on the study area is cattle ranching, currently a cow-calf operation. The area also supports several important game animals including white-tailed deer (*Odocoileus virginianus* Boddaert), javelina (*Pecari tajacu* L.), and nilgai antelope (*Boselaphus tragocamelus* Pallas). Feral pigs are abundant, but no estimates of their population density are available.

Methods

Food habits were determined by stomach content analyses. Forty-one feral pigs were collected at 1- to 2-week intervals from November through February over a 2-year period. Twenty-two animals were collected in 1975-76 and 19 were collected in 1976-77. Many of the sample pigs were killed by hunters.

Study animals were normally collected during early morning and late evening feeding hours. Thirty-seven animals were collected from the tight sandy loam range site and four were collected from the small laguna sites. We did not separate animals by range site, since the lagunas occupied such a small part of the study area.

Plant species composition data were obtained from the tight sandy loam and laguna sites, and also from the sandy mound site, since pigs frequently used this site even though it was not on the immediate study area. Plant composition data were taken to determine preference ratings for plant species in pig diets. Woody species composition was determined by means of ten 30.5-m line transects

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(Canfield 1941). For the tight sandy loam and sandy mound sites, herbaceous composition was determined by clipping all vegetation at ground level in 20 quadrats, each 50 × 50 cm (Stewart and Hutchins 1936). Composition was determined by dry weight by separating species in each quadrat. Since the laguna sites were partially inundated, species composition was determined by a point frame (Tothill and Peterson 1962). The point frame was placed every 3.05 m along each line transect, giving a total of 100 point frames for herbaceous species composition. Vegetational sampling sites were selected at random on the range sites. Vegetation was sampled twice during each pig collection period.

A 0.95-l random sample was taken from the entire stomach contents of each pig. Samples were preserved in formalin and later analyzed for composition by the point frame method (Chamrad and Box 1964). We collected most herbaceous plant species (including roots) on the study area to assist us in identifying stomach contents. We grouped the stomach contents into six classes: forbs, grasses, sedges, woody plants, animal matter, and unknown plant material. All data are reported as averages for each category.

Preference ratings were developed for each major plant species in pig diets by using the formula described by Chamrad and Box (1968):

$$\text{Preference Rating} = \frac{\text{\% Frequency of Occurence} \times \text{\% Volume}}{\text{Availability Factor}}$$

Percentage volume for each plant species eaten was derived from the percentage of total points contacting that species in the stomach sample. Percentage frequency of occurrence was the percentage of pig stomachs in which a given plant species was found. The availability factor is a numerical value related to plant abundance on the range, determined from range data on plant species composition. The following availability classes and numerical values were used: rare (0 to 0.50% composition) – 1; occasional (0.51 to 2.50% composition) – 2; frequent (2.51 to 5.00% composition – 3; and abundant (>5.00% composition)–4. All plant species growing on the laguna and sandy mound sites were considered rare in availability, since these sites made up such a small part of the study area or were outside the study area.

Data were analyzed by analysis of variance and by the t-test. All statistical comparisons were made at the 5% probability level.

Results and Discussion

Overall Food Preferences

Based on the analyses of 41 stomachs, average volume percentages for the various food classes were 55.8% forbs, 17.3% grasses, 9.8% sedges, 7.6% woody plants, 4.7% unknown plants, and 4.8% animal matter. The percentage of forbs was significantly higher than those of the other classes.

Thirty-six food items were identified in the pig diet. This included 32 plant taxa and four types of animal matter. The plant taxa included 18 forbs, 8 grasses, 1 sedge, and 5 woody plants. These data showed that feral pigs relied chiefly on herbaceous plants for the bulk of their diet. All plant parts were consumed; roots made up a large percentage.

Twelve items made up 73.4% of the pigs diet (Table 1). These included eight forbs, one sedge, one grass, one woody plant, and carrion. Mossrose, an annual forb that often remains green through the mild winters, was the most important item in their diet. It had a higher percentage frequency of occurrence and preference rating than any other plant species in their diet. Three stomachs contained more than 90% mossrose by volume.

Sedges (*Cyperus* spp.) were the second most important item in the diet. Longtom (*Paspalum lividum* Trin.) was the most utilized grass species. Live oak was the only woody plant of importance in the diet, and pigs ate only acorns. Moreover, live oak was the only important plant in the pigs' diet from the sandy mound site, indicating that the pigs were going to this site to eat acorns. They consumed acorns in November and December. These findings support those reported by Henry and Conley (1972) and Springer (1975), who found acorns to be an important constituent in the fall diet of wild hogs. Carrion comprised the major portion of the animal matter in the diet.

Since the lagunas often hold water through the winter, green growth on them is more available than on the upland tight sandy loam and sandy mound sites. Although lagunas made up only 3 to 5% of the total land area, the high use of burhead

Table 1. Frequency of occurrence, volume, availability, and preference rating of major food items eaten by feral pigs in the late fall and winter of 1975-76 and 1976-77 in south Texas.

Species or variety	Frequency[1]	Volume[2]	Availability Factor[3]	Preference rating[4]
Plants[5]				
Portulaca mundula I.M. Johnst.	68	21.8	4	370
Cyperus spp.	37	9.8	1	363
Paspalum lividum Trin.	37	8.4	1	311
Echinodorus rostratus (Nutt.) Engelm.	24	5.8	1	139
Quercus virginiana Mill.[6]	15	5.3	1	80
Ambrosia psilostachya DC.	32	4.1	4	33
Urtica chamaedryoides Pursh	10	3.5	3	12
Phyla nodiflora (L.) Greene	24	3.3	1	79
Tradescantha micrantha Torr.	24	2.7	2	32
Marsilea macropoda A. Br.	27	2.4	1	65
Phyla incisa Small	12	2.0	1	24
Animal Matter				
Carrion	10	4.3	–	–

[1] Frequency of occurrence in 41 stomachs.
[2] Percentage volume = Number of point hits per food item ÷ Total number of sampling points in 41 stomachs.
[3] Availability factor: Rare = 1, Occasional = 2, Frequent = 3, Abundant = 4.
[4] Preference ratings = (% Frequency of occurrence × % volume) ÷ availability factor
[5] Plant names are according to Correll and Johnston (1970).
[6] Mast.

(*Echinodorus rostratus* (Nutt.) Engelm.), water clover (*Marsilea macropoda* A. Br.), frog-fruit (*Phyla incisa* Small), turkey-tangle (*Phyla nodiflora* (L.) Greene), longtom, and sedges, which grow primarily on these sites, indicated the importance of these areas to feral pig diets during the fall and winter. These six plants contributed 31.7%, by volume of the diet. This corresponds with the findings of Springer (1975), who reported that marshy areas provided feeding areas as well as relief from the heat for wild hogs on the Texas Gulf Coast. Scifres and Mutz (1975) and Everitt and Gonzalez (1979) showed that these areas were frequently used by both wildlife and livestock as watering and feeding areas. We think another reason that pigs used these lagunas was that the soil was soft and moist and they could uproot the plants more easily. We observed a large amount of rooting in these areas (Fig. 1).

Fig. 1. *Rooting by feral pigs destroys plants but provides lower-successional microhabitats.*

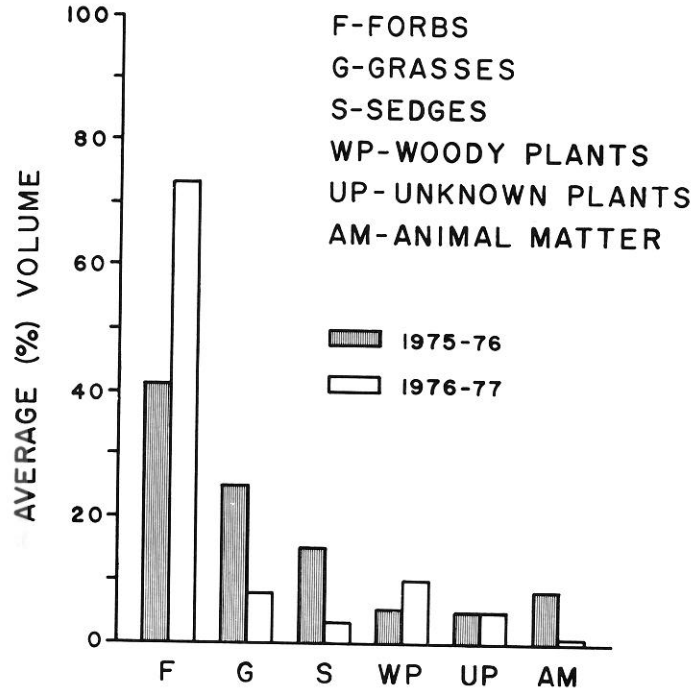

Fig. 2. *Feral pig food habits on the Yturria Ranch in south Texas for the late fall and winter of 1975-76 as compared with the late fall and winter of 1976-77.*

Comparison of 1975-76 and 1976-77 Food Habits

Proportions of food classes in the pig diet differed between years (Fig. 2). There was a significant difference in the percentage of forbs consumed between the 2 years. The late summer and fall of 1975 was abnormally dry, and as a result forb production was low. The same period in 1976 had adequate moisture, which allowed higher forb production. The high consumption of forbs in the diet during the second year of the study was in direct proportion to the higher production during the same period. Forb production on the tight sandy loam range site averaged 375 kg/ha during the second year as compared with 90 kg/ha during the first year. Mossrose was the most important forb in the diet both years but was much more important during 1976-77. It comprised 10.8% by volume in 1975-76 and 34.4% by volume in 1976-77. Burhead was more important in 1976-77, when it comprised 8.3% by volume, as compared with 3.6% by volume in 1975 to 1976. However, nettle (*Urtica chamaedryoides* Pursh) and turkey-tangle comprised larger percent volumes in 1975-76 than during 1976-77. Other forbs, such as western ragweed and water clover, made up large percent volumes both years.

The percentages of grasses and sedges were both significantly higher during the late fall and winter of 1975-76 than during the same period of 1976-77. Longtom was the major grass species during both years, comprising 12.3% of the volume during 1975-76 and 3.7% in 1976-77. Sedges and longtom grow primarily in the moist laguna sites and were readily available both years. The higher use of both grasses and sedges during the first year was caused by the lower availability of forbs during this period.

There was a significant difference in the percentage of acorns consumed between the 2 years—the volume was 3.4% in 1975-76 as compared with 7.6% in 1976-77.

Animal matter was more important during the first year of the study because of the larger percentage of maggot-infested carrion eaten by two animals; however, it had a low frequency of occurrence during both years. There was a significant difference in the percentages consumed between the two years.

Data from this study imply that feral pig food preference could be competitive with other wildlife and livestock in south Texas. The high consumption of herbaceous plants by feral pigs indicated that pigs may compete with white-tailed deer and cattle for these foods (Davis 1952; Chamrad and Box 1968; Drawe 1968; Everitt and Drawe 1974). Several of the foods recorded in the pig diet are also reported to be eaten by sandhill cranes (*Grus canadensis* L.) Guthery 1975). Although the pigs' extensive rooting may result in at least partial removal of many plant species from the range, these disturbed areas cause a shift in plant succession on the immediate site which is beneficial to some wildlife (Springer 1975). The earlier-successional plants found on these sites provide food for wildlife which feed mainly on herbaceous plants.

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Food Habits of the Plains Pocket Gopher on Western Nebraska Rangeland

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Abstract

Plains pocket gophers (*Geomys bursarius*) were trapped during 10 months (June and July excluded) of 1974, 1975, and 1976 to determine their food habits. Using a microscopic technique, twenty species of grasses, forbs, and rushes were identified in the stomach contents of 141 pocket gophers. Of the total diet, forbs comprised 9.9%, grasses 44.9%, and rushes 14.8%. Root and leaf-stem materials were found to make up 30.9% and 38.7% of the diet, respectively. Winter food constituents were difficult to identify with 30.4% of the total diet being unidentified material. Gophers exhibited diet selectivity; major species in the vegetation were not necessarily major species in the diet.

Little is known about the food habits of the plains pocket gopher (*Geomys bursarius*). Foster (1977) reported that plains pocket gophers had a significant impact on forage production on western Nebraska rangeland, decreasing production by approximately 46%. Myers and Vaughan (1964) reported that plains pocket gophers in eastern Colorado fed preferentially on forbs. In their study area, 88% of the vegetation was grasses, but these grasses comprised only 66% of the gophers' yearly diet.

Food habits of the northern pocket gopher (*Thomomys talpoides*) have been studied thoroughly (Keith et al. 1959; Ward and Keith 1962; Vaughan 1967). Data published by these authors as compared to data published by Myers and Vaughan (1964) indicted that forbs comprised a much larger portion of the northern pocket gopher diet (67%−93%) than of the plains pocket gopher diet (30%). This study was designed to determine plant species and plant parts (roots or leaves and stems) eaten by plains pocket gophers in western Nebraska.

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Methods and Materials

The study area was located 35 kilometers (22 miles) south and 11 kilometers (7 miles) east of Chadron, Nebraska. The climate is semiarid with a 30-year mean annual precipitation of 399 mm, with 69% occurring during the 130-day growing season (U.S. Dep. of Commerce 1973). Soils vary from fine sand to silty clay. Species comprising vegetation on the research area were primarily deep-rooted rhizomatus grasses such as prairie sandreed (*Calamovilfa longifolia*), sand bluestem (*Andropogon hallii*), western wheatgrass (*Agropyron smithii*), and sandhill muhly (*Muhlenbergia pungens*). Additional perennial grasses present were needleandthread (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), and sand dropseed (*Sporobolus cryptandrus*).

Gophers were trapped during all months of 1974, 1975, and 1976 except June and July. Personnel were not available for trapping during June and July. The specimens were frozen and stomachs were removed later. Stomach contents of 141 pocket gophers, 57 males and 84 females, were examined to determine their food habits.

Vegetation data were compiled (Foster 1977) during the 3 years of trapping. Gophers generally were trapped away from vegetation sampling sites. However, 16 gophers were trapped on one of Foster's specific vegetation sampling sites so that plants eaten could be compared with plant species composition (South Sand Canyon study site).

A representative plant collection was made on the study area during August, 1976. Tissues of each plant species were finely ground and mounted on microscopic slides. These slides served as reference material for comparison with stomach content slides which were prepared using a modification of techniques described by Dusi (1949), Hansen (1976), Keith et al. (1959), and Williams (1962).

Two microscopic slides were prepared from each stomach, and 10 fields were observed on each slide. Relative amounts of food items in a stomach were estimated by counting the number of fields in which each item occurred out of 20 fields. Each field was randomly selected and observed at 100 × magnification. Percentage of total composition was calculated for each species as well as the percentage of root and leaf-stem material eaten. Total and monthly percentages describing the diet of pocket gophers were based on the mean percent plant composition of the stomach contents.

Results and Discussion

Twenty species of grasses, forbs, and rushes were identified in the stomach contents of pocket gophers (Table 1). Four species made up 50.0% of the total diet. Needleandthread occurred in 81.0% of the stomachs and comprised 27.5% of the yearly diet. Common scouring-rush (*Equisetum hyemale*) was the second most important species in the diet. It was found in 28.2% (occurrence) of the stomachs and comprised 14.8% (composition) of the diet. Prairie junegrass (*Koeleria cristata*) and Kentucky bluegrass (*Poa pratensis*) were found in 12.9% and 10.3% of the stomachs, respectively. No other species was found in nor comprised more than 10% of the diet.

The percentage of needleandthread in the diet of gophers in this study was similar to that of the same species of gopher in Colorado (Myers and Vaughan 1964). In their study, the yearly diet consisted of 22% needleandthread. Myers and Vaughan (1964) reported diets containing 14% western wheatgrass, 12% blue grama (*Bouteloua gracilis*), and 9% spreading pricklypear (*Opuntia humifusa*). In our study, western wheatgrass and blue grama were minor items in the gopher's diet, each making up less than 1%, while spreading pricklypear was not present.

Even though it was a major species in the vegetation (Foster 1977), prairie sandreed comprised only 0.3% of the gopher diet. Common scouring-rush and prairie junegrass were present only in trace amounts on the research area, even though the two species comprised 20.2% of the diet.

Seasonal trends of the two major species eaten were noted. Needleandthread made up a major portion of the diet in summer and fall, and common scouring-rush was eaten mainly during winter and spring. The major species in the diet varied during the 10 months studied during each of the 3 years. Either needleandthread or common scouring-rush was the major species in the diet, except during May. Prairie junegrass was the major food item in May, when it made up 40.3% of the diet. Prairie junegrass was eaten only from February through May.

Forbs were a more important component of the diet during the growing season than during other parts of the year (Fig. 1). Only a small amount of forb material was eaten during the winter months although a large portion of the unidentified material may have been forb roots.

Table 1. Frequency of occurrence and composition of food items in the diet of plains pocket gophers.

Plants	% occurrence	% composition
Grasses		
Agropyron smithii	7.3	.5
Bouteloua gracilis	1.1	.1
Bromus sp.	3.3	.3
Buchloe dactyloides	7.7	1.3
Calamovilfa longifolia	2.1	.3
Koeleria cristata	12.9	5.4
Poa pratensis	10.3	2.3
Sorghastrum nutans	.7	.1
Stipa comata	81.0	27.5
Stipa or *Sporobolus*	35.9	7.1
Grass roots	64.5	9.2
Grass leaf and stem	97.9	35.7
All grasses	97.9	44.9
Forbs		
Ambrosia psilostachya	6.3	1.4
Astragalus sp.	.7	.6
Cirsium sp.	2.1	1.3
Croton texensis	.7	.3
Eriogonum annuum	1.4	.3
Melilotus sp.	4.6	3.6
Opuntia fragilis	5.6	1.7
Opuntia macrorhiza	1.5	.9
Psoralea tenuiflora	.7	.5
Forb roots	19.1	7.7
Forb leaf and stem	14.9	2.2
All forbs	19.9	9.9
Rush		
Equisetum hyemale	28.2	14.8
Rush roots	24.8	14.0
Rush leaf and stem	9.9	0.8
Totals		
Roots of all plants	79.4	30.9
Leaf and stem of all plants	97.2	38.7
Unidentified plant material	70.9	30.4

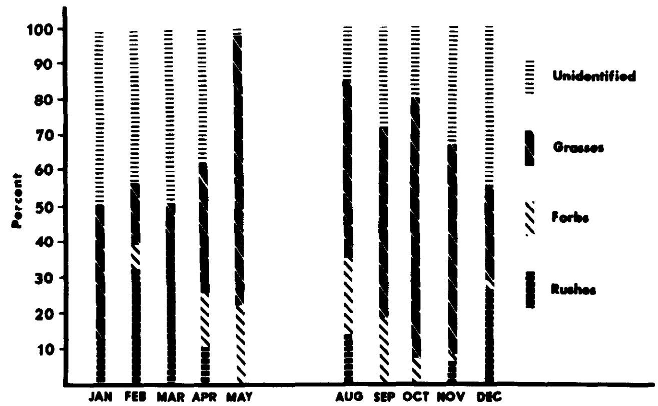

Fig. 1. *Percent of grass, forb, and rush in the monthly diet of plains pocket gophers.*

The ten grass species made up a larger part of the diet than the nine forbs or one rush. The rush, common scouring-rush, made up 14.8% of the yearly diet, while all forbs comprised only 9.9% of the diet. Common scouring-rush made up only a trace of the vegetation, while forbs comprised a much larger portion (30%). No shrub or animal matter was detected in stomachs examined.

Root and aboveground materials were nearly equal in the gopher's diet, comprising 30.9% and 38.7%, respectively (Table 1). A total of 30.4% of the stomach contents could not be identified. Special difficulties were encountered in identification of stomach contents of gophers collected from November through March. Common scouring-rush roots were easier to identify than grass or forb roots. They made up nearly equal portions of the yearly diet (14% common scouring-rush, 16.9% grass and forbs). Grass leaf and stem parts were eaten more often than leaf and stem parts of forbs and the rush.

