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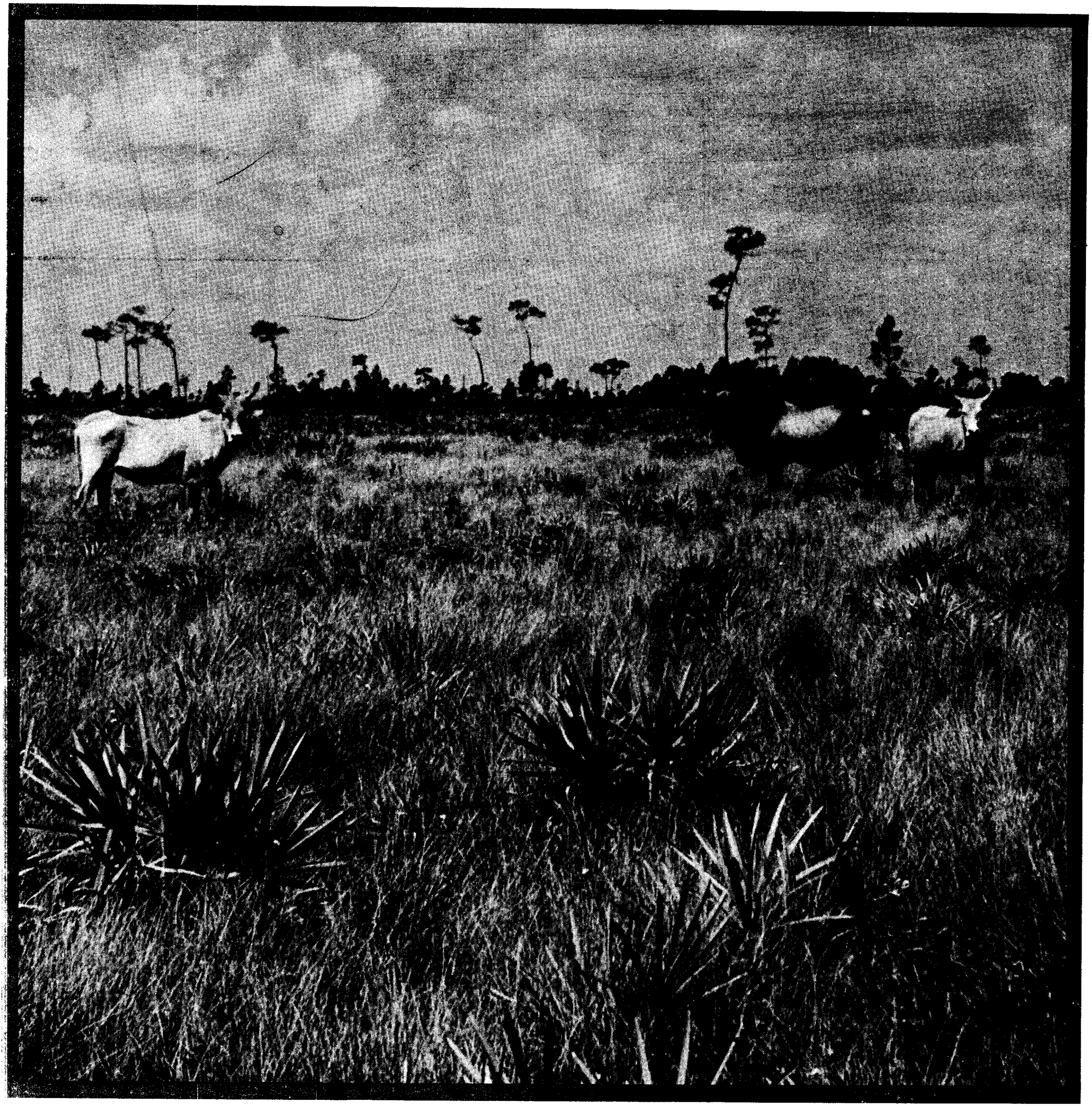
JOURNAL OF RANGE MANAGEMENT

SOCIETY FOR RANGE MANAGEMENT



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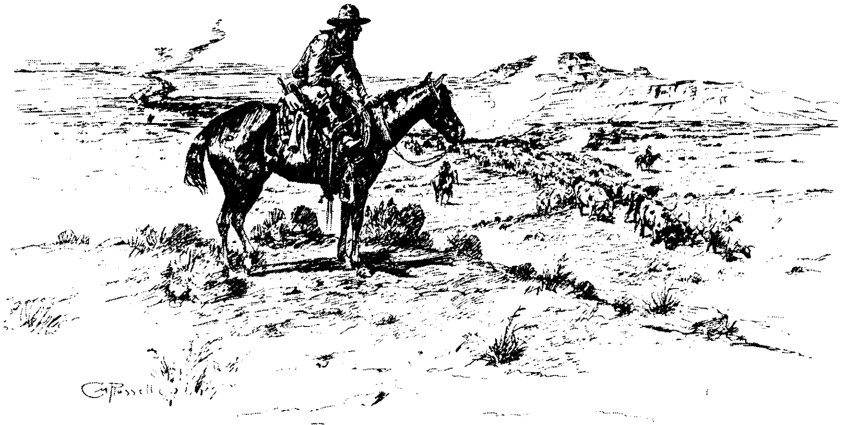

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The objectives for which the corporation is established are:

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

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

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

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

–to promote professional development of its members.

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

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

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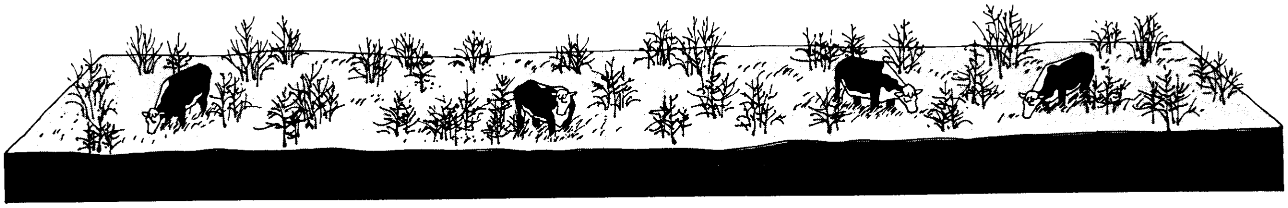
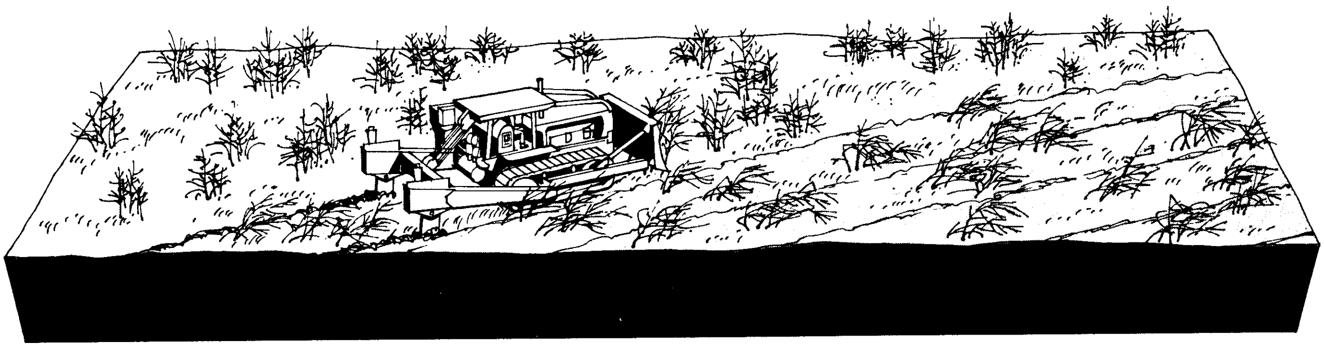
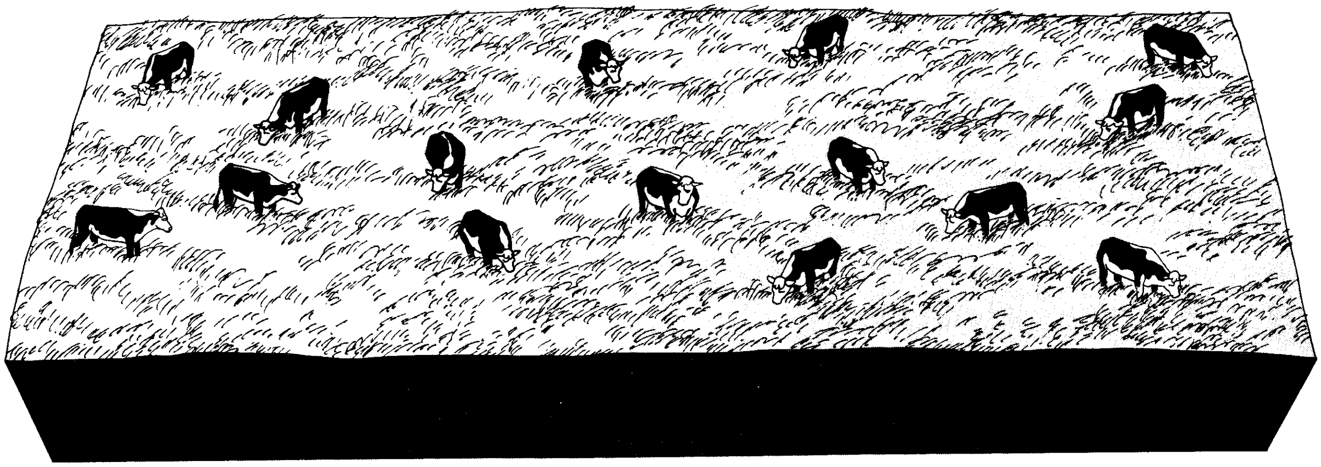






Growing Strength for Greater Challenges

MARTIN H. GONZALEZ

Sixteen years ago, in 1958, I came to Arizona to attend, for the first time, an annual meeting of the American Society of Range Management. At that time, we submitted the application to form the Mexico Section—a Section that began with 18 charter members, all ranchers from Chihuahua.

Now, 16 years later, I have the great honor to come back to this wonderful State as president of the Society for Range Management and accompanied by many of the 280 members that our Mexico Section has at the present time.

It is only fair to mention that the growth of the Mexico Section would have not been possible without the help, the sound advice, and the guidance of the Society officers through all these years. The names of Clouston, Campbell, Tisdale, Hervey, Kennedy, and many others are remembered with love and deep respect by all our members in Mexico.

How interesting, educational, and rewarding in many ways it has been to be closely associated with members of all of our Sections. It was impossible, unfortunately, to attend the meetings of all the Sections, but in traveling for over 51,000 km (32,000 miles for those not caught up with "progress") from Canada to Mexico, from Oregon to Mississippi, from the national capital to California, and all over the western states, it was possible to sense the way our members are thinking and how they are working for the Society.

It has been, indeed, a wonderful year, and I want to express my sincere appreciation to all of you, friends, who made this possible. For your warm hospitality, for the sincere friendship shown to me and my family during all these trips and visits, thank you all very much.

You may remember that, when I became president of the Society exactly one year ago in Boise, I did not want to talk about promises but said that I would rather talk about results when my term expired. Well, this is the time now, and we have some results for you; not as many as we would like, but enough to let us see the progress of the Society, the potential of our organization, and the great challenge that we have to face right now and in the immediate future.

If we have not achieved all the results we wanted to, believe me, it is not because we have not tried. I feel very proud of all my committees, their chairmen, and particularly of all the members of the Board of Directors and our staff in Denver, who have made such a tremendous effort to serve the Society.

During my visits with the Sections and with individual members, I could sense their "feelings" concerning the Society. Even though these "feelings" or attitudes were quite variable, there were some that were like a common denominator and were a guide for determining the course of action for myself and the Board of Directors during 1973.

Some of the issues most "talked about" by our membership were the following: (1) the role of the Society in defending our position in important public issues like, for example, grazing in public lands and the red meat crisis; (2) ways in which the Society has been or can be of better service to the livestock producer; (3) the role of the Society as a cause of inspiration to our young people, our students, those who will strengthen the organization in the future; (4) means to improve the relations among Sections and the parent Society, particularly among Section members and the international officers; (5) headquarters for the Society; and (6) the need for our Society to make the front pages when the time comes to speak out in defense of rangeland resources in different countries and to let our voice be heard with due authority in issues related to livestock production.

These are just *some* of the issues our members are discussing or at least have been thinking about for some time.

Now, I would like to comment on what we have tried to do and what we have accomplished during the few months we have been in office.

Public Affairs

In the first place, I believe that during 1973 the Society for Range Management has participated more actively than in any other year in some very important public issues.

We all have heard about the great debate on "to graze or not to graze" in public lands. Our Information and Education Committee prepared a white paper which, although it was not presented in its final form, expresses clearly the position of SRM on this issue. I had the opportunity to discuss statements from this document with the directors of the Utah Cattlemen's Association, the Alberta Stockgrowers, and the Foot Hill Forage Association in Alberta; with individual ranchers in California, Texas, Oregon, Colorado, New Mexico, Canada, Wyoming, Oklahoma, and Montana; and with students and professors in several universities in the United States.

It was the general opinion that the position adopted by the

Address by the retiring president of the Society for Range Management at the 27th Annual Meeting, February 4-8, 1974, Tucson, Arizona.

Society in this "hot" issue was the one really needed and one which raised the enthusiasm of everybody, members and nonmembers, particularly of livestock producers directly involved in this controversy.

But that was not all. Recently, a task force composed of 16 of the most recognized personalities in the art and science of range management prepared a report on "Livestock Grazing on Federal Lands in the Eleven Western States." This report, prepared for the Council for Agricultural Science and Technology (CAST) and aimed at reaching the highest authorities in the United States Government, is a magnificent document complete with statistics and information justifying the grazing of public lands. This document, I assure you, is going to make lots of noise; it will have tremendous impact on all political and public opinions concerning the issue.

This report and the task force itself are further indications that we have most capable people and most convincing, factually-supported arguments to strongly defend before any authority, before any public opinion, before any organization, the principles of proper management of our rangeland resources on which the Society for Range Management stands.

The polemics will still continue, both here in the United States and in Canada, but we know that we are thinking and acting with reason and common sense. Our Society has a moral responsibility to make a strong stand for the defense of an adequate, rational use of forage production on public lands which does not damage other economic and/or aesthetic values of these areas.

No strange group of extreme, false conservationists, of political opportunists, or of pseudo-environmentalists is going to tell us how to manage and take care of the resource that we love more than anybody else—that we know and understand better than anybody else!

The Society and the Livestock Producer

In connection with the interesting issue of grazing or not grazing in public lands, we must analyze the role of rangelands —public and private—in the present and the future of the production of red meat in the world. Here is where our ranchers play a very important part, and it is here that the Society really is being of service to those producers.

Again, all of us have heard the protests of housewives, butchers, feed lot operators, lawyers, economists (especially economists!) complaining about the high prices of red meat and the difficulties in buying as much as they used to. And, of course, the whole blame is placed on the rancher.

Do these people really know some of the main factors involved in range livestock production? Beef or lamb production is not just fattening animals in the feed lot or in irrigated pastures. Red meat production begins on the range where the "raw material" is produced and where this type of operation is the one best suited for over 40% of the land on our planet.

We know that the demand and the supply of animal products for mankind in the immediate future—and right now, actually—represents a very serious problem and that we are facing a challenge of an intensity never faced before. We are aware of the importance of rangelands in helping to solve this problem, and we are sure that with scientists, livestock producers and government authorities working together, the proper solutions will be obtained.

Internationalism of SRM

In the international field, the Society has had an outstanding year. Our membership in other countries has increased, although still not at the rate we would like it to. Several factors have limited this expansion, but we can see with satisfaction that limitations are being overcome and foresee a very significant increase in international membership, particularly from South America. Giving the Society an international dimension has been one of my goals for some time, and we are achieving this, thanks to our key-rangemen in different countries: Mexico, Argentina, Peru, Bolivia, Australia, East Africa, and the Middle East.

We are aware that in many of the countries of the world the technical and scientific programs are dominated by political decisions. But the growing interest—and more than just interest—a *growing need* to use natural resources more efficiently is changing the panorama. Authorities are finally realizing that people cannot be fed with false promises and demogogic measures, and that our limited economic resources must be used in well-planned programs for the development, the management, and the preservation of our soil, our water, and our vegetation. We in the so-called developing countries cannot afford the luxury of wasting funds in ill-planned, strictly political programs made by persons who are not aware of the social and technological changes now taking place in many areas.