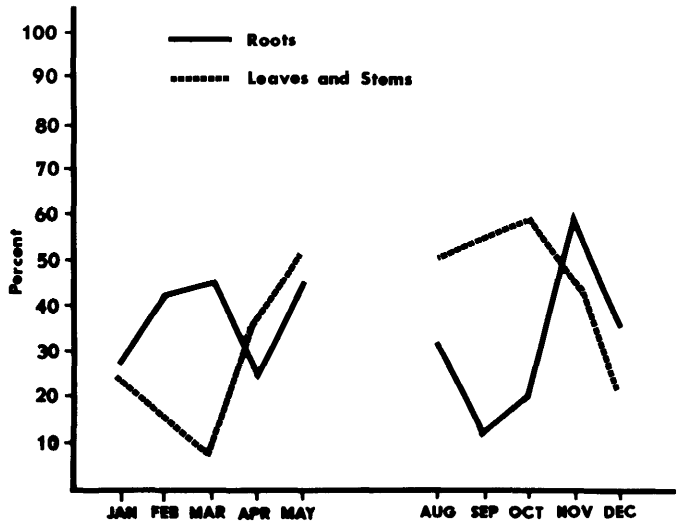

Fig. 2. *Percent of root material and leaf and stem material in the monthly diet of plains pocket gophers.*

Root material occurred in more stomachs than leaf and stem material during the late fall and winter (Fig. 2). Beginning in April, leaf and stem material became more important to gophers than root material. This trend probably resulted from changes in the availability of green herbage.

The sex ratio (40% males, 60% females) of trapped gophers was similar to that reported by Vaughan (1962). Percent composition of the two major plant species in the diet appeared to vary little between sexes. Frequency of occurrence of the two major species in the diet was also very similar for both sexes.

South Sand Canyon Study Site

Data indicate that gophers may influence the vegetative composition on rangeland. Species eaten by gophers tend to decrease while species apparently unpalatable to gophers increase in basal cover. Reductions in vegetation may not be due entirely to gophers because cattle were grazing this area. Prairie sandreed comprised 5.2% of the vegetation in an infested portion of a sands range site study area, while 25.4% of the basal cover of the vegetation in the uninfested portion was prairie sandreed. Blue grama showed a similar trend, comprising 7.0% of the basal cover in the infested portion and 16.1% of the vegetation in the uninfested portion of the rangeland. Prairie sandreed and blue grama each made up less than 1% of the diet possibly due to the scarcity of these species in this site infested by gophers.

Stomach contents of gophers trapped in this area consisted of 62.0% needleandthread, which was found in all 16 gopher stomachs analyzed from the study area on the sands range site. Needleandthread leaf and stem material comprised 52.5% of the total diet while roots constituted only 9.8%. In gopher infested areas, needleandthread comprised 25.8% of the basal cover in 1976 and made up 31.0% of the basal cover of an adjacent area that was not infested by gophers (Foster 1977).

Management Implications

In the present study, plains pocket gophers live in a habitat that is dominated by grasses. Of the identified plants, grasses made up 44.9% while forbs comprised only 9.9% and one species of rush 14.8% of the diet. Myers and Vaughan (1964) reported that grass made up 88% of the vegetation in their study area. The diet of plains pocket gophers in their study consisted of 77% grass.

Some species eaten by gophers are of poor forage value to livestock. Western ragweed (*Ambrosia psilostachya*), thistles (*Cirsium* sp.), and species of cactus are undesirable range plants that comprised 5.3% of the diet. Other food items of plains pocket gophers are range plants of good forage value. Buffalograss (*Buchloe dactyloides*), prairie junegrass, Kentucky bluegrass, and needleandthread are major range grasses that comprised 36.5% of the diet. Plains pocket gophers decrease forage availability of some desirable grasses on rangeland by their feeding habits.

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Factors Influencing the Feed Intake and Liveweight Change of Beef Cattle on a Mixed Tree Savanna in the Transvaal

IBO ZIMMERMANN

Abstract

This study was conducted as part of a broad ecosystem project to identify and quantify some of the significant relationships between cattle and their environment. Over a period of 1 year, monthly measurements were made of Africander cattle ranging on mixed tree savanna in the Transvaal, Republic of South Africa. The following data were obtained: feed intake, liveweight change, crude protein content (CP) and digestibility of the diet, as well as the time which was spent feeding and mean bite size. Both CP and digestibility of diets influenced the liveweight change of the cattle, but only digestibility influenced their feed intake. Their daily feeding time was short enough and their mean bite size was large enough to suggest that the accessibility and distribution of preferred plant species within the savanna did not directly limit their feed intake. Nutritional requirements of the cattle could be estimated from relationships between some of the factors, the most accurate relationship being that between digestible CP intake and liveweight change of the cattle.

The quality of a diet can influence the feed intake of ruminants through its effects on the digestion in the rumen, and it can influence the growth of ruminants through its effects on the efficiency of converting the food to animal tissue (Blaxter 1962). In addition, the accessiblilty and distribution of food items amongst the vegetation can influence the feed intake and liveweight change of cattle, by limiting the amount of feed which the animals can harvest with each bite and so affecting the time which the animal spends feeding (Chacon et al. 1978). The objectives of the study discussed in this paper were to examine the influence of such factors on the seasonal feed intake and performance of free-ranging beef cattle. This information could be used together with results from other ecological studies conducted by the South African Savanna Ecosystem Project: "to develop the understanding necessary to predict changes in the ecosystems stability induced by various natural and man-made stresses" (Anon 1978). Furthermore, the quantification of relationships between nutritional factors and the liveweight change of cattle can provide estimates of the nutritional requirements of the cattle (Pearson 1972).

Methods

This study was carried out on the Nylsvley Nature Reserve situated in a mixed tree savanna of the Transvaal at 24°29′S, 28°42′E. Climatic data for the period of the cattle study are summarized in the Climatogram (Fig. 1), showing that most of the annual rainfall of about 630 mm fell during the hot, wet season from October/November to March. The soils of the reserve have been described by Harmse (1977) and the vegetation classified by Coetzee et al. (1976).

Twelve 2-year old Africander steers of about 325 kg liveweight were maintained in a single 190-hectare paddock for the duration of the study, May 1976 to April 1977. The paddock consisted mostly of *Eragrostis pallens-Burkea* Tree Savanna on poor sandy soils, interspersed with a few patches of *Acacia-Eragrostis lehmanniana* Short Tree Savanna on eutrophic soils. These were areas which had previously been occupied by subsistence farmers and were then preferred feeding sites of the cattle.

Samples of food eaten by the cattle were obtained each month from three esophageal fistulated steers, which were caught and sampled in the same places where they were found feeding, using the method of Alder (1969). Sampling was carried out for 30 minutes during the intensive feeding periods in the early morning

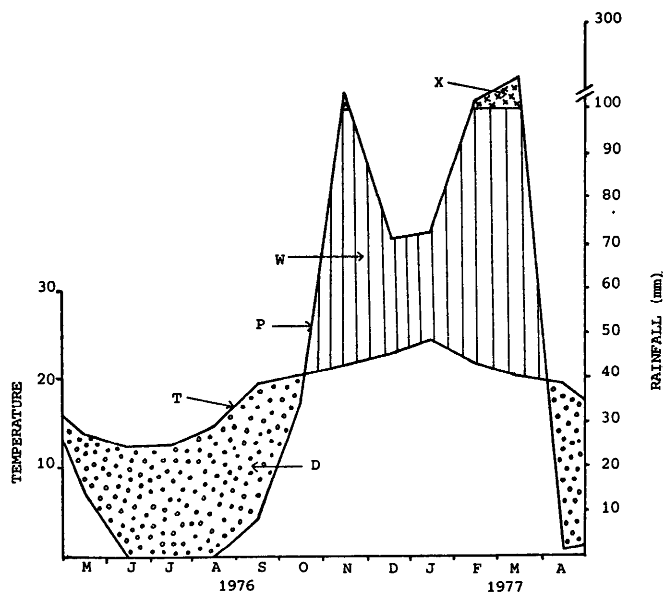

Fig. 1. *Climatogram for Nylsvley Nature Reserve during the period of the cattle study.*

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This study formed part of a larger project supervised by Professor J.D. Skinner and Dr. G.K. Theron. I am grateful to the Transvaal Division of Nature Conservation for the use of facilities at Nylsvley Nature Reserve and to Mr. B.J. Huntley co-ordinator of the Savanna Ecosytem Project. This paper is a publication of the South African Savanna Ecosystem Project which was funded by the National Programme for Environmental Sciences, Council for Scientific and Industrial Research.

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and late afternoon. A maximum of eight fistula samples were collected over a maximum of four consecutive days each month, collecting in turn from one steer at a time. In some months only six or seven samples could be obtained. These fistula samples were dried for 24 hours in a forced air oven at 70° C and hammermilled through a 0.5-mm sieve for analysis of crude protein content (CP) in the dry matter (Kjeldahl nitrogen × 6.25) and in vitro organic matter digestibility (IVOMD) by the method of Tilley and Terry (1963) modified slightly by the addition of 43.4 mg urea per ml of artificial saliva. The IVOMD results were used as a measure of feed digestibility by converting to predicted in vivo digestibilities (henceforth referred to as *digestibility*) using the regression of Engels, et al. (1974).

Fecal output was measured directly by collecting the feces in bags attached by harnesses to a maximum of four nonfistulated steers each month for the same consecutive days that fistula samples were collected. In some months the results from only three or two steers were used because the harnesses of the other steers broke, but differences in the fecal output between different steers and different days of collection were not significant (Zimmermann 1978). The feces bags were weighed and emptied every 12 hours, and after thorough mixing a subsample of feces was taken to determine water content (by weighing before and after drying for 48 hours in a forced air oven at 70°C) and for analysis of its CP content. The mean feces output for each month was used together with the monthly mean digestibility of the feed to calculate the feed intake for each month by:

$$\text{Feed intake} = \frac{\text{Feces output} \times 100}{100 - \text{Digestibility}}$$

The cattle were allowed access to a nutrient lick in the form of a block which contained 27.5% protein and 8.5% urea as well as carbohydrates and various minerals. The average amount of lick consumed by the cattle was measured by weighing the amount given and the amount remaining each month. The lick consumption was taken into account when calculating the feed intake, its CP content and digestibility.

Each nonfistulated steer was weighed once a week and the mean liveweight at each week was plotted on a growth curve. There was some week-to-week variation in mean liveweight, probably due to differences in rumen fill, so straight lines were drawn to represent the probable mean liveweight change of each month.

One 24-hour behaviour study was carried out each month, in which the activity which the cattle were involved in at every fourth minute was recorded (Taylor et al. 1955). From this time spent by the cattle in feeding was calculated. Some direct feeding observations were also made by counting the number of bites which one particular steer took of different plant species during 15-minute periods. One observer (the author) carried out all the observations at a distance of about 4 m from the steer. The observations were usually carried out shortly after fistula sampling had taken place, so there were a maximum of eight observations per month from which a mean biting rate could be calculated.

Estimates of the amount of vegetation available to the cattle in the paddock each month were made by clipping in 30 evenly spaced quadrats (0.5 m × 0.5 m) the plant material which was considered to be available to the cattle. This was then dried in a forced air oven at 70°C for 48 hours and weighed.

Results and Discussion

Seasonal Changes in Nutritional Variables

In Figure 2 the mean values for each month are plotted for digestibility CP content, feed intake, and liveweight change of the cattle (the latter two being expressed in terms of metabolic weight of $Wt^{0.75}$). There was no apparent seasonal change in the amount of lick consumed by the cattle, and the average was only 0.91 gm/$Wt^{0.75}$/day. The average amount of CP obtained from the lick was 0.33 gm CP/$Wt^{0.75}$/day, so the cattle obtained about 2.4% of their total CP intake from the lick during the wet season and about 7.7% during the dry season. The CP content of the feed in Figure 2 is shown separately for CP from the forage and CP from the lick, but the difference which the lick consumption made to forage intake and digestibility is so slight that it is not shown in Figure 2.

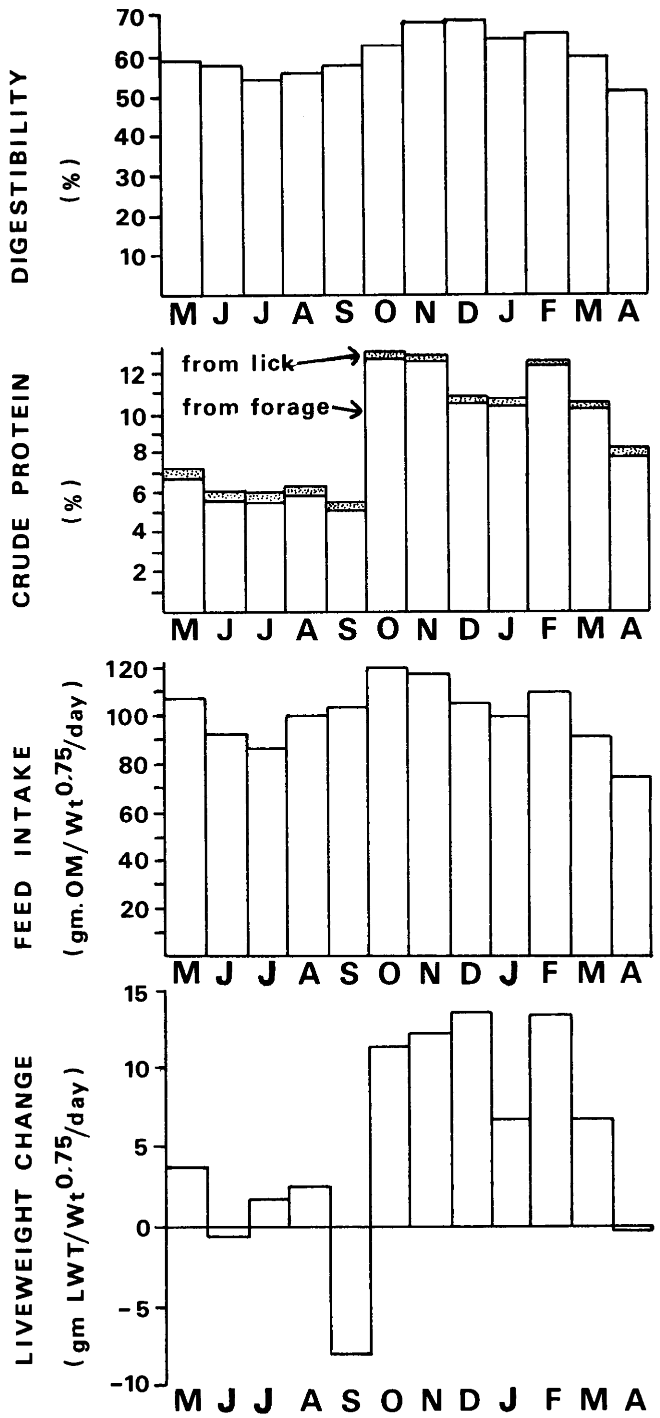

Fig. 2. *Seasonal changes in the digestibility and crude protein content of the food, the amount of food eaten by the cattle, and their liveweight gains.*

All the factors in Figure 2 were significantly higher during the hot wet season. The CP content peaked at the beginning of the wet season in October, while the digestibility peaked in the middle of the wet season (November/December). The great increase in CP content in the diet from about 5.5% at the end of the dry season in September to over 13% at the beginning of the wet season was due partly to the greater amount of browsing in October. In all other months browse only formed an insignificant part (less than 1%) of the cattle diets. In October the steers did a lot of browsing on the newly flushed leaves of the peeling bark of ochna (*Ochna pulchra*), which made up roughly 20% of the dry weight of their food consumption at this time; the fistula samples which contained some of these browse leaves had much higher CP contents than the other samples collected in October (Zimmermann 1978).

The monthly estimates of the cattle liveweight change in Figure 2 show that very little weight was gained in the dry season while a small amount of weight was lost in June and April. Furthermore in September at the end of the dry season when most of the vegetation was dry and of low quality, the cattle lost a considerable amount of weight. This, however, was due largely to the cattle eating some of the poisonous woody geophyte *Dichapetalum cymosum,* which has a large underground storage system and was flushing its new growth of leaf at this time.

Relationship between Different Nutritional Variables

Linear regressions were calculated to examine the relationships between the monthly estimates of various factors which are shown in Table 1. The September result was omitted when the monthly estimates of liveweight change were related to other seasonal changes, because of the effect of *Dichapetalum* poisoning in this month.

Table 1. Linear regression equations relating mean monthly variables concerning nutritional ecology of cattle. All the regressions are significant to at least the 5% level.

Equation Number	Linear regression equations	95% Confidence limits	Coefficient of determination (r^1 or R^1
Eq. 1	Intake[1] = 1.69 Digestibility[2] – 1.9	± 17.2	0.56
Eq. 2	LWT change[3] = 0.83 Digestibility – 4.41.	± 4.6	0.82
Eq. 3	LWT change = 0.30 Intake – 24.1	± 7.1	0.58
Eq. 4	LWT change = 0.36 DOM intake[4] – 16.0		
Eq. 5	Intake = 2.53 CP[5] + 77.7	± 21.3	0.32
Eq. 6	LWT change = 1.70 CP – 9.7	± 5.0	0.79
Eq. 7	Digestibility = 1.51 CP + 46.9	± 7.2	0.59
Eq. 8	LWT change = 0.50 Digestibility + 0.91 CP– 32.32 –		0.91
Eq. 9	LWT change = 1.27 CP Intake[6] – 5.9	± 4.3	0.84
Eq. 10	LWT change = 1.72 DCP Intake[7] – 4.0	± 3.6	0.89
Eq. 11	Intake = 1.59 Digestibility = 0.50 CP 1.15	—	0.60

[1]Intake = Organic matter food intake per metabolic weight of steer (gm IM/ $WT^{0.73}$/ day.)
[2]Digestibility = Organic matter digestibility of the cattle diets (%).
[3]LWT change = Liveweight change of the cattle (gm LWT/ $Wt^{0.73}$/ day).
[4]DOM Intake = Digestible organic matter intake per metabolic weight of steer (gm DOM/ $Wt^{0.73}$/ day).
[5]CP = Crude protein content of cattle diets (% in dry matter).
[6]CP Intake = Crude protein intake per metabolic weight of steer (gm CP/ $Wt^{0.73}$/ day).
[7]DCP Intake = Apparent digestible crude protein intake per metabolic weight of steer (gm DCP/ $Wt^{0.73}$/ day).

Equation (Eq) 1 in Table 1 shows that digestibility of the feed correlated to some extent with the feed intake of the cattle (r^2 = 0.56). Since digestibility and feces output were both used to calculate feed intake, the variations in feces output contributed less to intake variability.

Good relationships are generally found between digestibility of feed and intake of ruminants (Holmes and Jones 1965), but Thomas and Campling (1976) concluded that at high levels of digestibility (over 70%), there may no longer be any relationship. At lower levels of digestibility, it is primarily the rate of fermentation of the cellulose and hemicellulose content of the food which determines the rate of passage of food through the rumen and hence the feed intake (Blaxter 1962). Since digestibility is often related to the rate of fermentation in the rumen, there is also some relationship between digestibility and intake.

Digestibility correlated well with the liveweight change as seen from Eq. 2 in Table 1 (r^2= 0.82); but since Eq. 1 gave a poorer correlation, the influence of digestibility on liveweight change does not seem to have been due mostly to the influence of digestibility on feed intake. In fact the feed intake did not correlate particularly well with the liveweight change as seen in Eq. 3 (r^2= 0.58) while the digestible organic matter intake resulted in a better correlation to liveweight change (Eq. 4 r^2 = 0.78). The fact that digestibility is an integral part of the digestible intake is probably the reason why digestibility correlated better with liveweight change than with feed intake.

From Eq. 2 and 4 it would seem that for maintenance these steers would require food with a digestibility of about 53% or a digestible organic matter (DOM) intake of about 44 gm DOM/ $Wt^{0.75}$/ day. This is somewhat higher than the maintenance requirement of about 30 gm DOM/ $Wt^{0.75}$/ day determined by Elliot et al. (1961) for Africander cows ranging on *Brachystegia* savanna in Rhodesia.

The CP content of the food correlated poorly with the feed intake (Eq. 5, r^2= 0.32) but correlated more closely with the liveweight change of the cattle (Eq. 6, r^2= 0.79); however, since there is also some degree of relationship between CP content and digestibility of the food (Eq. 7, r^2= 0.59), it was not clear whether the relationship between CP and liveweight change was due to auto correlation. A multiple linear regression performed on the data, using both CP and digestibility as independent variables on liveweight change (Eq. 8), gave an R^2 of 0.91. This is an improvement on using either digestibility alone (Eq. 2, r^2= 0.82) or CP alone (Eq. 6, r^2= 0.79), so both CP and digestibility of the food had some influence on the liveweight change of the cattle. Since these factors are both used in calculating the CP intake and the apparent digestible crude protein (DCP) intake of the cattle, it is not surprising that the liveweight change correlated well with the CP intake (Eq. 9, r^2= 0.84) and with the DCP intake (Eq. 10, r^2= 0.89) from which maintenance requirements can be estimated as 4.7 gm CP/ $Wt^{0.75}$/ day or 2.3 gm DCP/ $Wt^{0.75}$/ day. The latter is somewhat lower than the maintenance requirement for nonlactating Africander cows of about 2.5 gm DCP/ $Wt^{0.75}$/ day calculated from the data of Elliot et al. (1961). From Eq. 6 it was estimated that the steers needed food with a CP content of about 5.7% for maintenance. Plowes (1957) reported that Africander cattle grazing in Rhodesia required a CP content in the feed of 5–6%; and Karue (1975) reported that to supply the minimum protein requirements for maintenance of East African zebu cattle, grass with a CP content of about 7% was required. Equations 2–6 together with Eq. 9 and 10 could be used to estimate the nutritional requirements of the steers for particular liveweight changes.