However, we do not see these problems as insurmountable obstacles; on the contrary, we accept them and approach them as a great challenge, with a confidence based on the principles on which our Society and our profession stand.

During 1973, the Society for Range Management participated in important symposia in Mexico City and Alberta, Canada. Unfortunately, our planned short course for South America has been postponed—again, for political reasons out of our control—but we have obtained the funds to do it, and we will try this year.

Youth Programs—Student Activities

We are very proud of our student membership and feel very happy to have present many students sharing an interest in range management. We have more plant judging teams participating each year, not only at the Annual Meeting, but also at the Section level, as in California.

I am particularly happy to have here, many for the first time, groups of students from different schools of agriculture and animal science in Mexico: Monterrey Tech, University of Chihuahua, University of Sonora, University of Sinaloa, who come to learn and communicate with their fellow students from the United States, Canada, and many other countries. Mexico will present several plant judging teams next year, and we hope this trend will continue for the following meetings.

This is the kind of interest and enthusiasm we need from young people to make our Society bigger and stronger every day.

One more year has passed by—a hectic, enjoyable, educational, rewarding year full of satisfaction for myself and my family. Undoubtedly, it was a most wonderful year for having the privilege of serving as president of the Society for Range Management. In this year I had the very distinguished honor of the custody of the gavel symbolic of the brotherhood of our Society and of the recognition of the importance of our profession—a gavel shaped by the hands and the hearts, by the wisdom and the dedication of those great men who founded our Society 28 years ago, those men whom we respectfully consider the fathers of the art and science of range management. To them, and to you, fellow members, my thanks.

Vegetation Changes Following Fire in the Pinyon-Juniper Type of West-Central Utah

MILO A. BARNEY AND NEIL C. FRISCHKNECHT

Highlight: *The stages of succession following fire began with weedy annuals that reached a peak within 3 to 4 years. Juniper woodlands were well developed 85 to 90 years following fire. Intermediate stages of succession varied, but followed a general pattern of perennial grasses, perennial grasses-shrubs, and perennial grasses-shrubs-trees. The percentage of dead sagebrush was positively correlated with density of junipers. Thirty-three years was the average minimum age at which Utah juniper produced seed.*

Juniper and pinyon trees in the Intermountain region have expanded their range greatly since settlement, primarily in the last 100 years. Existing speculation suggests that a major cause of this expansion, either directly or indirectly, was the reduction in fires following settlement. Some authors consider the juniper-pinyon expansion to be several times that of the original cover (Cottam and Stewart, 1940; Woodbury, 1947). In 1951 it was estimated that this type covered about 30% of the State of Utah (Reuss and Blanch, 1951). The expansion has been primarily into the sagebrush-grass community on the lower edges of original pinyon-juniper. If unchecked, trees become dominant and eventually crowd out most herbaceous and shrub species that provide forage for livestock and big game.

The purpose of this study was to examine the vegetation on burns of various ages and determine the successional patterns following fire. The study was conducted primarily on the lower slopes and foothills of the Sheeprock Mountains in Utah and surrounding areas in the vicinity of the Benmore Experimental Range; however, one area was located in the Valley Mountains west of Fayette, Utah. Fire scars of various ages are generally evident in these areas. Tree species in the areas studied were Utah juniper (*Juniperus osteosperma*) and singleleaf pinyon (*Pinus monophylla*).

Location and Description of Study Area

The Sheeprock Mountain Range is approximately 20 miles long and 6 to 10 miles wide and most of it lies within the Vernon division of the Wasatch National Forest. The Sheeprocks, which merge with the West Tintic Mountains to the east, rise to a maximum elevation of 9,000 ft; but the pinyon-juniper type occurs mainly between 5,800 and 7,800 ft elevation. The Sheeprocks are separated from the Onaqui Range to the north by Lookout Pass and from the Simpson Range to the west by Erickson Pass. The Sevier Desert lies to the south and Rush Valley to the north.

The Sheeprock Mountains are composed chiefly of consolidated sedimentary rocks of Precambian and Paleozoic age. Several areas of both intrusive and extrusive rocks are also present. Unconsolidated sediments cover much of the foothill region as pediment gravels, lake deposits, and alluvium (Cohenour, 1957). The average annual precipitation is 12.8 inches for a 60-year period (1911-1971) as recorded at the Benmore Weather Station (elevation 5,975 ft) on the north side of the Sheeprocks.

No quantitative data are available on past or present grazing of the areas studied. However, it is generally agreed that rangelands in Utah were grazed heavily by domestic livestock during the late 1800's and for at least the first 30 to 40 years of the present century. Livestock numbers in Utah reached their peak around the turn of the century (Pickford, 1932). Glynn Bennion (1924), grandson of the earliest settler in the Benmore area, wrote that in 1870 upwards of 25,000 head of cattle and horses were summered and wintered in Rush and Skull Valleys. He further indicated that by 1924, less than one-tenth that number could be summered in the same areas.

Methods

Data were collected from 28 different burns in 17 localities of west-central Utah. Aerial photographs, where available, were used to delineate areas that had burned. Information on the age of the most recent burns was obtained from the Forest Service, Bureau of Land Management, and private individuals. Ages of older burns were estimated from ring counts of old trees that did not burn and from ring counts of the invading trees. Further, at each burn, ring counts were made on stem cross sections of trees that appeared to be the youngest producing seeds.

Depending upon size, burns were sampled on two to eight transects of from five to 10 plots each. At each plot location a series of nested circular plots having a common center were used for taking data on trees, shrubs, and herbaceous species. Sizes of plots used for sampling vegetation were: trees 0.01-acre (radius 11.77 ft); shrubs 100 ft^2 (radius 5.64 ft); and herbaceous plants 10 ft^2. Tree data included density (numbers), height, crown diameter, and stem diameter at 1 ft above ground level. Shrub data included density by species, estimated yields of shrub herbage in grams per plot, and counts of dead sagebrush plants.

Frequency of herbaceous species was determined from plot data. Cover for both shrub and herbaceous species was determined by a line-point adapted from Levy and Madden (1933). Our method employs a 12-ft aluminum rod marked in 1-ft segments and having pins projecting down at each foot marker. The rod is placed along the transect line, first on one side of the plot center and then on the opposite side, so as to give 25 points per plot. Nomenclature follows Welsh et al.

The authors are range research technician and range scientist, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah, stationed in Provo, Utah, in cooperation with Brigham Young University. Milo A. Barney is at present land specialist, Division of State Lands, State Capitol, Salt Lake City, Utah.

Manuscript received July 7, 1973.

Table 1. **Crown cover (%) and basal area (ft^2/acre) of** ***Juniperus osteosperma*** **and** ***Pinus monophylla*** **by age of burn (years).**

Approximate age of burn	Crown cover	Basal area
3	–	–
6	–	–
11	t[1]	t[1]
22	0.5	0.6
36	1.2	1.9
46	1.3	1.6
71	16.0	21.5
86	17.2	33.4
100+	31.8	142.6
	0.9[2]	2.9[2]

[1] Trace.

[2] *Pinus monophylla.*

Table 2. **Density (trees/acre) of** ***Juniperus osteosperma*** **and** ***Pinus monophylla*** **by height class (ft) and age of burn (years).**

Approximate age of burn	Height class				Total
	0-1	1-4	4-9	9+	
3	–	–	–	–	–
6	–	–	–	–	–
11	0.1	0.0	0.0	0.0	0.1
22	4.1	18.3	6.1	0.0	28.5
36	9.6	43.2	30.4	1.6	84.8
46	12.3	42.2	42.2	0.0	96.7
71	20.0	65.0	140.0	55.0	280.0
86	54.3	61.4	187.1	92.9	395.7
100+	73.3	36.2	101.2	110.2	320.9
	4.7[1]	0.0[1]	6.9[1]	2.3[1]	13.9[1]

[1] *Pinus monophylla.*

(1965), except as updated by him (personal communication, 1972).

A soil pit was opened at each location and the profile described. Soil texture was determined by the Bouyoucos (1936) technique. The pH was determined from a saturated soil paste. An extract was obtained from the paste and the soluble salt content determined by use of a solu-bridge (U.S. Department of Agriculture, 1954).

Data from the 28 burns were grouped for analysis into nine age classes, based on age of burn. These age classes and number of burns studied (shown in parentheses) are as follows: 3(2); 6(1); 11(3); 22(3); 36(6); 46(1); 71(2); 86(5); and 100+(5). The actual age is known for the burns in the first three classes; age was approximated for the remaining burns. Ages shown for classes 11, 22, 36, and 86 represent a midpoint year for those burns in each class. Study areas in the 100+-year-old class were adjacent to known burns; also, they appeared to have burned at some time, but an accurate age was not determined for these burns.