Multiple linear regression of CP and digestibility on the feed intake of the cattle gave an R^2 = 0.60 (Eq. 11) which is almost the same as digestibility alone (Eq. 1 r^2 = 0.56). Therefore it seems that CP content of the forage did not affect feed intake; the small amount of correlation existing between these two factors (Eq. 5, r^2 = 0.32) must have been due to the influence of digestibility.

Digestibility and CP content were obviously not the only factors which influenced the cattle liveweight changes since even the best correlation in Table 1 only gave a coefficient of determination of 0.91 (Eq. 8). Factors such as other nutrients, toxic compounds, prevalence of internal parasites, and the adaptability of rumen microbes to change in feed quality might also have had some influence. Such factors might have been partly responsible for the reduced liveweight gains by the cattle in January and March for example.

The influence of Feeding Behaviour

The results from the behaviour studies were insufficient to indicate seasonal changes in feeding time probably because the day-to-day variation was too great so that results from one day did not represent the average for the month. However, the results from all 12 months were used to calculate a mean daily feeding time of 546 ±52 minutes (95% confidence limits).

The longest feeding time recorded was 666 minutes during the October behaviour study; this was probably due to the considerable amount of browsing which occurred at this time. Since cattle are not well adapted for browsing (Hafez and Schein 1962), they presumably had to spend more time for each unit of intake than they would when grazing; so the higher CP content of the browse probably warranted the extra time spent consuming it, since there was already sufficient good quality grass by this time (Zimmermann 1978).

During the progessive defoliation of a grass sward, Chacon et al. (1978) found that cattle increased their feeding time up to a peak and then decreased their feeding time as even less suitable herbage became available. They found that this decreased feeding time greatly reduced the feed intake, and presumably it occurred because the extra maintenance requirements of longer feeding times were not worth the effort. The daily feeding time of zebu steers in Zambia was found by Smith (1959) to vary from 480 minutes during the wet season to about 780 minutes during the dry season when the steers were losing weight. This latter feeding time probably approaches the maximum which cattle could achieve, since no data were found in the literature to indicate longer feeding times. The condition of the vegetation at Nylsvley does not appear to have been too poor, since all the daily feeding times observed were considerably less than 780 minutes.

The biting rate data were unreliable for the months May to July, and even for the other months they were too variable to indicate seasonal changes. The results from these other 9 months were used to calculate a mean biting rate, which was then used together with feed intake results and daily feeding time results to calculate a mean bite size for each month. When averaged over the 9 months the mean bit size was 0.34 ± 0.07 gm OM per bite. From theoretical considerations Stobbs (1974) calculated that the critical level for a 400-kg animal to achieve adequate intake is 0.3 gm OM per bite. Since the average liveweight of the steers at Nylsvley rose from 255 kg to 395 kg over the year of the study, it seems that the bit size which they were able to achieve was large enough to have resulted in adequate feed intake.

The estimates of the amount of plant material available to the cattle varied from about 500 kg/ha in September to about 960 kg/ha in March. So even in September the amount of forage consumed by the 12 steers was less than 0.1% of what was available. However the cattle were highly selective amongst the plant material for plant species, plant parts, and plant material of different growth stages, and there was some competition from wild herbivores for the preferred material (Zimmermann 1978). So although there was plenty of material available to the cattle, the distribution of the preferred material amongst the vegetation could still have had a significant influence on the cattle feeding.

Conclusions

Under the conditions of this study, both the digestibility and CP content of the food eaten by the cattle had roughly the same influence on their liveweight change. However, in neighbouring Botswana, Pratchett et al. (1977) concluded that CP content of the food had a greater influence on cattle liveweight gains than did digestibility, so the relative influence of CP and digestibility can vary, possibly depending on the combination in which they occur and their association with other factors such as minerals and toxic compounds.

The fact that CP content of the food *per se* had no influence on the feed intake of the cattle would suggest that the CP levels experienced in this study were not limiting to the rumen microbes. When the amount of CP per unit of digestible OM is very low, then the feed intake of ruminants can be limited (Weston 1967). Since CP content did not affect the liveweight change of the cattle but not their feed intake, it seems that a unit of DM intake with a high CP content will be converted more efficiently to animal tissue than intake with a lower CP content.

It seems probable that the cattle were managing to fill their rumens, since digestibility correlated reasonably with the feed intake, so it seems unlikely that the distribution and accessibility of food items amongst the vegetation were directly limiting the feed intake. This conclusion is supported by the relatively short daily feeding times and the relatively large mean bite size which the cattle were able to achieve. However it is likely that the accessibility and distribution of food items were indirectly limiting the feed intake by influencing the quality of the diet which the cattle could obtain in their bites, particularly since the most common grass, *Eragrostis pallens,* was largely avoided by the cattle (Zimmermann 1978).

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Habitat and Dietary Relationships of the Pygmy Rabbit

JEFFREY S. GREEN AND JERRAN T. FLINDERS

Abstract

Vegetal habitat characteristics and annual dietary selection were examined for the pygmy rabbit in southeastern Idaho. Areas selected for habitation by pygmy rabbits had a significantly greater woody cover and height than other areas. Total grass-forb biomass was similar in rabbit and nonrabbit sites. Grass biomass was least and forb biomass greatest where pygmy rabbits were most abundant. Sagebrush was eaten throughout the year, although in lesser amounts in summer (51%) than in winter (99%). Grasses and forbs were eaten through the summer (39 and 10%, respectively) and decreased in the diet through fall to winter. Sagebrush is critical to the pygmy rabbit for both food and cover, although in this study, cover and height of woody vegetation appeared to be the critical features of the habitat selected for. This fact should be considered before brush removal treatments are applied within pygmy rabbit range.

Wildlife habitat research has been termed the "cornerstone in management" (Reynolds 1974) but is often poorly accomplished or entirely neglected. Manipulation of habitat is common, but should be undertaken with an understanding of resident wildlife species' requirements for food and space. Throughout the western United States, there is an historical and present day practice of removing sagebrush (*Artemisia* spp.) by spraying, mechanical treatment, and burning to increase forage production. Only recently has the impact of this activity on wildlife been considered and then only for a few species (Powell 1969; Braun et al. 1977; Renwald 1977). Additional information is required before habitat can be altered for range improvement with a knowledge of possible impacts on wildlife populations.

Fig. 1. *Adult pygmy rabbit in winter pelage from Clark Co., Idaho (photo by J.S. Green).*

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An examination of annual dietary habits is critical in a study of an animal's relationship to habitat. Food eaten depends on availability and preference. It is, therefore, imperative that an analysis be made of what is eaten and what is available. This necessitates direct observation, stomach or fecal analyses as well as vegetational examination of the habitat.

Leporids and particularly hares (*Lepus*), are important in the rangeland ecosystem and have been studied with respect to dietary habits and habitat (Hansen and Flinders 1972). Dietary data have also been compiled for cottontails (*Sylvilagus*) (Bailey 1969) and other members of this genus (Orr 1940).

The pygmy rabbit (*Brachylagus idahoensis*) (Green and Flinders 1980) (Fig. 1) is associated with the sagebrush complex of the Great Basin (Grinnell et al. 1930) and has escaped comprehensive investigation perhaps due to its inconspicuous nature (Severaid 1950). Janson (1946) noted some foods eaten by the pygmy rabbit and recently Wilde (1978) presented further dietary detail. However, information relating pygmy rabbit diet to vegetational availability has not been reported. This paper presents the results of a 2-year study of the pygmy rabbit relative to habitat characteristics and dietary selection. Included are information concerning deposition of fecal pellets and implications from grazing livestock.

Study Area and Methods

This study was conducted in 1977 and 1978 on the U.S. Sheep Experiment Station near Dubois, Idaho. The vegetation is characteristic of the sagebrush-grass complex of the Upper Snake River Plains and is detailed by Blaisdell (1958). Topography and soils are largely a result of volcanic activity. Precipitation averages 25 cm per year. This area is near the northeastern distributional boundary for the pygmy rabbit (Hall and Kelson 1959) and is also inhabited predominantly by the following small mammals listed in order of decreasing relative abundance: deer mouse (*Peromyscus maniculatus*), least chipmunk (*Eutamias minimus*), pocket mouse (*Perognathus parvus*), meadow vole (*Microtus montanus*), yellow-bellied marmot (*Marmota flaviventris*) and the Uinta ground squirrel (*Spermophilus armatus*).

Seven sites were chosen to represent preferred pygmy rabbit habitat based on sightings of the study animals and evidence of abundant rabbit activity (pellets, runways, dusting areas and burrows). In each of the seven areas, 21 sampling points were established at 3-m intervals along .2 intersecting perpendicular transects, each 30 m long. At each point, 2 permanent reference stakes were placed to allow consistent placement of a ¼ m² quadrat.

Rabbit fecal pellets were cleared initially from all quadrats in late April 1977 and were subsequently collected from each site as follows: late June, August, and October 1977, and late April, June, August, and October 1978. Fresh pellets were collected in winter in the general area of each site. Rabbit pellets from each site were pooled, counted, and analyzed for each collection period by microscopic examination of epidermal characters of vegetation (Flinders and Hansen 1972). [Dietary analysis of feces may underestimate some forbs in diets due to greater fragmentation of epidermal tissues that have decreased lignification (Hansson 1970).] Relative percent density of each food item was determined for all samples examined (Sparks and Malechek 1968).

Grasses and forbs were sampled in 6 of the 7 sites in late June 1977 and early July 1978 using a nested plot technique. Four random points were selected from the 21 permanet points in each site per year. Five ¼ m² sampling plots were established at each point for a total of 20 plots per site. All grasses and forbs were clipped and weighed by species and oven dried to determine dry biomass.

Shrubs were sampled in late summer 1977 by measuring each plant by species in five 10-m² circular plots in each of the 6 sites as follows: (1) longest diameter of canopy; (2) longest diameter of the canopy measured at right angles to the dimension in (1); and (3) maximum height. Percent canopy cover for each species and total shrub cover were determined using the product of measurements (1) and (2). Dry biomass was estimated for each species by double sampling and linear regression (Uresk et al. 1977). Twenty plants of each species were chosen subjectively to represent various sizes ranging from small to large. After the aforementioned measurements were made, these plants were cut at ground level, dried at room temperature for 6 to 8 months, and weighed. Regression equations were calculated with volume (length × width × height) and dry biomass, and were used to estimate dry biomass of all other shrubs measured.

Comparable vegetative data were collected from 30 other sites on the Sheep Station in summer 1977. Some sites were selected randomly as small rodent areas while others were chosen as representative habitat for yellow-bellied marmots and Unita ground squirrels. One site within a livestock grazing exclosure was also examined. With respect to habitats for pygmy rabbits, the 30 sites were considered random since they represented a cross section of "other" habitats available but not selected for occupancy by pygmy rabbits. Woody and grass-forb vegetation were measured in the 30 sites by selecting random quadrats in a manner similar to the rabbit areas. In the grazing exclosure 20 grass-forb plots and five shrub plots were measured, while five grass-forb plots and two shrub plots were measured in all other sites.

Table 1. Regression equations and *r* values to determine estimates of dry shrub biomass. ($\hat{y}=a+bx$ for all shrubs except *Purshia tridentata*, which is $\hat{y}=ax^b$)

Species	Regression equation	Correlation coefficient (*r*)
Amelanchier alnifolia	$\hat{y}=6.44+.001311x$	.96
Artemisia tridentata	$\hat{y}=7.589+.001x$ (for plants with volume $\leq$ 61,000 cm³)	.99
	$\hat{y}=136.837+.00128x$ (for plants with volume 61,000 cm³)	.94
Artemisia tripartita	$\hat{y}=.53+.00215x$ (for plants with volume $\leq$ 65,000 cm³)	.99
	$\hat{y}=-38.948+.00238x$ (for plants with volume $>$ 65,000 cm³)	.96
Chrysothamnus nauseosus	$\hat{y}=-4.79+.00114x$	.94
Chrysothamnus viscidiflorus	$\hat{y}=.52+.00234x$	.82
Leptodactylon pungens	$\hat{y}=7.18+.00119x$	.85
Purshia tridentata	$\hat{y}=.0193x^{.802}$	.79
Rosa sp.	$\hat{y}=.42+.00062x$	.95
Symphoricarpos oreophilus	$\hat{y}=16.9+.00061x$	.92
Tetradymia canescens	$\hat{y}=12.21+.00186x$	.95
Xanthocephalum sarothrae	$\hat{y}=69+.000637x$	.89

[a]y=estimated dry weight, x= shrub volume (maximum length x maximum perpendicular width × maximum height)

Results and Discussion

Woody Vegetation

Regression equations to determine dry biomass were developed for the major shrub species found in the rabbit-occupied sites and other areas (Table 1). The highly significant ($P \leq 0.01$) correlation coefficients indicate predictions of dry biomass are acceptable. Mean percent cover and dry biomass estimates for the shrubs are listed in Table 2. Analysis of variance for cover measurements on individual plots within each site showed no significant difference in total cover between any sites except the rabbit areas. (Nonsignificance in all tests is $P > 0.05$.) Pygmy rabbit habitat had a significantly greater ($P \leq 0.01$) cover and corresponding biomass of woody vegetation than any other site examined. There was, however, no significant difference in mean percent cover between individual pygmy sites.

There was no significant difference in mean percent cover for bitterbrush (*Purshia tridentata*) between any pygmy sites except site 3, where this shrub was absent. Combining both threetip and big sagebrush (*A. tripartia* and *tridentata*), there were no significant differences for cover between pygmy sites except site 1 ($P \leq 0.01$).

Mean height of the shrub canopy for all pygmy rabbit sites was 56 cm ($S_x = 2.8$) with no significant differences between sites. The mean height of the canopy for all other sites was 25 cm ($S_x = 1.4$). There were no significant differences between sites. A highly significant difference ($P \leq 0.01$) was found between the shrub canopy height of the pygmy rabbit sites compared to all other sites.

The greater shrub cover and height in pygmy rabbit habitat was expected from a review of the literature. Orr (1940:194) stated that tall sagebrush in "dense clumps" was apparently essential to the rabbit, and others have made similar observations (Grinnell et al. 1930; Borell and Ellis 1934; Severaid 1950).

Grass-Forb Vegetation

Dry biomass data for grasses and forbs from all areas sampled are detailed in Table 3. Analysis of variance and the least significant difference test showed no significant difference in total mean biomass for any sites. Considering grass biomass alone, the exclosure and pygmy sites were significantly different ($P > 0.01$) from the ground squirrel sites. Our other research shows ground squirrels feed primarily on grasses and thus inhabit moist sites where grass vegetation is more abundant. There was no significant difference in mean forb biomass between sites.

Grass-forb vegetation for the pygmy rabbit sites is listed in Table 4. There are no significant differences between sites with respect to total biomass. However, sites 5 and 6 had a significantly lower ($P \leq 0.05$) grass component than the other sites and a significantly higher ($P \leq 0.05$) forb component than sites 1, 2, and 3. Site 7 had a significantly lower ($P \leq 0.05$) forb biomass than site 5. Possible reasons for this disparity will be discussed later.

Diet

Foods eaten by pygmy rabbits on an annual basis are detailed in Table 5. Food items were taken in similar amounts from shrubs, grasses, and forbs from spring (May) through fall (October) (hereafter termed summer period). During this period, a mean relative density of 51% shrubs, 39% grasses, and 10% forbs appeared in rabbit pellets in all sites. No significant differences between sites were observed. Significant differences ($P \leq 0.01$) were found, however, between amounts of foods consumed in the summer, winter (December through February), and early spring (March through April) periods. Sagebrush was eaten almost exclusively during winter. With the onset of spring and coincident vegetation "green-up," grasses and forbs increased in frequency of occurrence in fecal pellets. On an annual basis, a mean of 67% shrubs, 26% grasses, and 6% forbs was consumed (Table 5).

Wilde (1978) reported that on the Idaho National Engineering Site in southeastern Idaho, the pygmy rabbit had two main dietary periods: winter, extending from

Table 2. Mean percent cover and total dry biomass for the major woody species found in the rabbit sites and other areas.

Speces	Pygmy rabbit sites	Marmot sites	Trap sites	Squirrel sites	Grazing exclosure
n=	6	14	10	5	1
			$\bar{x}$ % cover		
Purshia tridentata	19	4	4	16	9
Artemisia tripartita	6	8	16	—	15
Artemisia tridentata	19	10	6	12	—
Chrysothamnus viscidiflorus	.3	1	1	.02	.1
Tetradymia canescens	1	.4	1	1.4	.6
Xanthocephalum sarothrae	.1	.2	.3	—	4
Leptodactylon pungens	.1	.7	.3	—	.6
Other	1	2	trace	1	1
Total	46	26	29	30	30
			$\bar{x}$ dry total biomass (kg/ha)		
Purshia tridentata	2125	325	368	1453	812
Artemisia tripartita	622	620	1291	—	962
Artemisia tridentata	2541	1015	522	1466	—
Chrysothamnus viscidiflorus	22	69	45	trace	6
Tetradymia canescens	83	28	128	136	55
Xanthocephalum sarothrae	1	3	4	—	53
Leptodactylon pungens	5	32	14	—	37
Other	70	1	12	trace	4
Total	5469	2093	2384	3055	1924

Table 3. Mean dry biomass ($\bar{x}$ kg/ha) for major grass and forb species in the pygmy sites and other areas.

Species	Rabbit sites	Marmot sites	Trap sites	Squirrel sites	Grazing exclosure
Grasses					
Agropyron dasystachyum	103	120	72	344	12
Agropyron spicatum	40	44	129		156
Calamagrostis montanensis	6	32	72	236	
Carex spp.	12	7	6	14	trace
Koeleria cristata	3	6	24	5	36
Poa nevadensis	67	23	98	78	36
Poa spp.	<36	—	—	—	<18
Stipa comata	34	68	15	48	28
Forbs					
Achillea millefolium	11	1	14	5	—
Antennaria rosea	6	53	26	23	8
Astragalus spp.	4	5	27	20	12
Balsamorhiza sagittata	178	1	17	—	76
Eriogonum spp.	18	21	8	8	102
Lupinus caudatus	12	—	3	—	10
Phlox spp.	14	4	10	trace	4
Total x grass biomass	316 (51)[1]	522 (77)	474 (73)	742 (85)	286 (46)
Total x forb biomass	309	153	171	131	330
Total x grass-forb biomass	625	675	645	873	616

*Number in parenthesis is a percent of total grass-forb biomass.

October to May, and a summer period, the remainder of the year. He further reported that sagebrush was the single most important food item throughout the year, never with a relative frequency< 36%. Forbs were not found in scat with a frequency> 12% and grass consumption peaked to 30 to 40% in June through August.

Wheatgrass (*Agropyron* spp.) and Nevada bluegrass (*Poa nevadensis*) were consumed with greater frequency than other grasses. Wheatgrass occurred in pellets uniformly throughout the summer period while bluegrass occurred with greater frequency in early summer (Table 5). Wheatgrass and bluegrass consumption was greater in early summer 1978 than the same period in 1977 (56% and 37%, respectively) while availability of those grasses did not differ appreciably between years (2.5% and 3%, respectively). The reason for this differential consumption is not known. Wilde (1978) reported a dietary transition from wheatgrass and bluegrass in early summer to wildrye (*Elymus* sp.) and needleandthread (*Stipa* sp.) in August and September. Although needleandthread occurred in the habitat with the same frequency as bluegrass in our study, it never appeared in significant amounts in the diet.

Mean preference indices (PI) for the major plant species eaten by pygmy rabbits in all sites were calculated using the formula: PI= (relative % of item in diet)÷(relative % of item in habitat). The PI for sagebrush was 1, indicating that it was eaten in the same proportion as it occurred in the habitat. Indices greater than 1 indicate that the item was eaten in a greater proportion than it occurred in the habitat. Therefore, the PI may show preferred food items (high values) and also the relative amount of energy expended by the rabbits to seek and consume the item. Bluegrass and wheatgrass had the highest PI's of all food items (14 and 37, respectively) and were the grasses found most frequently in fecal pellets from all sites. Consequently, a greater energy expenditure is required to seek and consume these two grass species than any other plants regularly eaten. Preference indices for other plants eaten were as follows: cheatgrass (*Bromus tectorum*), 5; sedge (*Carex* spp.), 5; needleandthread, 1; common yarrow (*Achillea millefolium*), 8; rose pussytoes (*Antennaria rosea*), 4; astragalus (*Astragalus* spp.), 7; and lupine (*Lupinus* spp.), 3.