Results and Discussion

Trees

Both the tree crown cover and basal area increased with age of burn and reached maximum values in the oldest stands (Table 1). (Pinyon pine occurred in minor amounts only in one of the oldest stands and will not be considered further in this paper.) Overall tree density (numbers) followed a slightly different pattern, reaching maximum value on the 86-year-old burns and decreasing slightly in the oldest stands (Table 2). Decreases, however, occurred only in the intermediate height classes; trees over 9 ft high and those less than 1 ft were most numerous on the oldest burns. Most of those stands in the 100+-year-old class were growing on shallow rocky soils, and perhaps the decrease in density of the intermediate height classes was due to failure of the young trees to develop on these sites because of a closed community.

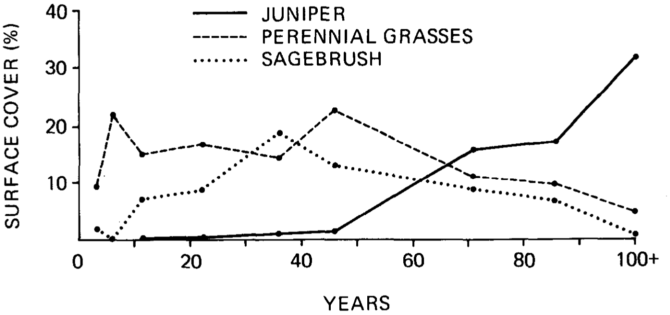


Fig. 1. *Surface cover of juniper, perennial grasses, and sagebrush by age of burn.*

Juniper crown cover increased slowly during the first 46 years following fire and then accelerated (Table 1). Basal area followed a similar pattern but showed greater proportional increase in the oldest stands. It appears that trees begin to dominate these sites 46 to 71 years after burning (Tables 1, 2, and Fig. 1). During this period the first generation trees have been producing seeds for possibly 15 years or more, and the second generation trees are beginning to exert an influence on the understory vegetation. The increase in juniper crown cover occurs along with a decline in cover of both sagebrush (*Artemisia* spp.) and perennial grasses (Fig. 1).

No trees were found in sample plots on either the 3- or 6-year-old burns; one small tree was observed outside the plots in the 6-year-old burn, apparently originating from a residual seed. However, on sample plots of all older burns, young juniper trees were evident. Ages of trees on the 11-year-old burns indicated that most were established within 1 or 2 years following the fire; others were established within 4 or 5 years following the fire. The Utah juniper established immediately following fire was found both adjacent to and under the crowns of trees killed by fire. This indicates that these junipers started from residual seeds. Pinyon pine occurred only in one of the oldest stands.

Analysis of tree stands on burns of various ages indicates that on 22-year-old burns approximately two-thirds of the

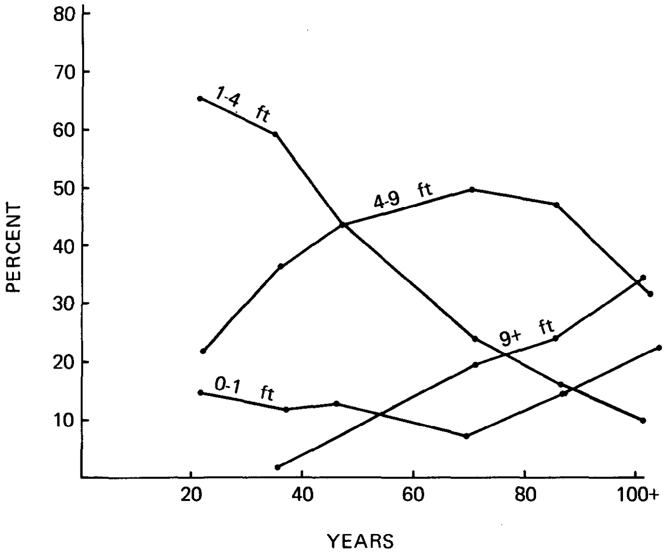


Fig. 2. *Percentage of total trees in different height classes.*

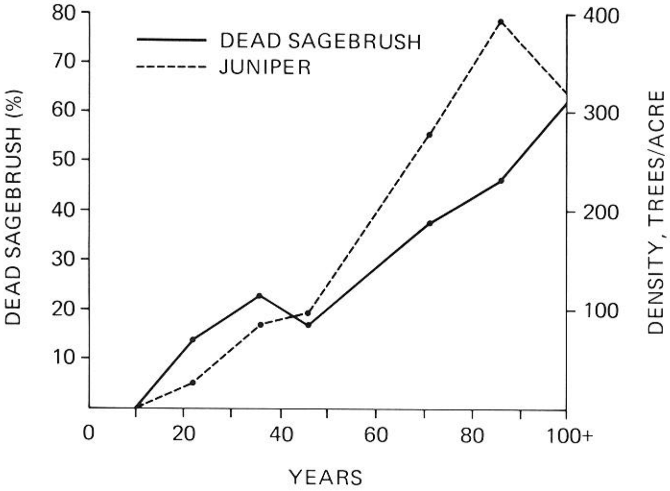


Fig. 3. *Density of juniper (trees/acre), and percent of sagebrush plants that are dead, by age of burn.*

Fig. 4. *An 86-year-old stand at Redskin Knoll showing sparse understory vegetation and decadent nature of sagebrush plants.*

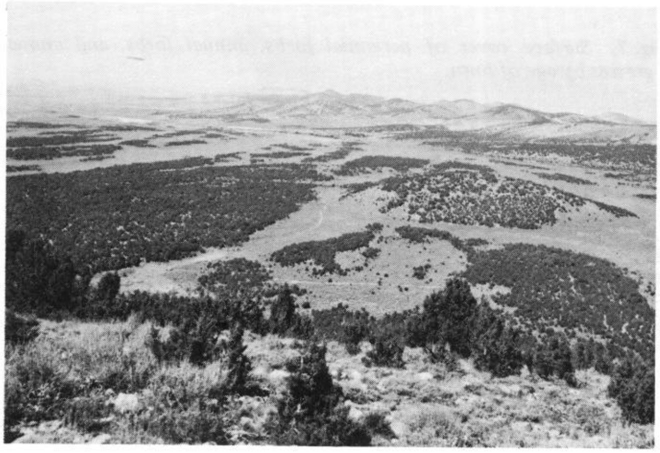


Fig. 5. *A view of the Redskin Knoll area showing burn patterns in the juniper stands.*

trees were in the 1- to 4-ft height class, 20% in the 4- to 9-ft height class, and 14% in the 0- to 1-ft height class (Fig. 2). A few trees exceeded 9 ft in height as burns approached 40 years of age and, of course, trees of this size became more numerous as age of burn increased. Tree stands on burns approximately 70 years old showed the highest percentage (50%) of trees in the 4-to-9 ft height class. The percentage of trees less than 1 ft high was most consistent of any height class over the age-range of burns—mostly between 10 and 15% of the stand.

Shrubs

Sagebrush occurred on all burn areas studied, although it was not found on the sample plots of the 6-year-old burn (Table 3). This shows that it can reinvade rather quickly following fire if a seed source is available. This ability is significant because sagebrush does not resprout following burning as several of the other shrubby species do. The pattern of invasion observed on the 11-year-old burns is probably typical. A few small plants became established from residual seed the first or second year following the fire. As these plants matured and produced seed, a second age class of sagebrush plants developed and filled in the interspaces. General observations suggest that in many cases sagebrush acts as a nurse plant for the establishment of juniper seedlings; most juniper seedlings occurred either under the crown of sagebrush plants or closely adjacent to them.

The percentage of dead sagebrush plants increased from none in the first three age classes of burns, to 16.2% in the 46-year-old burn, and 66.6% in stands that were over 100 years old (Fig. 3). As junipers began to exert an influence in the sagebrush community, sagebrush began declining and reached a point of either partial or total elimination (Figs. 4 and 5). Although mortality of sagebrush plants could be due to factors other than competition from junipers, the latter gradually dominate a site to the exclusion of sagebrush.

Two other shrub species occurring consistently on the burns studied were little rabbitbrush (*Chrysothamnus viscidiflorus*) and snakeweed (*Gutierrezia sarothrae*). These species were observed on eight of the nine age classes of burns. Little rabbitbrush was not found on the 6-year-old burn and snakeweed was not found on the 71-year-old burns. Both resprout following fire and the new plants tend to invade open areas rather rapidly. Peak frequencies were found on 22-year-old burns for snakeweed and 36-year-old burns for little rabbitbrush (52% and 42%, respectively); both declined thereafter to less than 10% on 100+-year-old burns (Fig. 6).

Black sagebrush (*Artemisia nova*), bitterbrush (*Purshia tridentata*), and snowberry (*Symphoricarpos vaccinioides*) were important on certain areas. Black sagebrush occurred mainly on areas having shallow soils within the older burns. Bitterbrush occurred on only three of the nine burn classes; it resprouted following fire, but did not invade so quickly as little rabbitbrush or snakeweed. Although snowberry occurred on five of the nine classes of burns, it was an important constituent on only three of the five on north or northwest-facing slopes.

Herbs

Total perennial grass cover varied among burns; but in general, it increased rapidly during the first 5 to 6 years after fire, maintained a somewhat uniform value for the next 40 years, and then declined (Fig. 1). The lowest point of grass cover was reached in the oldest stands. The point at which juniper cover began to increase rapidly corresponded to that point of decrease in perennial grass cover. On all, except the 3- and 36-year-old burns, bearded bluebunch wheatgrass (*Agropyron spicatum*) was the most important native perennial species in terms of cover. Within the 3- and 36-year-old burns were draw bottoms containing heavy soils where bluestem wheatgrass (*A. smithii*) was most prominent. Sandberg bluegrass (*Poa secunda*), Indian ricegrass (*Oryzopsis hymenoides*), and bottlebrush squirreltail (*Sitanion hystrix*) were the next most important native perennial species. Of the three, *P. secunda* was the most abundant species. Fairway wheatgrass (*A. cristatum*) and intermediate wheatgrass (*A. intermedium*) occurred on a few recent burns where they had been aerially broadcast following fire.

Perennial forbs did not constitute a large amount of the cover on any of the burns sampled (Fig. 7), although the frequency of perennial forbs was high on all burns.

The cover value of cheatgrass brome (*Bromus tectorum*), which was the only annual grass on the sampled burns, varied from 12.6% in the 3-year-old burns to 0.9% in the oldest stands. *B. tectorum* declined in cover the first 22 years after fire, then leveled off and stayed about the same for the remainder of the invasion sequence (Fig. 7).

Annual forbs followed a pattern similar to *B. tectorum*. They were most abundant during the first 3 or 4 years following fire, constituting 21.0% of the cover on the 3-year-old burns. On the 6-year-old burn, annual forb cover was less than 5.0%. Cover of annual forbs remained low on all older burns studied. The lowest point was reached in the 100+-year-old burns (Fig. 7). The most abundant annual forbs during the first stages of succession were pale alyssum (*Alyssum alyssoides*), flixweed tansy-mustard (*Descurainia sophia*), sunflower (*Helianthus annuus*), coyote tobacco (*Nicotiana attenuata*), and Russianthistle (*Salsola pestifer*). In each of the six burn classes, *A. alyssoides* and *D. sophia* were present but were much more abundant on the recent burns.

The percentage of bare ground, which varied with the age of the burn, was highest in the most recent burns and in the oldest stands due to lack of herbaceous vegetation. Litter cover was lowest in the 3-year-old burns and reached its peak in the 86-year-old burns; then it dropped in the oldest stands (Fig. 8) where most of the litter occurred under the crowns of trees.

Soils

Soils on juniper sites varied from deep alluvial to shallow residual. Residual soils, generally found on ridgetops and upper slopes, were frequently interrupted by rock outcrops of limestone or quartzite. Depth to the C horizon, or bedrock, was often 1 ft or less. Generally, the older juniper stands were found on these shallow residual soils.

Alluvial soils occurred mostly on the fans and in the draw bottoms. These soils were usually deeper than the residual soils but generally had less horizon development. North-facing slopes had deeper soils and better root penetration than south-facing slopes. Although texture varied from sandy loam to clay, gravelly loams and gravelly clay loams were most common. The pH down to the C horizon varied from 6.9 to 8.4, but most soils were within a pH range of 7.4 to 8.0. Soluble salts were well within the range for productive soils—the highest value being 160 ppm.

Factors Affecting Vegetation Change

The rate at which juniper invades a burned area varies

Table 3. Density (plants/plot), cover (%), and yield (g/plot) of ***Artemisia tridentata*** **by age of burn (years).**

Approximate age of burn	Density	Cover	Foliage yield
3	0.7	2.1	29.0
6	–	–	–
11	7.3	7.8	141.4
22	6.8	8.8	350.6
36	10.4	19.0	441.3
46	10.5	13.7	352.0
71	6.8	9.4	148.3
86	7.3	7.3	144.1
100+	1.5	1.2	19.5

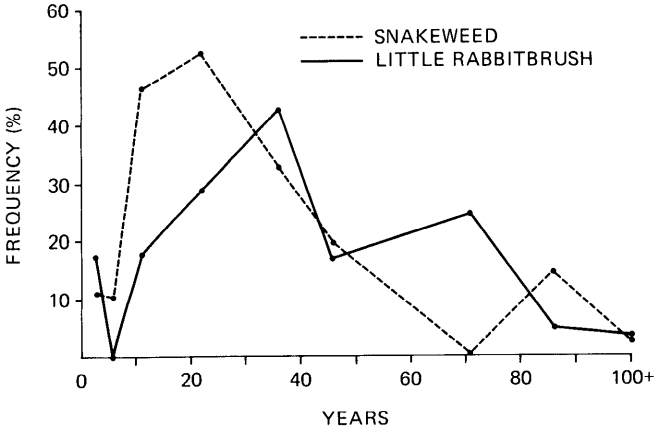


Fig. 6. *Percent frequency of snakeweed and little rabbitbrush by age of burn.*

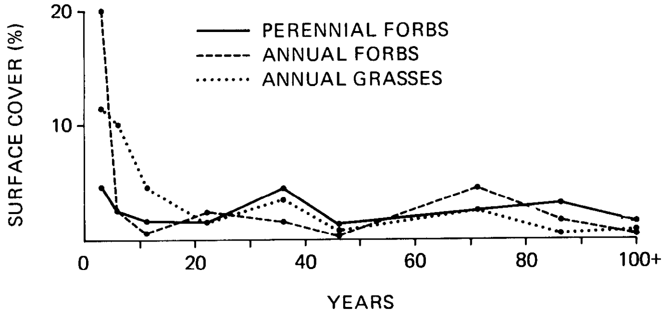


Fig. 7. *Surface cover of perennial forbs, annual forbs, and annual grasses by age of burn.*

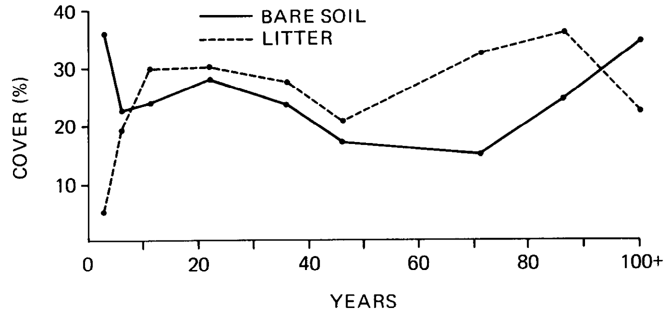


Fig. 8. *Ground-cover characteristics by age of burn.*

considerably, depending upon several factors working independently or together. The stage of stand maturity at the time of fire is an important factor. The rate of juniper invasion will be slower in a young stand having no seed-producing trees than in a mature stand which has been producing seed for a number of years. In the burns studied, many of the first trees to become established appeared to be from residual seed. These initial trees, in approximately 33 years, would then be a potential new source of seed, inasmuch as it was determined that the youngest seed-producing trees were approximately 33 years old.

Factors such as seed source, seed dissemination, size of burn, and grazing also influence the rate of succession. Succession could be a slow process if the invasion occurred only from the burn edge; this is especially true on large burns, but rate of succession would depend on the kinds and numbers of seed-dispersing agents. Of these agents, water and animals are probably the most important. Birds and many large and small herbivores and even some carnivores consume the so-called "berries." Rodents carry and store juniper seeds. Some seedlings on the burns studied appeared to be from rodent caches; several seedlings were growing at a single spot. Jackrabbits were probably the most important means of dispersal observed in this study. Juniper seeds were observed in jackrabbit pellets over a half mile from the nearest juniper tree; as many as 12 seeds were found in a single pellet.