An index of similarity (SI) between pygmy rabbit diet and each habitat grouping was calculated for early summer 1977 using the formula: SI= (Σ minimum value ÷Σ maximum value) (100). The following values were obtained: for pygmy rabbit habit, 48%; for the grazing exclosure, 47%; for the marmot sites, 49%; for the rodent trapping sites, 34%; and for the Uinta ground squirrel sites, 49%. An SI of 100% would indicate that food items were eaten in identical proportion to their occurrence in the habitat. The SI values for pygmy rabbit, marmot, and ground squirrel habitat are similar and indicate that each of these areas would be equally suited for pygmy rabbits with respect to availability of vegetation for food. The fact that pygmy rabbits are not found to any degree in marmot and ground squirrel habitat demonstrates that something other than diet may primarily influence habitat selection by pygmy rabbits in this study area.

Similarity indices for habitat and diet in six pygmy rabbit sites ranged from 13% to 64%. Although this range is relatively wide, consumption of food items was similar in all sites and did not appear to be controlled by vegetative availability.

Fecal Deposition

Fecal deposition data were collected from 9 adult pygmy rabbits (4 males and 5 females) which were part of a laboratory colony. Pellets were collected daily for 9 consecutive days, counted, dried, and weighed. Mean defecation rate for the rabbits was 36.09 ($S_{\bar{x}}$ = 2) pellets per hour for a 24-hour mean total of 866 pellets. Nine pellet groups were counted showing a mean of 67.78 ($S_{\bar{x}}$ = 5.4) pellets per group. By dividing daily defecation rate by the mean pellets per group, a mean of 12.78 pellet groups per day was determined in the laboratory for the pygmy rabbit.

Fecal pellets were collected from all field sites at 2-month intervals except during winter. Therefore, the late April

Table 4. **Mean grass-forb vegetative biomass for pygmy rabbit sites in 1977 and 1978 (kg/ha).**

Site	Total biomass	Grass biomass (% of total)	Forb biomass
1	609	494 (81)	115
2	543	316 (59)	227
3	573	388 (68)	185
5	917	199 (24)	719
6	734	111 (16)	623
7	777	420 (54)	357

1978 sampling represents a 5-month pre-collection period (November 1977 to April 1978) and is not used in calculation of the site means listed in Table 6. The mean collection totals for sites 5 and 6 were significantly greater ($P \leq 0.01$) than means for the other sites. There was no significant difference between the mean totals for each collection period.

The sampling scheme for vegetation effectively measured identical portions of pygmy rabbit habitat. Since the mean defecation rate for the pygmy rabbit appears to be relatively constant, the greater number of pellets found in sites 5 and 6 indicates more rabbits inhabiting those two areas. Correlation coefficients (r) were calculated using linear regression between the mean bimonthly number of pellets per site and the following variables: shrub cover and height, sagebrush, forb, and grass biomass. Forb biomass was positively correlated ($r = 0.92, P \leq 0.01$), and grass biomass was negatively correlated ($r = -0.91$, $P \leq 0.01$) with the number of fecal pellets deposited. No other associations showed significant correlations.

There are no published quantitative data available for pygmy rabbit habitat. Census methods for this species make subjective inference necessary when investigating population density. In this study, some habitat parameters and one means of objectively assessing relative numbers of pygmy rabbits in various sites have been quantified. Based on these parameters, there was a significant decrease in mean grass biomass and a significant increase in mean forb biomass where pygmy rabbit were most abundant.

Several factors may influence the grass-forb ratio in the pygmy sites. Season and intensity of livestock grazing influences vegetation. Fall grazing with light spring grazing is less injurious to grasses and forbs than summer grazing (Mueggler 1950). In this study, we assume the impact of livestock grazing has been similar in all pygmy rabbit sites; however, realistically, differences in grazing pressure may have occurred.

Soil characteristics within and between pygmy rabbit sites influence vegetative composition. Based on a soil survey completed on the Sheep Station in 1969 by the Soil Conservation Service, pygmy sites 1, 5, 6, and 7 are in the same soil complex and sites, 2, 3, and 4 are in related complex. There are likely soil phase differences within each site, however, that affect the vegetative component in a complex manner. Thus we cannot necessarily expect pygmy sites within a particular soil series to be comparable in all vegetative respects. Shrub height and canopy cover may be similar while the grass-forb ratio could be different.

Environmental conditions, particularly precipitation, may affect vegetation composition on an annual basis. Pygmy rabbit sites were ranked according to biomass of grasses, forbs, and total biomass for each of the 2 years of this study. Spearman's rank correlation coefficients (*rho*) were calculated for each ranking as follows: grass, .934; forbs, 1.0; and total biomass, .49. During the period of this study, therefore, there was little change in ranking of grass

Table 5. Vegetation eaten annually by pygmy rabbits in southeastern Idaho (figures are a mean % relative density for the 7 rabbit sites).

	May–June	July–Aug.	Sept.–Oct.	Dec.–Feb.	Mar.–Apr.	Annual mean[1]
Shrubs						
Artemisia spp.	47	43	57	99	80	
Purshia tridentata	—	2	1	—	2	
Chrysothamnus nauseosus	—	—	—	—	1	
Ribes spp.	—	1	—	—	—	
Other	1	1	—	—	—	
Total (7 species)	48	47	58	99	83	67
				—		
Grasses				—		
Agropyron spp.	27	36	26	1	7	
Bromus tectorum	—	1	—	—	trace	
Carex spp.	1	1	—	—	—	
Koeleria cristata	—	—	1	—	trace	
Oryzopsis hymenoides	trace	1	—	—	—	
Poa nevadensis	12	1	3	—	6	
Stipa comata	trace		—	—	—	
Other	3	2	1	—	2	
Total (13 species)	43	42	31	1	15	26
Forbs						
Achillea millefolium	3	trace	trace		—	
Antennaria rosea	3	3	4		—	
Astragalus spp.	1	2	3		trace	
Eriogonum heracleoides		—	2		2	
Lupinus spp.	trace	1	trace		—	
Penstemon spp.	1	trace			—	
Other	2	2	2			
Total (16 species)	10	8	11		2	6

[1] Note. Due to trace amounts and plants identified as unknowns, the annual mean column does not total 100.

Table 6. Data from collection of pygmy rabbit fecal pellets for 2-month intervals (except the late April 78 period).

	Total pellets from each of 7 sites							
Collection date	1	2	3	4	5	6	7	x̄
Late June 77	469	649	556	475	879	1368	343	677
Late Aug. 77	575	664	583	468	959	656	493	628
Late Oct. 77	405	443	472	57[1]	1521	973	465	713
Late Apr. 78	457	800	778	497	1356	826	585	762
Late June 78	375	333	174	95	810	1355	554	528
Late Aug. 78	377	326	568	191	981	666	136	464
Late Oct. 78	427	212	581	298	643	593	333	441
x[2]	438	438	489	305[3]	966	935	387	

[1] Partial snow cover precluded a 100% pellet collection.
[2] Omitting late April 78 collection data because of the potential 5 month pre-collection period.
[3] Omitting late Oct. 77 collection data.

and forb biomass between the six pygmy rabbit sites examined while total biomass ranking varied with years.

The data from this study may support the following hypothesis. Dietary analysis indicates that pygmy rabbits consume wheatgrass and bluegrass throughout the summer period while consuming forbs to a lesser degree. Therefore, rabbits may initially inhabit areas that contain abundant grass, provided that all other habitat requirements are met (i.e. adequate sagebrush cover and height). Following a period of time, total grass biomass may be reduced through selective removal by rabbits and forb biomass may increase due to negative selective pressure. Concurrently, a decrease in grass vigor would allow a competitive advantage to forbs. A similar process may have occurred in parts of the Wasatch Plateau, Utah, where forbs dominate in areas that have been grazed by cattle for many years (Ellison 1954). Cattle prefer grasses to forbs (Stoddart et al. 1975) and may have caused forbs to increase through selective pressure on grasses. Validity of the proposed grass depletion theory is related to the ability of the habitat to produce sufficient grass for summer food requirements of rabbits. From an evolutionary standpoint, it may not be advantageous for the rabbit to decrease the grass component to the point that a new habitat has to be selected.

Wilde (1978) observed that transition to grass consumption during the summer may insure minimal damage to sagebrush, which is the critical winter food for pygmy rabbits. He further observed that the pygmy rabbit does not respond to an abundant spring food supply in favorable years by producing extra litters similar to other rabbit species. Therefore, numbers of pygmy rabbits may fluctuate less than other leporids, indicating a close harmony with their climax-type vegetational community and a decreased reliance on variable grass production.

Consumption of grasses in spring through summer is also related to reproduction. Green vegetation is important for reproduction in small rodents (Van De Graaf and Balda 1973) and dietary restrictions influence breeding in rabbits (Kirkpatrick and Kibbe 1971). Wilde (1978) concluded that vegetation was also a key to reproductive readiness in the female pygmy rabbit.

There are implications with respect to the pygmy rabbit and livestock grazing. Comparisons between forage intake for rangeland grazers can be made using the formula reported by Dasmann (1971:33), where air-dry forage requirements are related to the seventy-three hundredth power of the live weight of the animal in question. For a 64-kg sheep, the formula shows a daily consumption of 2.08 kg of air-dry forage. This estimate compares to published values for sheep, which range from 1.35 to 2.25 kg/day depending on reproductive condition (Cullison 1975). Accordingly, the following daily forage consumptions are calculated: for a 46-kg deer, 1.63 kg/day [compare with 1.36 to 1.81 kg/day (Dasmann 1971)]; for a 2.5-kg jackrabbit, .20 kg/day [compare with .09 to .13 kg/day (Flinders and Hansen 1972)]; and for a .45-kg pygmy rabbit, .06 kg/day. It appears that the formula overestimates forage consumption as the size of the animal decreases but it has value for comparative purposes. The pygmy rabbit consumes about 1/4 the amount of forage as a jackrabbit and about 1/35 the amount of forage as a sheep. Sheep prefer forbs (Stoddart et al. 1975) and pygmy rabbits prefer grass to forbs in summer. Therefore, the pygmy rabbit may compete minimally with sheep for forage on rangeland where forbs are sufficiently abundant and may even enhance forb production by selective grazing of grasses. Pygmy rabbits may compete with cattle for grasses.

Summary and Conclusions

The pygmy rabbit is generally restricted to the sagebrush-grass complex of the Great Basin although Davis (1939) reported the animal also in areas where greasewood (*Sarcobatus*) was abundant. Six habitat sites occupied by pygmy rabbits were analyzed for vegetational characteristics and composition and compared to other random sites that were not inhabited by pygmy rabbits. Woody cover and shrub heights were significantly greater in the pygmy rabbit sites, while no significant differences were observed in total grass-forb biomass between sites.

Pygmy rabbits ate sagebrush throughout the year but in lesser amounts in summer (51%) than in winter (99%). Other shrubs were consumed infrequently. Grass and forb consumption was relatively constant throughout the summer (39 and 10%, respectively) and decreased to a trace amount through fall to winter. Wheatgrass and bluegrass were highly preferred foods in the summer period while forbs were eaten only occasionally in all sites.

Data from deposition of fecal pellets indicated relative abundance of rabbits, and decreased grass with increased forb biomass in the 2 sites where rabbits were most abundant. This may be due to selective grazing pressure on grasses by the pygmy rabbits and could benefit sheep but be detrimental to cattle where pygmy rabbit habitat coincides with livestock grazing.

Research with a captive colony of pygmy rabbit indicates that they have preferences for certain species and subspecies of sagebrush and quickly succumb when essential food items are not available. Compared to a maximum similarity index of 100%, which indicates items are eaten in proportion to their occurrence in the habitat, the SI of 48% between pygmy rabbit diet and their habitat indicates that dietary selection also takes place in the natural environment. However, comparable similarity indices were also obtained with pygmy rabbit diet and habitat for marmots and ground squirrels. These sites did not contain pygmy rabbits to any degree. Therefore, in this study area, cover appeared to be the critical habitat feature selected by the pygmy rabbit. Other subtle variations in the vegetative component of the habitat may help to explain why areas with "appropriate looking" woody vegetational physiognomy do not necessarily constitute suitable pygmy rabbit habitat. Due to specialized habitat features selected for by pygmy rabbits, prudent consideration should precede sagebrush eradication where these animals occur.

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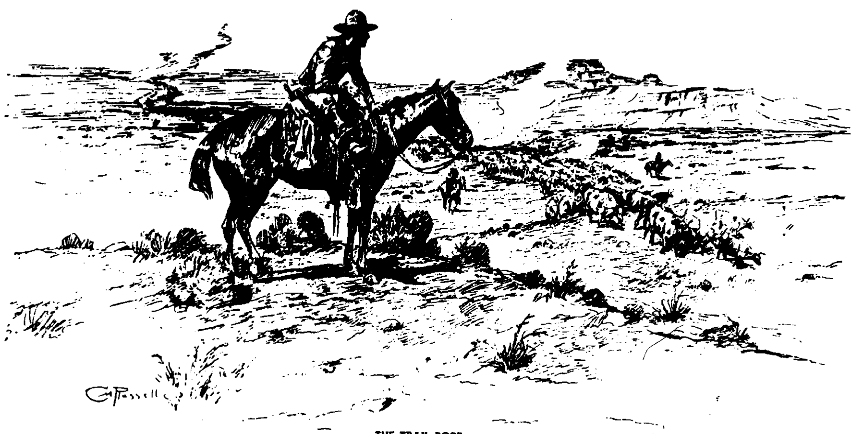

THE TRAIL BOSS

Range Grasses and Their Small Grain Equivalents for Wind Erosion Control

LEON LYLES AND BRUCE E. ALLISON

Abstract

An equation that estimates potential wind erosion requires that all vegetative cover (dry weight per area) be expressed as a small grain equivalent. Wind-tunnel tests were used to determine that equivalent for selected range grasses, either as single species or mixtures, at three grazing-management levels. Compared with flat small grain, range grasses evaluated effectively prevented erosion, with buffalograss (*Buchloe dactyloides*) the most effective and big bluestem (*Andropogon gerardi*) the least effective among those tested. A possible procedure for extending the results to other grasses or mixtures is suggested. The data on range grass to small grain equivalent for erosion control may be used to predict the wind erosion potential of range sites or to determine the amounts of range grass needed to hold potential erosion to tolerable limits.

Managing vegetative cover is the most effective practical method for controlling wind erosion (Woodruff et al. 1977). Effectiveness of wind erosion control depends on the quantity, kind, and orientation of vegetation in relation to the soil surface (including areal distribution) (Chepil 1944; Siddoway et al. 1965; Lyles and Allison 1976). Current procedures for evaluating or designing management systems for wind erosion control utilize the following equation (Woodruff and Siddoway 1965):

$$E = f(I, K, C.L. V), \qquad [1]$$

where E is the potential annual soil-loss rate; I, the soil erodibility; K, the soil ridge roughness factor: C, the climatic factor; L, the unsheltered distance across a field along the prevailing wind erosion direction; and V, the equivalent vegetative cover. To use the equation, one must express all vegetative cover (dry weight per unit area) in terms of its equivalent to a small grain standard. The standard (reference) has been defined as 25.4 cm of dry small grain stalks lying flat on the soil surface in rows perpendicular to wind direction with 25.4-cm row spacing, with stalks oriented parallel to the wind direction.

Although equivalents data are available for several agronomic crops, none have been obtained for range grasses. Consequently, we initiated this study to determine the small grain equivalents of several perennial range grasses as single species or mixtures at three levels of simulated grazing management.

Experimental Procedure

Native perennial range grasses made available by the U.S. Dep. Agr., Soil Conservation Service, from ungrazed sites in Nebraska were buffalograss (*Buchloe dactyloides*), sideoats grama (*Bouteloua curtipendula*), western wheatgrass (*Agropyron smithii*), and needleandthread (*Stipa comata*). Big bluestem (*Andropogon gerardi*), little bluestem (*Andropogon scoparius*), switchgrass (*Panicum virgatum*), and blue grama (*Bouteloua gracilis*) were obtained from the Plant Materials Center, Manhattan, Kansas (Table 1). All grasses were harvested after dormancy with 5.1 cm of intact roots for anchoring. In the laboratory, the plants were washed and air-dried before wind-tunnel testing. Properly grazed and overgrazed management levels were simulated by clipping the ungrazed material to various heights (Table 1).

The wind-tunnel, 1.52 m wide, 1.93 m high, and 16.46 m long, was a recirculating push-type tunnel with airflow generated by a 10-blade, variable-pitch axivane fan. The appropriate kind, amount, and height of grass was placed in standard test trays 148 cm long, 16.5 cm wide, and 4 cm deep (inside dimensions). The trays were then filled with sand 0.297 to 0.42 mm in diameter so that the grass stood in clumps, and were exposed for 5 minutes at 13.36 m/sec freestream

Table 1. Heights of standing perennial range grasses that were evaluated in a wind tunnel at three levels of grazing management for wind-erosion protection.

	Height (cm)			
Grass species	Ungrazed	Properly grazed	Overgrazed	Symbol
Sod-forming grasses				
Big bluestem (*Andropogon gerardi*)	[1]	15.2[2]	2.5	BB
Western wheatgrass (*Agropyron smithii*)	[1]	10.2	2.5	WW
Buffalograss (*Buchloe dactyloides*)	10.2	5.1	2.5	B
Bunch grasses				
Switchgrass (*Panicum virgatum*)	[1]	15.2[2]	2.5	
Little bluestem (*Andropogon scoparius*)	[1]	10.2	2.5	
Blue grama (*Bouteloua gracilis*)	33.0	5.1	2.5	
Mixtures				
Big bluestem (60%)	[1]	15.2[2]	2.5	M_1
Little bluestem (30%)	[1]	15.2	2.5	
Sideoats grama (*Bouteloua curtipendula*) (10%)	[1]	15.2	2.5	
Western wheatgrass (45%)	43.2	10.2	2.5	M_2
Needleandthread (*Stipa comata*) (30%)	43.2	10.2	2.5	
Blue grama (25%)	33.0	10.2	2.5	
Blue grama (45%)	33.0	5.1	2.5	M_3
Buffalograss (30%)	10.2	5.1	2.5	
Western wheatgrass (25%)	43.2	5.1	2.5	

[1] Species too tall to evaluate in wind tunnel.
[2] Shorter than "properly grazed" for these two grasses.