Large herbivores have great influence on the rate of succession. Heavy grazing following fire will reduce the vigor and cover of perennial grasses and increase the rate at which shrubby species, particularly sagebrush, invade the site (Fig. 9). Trampling by animals also may aid in planting juniper seeds

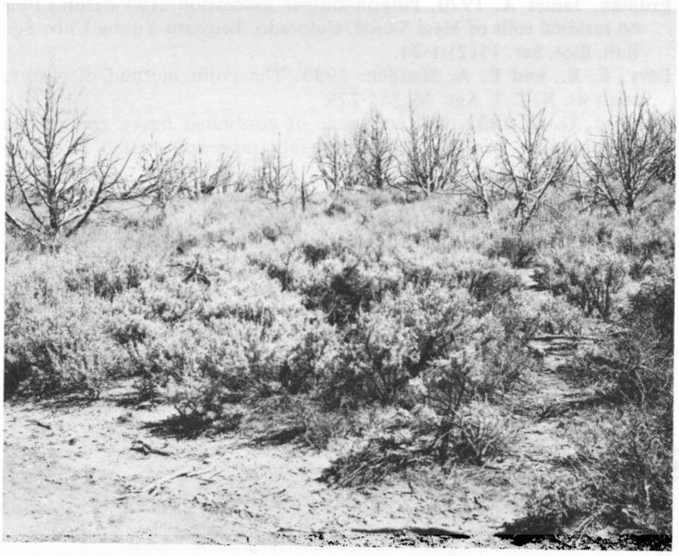
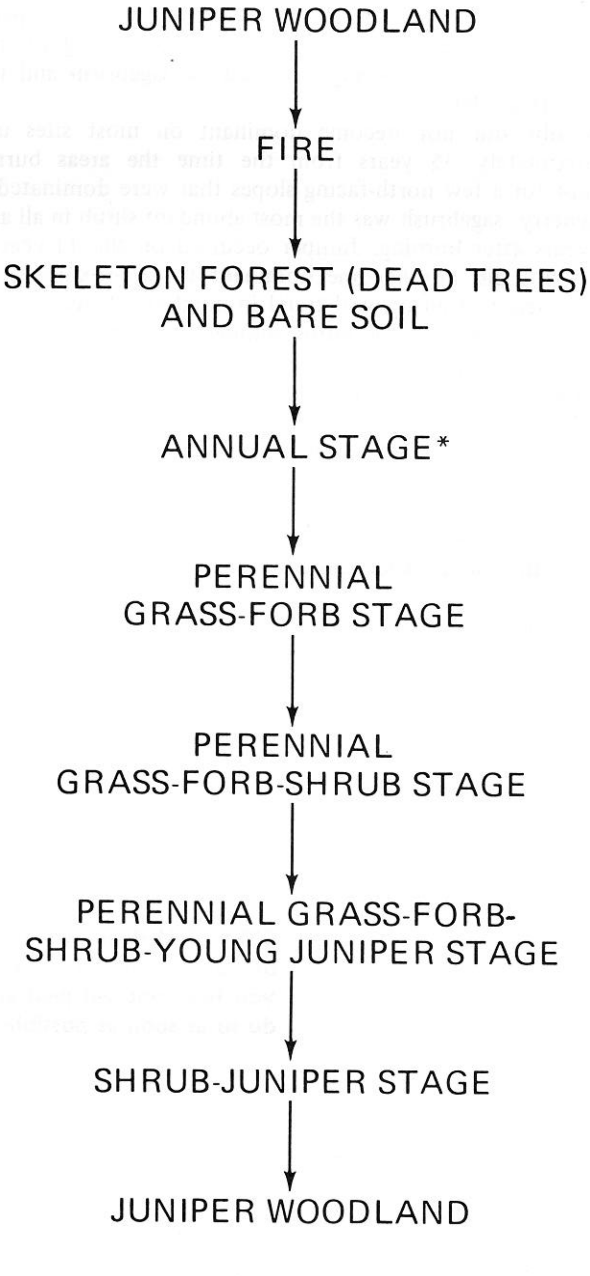


Fig. 9. *A sagebrush community that developed in 11 years on the Erickson Pass burn.*

Fig. 10. *A sagebrush-grass community on the Watts Pass burn. Note young trees invading the site (46-year-old burn).*



**Could be bypassed to some degree on areas having fair perennial herbaceous cover prior to burning.*

Fig. 11. *Vegetation changes following fire in the juniper woodlands of west-central Utah.*

distributed by other means.

Summary and Conclusions

In summarizing the pattern of succession following fire on areas studied, the initial stage was annual, reaching maximum development in the first 3 to 4 years. In such successions, the annual stage is generally replaced by a perennial-grass-forb stage by the fifth or sixth year if there is a fair remnant of native grasses prior to the burn. Under natural conditions, these would consist primarily of bottlebrush squirreltail, bearded bluebunch wheatgrass, Indian ricegrass, and Sandberg bluegrass. A shrub stage may follow the annual stage if shrubs are dominant to the exclusion of perennial grasses prior to the fire. Figure 9 shows a sagebrush community that developed in 11 years on the Erickson Pass burn. If a perennial grass stand develops first, it is usually followed by sagebrush and then juniper (Fig. 10).

Shrubs did not become dominant on most sites until approximately 35 years from the time the areas burned. Except for a few north-facing slopes that were dominated by snowberry, sagebrush was the most abundant shrub in all areas 35 years after burning. Juniper occurred on the 11-year-old burns but did not become dominant for approximately 70 years; there was an upward trend in numbers of trees after 46 years. On the 86-year-old burns, juniper completely dominated the site. Other plant species were sharply reduced in vigor and density. These successional stages are summarized in Figure 11. They are not greatly different from the ones outlined by Arnold et al. (1964) in Arizona and Erdman (1970) in Colorado.

The burns sampled do not give sufficient information to determine the place of pinyon in the successional sequence.

Two little-understood basic factors in tree invasion are the frequency of good seed crops and the combination of climatic factors that influence high germination. The variety and complexity of factors influencing succession demonstrate the need for multifacet research to answer the many questions involved and provide a sound basis for managing the vast acreage occupied by this type.

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Range Site and Grazing System Influence Regrowth after Spraying Honey Mesquite

C. J. SCIFRES, M. M. KOTHMANN, AND G. W. MATHIS

Highlight: *Honey mesquite (*Prosopis glandulosa *Torr. var.* glandulosa*) regrowth on the Texas Experimental Ranch in the Rolling Plains of northwest Texas was evaluated 8 years after aerial spraying with 2,4,5-T. Regrowth on rocky hill, rolling hill, and deep upland range sites was measured under two systems of grazing management: heavily stocked (4.86 ha/AU), continuous grazing; and, moderately stocked (6.48 ha/AU), deferred-rotation grazing. Canopy cover, density, and topgrowth production of honey mesquite regrowth were significantly greater under moderate, deferred-rotation grazing than under heavy, continuous grazing of the deep upland site. Honey mesquite density, canopy cover, and topgrowth production did not differ between grazing systems on the rocky hill site. Regrowth on the rolling hill site was usually intermediate between the rocky hill and deep upland sites. Honey mesquite plant density, topgrowth production, canopy cover, and rate of new stem initiation were greater under moderately stocked, deferred-rotation than heavily stocked, continuous grazing. Averaged across grazing systems, regrowth, regardless of variable evaluated, was greatest on the deep upland site.*

The Rolling Plains of Texas occupies some 10 million ha of gently rolling to moderately rough topography in semi-arid, northwest Texas (Gould, 1969). About two-thirds of the area is rangeland supporting cow-calf operations. Honey mesquite (*Prosopis glandulosa* Torr. var. *glandulosa*)[1] is the most troublesome woody invader of these rangelands.

Standard spraying treatment for honey mesquite control in the Rolling Plains is 0.56 kg/ha of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in 15 to 20 liters/ha of a 1:4 or 1:3 diesel oil:water emulsion. Usually, only 20 to 25% of the honey mesquite plants in the treated population are "root-killed" by such applications (Fisher et al., 1972). The remainder of the population, with the tops killed by spraying, develop new aerial growth by sprouting from the stem base or the "crown" (Young et al., 1948). The "crown" is now recognized as a compressed section of stem, and evidently the result of a morphological or genetic adaptation to environmental conditions. When released from apical dominance, buds along live stem segments, aerial or buried, readily produce new stems and leaves (Meyer et al., 1971). Prolific sprouting gives rise to a many-stemmed, shrubby-type growth that often presents more difficult range management problems than the original, single-stemmed, tree-type infestations of honey mesquite.