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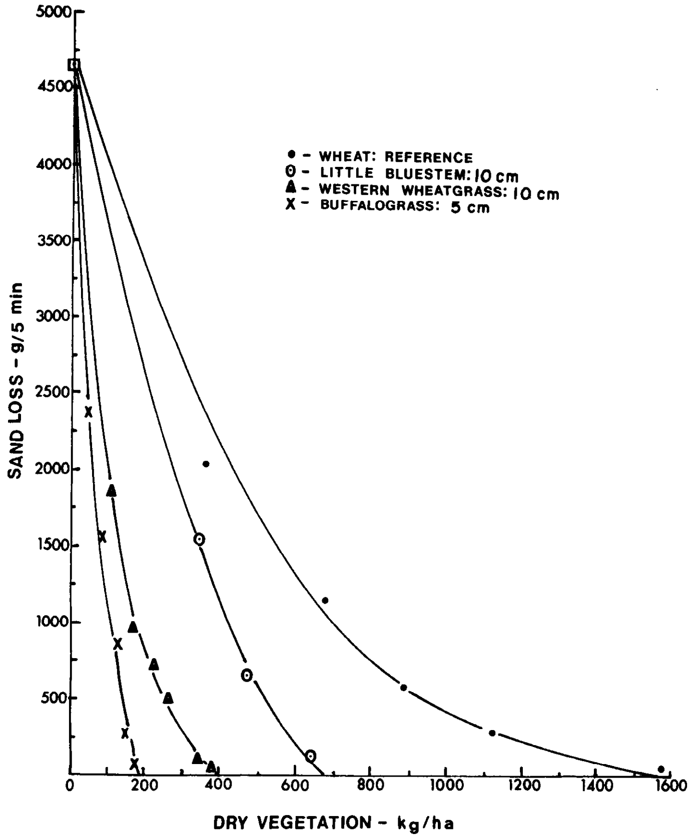

Fig. 1. *Wind-tunnel sand loss as related to amount of standing vegetation for selected range grasses. Winter wheat is used as reference.*

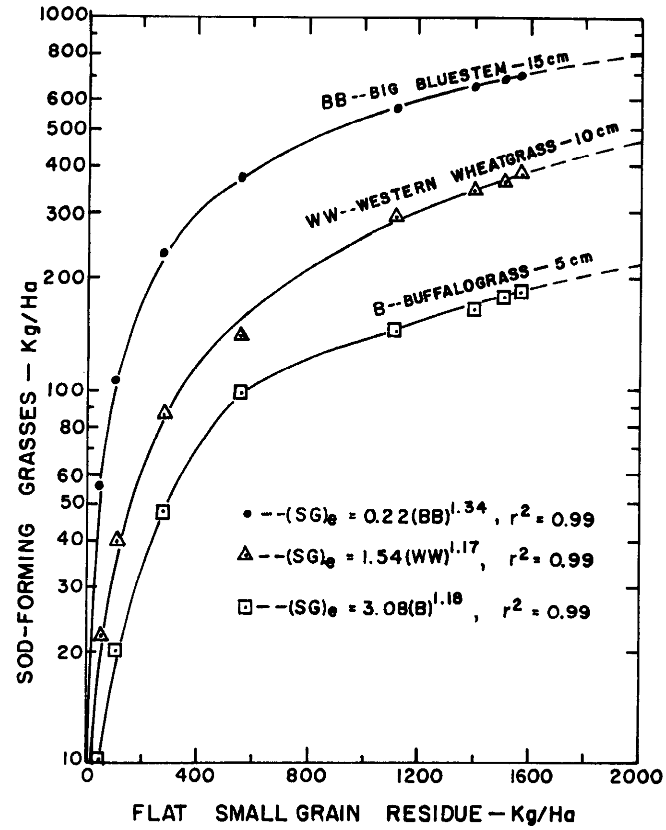

Fig. 2. *Conversion of properly grazed big bluestem (see footnote 2 in Table 1), western wheatgrass, and buffalograss to equivalent quantity of flat small grain residue* $[(SG)_e]$.

windspeed in the tunnel. Two test trays were located approximately 14.5 m downwind and 7 cm apart (side by side) during each exposure. The entire wind-tunnel floor area downwind and 4.9 m upwind from the test area was covered with the same number of grass "clumps" per unit area as the test trays contained. The sand loss was determined from the differences in tray plus sand weight before and after exposure to wind. Four to six runs for each single species or mixture at each height were conducted to establish a relationship between the sand-loss rate and the dry weight per unit area of the vegetation.

Small grain stubble (winter wheat) [displayed in the reference manner] was tested under the same conditions as the range grasses to provide the required data for determining their small grain equivalents.

Results

Typical curves of sand-loss rate as related to the amounts of dry vegetation for selected grasses and winter wheat (Fig. 1) and similar data for the other single grasses and mixtures for the three levels of grazing management were converted to an equivalent quantity of flat small grain residue as illustrated in Figure 2. We chose the abscissa as the dependent variable (small grain equivalent) and the logarithmic ordinate for the grasses to be converted, the method of plotting current charts used by the Soil Conservation Service. A power equation of the form

$$(SG)_e = aX^b \qquad [2]$$

resulted in high simple-correlation coefficients (r). In the power equation, $(SG)_e$ is the small equivalent and X is the quantity of grass to be converted, both as kg/ha, and a and b are constants. Specific equation coefficients for each grass or mixture and grazing level, and the corresponding r^2, are given in Tables 2 and 3.

Compared with the flat small grain, range grasses effectively prevented wind erosion. Buffalograss was the most effective and big bluestem the least effective among the grasses tested. For example, 150 kg/ha of properly grazed buffalograss was equivalent to about 1,150 kg/ha of flat small grain and 600 kg/ha of properly grazed big bluestem was equivalent to about 1,200 kg/ha of flat small grain (Fig. 2).

Table 2. Coefficients in prediction equation, $(SG)_e = aX^b$, for conversion of range grasses to equivalent quantity of flat, small grain residue (equation 2).

Grass species	Grazing management[1]	Prediction equation coefficients a	b	r^2
Blue grama	Ungrazed	0.60	1.39	0.98
Buffalograss	Ungrazed	1.40	1.44	0.97
Big bluestem	Properly grazed	0.22	1.34	0.99
Blue grama	Properly grazed	1.60	1.08	0.99
Buffalograss	Properly grazed	3.08	1.18	0.99
Little bluestem	Properly grazed	0.19	1.37	0.99
Switchgrass	Properly grazed	0.47	1.40	0.99
Western wheatgrass	Properly grazed	1.54	1.17	0.99
Big bluestem	Overgrazed	4.12	0.92	0.99
Blue grama	Overgrazed	3.06	1.14	0.99
Buffalograss	Overgrazed	2.45	1.40	0.99
Little bluestem	Overgrazed	0.52	1.26	0.99
Switchgrass	Overgrazed	1.80	1.12	0.99
Western wheatgrass	Overgrazed	3.93	1.07	0.99

[1] See Table 1 for heights.

Except for switchgrass, mixture 1, and mixture 2, the small grain equivalents for overgrazed grasses were greater for the same amount of plant material per area than for the properly grazed grasses (Tables 2 and 3). That was also generally true for the overgrazed as compared with the ungrazed grasses. These results do not suggest that overgrazing provides greater protection against wind erosion than does proper grazing or undergrazing! Under actual grazing, maintaining the same quantity of vegetation per unit area in overgrazed and properly grazed or ungrazed areas would be impossible because livestock consume most of the above-ground plant parts. In our wind-tunnel study, we increased the number of "plants" per unit area to make the quantities of overgrazed, properly grazed, and undergrazed grasses equal, because the properly grazed and ungrazed grasses were taller. Apparently, for these thin stands, the tendency for reduced plant height to increase erosion was more than offset by the stabilizing influence of more plants per unit area.

Table 3. Coefficients in prediction equation, $(SG)_e = aX^b$, for conversion of range grass mixtures to equivalent quantity of flat, small grain residue (equation 2).

Grass mixture[1]	Grazing management	Prediction equation coefficients a	b	r^2
M_2	Ungrazed	0.29	1.30	0.99
M_3	Ungrazed	1.48	1.23	0.99
M_1	Properly grazed	4.21	0.94	0.99
M_2	Properly grazed	6.16	0.94	0.99
M_3	Properly grazed	5.39	0.97	0.99
M_1	Overgrazed	1.50	1.06	0.99
M_2	Overgrazed	1.64	1.17	0.99
M_3	Overgrazed	2.34	1.32	0.99

[1] See Table 1 for mixture composition.

Discussion

Because only small quantities of grasses are required to reduce erosion to low values in the wind tunnel, measured field amounts of grasses generally will exceed the maximum values we evaluated, and will also exceed the upper limit used to determine equation [2]. We could safely say that there is no wind erosion hazard if the amounts of grasses in the field greatly exceed those indicated in Figure 2. If a small grain equivalent is desired for tall grasses, the field sample could be clipped to the properly grazed height before determining areal dry weight.

Concerning grass mixtures, two questions are important: (1) are the results using grass mixtures similar to the weighted effects of the single species making up the mixtures, and (2) how do we evaluate grass mixtures (or single species) other than those tested, either for the same or for different percentages? Only in mixture 3 (blue grama, buffalograss, and western wheatgrass) did we also test all the mixture grasses separately. Equation [3] may be expressed on a weighted basis:

$$(SG)_e = a_1^{P_1} a_2^{P_2} \ldots a_n^{P_n} X^{P_1 b_1 + \ldots + P_n b_n} \quad [3]$$

where n is the number of grasses in a mixture, P is the proportion of each grass (by weight) in a mixture, and X is the total dry weight of the mixture per unit area. If $n = 1$, i.e. a single species, then equation [3] becomes equation [2].

For mixture 3, agreement between the mixture equation and the weighed equation was good for the properly grazed level but only fair for the ungrazed and overgrazed levels (Table 4). The ratios in Table 4 for mixture 3 suggest that as height decreases, grasses in this mixture become more effective in reducing erosion than the weighting of their single effects suggests. Perhaps this mixture, as height decreases, is dominated by buffalograss—the most effective of all grasses tested in preventing erosion. When overgrazed, buffalograss has been reduced no more than 7.6 cm from the ungrazed height, but blue grama and western wheatgrass have been reduced 30.5 and 40.6 cm, respectively. The weighted approach could be extended to mixture 3 grasses at percentages different from those tested.

The best approach to evaluating other grasses, of course, would be to test them in a wind tunnel. The large number of grasses makes that unlikely in the near future. Lacking experimental data, a range specialist or agronomist and scientist group could make composite judgments about which tested grass is most similar physically to an untested grass. Data for the tested grass than could be used for the grass in question. We used that approach by assuming sideoats grama in mixture 1 and needleandthread in mixture 2 were similar to western wheatgrass (Table 4). The results were fair to poor, depending on mixture and grazing level. The reasons for disagreement of equation [2] and equation [3] for those mixtures (M_1 and M_2) are not clear. Experimental error and/or lack of similarity of the two grasses (sideoats grama and needleandthread) to western wheatgrass were assumed as explanations. However, errors of 18 to 41% in the small grain

Table 4. Comparison of small grain equivalents for three range grass mixtures at various levels of grazing management using mixture equation [2] and weighted equation [3].

Grass mixture[1]	Management level	Total dry weight	Small grain equivalent Eqn [2]	Eqn [3]	Ratio Eqn [2]/Eqn [3]	Error
		kg/ha	kg/ha	kg/ha		%
M_3	Ungrazed	300	1649	2163[2]	0.76	31
M_3	Properly grazed	300	1363	1232	1.11	10
M_3	Overgrazed	150	1744	1248	1.40	28
M_1	Properly grazed	500	1450	1007[3]	1.44	31
M_1	Overgrazed	500	1089	1387[3]	0.79	27
M_2	Properly grazed	300	1312	1082[4]	1.21	18
M_2	Overgrazed	300	1297	1824[4]	0.71	41

[1] See Table 1 for mixture composition.
[2] Properly grazed data was used for western wheatgrass.
[3] Sideoats grama was assumed similar to western wheatgrass.
[4] Needleandthread was assumed similar to western wheatgrass.

equivalents when grasses were substituted may be acceptable for estimating wind erosion on range, pasture, and hay sites, especially if no experimental data are available.

Hopefully, these guides for calculating the small grain equivalents of range grasses will be useful to conservationists, environmentalists, and others. With a wind erosion equation (Woodruff and Siddoway 1965), the guides can be used to estimate the wind erosion potential of range, pasture, and hay sites and to determine the approximate amounts of grass needed to hold potential erosion to tolerable levels.

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Bite-count vs Fecal Analysis for Range Animal Diets

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Abstract

This study indicated that the bite-count and fecal analysis methods give similar results for estimating major components of cattle diets in Texas. The bite-count method could not be used on large, brush-infested pastures with rough terrain; however, the fecal analysis method was easily used under such conditions. Other advantages of fecal analyses were: samples were collected with a minimum of field work, diets of wild and domestic animals could be obtained, and bad weather and poor field conditions were not problems. Major disadvantages of the fecal analysis technique were: forages with dense stellate trichomes were overestimated; mesquite beans were retained in the digestive tract for abnormally long periods; the laboratory phase required a trained technician; and the work was tedious.

Knowledge of the species consumed by grazing-animals, season by season, is fundamental to proper grazing management. Commonly used methods for obtaining diet composition have included: direct animal observation, forage utilization, and identification of plant material collected by esophageal fistula from stomach contents, or from fecal material. Many researchers consider the esophageal fistula technique the most accurate (Harris et al. 1959; Rice 1970), and Cook (1964) found it less time consuming than other methods. However, identification of individual grasses or individual forbs is often impossible with fistula collections. Because of the obvious disadvantages of working with fistulated animals in large pastures; areas with rough, rocky, terrain; or areas heavily infested with brush, other methods that offer reasonably accurate data are often needed.

Ideally, a method for determining grazing-animal diets will: (1) allow free animal movement and completely natural selection of all available plants and plant parts regardless of pasture size; (2) allow for diet determination regardless of terrain; (3) be equally useful for wild and domesticated animals; (4) not require slaughter of test animals; (5) require a minimum of animal care; (6) be relatively objective; and (7) allow identification of each individual plant species consumed.

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Microscopic examination of fecal material fits the criteria outlined. Baumgartner and Martin (1939) identified food items in squirrel diets more than 40 years ago by microscopic examination. More recently plant species consumed by sheep (Hercus 1960), cattle (Malechek 1966; Free et al. 1971), and horses (Regal 1960) were identified by examination of feces and/or rumen contents through a microscope. Unequal digestibility among plants (Regal 1960) appears the most serious source of error in determining diet composition from fecal examination. Also, the laboratory analysis method is tedious (Ward 1970).

A technique commonly used and that also meets the criteria outlined is a variation of the feeding-minutes method termed the "bite-count" method used by Reppert (1960) and McMahan (1964). Free et al. (1971) working with steers obtained diet information comparable to the esophageal fistula method using the bite-count technique.

Because of brush infestation and the rough topography of most Texas ranges, obtaining usable diet information for management or research purposes is a major problem. Despite its limitations, microscopic evaluation of diets from fecal material seems to offer a viable choice. Therefore, the objective of this study was to find out if the fecal examination by microscope technique could provide diet compositions similar to those obtained from the bite-count method.

Methods

The study was conducted in 1972-73 on the R.A. Brown ranch in north-central Texas. Cattle diets were determined by the bite-count and fecal analysis methods at monthly intervals on two grazing systems, continuous yearlong use, and a short duration system.

Diets obtained by bite-count were collected each month by observing five animals in each system. All animals had free access to all parts of the pasture. Each animal was individually observed for 10 to 20 minutes at a time at close range (3 to 20 ft) from a pickup truck. Two, 2-hr sampling periods, one beginning at sunrise and another commencing approximately 2-hr prior to sunset, were used each day. Three sampling periods were normally required to complete all observations for each date.

The number of bite "units" of each species grazed was recorded as described by Reppert (1960). Unequal bite size due to different quantity available or different plant form was accounted for by estimating size of bite. If the actual animal bites were comparatively small, for a given species, two or more were recorded as one unit or bite.

Samples of fecal material were collected from 10 animals in each system during the same period that bite-count data was collected. Each sample was prepared for microscopic examination by adding hot water to the sample and blending for 1 or 2 minutes in a blender. This material was washed over a 200 mesh screen and a small portion of the washed material was used to make a microscope slide. Slides were prepared as described by Cavender and Hansen (1970). Fecal material was spread evenly on the glass slide using a clearing agent (Hertwig's solution). Most of the clearing agent was evaporated off by heating the slide over a bunsen burner. A cover slip was sealed on the slide using Hoyer's solution and the slide was then dried in an oven at 60° *C* for 3 days.

A reference collection was made of plant species found on the study area. Tissues of leaves, stems, flowers, and seeds of each species were mounted on slides in the same manner as the fecal material. Identification was based on epidermal tissue characteristics, such as guard cells, stomata, cell shape, and trichomes.

Two slides of fecal material were prepared for each animal. Each slide was viewed under a compound microscope at 100 power magnification. Ten fields or locations per slide were examined and the frequency of each species recorded. Frequency was converted to density using the tables prepared by Fracker and Brischle (1944). Relative density was calculated and used as an estimate of percent dry weight of each species in the diet (Sparks and Malechek 1968).

Dietary information from both methods was summarized into six categories: Texas wintergrass (*Stipa leucotricha*), sideoats grama (*Bouteloua curtipendula*) buffalograss (*Buchloe dactyloides*), other grasses, forbs, and shrubs.

Results and Discussion

Differences between grazing systems were minor and not significant ($P<.05$); therefore, the diet data are reported without regard for grazing system. Figure 1 shows the month-by-month changes in cattle diet as determined by bite-count and fecal examination. Fecal samples from 10 animals per grazing system (20 per date) were sufficient to give satisfactory data as standard error values seldom exceeded 10% of the mean. Observations of five animals per grazing system for diet determination from bite-count proved sufficient to provide seasonal trends of major species in the diet. However, variation among animals was larger than for the fecal examination method as standard errors exceeded 20% of the mean about ¼ of the time. Significant differences (Fig. 1) that occurred between bite-count and fecal analysis were apparently because of the different lengths of the sampling periods. Fecal analysis estimates an animal's diet for up to a 6-day period, as it takes this long for ingesta to pass through the digestive tract (Church 1969). However, in this study the bite-count method provided an estimated of the diet for only 7 to 8 hr out of a 2-day period. The animals observed sometimes grazed in a small area of the pasture during this relatively short period, whereas during several days they grazed in many communities over the entire pasture.

An example of a difference in diet because of a short vs a long sampling period occurred in August 1972. For this date fecal analysis showed that the diet consisted of only 7% buffalograss, but the bite-count method showed 41% (Fig. 1). All cattle in that pasture grazed only in a buffalograss-dominated plant community during the 2 day observation period. Thus, buffalograss was the only readily available species and the cattle mostly grazed on it. During the several days represented by the fecal collections, the cattle apparently had spent time in other communities eating other species. This kind of bias was essentially eliminated, except for the August 1972 date, because we observed animals scattered over the pasture rather than limiting observation to animals grazing only in one small area. Sampling intensively by ocular estimate to eliminate the few situations that might arise as described above probably would not be justified for the small increase in accuracy.

Some difficulty has been reported in identifying forbs with fecal analysis because they are so thoroughly digested (Storr 1961; Free et al. 1970). This could cause underestimation of forbs in the diet. However, underestimation did not appear serious in this study. Only 3 of the 33 diet comparisons between methods had significantly ($P<0.05$) different amounts of forbs. Number of forb species detected in the diet by the two methods was about equal.

Early in the study it appeared fecal analysis overestimated the amount of silverleaf nightshade (*Solanum elaeagnifolium*) in the diet. According to fecal analyses, as much as a third of the diet on some dates was silverleaf nightshade. Not only did the bite-count method contradict such data, but the amount of silverleaf nightshade available for grazing also precluded such high percentages. Also it is poisonous to cattle and one lb is sufficient to kill a 1,000-lb cow (Buck et al. 1960).

Silverleaf nightshade has large stellate trichomes. These trichomes are undigested and pass through the digestive tract in large numbers. Under the microscope, they appear so large (Fig. 2) that they blot out distinguishing characteristics of other species. Thus, only silverleaf nightshade might be noted as present in a microscope field, even though other species were also present. This results in overestimation of the silverleaf nightshade and underestimation of the other species in the diet. Examination of known species mixtures, determined by weight, confirmed that even trace amounts of silverleaf nightshade could yield a frequency as high as 25%. Therefore, silverleaf nightshade was excluded from all the results of fecal analysis. No attempt was made to determine the degree of overestimation and then apply a correction factor because of the minute amount potentially in the diets. Other suspect forb species gave no detectable bias. However, a unique problem was discovered concerning mesquite beans. Fecal samples only were collected from an adjacent ranch operated by R.A. Brown. From January to March of 1973, no beans were available to the cattle on this ranch; but fecal samples collected during those months showed cattle diets with 8 to 14% mesquite beans. New reference slides of mesquite beans were made and compared with the slides from fecal samples. Mesquite beans were definitely in the feces, verified by two different observers.