It is commonly thought that a "good grass cover," maintained through proper management of grazing animals, retards development of honey mesquite (Fisher et al., 1959). This has been substantiated relative to seedlings invading rangeland (Scifres et al., 1971). However, there are no quantitative data which describe the influence of range site or grazing management factors on regrowth potential or regrowth development following efforts to control established honey mesquite. The Texas Experimental Ranch near Throckmorton provided an opportunity to evaluate honey mesquite regrowth as influenced by range site and grazing management, following aerial spraying with 2,4,5-T at 0.56 kg/ha.

Grazing Management Systems

Two grazing management systems, each comprising about 450 ha, were included in the study. Both were grazed in a cow-calf operation, one yearlong at the rate of 4.86 ha/AU, heavy continuous grazing (HCG), and the other under a 4-pasture, deferred-rotation system stocked at 6.48 ha/AU, moderate deferred-rotation grazing (MDG). The 4-pasture system was grazed with three herds of livestock. One herd was rotated at each 4-month interval to give each pasture 12 months grazing followed by 4 months rest.

Description of Study Site

Three range sites (deep upland, rolling hill, and rocky hill) were studied within each grazing system. The Abilene, Crawford, Rowena and Tobosa soil series comprise the deep upland site. This is the predominant range site on the Experimental Ranch and accounts for 41% of the total study area. Characteristically, these are dark clays and clay loams, moderate to slowly permeable and well drained. Depth of top soil above parent material ranges from about 50 to 200 cm and slope varies from 0 to 3%. Soils in these series are generally highly fertile and have high available water-holding capacities. They differ mainly in distribution of calcareous material in the soil horizons.

Texas wintergrass (*Stipa leucotricha* Trin. A Rupr.) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) are the principal grasses on the deep upland site, with sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) as the next most abundant species (Table 1). Species composition of vegetation on this site has changed in response to different grazing treatments (Mathis and Kothmann, 1968). Under heavy, yearlong stocking, buffalograss is the dominant species with Texas wintergrass declining and sideoats grama remaining relatively stable as a minor species. On all moderately stocked pastures, Texas wintergrass is the dominant species associated with a significant decline in buffalograss. Honey mesquite and plains pricklypear (*Opuntia polyacantha* Haw.) are the primary undesirable species on the deep upland site.

The rolling hill site, comprising 34% of the experimental area, includes the Metera and Throck soil series. Surface

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[1] Scientific names follow Gould, F. W. (1969).

Table 1. Species composition (%) by weight and available forage (kg/ha) in 1972 on three range sites under two grazing systems, which were used for study of honey mesquite regrowth in the Rolling Plains near Throckmorton, Tex.

Species	Deep upland		Rolling hill		Rocky hill	
	Heavily stocked, continuous	Moderately stocked, deferred-rotation	Heavily stocked, continuous	Moderately stocked, deferred-rotation	Heavily stocked, continuous	Moderately stocked, deferred-rotation
Buffalograss	47	15	28	20	24	14
Texas wintergrass	31	52	25	22	6	11
Sideoats grama	5	11	7	31	26	18
Threeawn	4	3	18	9	14	12
Misc. grasses	6	9	13	12	19	34
Forbs	8	10	10	7	11	12
Available forage	1103	1617	1046	1475	728	1146

soils of these series are dark, greyish brown, silty clay loams ranging in depth from 38 to 50 cm with slopes of 1 to 5%. They are highly calcareous, and outcroppings of flat limestone occur frequently on the surface. These soils are moderately permeable and highly fertile, but water storage is restricted because of their shallow depth. Texas wintergrass, the dominant species on the rolling hill site, grows primarily on the deeper soils. Sideoats grama is the second most important species. Buffalograss and threeawns (*Aristida* sp.) are the other important forage species. Species composition changes are more rapid than on the deep upland site (Mathis and Kothmann, 1968). Under moderate stocking, sideoats grama and Texas wintergrass increase on this site. Deferred-rotation grazing has been effective in increasing the rate of change. Honey mesquite and lotebush (*Condalia obtusifolia* (Hook.) Weberb.) are the primary brush species on the rolling hill site.

Soils of the Owens-Tarrant complex constitute the rocky hill site. These are shallow, stony clays characterized by limestone rocks on the surface that vary in size from small cobbles to large boulders. Soil depth above parent material ranges from 13 to 50 cm. Fertility level is generally high but permeability is moderate to very slow. This range site occurs on steep slopes and rocky ridges where surface runoff is rapid. About 17% of the Experimental Ranch is contained in this site. Sideoats grama is the major species of the rocky hill site with threeawns, buffalograss, and Texas wintergrass the more important secondary species. This site generally responds quickly to improved grazing management. If properly grazed, the site has good production potential.

Evaluation Methods

Honey mesquite regrowth was evaluated on each range site in two pastures under both grazing management systems. The point-centered quarter (Cottam and Curtis, 1956) was used as the basic evaluation method. Four lines, 410 m long and about 100 m apart, were established on each site. Twenty-five, equally-spaced points were established along each line. The distance from the central point to the center of nearest honey mesquite plant in each quadrant was recorded. Data recorded for each regrowth plant included the height, canopy width and number of stems. On the first 10 points of each line, the basal diameter of each primary honey mesquite stem was recorded. Although it is realized that several branches may arise from a single branch beneath the soil line, *primary stems* are defined as those originating below ground line (Scifres et al., 1971). Twenty plants measured in the above manner were harvested from each site, separated into foliage and stems, and weighed. Subsamples were taken from each harvested plant for moisture determinations and all plant weights were converted to an oven-dry basis.

Canopy volumes were estimated using the formula $0.167\,\pi h\,(h^2 + 3\,r^2)$ where h = plant height to the tallest extended primary stem and r = canopy radius at the widest point. A regression equation was developed for canopy volume and honey mesquite production values as suggested by Cook (1960). The equation, $Y = 126.87 + 370\ (X)$ where Y = oven-dry honey mesquite production/plant (g) and X = canopy volume/plant (m^3), was utilized to estimate production of all plants evaluated along the original lines. The two plant attributes were highly correlated ($r = 0.98$). Average plant production and density values were used to estimate production per unit area (kg/ha) of aerial honey mesquite regrowth.

About 800 basal stem samples were collected to investigate the relationship between stem age and radial growth. This method was essentially the same as described by Scifres et al. (1971) in similar studies with honey mesquite. Linear, quadratic, and cubic regression equations were developed for each site and grazing system using stem diameter as the independent variable and number of growth rings as the dependent variable. The best predictive equation for each site was then utilized in estimating stem age to compensate for inherent variation in growth rate.

Results and Discussion

Regrowth Density, Canopy Cover and Topgrowth Production

On the rocky hill site, grazing management did not significantly influence regrowth plant density (Table 2). However, on the deep upland and rolling hill sites, regrowth densities were greater under MDG than under HCG. Plant densities for honey mesquite regrowth ranked by sites were: deep upland $\geqslant$ rolling hill $>$ rocky hill. Honey mesquite densities by grazing system averaged across sites were higher under MDG than under HCG.

Table 2. Density of live honey mesquite (plants/ha) on three range sites under two grazing systems in May, 1972 after aerial spraying in the Rolling Plains near Throckmorton, Tex., in June, 1964.[1]

Range site	Grazing system		Site avg
	Heavily stocked, continuous	Moderately stocked, deferred-rotation	
Deep upland	111 a	356 a	234 s
Rolling hill	170 b	248 c	209 st
Rocky hill	177 b	164 b	171 t
Grazing system avg	153 q	256 r	205

[1] Means followed by the same letter are not significantly different at the 5% level.