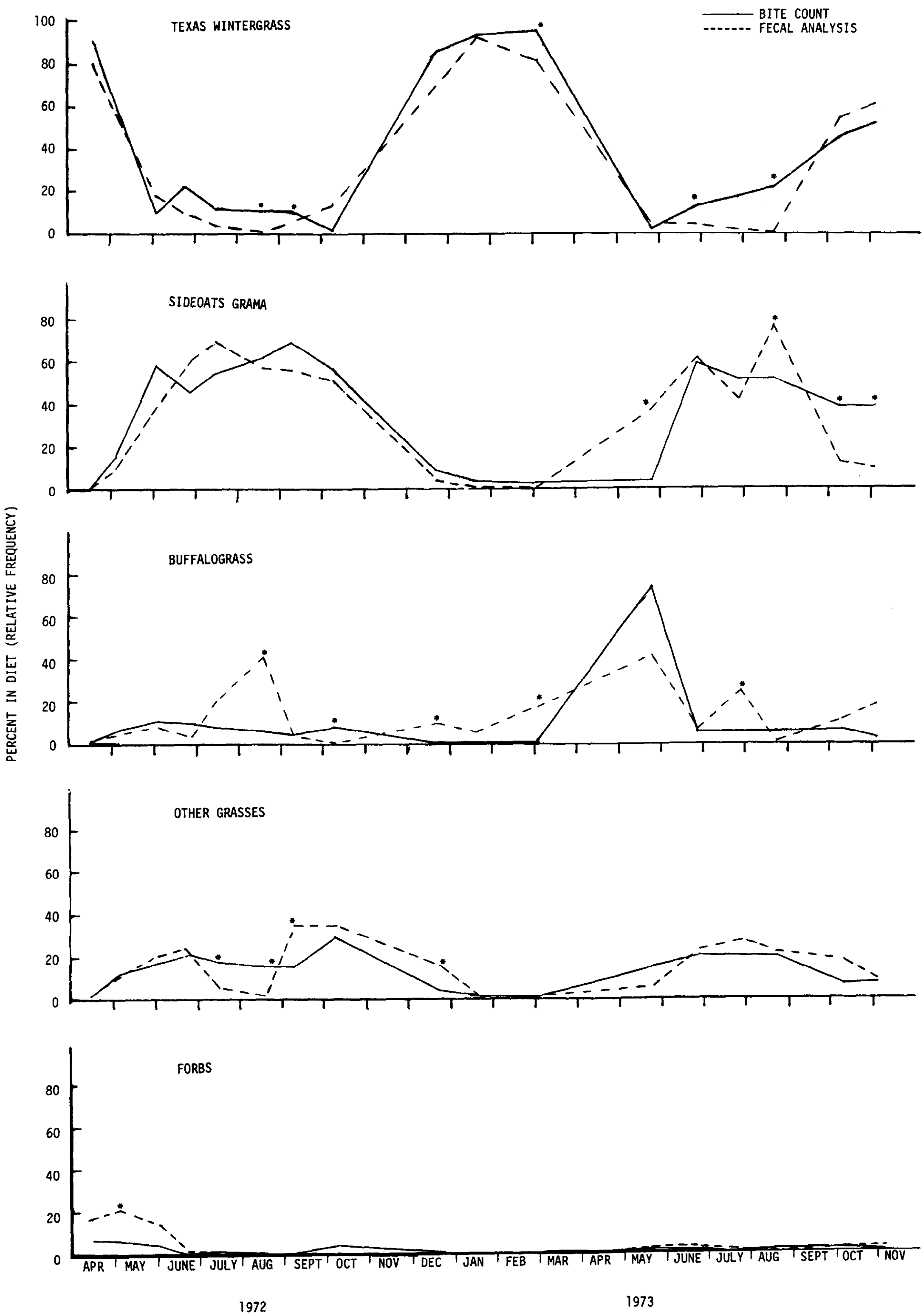

Fig. 1. *Cattle diets as determined for the bite-count and fecal analysis methods. Asterisks (*) indicate significant differences (P<0.05) for the sampling period.*

Dollahite and Anthony (1957) reported that mesquite beans had remained in the digestive tract of cattle as long as 9 months after consumption. They were frequently retained for 3 months. Mesquite trees growing on this adjacent ranch produced a large crop of beans in the fall of 1972, but by the end of December they were all gone, even from the ground. Apparently, some were retained in the digestive tract from fall consumption and released in January, February, and March the following year. Mesquite beans were not produced in 1973 and no beans were observed by fecal analysis that fall nor the following winter.

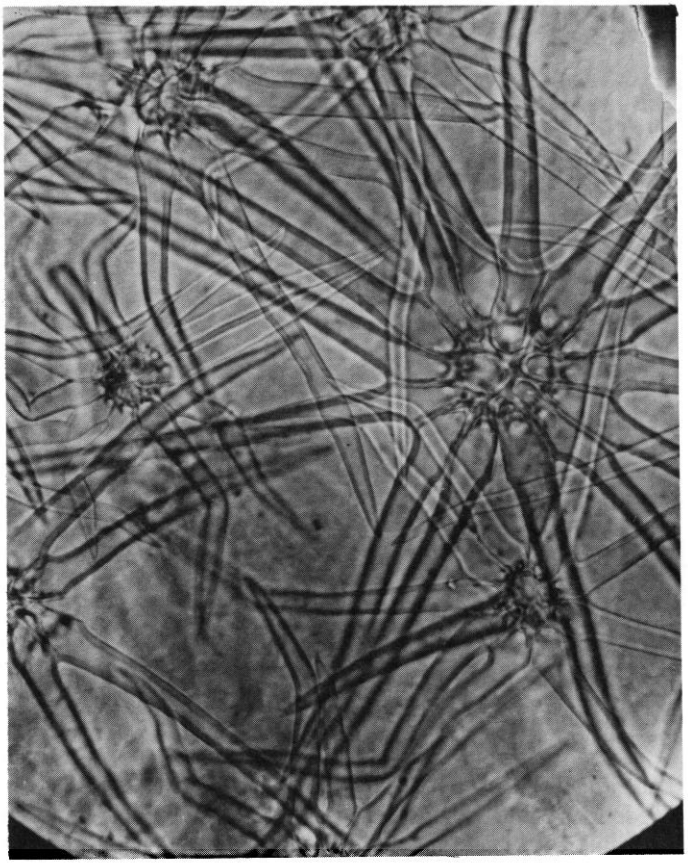

Fig. 2. *Stellate trichomes of silverleaf nightshade (400X).*

Conclusions

This study indicates that the bite-count and fecal analysis methods give similar results for major diet components. It would be difficult to use either the bite-count or the esophageal fistulae on animals grazing in the large brush-infested pastures commonly found in Texas. On the other hand, we collected fecal samples easily under such conditions. The fecal analysis method had the following additional advantages samples were collected with a minimum of field work; diets of wild animals (for another study) as well as domestic animals were obtained; it was not limited by weather or rough terrain; and it was not subject to observer bias, thus, it was relatively objective. Major disadvantages of the fecal analysis methods were: (1) forages with dense stellate trichomes could be overestimated; (2) mesquite beans were sometimes retained in the digestive tract for abnormally long periods indicating consumption when none occurred; (3) the laboratory phase required a trained technician and the work was tedious; and (4) it would be difficult to know which plant parts to collect and in what proportions for simulating diets for the chemical analyses needed for nutritional studies. Thus, the microscopic examination of animal feces cannot be considered the ultimate means of determining diets of range animals and it is probably more accurate for determining seasonal diets than for an individual date. However, it can be used with confidence in many areas where other methods cannot be used.

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Microhabitat Relationships of Six Major Shrubs in Navajo National Monument, Arizona

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Abstract

Six shrub species were studied to determine their microhabitat relationships as well as their effect on the immediate environment. Analysis of site characteristics and mineral composition of soils in open areas adjacent to shrubs and beneath shrubs allowed for comparison of the different habitats following shrub establishment. Soil pH differs beneath the various shrubs and all six species tended to create more alkaline soils beneath their canopy. All species showed increased soil salinity beneath their canopy. However, the concentration of total soluble salts in the soil surface beneath the shrubs varied with the species and was highest beneath fourwing saltbush. Significant increases in the concentration of magnesium and potassium ions beneath shrubs were observed. Nitrogen and phosphorus were also found in greater concentration beneath the shrub canopy. Soil depth differed beneath the shrub species, with sagebrush and fourwing saltbush growing on the deeper more highly developed types. There was a positive relationship between the presence of shrubs and the depth of the soil profile.

It has long been known that shrubs influence the soil characteristics beneath their canopy (Fireman and Hayward 1952). Studies done in the last decade show that shrubs influence both the horizontal and vertical patterning of soil chemicals (Charley and West 1975). Sharma and Tongway (1973) studied the effects of two species of saltbush (*Atriplex nummularia* and *Atriplex vesicaria*) on soil salinity and related properties. They recognized an accumulation zone beneath the shrubs, a zone of compensation where leaching of minerals replaced those absorbed, and a depletion zone from which mineral absorption exceeded the rate of replacement. Salt accumulation under shrubs, therefore, represents a redistribution of salts from peripheral regions of root activity (Charley and West 1975).

Plants employ several "strategies" for the removal of mineral wastes. Leaching of minerals from leaves is accomplished when the solution of the leaf surface connects with that of the intercellular spaces of the mesophyll and ions are lost by diffusion. Salts are also excreted with the aid of salt glands, as is the case with many *Atriplex* species. Salts are also concentrated in the extracellular spaces of leaves during the process of transpiration, thus accumulating minerals in leaves. Leaf fall subsequently serves as a mechanism for the elimination of mineral wastes (Epstein 1972).

Charley and West (1975) used the distributional patterns of carbon and nitrogen under and between shrubs as a measure of the soil organic pool. They showed that as precipitation increases, the average depth of soil wetting improves and so does the overall concentration of soil organic matter beneath shrubs. The mineral concentration in the soil surface layer was found to be the best indicator for the patterns observed.

Harner and Harper (1973) dealt with the increase in mineral concentration of vegetation along a moisture gradient and concluded that soil moisture allows for greater solubility and, therefore, greater absorption of minerals in more productive sites.

A few papers have treated the effect of mineral enrichment beneath shrubs on the productivity of associated grasses. Tiedeman and Klemmedson (1973) reported that beneath mesquite trees (*Prosopis juliflora*) the nutrient availability was elevated and accounted for significantly increased yields of Arizona cottontop (*Trichachne californica*) and plains bristlegrass (*Setaria macrostachys*). Rickard, et al., (1973) showed greasewood (*Sarcobatus vermiculatus*) and spiny hopsage (*Grayia spinosa*) induce predictable changes in mineral composition of soil and create more favorable conditions for production of cheatgrass (*Bromus tectorum*).

The purpose of this study was to compare the interaction of six species of shrubs with their immediate environment, the shrubs' general influence on their microhabitat, and the mineral content of the shrubs' foliage relative to their uptake patterns.

Study Area

Navajo National Monument is located in northeastern Arizona about 16 kilometers north and west of Black Mesa, Navajo County, Arizona. The monument headquarters are located on the Shonto Plateau near the head of Betatakin Canyon, a small side canyon of the Tsegi Canyon. The principal features of the monument are three large cliff dwellings of the Anasazi culture. Betatakin and Keet Seel are located in the Tsegi Canyon complex, while Inscription House is located in Nitsin Canyon, a branch of Navajo Canyon.

All three units typify a pinyon-juniper slickrock environment. Average annual temperature at Navajo National Monument headquarters is 10°C. Yearly maximum temperatures range from 32° to 38°C with an average of 36°C; yearly low temperatures range from −23° to −13°C with an average of −17°C. The frost-free season ranges from 107 to 213 days with an average of 155 days.

Total annual precipitation at Betatakin has historically ranged from a low of 17 centimeters to a high of 48 centimeters, with an average of 29 centimeters. The period of greatest precipitation is late summer and early fall. Most storms are localized and convectional in nature and, therefore, of high intensity and spotty distribution. This reduced and unpredictable rainfall, so characteristic of arid rangelands, has a profound effect on plant production and also mineral cycling (Charley 1977).

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Navajo Sandstone is the major geological formation in each of the three units. At Keet Seel and Inscription House, the Navajo Sandstone is the only exposed rock formation. At Betatakin, the Kayenta formation outcrops beneath the Navajo Sandstone and can be observed in the lower reaches of the canyon. In all three canyons the Navajo Sandstone forms tall, sheer cliffs up to 225 meters in height. At the base of these cliffs, tallus accumulations occur and the canyon bottoms are filled with deep deposits of sandy alluvium.

Methods

Three shrub-dominated communities were found on the rim of Betatakin Canyon. Big sagebrush (*Artemisia tridentata*) dominated the mesa above the canyon where the soil was well developed. A mixed-shrub community composed of cliff fendlerbush (*Fendlera rupicola*) was found occupying primarily the sloping terrain below the mesa and was characterized by rugged, tallus-like topography and shallow soils. Needle-leaf mountain mahogany (*Cercocarpus intricatus*) was restricted to the slickrock areas and appears to function in soil development and the establishment of islands of vegetation. Four-winged saltbush (*Atriplex canescens*) was found on tallus slopes and sandy alluvium above the streambed in Keet Seel Canyon. In order to avoid sampling heavily grazed areas, all plots were established within the fenced boundary of the park.

Line transects (one per species) were established for each shrub type. The placement of transects were biased in order to sample areas of optimal habitat for a study species. At 15-meter intervals along the transect the nearest individual (ten in all) of the species being sampled was centered in a plot that measured 4 × 4 meters. Each plot was subsampled with ten quadrats (1/16m^2) to determine vegetative cover of associated species. Composite soil samples were taken with a tubular soil probe to a depth of 15 cm underneath the shrub canopy and from adjacent open areas. In the mineral analysis only five of the ten composite soil samples were used. Plant samples included only current growth and were taken in mid-summer for all the shrubs to determine mineral composition. The following characteristics were recorded for each plot: exposure, percent slope, topographic position (ridgetop, midslope, or drainage accumulation area), and soil depth under and between the shrubs.

Soil samples were analyzed for texture (Bouyoucos 1951), pH, soluble salts, and mineral composition. Soil reaction was taken with a glass electrode pH meter. Total soluble salts were determined with a Beckman electrical conductivity bridge. A 1:1 soil-water paste (Russell 1948) was used to determine pH and total soluble salts. Soils were extracted with 1.0 normal ammonium acetate for the analysis of calcium, magnesium, potassium, and sodium. Zinc, manganese, iron, and copper were extracted from the soils with DPTA (diethylenetriaminepentaacetic acid). Ion concentrations were determined using a Perkin-Elmer Model 290 atomic absorption spectrophotometer. Soil phosphorus was extracted with sodium bicarbonate. Total nitrogen analysis was made using macrokjeldahl procedures (Jackson 1968).

Plant material was air-dried, ashed, and later analyzed for mineral composition by atomic absorption spectrophotometry.

Results

Measurements of canopy cover were taken for species associated with the different shrubs to determine if modification of the environment by the shrubs resulted in the establishment of distinct associations of plants (Table 1). Perhaps 16 of the 52 species sampled showed some degree of preference for one shrub habitat over the others. Since understory vegetation in pinyon-juniper communities is often sparse, it was expected that tree canopy also greatly influenced composition of the understory.

Cluster analysis (Sneath and Sokal 1973) was used to group shrub types that were similar with respect to the community composition of the various microhabitats (Fig. 1). Cliff fendlerbush and buffaloberry communities were most similar in this respect although they were also similar to sagebrush and cliffrose. The plant understory associated with fourwing saltbush and mahogany were also highly similar. The greatest amount of exposed rock was also found in these two areas.

Table 1. Average percent cover for the important plant species of the six microhabits.

	Site[a]					
Species	Cliff	Salt	Rose	Buff	Sage	Maho
Amelanchier utahensis				.02		
Arabis perennans	.2					.19*
Artemisia frigida		1.45*				.15
Artemisia ludoviciana		.04		.02		
Artemisia tridentata		.04	.90*	.78	9.24*	
Astragalus mollissimus						.02
Atriplex canescens		10.72*				
Bouteloua gracilis	1.80*	2.64*	2.47*		2.06*	2.39*
Bromus tectorum		1.50*				
Cercocarpus intricatus						27.36*
Chrysothamnus nauseosus		.17*				.18
Cowania mexicana	1.15		17.67*	2.18*		
Cryptantha flava		.15	.15		.05	
Descurainia sophia			.02			
Echinocactus fendleri			.32			.98
Ephedra viridis		.37	.30	1.35		.15
Erigeron concinnus	.06					
Eriogonum microthecum		.30				
Eriogonum umbellatum					.15	
Erysimum asperum	.02		.04		.04	.31*
Fendlera rupicola	16.99*	.02		2.88*		.98
Vulpia octaflora	.04	.02	00.39*			
Gilia aggregata					.22*	
Xanthocephalum sarothrae	.54*	.92*	1.88*			.30
Haplopappus nutallii				.17		.15
Hymenopappus filifolius		.15				
Hymenoxys richardsoni	.02	.32	.05	.26	.02	
Juniperus osteosperma	.30		.02	6.72*	3.77	
Lappula redowskii		.02	.02			

[a] Cliff fendlerbush, Salt = Saltbush, Rose = Cliffrose, Buff = Buffaloberry, Sage = Sagebrush, Maho = Mahogany

* Among the most prevalent species for the shrub type.

The flexibility of the various shrub populations to changes in the environment is shown in Table 1. Needle-leaf mountain mahogany was restricted to the slickrock areas. Fourwing saltbush also was apparently limited in its ability to become established in areas best suited for other shrub species. Sagebrush dominated the mesa tops and was the most widely distributed shrub. The shrub species in the mixed-shrub community (cliff fendlerbush, cliffrose, and buffaloberry) occupied similar sites although areas existed where each was most abundant.

Analysis of the site characteristics in open areas adjacent to the shrubs allows for comparison of the different areas prior to shrub establishment (Table 2a). Soil texture did not vary significantly between shrub types. Average percent sand, silt, and clay was 83%, 12%, and 5% respectively. The pH of the soil was lowest in areas near cliff fendlerbush, sagebrush, and mountain mahogany; intermediate for cliffrose and buffaloberry and most alkaline in areas adjacent to fourwing saltbush. Soil development varied significantly between the different sites. The deepest soil was found in fourwing saltbush and sagebrush areas and averaged 32 centimeters in depth. Sagebrush also grew in areas of shallow soils with an average depth of 10 centimeters.

Topographic position (Table 2) of the different species was represented by index values ranging from 1−3. Drainage

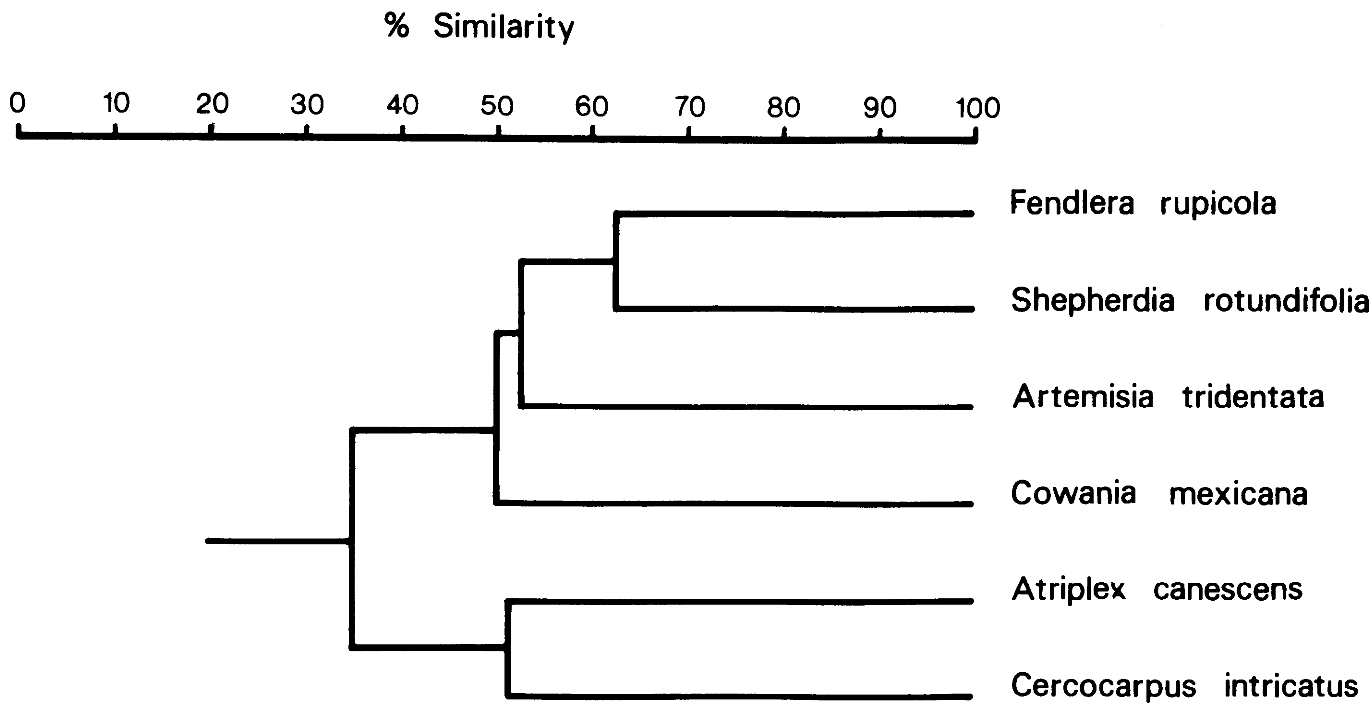

Fig. 1. *Similarity in understory composition of the six shrubs.*

accumulation areas, midslope, and ridgetop areas correspond to values of 1, 2, and 3 respectively. Optimum habitat for sagebrush was on nearly level terrain while all other shrubs occupied midslope positions.

Slope aspect data was transformed according to Beers et al. (1966) to allow the use of aspect as an independent variable in statistical analysis of the six shrub habitats. Northeast aspects receive a value of 2.0, the southwest a value of 0.0, and intermediate aspects vary from 2.0 to 0.0 in both directions. The low index value for sagebrush (0.60) indicates a more southwestern exposure than is the case for the other shrubs. Cliffrose had an intermediate value for aspect (1.21), while the remaining shrubs averaged 1.74.

Discriminate analysis (Klecka 1975) was used to determine if site characteristics of areas adjacent to shrubs had an influence in their distribution and possible establishment. Data on site characteristics from five plots were used to group each shrub habitat type. Based on these characteristics, 73% of the plots were classified correctly. The most important characteristic for grouping the six habitat types was percent slope, followed by soil depth, aspect, topographic position, pH, and soluble salts. All of the fourwing saltbush plots were classified

Table 2. Site characteristics in open areas adjacent to shrubs (A) and beneath shrubs (B).

	Site characteristics									
Shrubs	Sand (%)	Silt (%)	Clay (%)	Fines (%)	pH[a]	Soluble[a] Salts (ppm)	Soil[a] depth (cm)	Slope (%)	Aspect	Topographic position
A										
Cliff fendlerbush	82.8a*	12.4a	4.8a	17.2a	7.16a	194.6a	10.40a	22.2ab	1.92a	1.80a
Saltbush	83.0a	12.8a	4.2a	17.0a	7.70b	167.4a	25.80b	70.4c	1.65a	2.00a
Cliffrose	82.8a	12.4a	4.6a	17.0a	7.46ab	160.2a	8.40a	31.8ab	1.21ab	2.20a
Buffaloberry	81.8a	12.8a	5.4a	18.2a	7.42ab	185.6a	10.80a	39.2bc	1.79a	2.00a
Sagebrush	84.8a	10.4a	4.8a	15.2a	7.08a	145.6a	37.80b	16.40a	.60b	2.80b
Mahogany	85.4a	9.8a	4.8a	14.6a	7.18a	136.0a	10.58a	29.90ab	1.63a	2.00a
Average	83.4	11.8	4.8	16.6	7.33	164.9	17.3	35.0	1.47	2.10
B										
Cliff fendlerbush	81.8a	14.2a	4.0bc	18.2a	7.46ab	269.0ab	26.4a	22.2ab	1.92a	1.80a
Saltbush	82.4a	13.2a	4.4ab	17.6a	7.84c	327.0a	60.0c	70.4c	1.65a	2.00a
Cliffrose	81.6a	13.6a	4.8ab	18.4a	7.70bc	190.8bc	17.8a	31.8ab	1.21ab	2.20a
Buffaloberry	79.4a	14.8a	5.8a	20.6a	7.46ab	216.8abc	23.6a	39.2bc	1.79a	2.00a
Sagebrush	82.4a	12.4a	5.2ab	17.6a	7.34a	126.6c	45.2b	16.4a	.60b	2.80b
Mahogany	88.6b	8.4a	2.8c	11.4b	7.50ab	130.6c	23.0a	29.9ab	1.63a	2.00a
Average	82.7	12.8	4.5	17.3	7.54	210.1	32.7	35.0	1.47	2.10

[a] Average values for these characteristics differ significantly (0.5 level) under and between shrubs.
* Duncan's multiple range separations (calculated for each microhabitat): within columns for each site characteristic, values without common letters are significantly different at the 5% level.

correctly indicating that unique habitats exist for saltbush establishment. Eighty percent of the sagebrush and mountain mahogany plots, and 60% of those for cliff fendlerbush, cliffrose, and buffaloberry were classified correctly. The use of discriminate analysis showed that the habitats of shrubs of the mixed-brush zone were less distinctive than those of the other shrubs.

Data presented in Table 2b indicate that shrubs exert a varied influence on their immediate surroundings. With respect to soil texture, areas under mountain mahogany had significantly more sand and less clay in the soil than soils under other shrubs. Mountain mahogany pioneers newly established soils of the slickrock areas. When percent fines (clay plus silt) of the different habitat types are compared, it is evident that the extent of soil development in mountain mahogany areas was less than in areas occupied by the other shrubs.

Shrubs also seem to affect pH of the soil in a different manner. Average values ranged from 7.3 to 7.8 for sagebrush and fourwing saltbush respectively. Due to the sample variation, it was difficult to show statistical differences but it appears that patterns do exist. For example, sagebrush showed the lowest pH values while cliff fender bush, buffaloberry, and mountain mahogany had intermediate values. Four wing saltbush and cliffrose showed the highest values.

The larger concentration of total soluble salts beneath the canopy of cliff fendlerbush and fourwing saltbush differed significantly from low values for sagebrush and mountain mahogany dominated soils. The value for cliffrose was similar to that of fourwing saltbush and cliff fendlerbush, whereas buffaloberry was quite variable in salt concentration and not significantly different from any of the shrubs. A comparison of soil depth under the shrubs shows the deepest soil existed beneath fourwing saltbush, sagebrush being intermediate, and the least depth found under the other shrubs.

When site characteristics for the microenvironment beneath shrubs were used to group different shrub types using discriminant analysis (Klecka 1975), 93% of the grouped cases were correctly classified. This compared with a 73% correct classification for the same plots using site characteristics of open areas adjacent to the shrubs. Soil depth was the most important factor used to classify different microhabitats beneath the shrubs. Other characteristics, in descending order of importance, were: percent slope, percent clay, topographic position, aspect, and soil pH. The microenvironments beneath cliff fendlerbush, fourwing saltbush, cliffrose, and sagebrush were very distinct. Eighty percent of the mountain mahogany plots were also correctly classified with one plot being grouped with buffaloberry. Such evidence indicates that the shrubs influence the general soil characteristics beneath the canopy.

Results of analyses of mineral composition of soils from open areas adjacent to shrubs are provided in Table 3a and are intended to give some idea as to the characteristics of the soil prior to shrub establishment. Of the ten nutrients analyzed from soils sampled between shrubs, the concentration of calcium, potassium, iron, and manganese varied significantly between the six habitats. Calcium was the most concentrated nutrient and was most abundant in the fourwing saltbush and buffaloberry sites. Potassium was also found in greater concentration in these areas. Buffaloberry and sagebrush sites exhibited the greatest concentration of iron. Buffaloberry sites were also high in manganese. Mountain mahogany-dominated areas were consistently low in soil minerals. The macronutrients magnesium, phosphorus, and nitrogen were uniformly distributed as were the micronutrients zinc and copper. When mineral composition in the soil between the shrubs was used to classify different habitat types, 70% of the plots were correctly classified by discriminant analysis (Klecka 1975). It appears that different habitats open to shrub establishment vary with respect to both site characteristics and mineral composition. Eighty percent of the cliffrose, sagebrush, and mahogany plots were correctly classified. Soil mineral composition in areas between these shrubs was fairly distinct. Only 60% of cliff fendlerbush, fourwing saltbush, and buffaloberry were classified correctly. The soil mineral composition of these habitat was not as characteristic. Elements most useful in classification of different shrub types were sodium, calcium, iron, copper, nitrogen, and phosphorus.

Mineral composition of the soil beneath the shrubs also varied between different habitats (Table 3b). Calcium was most concentrated under buffaloberry and fourwing saltbush and least concentrated under sagebrush and mahogany.

Table 3. Soil mineral concentrations (ppm) in open areas adjacent to shrubs (A) and beneath shrubs (B).

Shrubs	N[z]	P[z]	Ca	Mg[z]	K[z]	Na[z]	Zn	Fe	Mn	Cu
A										
Cliff fendlerbush	236.6a**	5.24a	2008.8a	658.8a	79.8b	9.6a	1.29a	4.27a	3.94bc	0.50a
Saltbush	324.4a	5.70a	3646.2b	368.8a	101.9a	9.6a	1.50a	3.26a	5.22ac	0.40a
Cliffrose	369.8a	7.84a	1700.0a	507.5a	66.8b	6.6a	1.13	3.44a	3.03bc	0.48a
Buffaloberry	492.8a	8.98a	2982.5b	556.2a	103.6a	9.7a	1.50a	6.02ab	6.08a	0.44a
Sagebrush	335.0a	4.60a	1515.0a	608.8a	75.0b	8.4a	1.09a	6.31b	4.22abc	0.46a
Mahogany	327.0a	7.14a	1675.0a	548.8a	52.8b	9.4a	1.18a	3.35a	2.32b	0.38a
Average	347.4	6.58	2254.6	541.5	80.0	8.9	1.28	4.44	4.14	0.44
B										
Cliff fendlerbush	478.8a	9.10a	2150.0bc	653.8a	142.2a	7.9a	1.24a	5.41a	4.83a	0.50a
Saltbush	545.0a	5.74a	3690.0ac	938.8b	502.5b	9.7b	1.54a	3.71a	7.69a	0.42a
Cliffrose	683.6a	10.50a	2357.5bc	638.8a	115.9a	7.7a	1.63a	4.70a	4.33a	0.46a
Buffaloberry	587.4a	14.28a	4905.0a	783.8ab	153.1a	8.1a	1.63a	7.68a	7.11a	0.55a
Sagebrush	559.6a	6.46a	1740.0b	682.5ab	101.7a	9.7b	1.22a	7.17a	4.16a	0.47a
Mahogany	540.4a	9.16a	1650.0b	530.0a	82.5a	7.9a	1.22a	4.71a	3.38a	0.30a
Average	565.8	9.21	2748.8	704.6	183.0	8.5	1.41	5.56	5.25	0.45

[z] Average values for these characteristics differ significantly (.05 level) under and between shrubs.

* Duncan's multiple range separations (calculated for each microhabitat): within columns for each mineral, values without common letters are significantly different at the 5% level.

Table 4. Elemental content of current year's growth of six shrubs expressed in micrograms per grams of plant material (ppm).

Shrub	Elements									
	N	P	Ca	Mg	K	Na	Zn	Fe	Mn	Cu
Cliff fendlerbush	6810	898	5430	1012	9865	312	19.2	147	15.5	6.2
Saltbush	12940	642	8200	2025	16150	350	6.0	115.5	30.0	6.0
Cliffrose	10360	634	9325	1225	3440	250	18.8	75.8	9.0	7.0
Buffaloberry	13125	1018	8040	1188	6915	275	16.8	137.5	24.0	5.5
Sagebrush	8315	975	4465	950	11640	375	26.5	186.0	27.8	8.8
Mahogany	7990	698	8265	962	2830	238	20.5	93.2	22.2	6.7
Average	9923	811	7288	1227	8473	300	17.9	125.8	21.4	6.7

Potassium was highly concentrated beneath the canopy of fourwing saltbush and was lowest beneath mountain mahogany. The concentration of potassium beneath other shrubs was intermediate. Cliff fendlerbush, cliffrose, and mountain mahogany-influenced soils were lowest in magnesium and significantly different from the soils influenced by fourwing saltbush. Buffaloberry and sagebrush-influenced soils were intermediate in magnesium concentrations. Sodium was most abundant beneath fourwing saltbush and sagebrush and did not differ significantly among the other shrubs. Phosphorus and nitrogen were uniformly distributed underneath the shrubs as were all the micronutrients except sodium.

Seventy-seven percent of the plots were correctly classified when mineral composition beneath shrubs was used as the basis for classification. Soil mineral composition beneath buffaloberry shrubs was highly characteristic and allowed all plots to be correctly classified. Eighty percent of cliff fendlerbush, fourwing saltbush, sagebrush, and mahogany plots were classified correctly, indicating that these shrubs alter the soil mineral composition in unique ways. Soil mineral composition beneath cliffrose was highly variable and resembled that of cliff fendlerbush, fourwing saltbush, and sagebrush. Eighty percent of the plots were correctly classified when soils between cliffrose shrubs were classified, but when the soil mineral composition beneath the shrub canopy was used to group the shrubs only 40% of the cliffrose plots were correctly classified. Cliffrose did alter the soil mineral characteristics of its environment, but did so in a manner highly similar to several other shrubs.

The mineral composition of the current year's growth for each shrub is outlined in Table 4. Unfortunately, not enough plant material was collected from each shrub to provide independent samples for analysis. As a result, statistical analysis of the data is not justified, although mean values are important and represent averages of two composite samples derived from the ten plants sampled per shrub species Information provided in Table 4 further shows that minerals were not absorbed in the same proportion as found in the soil. As expected, the macronutrients nitrogen, potassium, calcium, magnesium, and phosphorus were concentrated in the leaves and twigs to a greater degree than that of the micronutrients sodium, zinc, iron, manganese, and copper. When compared to the concentrations found to be adequate for higher plants, the concentration of nitrogen, potassium, and manganese appeared to be slightly deficient (Epstein 1972).

Discussion

It has been shown that different species of shrubs have a varied influence on the soil chemistry of their environment. If the influence of shrubs on various parameters of the soil surface is compared with the characteristics of the soil prior to shrub establishment, several trends become apparent.

The concentration of total soluble salts under the shrub canopy was significantly greater than that of open areas adjacent to shrubs (Table 2). Sharma and Tongway (1973) and Charley and West (1975) also found this to be the case. Salts are absorbed throughout the rooting volume of the plant and accumulate in the surface layer beneath the shrubs.

The concentration of total soluble salts in the soil of areas not influenced by a shrub canopy did not differ significantly. However, the six shrubs did differ as to their impact on the concentration of salts in the soil. Sagebrush and mountain mahogany had an insignificant affect on the accumulation of soil salts. Saltbush and cliff fenderbush showed a greater impact on soil salinity in that the soluble salts in the soil beneath their canopies were generally much higher.

The soil pH under the shrub canopy was significantly greater than that of adjacent open areas (Table 2). Although the margin of difference was not great, little variation was found under and between shrubs. Sharma and Tongway (1973) and Greenwood and Brotherson (1978) have reported an increase in pH under shrubs, whereas Charley and West (1975) found that such differences were not always predictable.

Soil depth beneath shrubs and that found in open areas adjacent to shrubs was shown to be significantly different and might be attributed to shrub influence. However, soil depth between the different shrubs is not so easily explained. For example, soil depth in the mixed shrub zone and slickrock areas was relatively shallow when compared to soil depths beneath saltbush and sagebrush. Saltbush was found growing in areas of greatest soil depth. These differences are more likely due to genetic variations in the shrubs themselves than in their effects on soil accumulation beneath their canopies.

It was possible to rank the six shrubs according to the variation in concentration of calcium, magnesium, potassium and sodium in the soil beneath them. The concentration of a particular mineral was classified as high, intermediate, or low for each shrub and assigned values of 3, 2, and 1 respectively. Theoretically, a species could receive a value of 12 if the concentration of the four minerals were always among the highest group.

We should note that of the minerals that did differ significantly under the shrubs, the greatest concentrations were consistently found under fourwing saltbush (Table 5). Saltbush grew in the deepest soils and the greater rooting volume might account for more extensive redistribution of minerals from other zones. The species is also equipped with salt glands to facilitate the removal of excess minerals.

Buffaloberry was ranked second, although the depth of the soil underneath the canopy did not differ from the other shrubs of the mixed-brush zone. It has been postulated that leaf size might account for some of the variation in the soil mineral composition beneath shrubs (Sharma and Tongway 1973). It is

Table 5. Ranking of six shrubs according to extent of mineral enrichment (calcium, magnesium potassium, and sodium) beneath shrub canopy. The concentration of a particular mineral was classified as high, intermediate or low for each shrub and assigned a value of 3, 2, or 1 respectively. Theoretically, a species could receive a value of 12 if the concentration of the minerals were aways among the highest group.

Shrub	High	Intermediate	Low	Total
Saltbush	3[a]	1	0	11[b]
Buffaloberry	1	2	1	8
Sagebrush	1	1	2	7
Cliff fendlerbush	0	2	2	6
Cliffrose	0	1	3	5
Mahogany	0	0	4	4

[a] Numbers indicate that of the four minerals, three were among the highest concentrations.
[b] Number was derived when 3 of the 4 minerals were among the highest concentrations and one way among the intermediate concentrations (i.e. 3 × 3 = 9 and 1 × 2 = 2 thus 9 plus 2 equal 11).

interesting to note that buffaloberry had the largest leaf of all the shrubs studied.

Sagebrush, cliffrose, and cliff fendlerbush all had similar sized leaves, although the greater soil depth under sagebrush may account for the difference in mineral accumulation. Mountain mahogany had the smallest leaves of all the shrubs and was found in shallow soils and cracks in the sandstone.

Of special interest was the percent increase in nitrogen, phosphorus, potassium, and magnesium in soils under shrubs compared to soils adjacent to shrubs. Magnesium was also highly concentrated under the shrubs. Since potassium and magnesium were the only macronutrients that function as cofactors of plant enzymes, it is possible that the shrubs recycle more of these cations as a result of their inefficiency in enzyme systems (Epstein 1972).

Nitrogen was also highly concentrated under shrubs. Charley and West (1975) and Garcia-Moya and McKell (1970) reported nitrogen accumulation under shrubs and an associated concentration decline in the surround environment. Charley (1977) suggested the possibility of this also being attributed to an increase in nitrogen fixation by free living microorganisms in and under litter mats, animal activity, and canopy capture of wind transported soils.

The concentration of phosphorus was found to be significantly greater in soils under shrubs. Organic matter accumulation under shrubs probably accounted for the increase. Charley and West (1975) found greatest differences in the concentration of organic phosphorus and also found differences in available phosphorus under and between shrubs. Average values of all minerals were shown to be greater under shrubs, but too much variation was found in the samples to prove statistical differences.

Mineral concentration of plant materials versus that of the soil serves to show the extent that minerals are concentrated in the plants. Although mineral composition of the soil differed between the six shrubs, the plants were fairly consistent in their ability to accumulate minerals. On the average, shrubs concentrated phosphorus about 110 times that found in the soil. The concentration of phosphorus found in the soil was far below the 200 ppm suggested by Epstein (1972) as being adequate for maintenance of healthy plant tissue.

Potassium was 68 times more concentrated in plant tissue than in the soil surface. According to Epstein (1972), plants have evolved a mechanism for high accumulation of potassium from the soil to allow for the inefficiency of potassium as a cofactor in enzyme systems. Potassium is the only monovalent cation essential for all higher plants. Arid regions are often characterized by having a greater concentration of potassium in the plant (Epstein 1972). In this study, potassium was found in greater concentration than sodium in both the soils and in the plant material

Table 6. Comparison of the mineral composition of shrubs.

Species	Elemental concentration (%)					
	H	P	M	Na	Ca	Mg
Atriplex confertifolia	1.66	.07	1.84	5.75	2.69	.77
Atriplex canescens	1.74	1.38	2.88	.16	2.57	1.23
Larrea divaricata	1.86	.15	2.20	.03	.68	.13
Lycium pallidum	1.97	.08	2.41	1.49	2.46	1.05
Grayia spinosa	1.67	.05	4.29	.52	1.67	1.19
Ceratoides lanata		.22	3.24	.05	1.43	.49
Franseria dumosa		.48	4.78	.10	2.49	.59
Artemisia tridentata	1.24	.19	.95	.09	1.02	.40
Atriplex inflata	3.10	.28	3.20	5.90	1.40	2.10
Atriplex vesicaria	2.50	.15	3.90	6.50	1.20	
Kochia sedifolia	2.06	.11	2.80	7.60	1.32	.81
Acacia aneura	2.14	.08	.68	.13	1.47	.51
Coleogyne ramossissima	1.94	.17	1.42	.07	2.23	.41
Average*	1.99	.26	2.66	2.18	1.74	.81
Cercocarpus montanus	.90	.07	.31	.04	.55	.26
Juniperus osteosperma	.77	.05	.35	.03	1.45	.15
Average+	.84	.06	.33	.04	1.00	.21
Average of six shrubs from this study	1.16	.09	.99	.04	.85	1.4

* Charley, J.L., (1977)
+Osayande, S. (Unpublished M.S. thesis)

When compared to soil mineral concentration, calcium and magnesium were the least concentrated nutrients in the tissue of the shrubs. Their relatively high concentration in soils compared to those values determined by Epstein (1972) as being adequate for higher plants may account for the lower values.

Calcium to phosphorus ratios that are close to 2.0 are considered optimum for the nutritional needs of most animals, although there is evidence that suggests that ruminants can tolerate higher ratios (McDonald et al. 1973). Mule deer (*Odocoileus hemionus*) are found in the monument and, since they feed almost exclusively on shrubs during the winter, the balance of these minerals in the diet is important. The most satisfactory calcium to phosphorus ratios were found in the leaves and twigs of sagebrush, cliff fendlerbush, and buffaloberry with values of 4.58, 6.05, and 7.90 respectively. Cliffrose had the highest ratio, 14.71, and was followed by fourwing saltbush (12.77) and mountain mahogany (11.84). The concentration of calcium and phosphorus in leaves and stems was negatively correlated with an r value of 0.67.

The average potassium to calcium ratio for the plant material from the six shrubs was 1.33 and compared favorably with the value of 1.4 for shrubs in a study by Harner and Harper (1973). In their study, the ratio for shrubs was lower than that for forbs and grasses. They suggested that the low values for shrubs was related to root cation exchange properties. Dicot roots were found to be more negatively charged than monocot roots and were expected to compete more effectively for divalent cations. The variation in potassium to calcium ratios among the shrubs in this study might also be attributed to root cation exchange capacity. Cliff fendlerbush, fourwing saltbush, and sagebush had high values and averaged 2.13, whereas cliffrose, buffaloberry and mountain mahogany averaged 0.52.

The mineral composition of shrubs from various studies are compared with the results from this study in Table 6. It is evident that the mineral composition of shrubs varies among species and individuals on rangelands. The large discrepancies found in mineral composition between the shrubs in this study and those from other studies may be due in part to the fact that in arid rangelands, yearly and seasonal variations in mineral cycling is highly dependent upon the amount, kind, and distribution of rainfall. This variation is partly responsible for the heterogeneous patterning of minerals in a rangeland ecosystem since soil mineral composition beneath shrubs is mostly affected by retention of litter fall, shrub age, and specific chemical composition of inorganic residues (Charley 1977).

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TECHNICAL NOTES

Seasonal Concentration and Toxicity of Saponins in Alfombrilla

M. COBURN WILLIAMS AND LUIS C. FIERRO

Abstract

Alfombrilla collected monthly for 1 year in Chihuahua, Mexico, was analyzed for percentage of saponin and for toxicity to 1-week-old chicks. Saponin level ranged from 2.8% in dormant plants collected in January to 6.3% in mature fruiting plants collected in September. Saponin level was low in seeds. High saponin levels may persist in dormant plants into December. The amount of plant required to kill 50% or more of the chicks was inversely proportional to the saponin level of the plants.

Alfombrilla, *Drymaria arenarioides* H.B.K., is a highly poisonous species of the family Caryophyllaceae. The species is native to the Mexican states of Chihuahua, Sonora, Hidalgo, San Luis Potosi, and Zacatecas (Martínez 1960). The toxicological properties of alfombrilla are being investigated by the United States and Mexico because the species threatens to invade the United States from Chihuahua and Sonora.

Saponins were isolated as the poisonous compound by Williams (1978). Six saponins accounted for approximately 3% of the dry weight of the plant when collected in vegetative growth. Although the precise structure of the saponins is unknown they are highly toxic, and livestock may be poisoned by eating alfombrilla at 0.1% of body weight. Alfombrilla ingested at 0.5% of body weight is nearly always lethal (Jacoby and Morton 1974; Larios and Javalera 1976).

No information is presently available on the seasonal variation in the concentration of saponins in alfombrilla. Presumably, saponins in alfombrilla fluctuate during the growing season so that the species is more toxic at certain growth stages. The stability of saponins in dormant plants is also unknown. Many plant poisons, such as nitro compounds, virtually disappear at senescence (Williams and Norris 1969); others, such as oxalates in halogeton, (*Halogeton glomeratus* (Bieb.) C.A. Mey,), persist to render the plant poisonous far into the winter (Williams and Cronin 1966). A saponin level of 5 to 7% reported in the seed of corn cockle, (*Agrostemma githago* L.) (Kingsbury 1964) suggests that levels of saponins may be high at fruiting in some saponin-containing species of the Caryophyllaceae. Such data on alfombrilla would be of great value to Mexican ranchers who graze or trail livestock on alfombrilla-infested range.

This paper presents data on the seasonal variation in the concentration of saponins in alfombrilla during 1977 and the toxicity of monthly plant samples to 1-week-old chicks.

Materials and Methods

Alfombrilla was collected and dried monthly from January 1977 through December 1977 at Rancho Experimental La Campana in Chihuahua, Mexico. Seed samples collected in October and December were combined for chemical analysis and feeding. Pland and seed were first shipped to the Animal and Plant Health Inspection Service Laboratory, U.S. Dep. Agr., in Los. Angeles for fumigation to destroy viable seed. The plant was then forwarded to the Poisonous Plant Research Laboratory at Logan, Utah. Each monthly plant sample and the pure seed were ground to pass a 40-mesh screen and then analyzed for percentage of saponins by the method of Wang (1969).

Fifty grams of alfombrilla was extracted with 70% ethanol for 24 hours on a Soxhlet extractor. The extract was reduced to dryness on a rotary evaporator, then redissolved in 75 ml of water. The water was extracted twice with 75-ml volumes of benzene. The benzene was discarded, and the water phase was reduced to 50 ml on a rotary evaporator so that 1 ml equalled the extract from 1 g of dried plant. Seed was processed as above except that 40 g was used rather than 50.

Chick Bioassy

One-week-old chicks (avg wt = 70 g) were held overnight without food or water. At 8 a.m. they were dosed with alfombrilla extract that was introduced into the crop by a catheter. Two birds each were dosed with 0.5, 1.0, 1.5, 2.0, 3.0, and 4.0 ml of extract. After treatment, the birds were given food and water free choice. The chicks were observed for toxic signs, and the LD^{50} (lethal dose for a 50% kill) was determined.

Results and Discussion

Saponin level in alfombrilla was greater than 3% each month except January (Table 1). Saponin level of alfombrilla increased throughout the growing season and peaked in September when seed was mature. An unusually high saponin level recorded in May

Table 1. Saponin level and toxicity of alfombrilla[1] collected during 1977 in Chihuahua, Mexico.

Month collected	% saponin (dry wt)	Stage of growth	LD^{50} ml[2]
January	2.8	Dormant	4.0
February	3.1	Dormant-early vegetative	3.0
March	3.5	Vegetative	2.0
April	3.6	Flowering	2.0
May	5.3	Flowering	1.5
June	3.7	Seed formation	2.0
July	4.2	Seed formation	1.5
August	5.2	Seed mature or dispersed	1.5
September	6.3	Seed mature or dispersed	1.0
October	4.1	Seed mature or dispersed	1.5
October	1.3	———	4.0
November	6.0	Dormant	1.5
December	6.0	Dormant	1.5

[1]Aerial parts were tested each month except October, when both aerial parts and mature seed were tested.
[2]1 ml=saponin from 1 gram of dried plant.

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was reflected in increased toxicity to chicks. Saponin level in alfombrilla collected in November and December remained high, and extracts from these collections were highly toxic to chicks. Seeds were low in saponins.

Alfombrilla was very toxic from early spring growth in February through December, when plants were dormant. Saponins were relatively stable in dormant alfombrilla so that plants remained poisonous well into the winter months.

The amount of alfombrilla required for LD^{50} in chicks was inversely proportional to the saponin level in the plants. Chicks given a minimum lethal dose became depressed and stood with feathers ruffled and eyes closed within 1 hour of dosing. They usually became comatose within 2 to 4 hours and died shortly thereafter.

If alfombrilla contains 3% saponins, sheep are acutely poisoned at 0.5% of body weight or at approximately 150 mg of saponins/kg of body weight. If chicks are acutely poisoned by alfombrilla at an equivalent of 2 grams of plant or less, the saponins in the plant exceed 3% (Table 1). Thus, the chick bioassay can be used to approximate the saponin content and the relative toxicity of the plant to livestock.

Alfombrilla poisoning of livestock in Chihuahua is particularly serious in late summer and early fall (Sánchez Muñooz 1978). Saponin levels are highest then and the plant becomes more attractive to cattle since grasses are largely dormant.

Since alfombrilla is toxic at all stages of growth, careful management of livestock and range is necessary to avoid losses. Studies by Jacoby and Morton (1974) indicate that alfombrilla can be controlled by 2,4,5-T in 0.5 solution. Alfombrilla can be effectively controlled by deferred rotation grazing or resting infested pastures one or two productive growing seasons to allow for recovery of grasses.

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BOOK REVIEWS

Common Texas Grasses—An Illustrated Guide. by Dr. Frank W. Gould. Texas A&M University Press, College Station, Texas 77843. 1978. 267p. $10.95.

Every author reserves the right to include within a book the material he believes most relevant to the subject. The preface of this book mentions that, "150 of the most common and familiar grasses in Texas" are illustrated. The book was written to provide a layman with a manual to identify these 150 or so species and/or varieties. Working on and near the High Plains of Texas, I have found the species described and illustrated in this work do not exactly correspond to the list I would have made. For example, *Sporobolus flexuosus, Muhlenbergia torreyii, Muhlenbergia arenicola, Eragrostis lehmanniana, Chloris pluriflora,* and others have not been included. However, such grasses as *Cortaderia selloana, Erianthus giganteus, Oryza sativa, Phragmites australis,* and *Zizaniopsis miliacea* are discussed.

The format of this book is logical in that the Introduction discusses the grass plant by parts and how to "go about" identifying grasses. All genera are arranged alphabetically, giving the scientific name(s). A rather lengthy discussion follows giving specific vegetative and floral characteristics.

Following is a brief on the grasses' distribution, habitat, and use. Within these briefs, I find many generalizations and often nonconclusive and sometimes inaccurate information. This reviewer realizes that it is difficult to assess accurately the distribution and habitat of a species.

The book in my opinion emphasizes more the east-southeast Texas grasses then west Texas species. However, the prefaced quote above concerning familiarity perhaps explains this.

A few misspellings and technical errors were found. An example on page 6 lists cultivated oats as *Hordeum vulgare*. On two occasions the metric measure cm was used rather than mm. Few words were mistyped.

A key to the genera and a glossary follows the text. The glossary appears to be quite complete and understandable. In using Dr. Gould's book entitled *Grass Systematics* for a supplement to a range plants course, I have found that students have considerable difficulty with Gould's dichotomous key to the genera. In particular, the type of inflorescence seems to be difficult for beginning taxonomists. Illustrations of these inflorescence types would simplify the keying process in the present book.

In reference to Group IV (panicle with rebranched primary branches; perfect florets two or more), subgroup D, I note that *Melica, Koelera,* and *Spehnopholis* lemmas may be single awned. I believe this to be extremely rare or nonexistent in the Texas species listed. Fortunately, subgroup DD also picked up these genera as having an awnless lemma. The genus, *Sphenopholis,* appeared in the key; however, it was not referred to in the text.

I believe any layman could take this book and generally "picture-key" a grass plant to genus providing some magnification was used and a spikelet was isolated. With a little experience, the keying of an unknown grass would not be difficult. For those not requiring a detailed treatment of the grasses of Texas, this book would be ideal. For others, needing a complete treatise, Dr. Gould's *Grasses of Texas* would be a better choice.—*Russell D. Pettit*, Lubbock, Texas.

Handbook of Tropical Forage Grasses. By B. Ira Judd. Garland and STPM Press, 545 Madison Avenue, New York, N.Y. 1979. 116 p. $14.50.

This is a small 5¼ × 8¼ inch book and contains 116 pages. The majority of the contents appeared originally in *World Crops*, London, England. More than 30 species are briefly reviewed. Most of the illustrations are from Hitchcock's *Manual of the Grasses of the United States*. Seven black and white photographs are included, five from Puerto Rico and the Virgin Islands. The preface is J.J. Inglall's "In Praise of Blue Grass" from the 1948 Yearbook of Agriculture.

Chapter I briefly outlines the uses of grasses including food, forage, hay, soil-building and -holding, silage, industrial, and ornamentals. A number of temperate zone grasses such as red fescue (*Festuca rubra*), Kentucky bluegrass (*Poa pratensis*), and ryegrass (*Lolium* spp.) are used to illustrate the distribution of grasses. Species of *Agropyron* and *Elymus* are similarly used to illustrate grasses for soil-holding. This appeared to be in contrast with the title of the book. A brief review of grass morphology includes vegetative organs, roots, stems, the leaf, floral organs, and the inflorescence. Two concluding sections, "Grassland Improvement" and "History and Importance of Grasslands," could have been included in the historical resume.

Chapters II through V briefly describe species common to the tropical regions. Common names of most species are given in English, Spanish, or French. Chromosome numbers are also given in most instances. Descriptions include distribution and adaptation, agricultural value and utilization, diseases or insects, and establishment and management. All management is treated agronomically and range management aspects are absent. The descriptions are not without error. For example, pangolagrass (*Digitaria decumbens*) is grown and managed extensively only in the southern half of Florida with white dutch clover. Natal grass (*Rhynchelytrum repens*) was introduced into Florida prior to 1866 and proved to be a failure for hay and grazing.

Chapter VI has one paragraph which lists the major insects or diseases not mentioned under the description of individual species. These include chinchbug, armyworm, and grassworms. A brief summary concludes Chapter VI and includes grazing, harvesting for hay or silage, weed control, stocking rates, and fertilizer rates. Twenty-eight references are listed, fourteen from Puerto Rico sources.

I found the book very brief and the contents not up to the expectations of the title.—*Lewis L. Yarlett*, Gainesville, Fla.

Plant Strategies and Vegetation Processes. By. J.P. Grime. John Wiley and Sons, Inc. New York, N.Y. 1979. 222 p. $28.95.

I have attempted to summarize Grime's stimulating theme. As a result, many of the ideas and applications to theory and management are lost but hopefully not misrepresented.

External environmental factors of an organism's habitat can be divided into two categories: "stress" factors which determine production and "disturbance" factors which destroy production. These two major factors can be outlined as the four cells of a 2 × 2 table conforming to three distinct strategies: competitors (C) in low stress and low disturbance habitats, stress-tolerators (S) in high stress and low disturbance habitats, ruderals (R) in low stress and high disturbance habitats, and no viable strategy in habitats with high stress and high disturbance. Habitats vary continuously between the four extremes and plant strategies vary continuously between the three primary strategies. Due to this continuous variation, Grime represents the viable spectrum of habitats and plant strategies in an equilateral triangle and classifies all strategies into seven categories. Therefore, the familiar r-K selection theory of MacArthur and Wilson has been replaced by the C-S-R selection theory of Grime.

Though organisms adapt to particular stresses specificially, major adaptations to different kinds of stress are similar. Likewise, adaptations to different kinds of disturbance are similar. These differences can be ordinated in the triangle by plotting the logarithm of their relative growth rate (gm/gm/week) on its base and size (height + width + litter production) on its altitude.

Grime demonstrates the applicability of his scheme to vegetation variation in time and space. Position of stands occupying stressful, productive, and disturbed sites are appropriately ordinated in the basic triangle. More interesting is the model that summarizes the seral change in dominance from ruderal species to competitors to stress tolerant species of proclimax and climax.

The best competitor in any community—disturbed, productive or stressful—assumes dominance and inhibits its neighbors. The trend to dominance will be aggravated by any enrichment of the environment and ameliorated by increases in stress or disturbance. By plotting species density against environmental richness, diversity is expected to decline logarithmically. Species diversity of a site must be determined by the temporal and spatial heterogeneity as well as the availability of taxa on both regional and local bases. Given these qualities of a site, one might expect diversity to increase logarithmically in increasingly favorable environments (indicated by maximum standing crops).

I do not object to the concept of "plant strategies" even though the strategy of an organism is determined by its evolutionary history rather than any geological foresight. Resultant behavior will be similar if environmental continuity (including change) is maintained.

Deficiencies of the book are editorial. Words basic to the theme, such as, "relative growth rate" and "proclimax", might have been defined for students. Figure 12 is misreferenced (p. 113 and 150), units are omitted from table 15 and misrepresented in figure 45, *Hordeum* is called a forb (p. 144), and two typographical errors occur (p. 40 and 41).

Grime's book will stimulate the individual reader or serve as the nucleus for a graduate seminar since it develops a theme useful in both pure and applied ecology. Illustrations are chosen from the animal kingdom (despite the title) and many vegetation types, including grasslands.—*Tad Weaver*, Bozeman Montana.

New Publications

The Natural Vegetation of North America—An introduction by John L. Vankat. John Wiley and Sons, Somerset, New Jersey 08873. 1979. 261 p. $8.95. This book is intended for two types of university courses and is intended to be complementary to fundamental treatises on ecology, plant geography, and other subjects with a purpose of helping readers better understand the environment. In upper level courses it would supplement texts in ecology and biogeography courses. For lower level courses it would contribute to understanding the description and explanation of biomes. The book is divided into two sections. Part I covers the basics of vegetation science as they apply to North America. Part 2 covers the major terrestrial vegetation types of North America.

Vegetation of the Earth—and Ecological Systems of the Geo-biosphere. 2nd edition by Heinrich Walter. Springer-Verlag New York, Inc. Secaucus, New Jersey 07094. 1979. 274 p. $13.90. In this edition a basic alteration has been introduced in that climate and vegetation are dealt with as components of the various ecosystems that together constitute the geo-biosphere. The continents are subdivided into large ecological units, zonobiomes, pedobiomes and orobiomes based on ecological climate diagram type, soil properties and orographical features. Within continents, the vegetation communities provide descriptions of biogeocenes and synusiae. The book is intended to provide biologists and geographers with a global persepective on ecological and environmental problems.

Emphasis is on climate and the biotic producers which represents the most important factors affecting ecosystems.

Agricultural Ecology—An Analysis of World Food Production Systems. By George W. Cox and Michael D. Atkins. W.F. Freeman and Co., San Francisco, Calif. 94104. 1979. 721 p. $25.00. This book is focused on an interdisciplinary approach to agricultural science. It is intended as a text book in agricultural ecology. Divided into three parts, the 27 chapters cover a range in topics from The World Food Balance through Climate and Agriculture, Soil Formation and Structure, Agriculture Pest Problems to a chapter on International Agricultural Policy. Also included is one chapter on the impacts of cultivation and grazing on soil. This chapter comparable to the rest of the book does not consider the subject matter in depth. The information presented is best suited to a survey or introductory course for an understanding of total agriculture.

Careers in Conservation—Opportunities in Natural Resource Management. 2nd edition edited by Henry Clepper. John Wiley and Sons, Somerset, New Jersey 08873. 1979. 169 p. $11.95. Revised updated edition which describes jobs available to college graduates and educational requirements for the jobs.

How to Collect Plants and Prepare a Herbarium. By George H. Maduram. Alberta Energy and Natural Resources, Alberta Forest Service ENR Report No. 122. No charge. Limited copies available for libraries, schools and agencies regularly needing or instructing proper collection and care of plant specimens and herbarium mounts. An excellent "how to do it" booklet on equipment needed, methods, procedures, care against insect damage, mounting, labeling, storage and use of a herbarium.

Animal Nutrition. 7th edition by Leonard H. Maynard, John K. Loosli, Harold F. Hintz, and Richard G. Warner. McGraw Hill Book Co., New York, NY 10020. 1979. 602 p. $21.00. General order of presentation of earlier editions is maintained but with thorough revision. The main objective of this text is to point out the developments in nutrition over the last 10 years and describe their significance to today's feeding practices. Also includes a glossary and an appendix listing of the National Research Council's nutrient requirements for farm animals with recommendations up through 1978.

New Price List for Publications

Rangeland Entomology	$ 2.75
Quotable Range Quotes	$ .75
Proceedings: First International Rangeland Congress	$72.00
Rangeland Reference Areas	$ 2.00
Glossary of Terms	$ 1.50
Jornada Experimental Range	$ 2.50
Proceedings of U.S. Australia Workshops: Arid Shrublands	$ 3.50
Rangeland Ecosystem Evaluation and Management	$ 8.00
Symposium on Resources for Beef Cattle Production	$ 3.50
Rangeland Plant Physiology	$14.50
Special Management Needs of Alpine Ecosystems	$ 4.50

Prices will become effective June 1, 1980.

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 any phase of range ecosystems or their management. Short articles concerning research results, experimental equipment, or techniques may be published as a "Technical Note." 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 any application of the results to range management problems.

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 **Dr. Rex D. Pieper, Dept. of Animal and Range Sciences, New Mexico State University, Las Cruces, NM 88003.**

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 × 11 with numbered lines. Use only one side of the paper and number all pages. Three good copies of the manuscripts 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. An Abstract, typed on a separate page, should accompany each manuscript. The Abstract 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. The metric system should be used throughout the manuscript, but English units may be included in parentheses in the text.
7. 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.
8. 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 × 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.
9. Tables should be as 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.
10. 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.

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