Canopy cover followed the same general trends as did plant density (Table 3). However, canopy cover was not significantly different among sites under HCG. There was no difference between rolling hill and rocky hill sites relative to honey mesquite regrowth canopy cover regardless of grazing system. Both the lowest

Table 3. Canopy cover (%) of honey mesquite regrowth on three range sites and under two grazing systems in May, 1972, after aerial spraying in the Rolling Plains near Throckmorton, Tex., in June, 1964.[1]

Range site	Grazing system		Site avg
	Heavily stocked, continuous	Moderately stocked, deferred-rotation	
Deep upland	1.6 a	8.0 c	4.8 v
Rolling hill	2.8 ab	3.5 b	3.2 vw
Rocky hill	2.2 ab	2.8 ab	2.5 w
Grazing system avg	2.2 x	4.8 y	3.5

[1] Means followed by the same letter are not significantly different at the 5% level.

(HCG) and the highest (MDG) canopy covers occurred on the deep upland site. Sites under HCG had lower canopy cover of honey mesquite regrowth than those under MDG.

Production of honey mesquite topgrowth did not differ among range sites under HCG (Table 4). Under MDG, honey mesquite regrowth production was greatest on deep upland and least on rocky hill. Production of honey mesquite regrowth under HCG was about a third of that from MDG.

Regrowth Stem Development

Density of stems originating in 1963 or earlier was used as an index of survival of the spray operation. Stem density cannot be related to plant density since original stems/plant are not known. Stems surviving the 1964 spray treatment were 66/ha (HCG) and 56/ha (MDG) for rocky hill; 189/ha (HCG) and 427/ha (MDG) for rolling hill; and, 13/ha (HCG) and 85/ha (MDG) for deep upland.

The greatest difference in rate of stem initiation between grazing systems occurred on the deep upland site (Fig. 1). Under MDG an average of about 300 new stems were initiated/ha/year. Under HCG about 15 new stems/ha were initiated in 1964, followed by a steady increase to 125 stems/ha in 1971. During 1971 and 1972, there was little difference between grazing systems on the deep upland site relative to new stem initiation. Total numbers of stems initiated during the 8-year period were 666 (HCG) and 2848 (MDG). These were about 50- and 35-fold increases over the stem densities that survived the spraying.

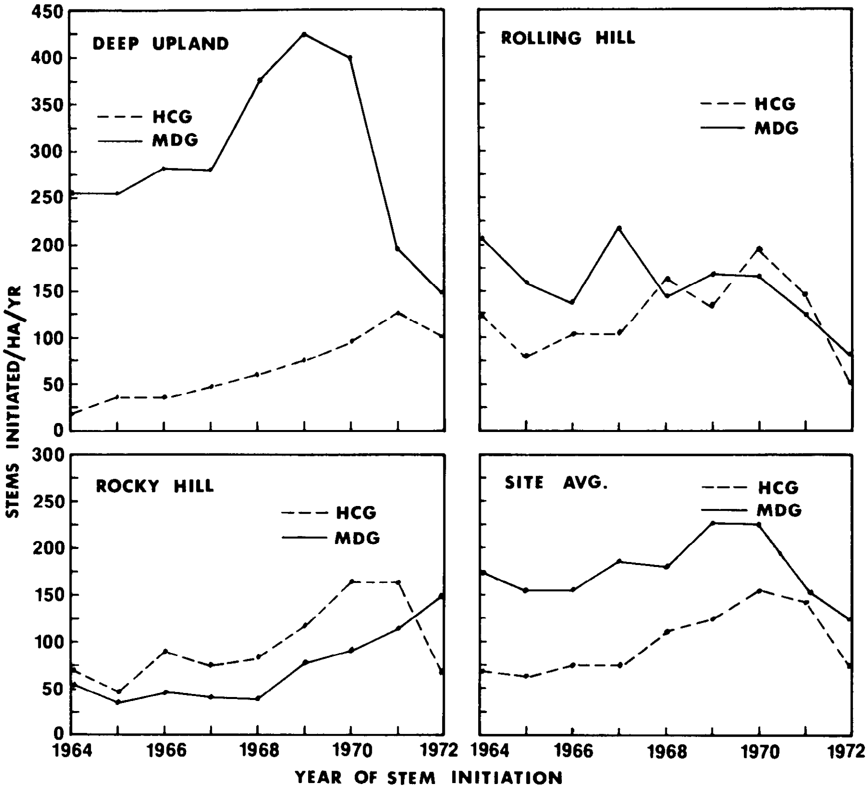

Fig. 1. *Honey mesquite regrowth stems initiated annually following application of 2,4,5-T at 0.56 kg/ha in spring, 1964, to three range sites under two grazing management systems on the Texas Experimental Ranch near Throckmorton.*

For the first 4 years after spraying, an average of about 75 more primary stems/ha/year were initiated under MDG than under HCG on the rolling hill site (Fig. 1). There was no apparent difference between grazing systems in primary stem initiation on the rolling hill site from 1968 to 1971. Rate of increase in new stem initiation was less on rolling hill than on the other two range sites. Stem densities increased 4- and 7-fold during the eight seasons following spraying under MDG and HCG, respectively. Average numbers of new stems initiated/ha/year were 119 (HCG) and 159 (MDG), with cumulative totals of 1258 and 1860 new stems/ha.

Table 4. Oven-dry production (kg/ha) of honey mesquite aerial, plant parts on three range sites under two grazing systems in May, 1972, after aerial spraying in the Rolling Plains near Throckmorton, Tex., in June, 1964.[1]

	Grazing system		
Range site	Heavily stocked, continuous	Moderately stocked, deferred-rotation	Site avg
Deep upland	123 a	1,013 c	568 u
Rolling hill	269 a	622 b	446 v
Rocky hill	192 a	233 a	213 w
Grazing system avg	195 x	623 y	409

[1] Means followed by the same letter are not significantly different at the 5% level.

No obvious difference in rate of initiation of primary stems following herbicide application was apparent between grazing systems on the rocky hill site (Fig. 1). In contrast to the other sites, there was a trend for greater initiation of new stems under HCG than under MDG. Average rates of stem initiation were 103 and 72 stems/ha/year for HCG and MDG pastures, respectively.

Averaged across sites, there were more primary stems initiated/ha/year under MDG than under HCG (Fig. 1). Associated with the general decline in stem initiation in 1971 and 1972 was a period of below normal rainfall from summer of 1970 until summer, 1971. Yearly differences in stem initiation, however, were not correlated with total annual precipitation ($r = 0.14$).

There were few significant differences among sites within grazing systems as to number of primary stems per regrowth plant (Table 5). Under MDG there were significantly more primary stems on regrowth plants on the deep upland site than on the rocky hill site. When averaged across grazing systems, there were fewer primary stems/regrowth plant on rocky hill than on the other range sites.

Although there were no significant differences in height of primary stems of regrowth honey mesquite among range sites within grazing systems studied, there was a trend toward shorter stems on regrowth on rocky hill sites (Table 5). Grazing systems, averaged across sites, had no significant influence on height of regrowth stems.

Response of honey mesquite regrowth to range site and grazing system influences should not be confused with environmental pressures on seedling establishment. The requisites for ecesis, primarily opening of rangeland communities, adequate moisture, and optimum temperature for seed germination and seedling growth of honey mesquite, have been documented (Fisher et al., 1959; Scifres et al., 1971; Scifres and Brock, 1972). Regrowth honey mesquite consists of

Table 5. Primary stems/plant and average height (m) of honey mesquite regrowth plants on three range sites under two grazing systems in May, 1972, after aerial spraying in the Rolling Plains near Throckmorton, Tex., in June, 1964.[1]

Measurement and range site	Grazing system		
	Heavily stocked, continuous	Moderately stocked, deferred-rotation	Site avg
Primary stems/plant			
Deep upland	6.0 ab	8.0 b	7.0 y
Rolling hill	7.4 ab	7.5 ab	7.5 y
Rocky hill	5.3 ab	4.3 a	4.8 z
Grazing system avg	6.2 x	6.6 x	
Height/plant			
Deep upland	1.30 c	1.62 c	1.46 r
Rolling hill	1.12 c	1.54 c	1.33 qr
Rocky hill	1.09 c	1.28 c	1.19 q
Grazing system avg	1.17 s	1.48 s	

[1] Means followed by the same letter are not significantly different at the 5% level.

new stems that arise from the crowns of plants with established root systems.

In this study, regardless of range site, extent of regrowth was reduced on heavily stocked, continuously grazed pastures when compared to moderately stocked, deferred-rotationally grazed pastures. Although occasionally utilized during certain growing seasons, browsing of honey mesquite by livestock is probably not responsible for this difference.[2]

The increased regrowth of honey mesquite under MDG probably can be attributed to changes in site conditions that were generally more favorable to plant growth. More research is needed in this area to clearly understand such vegetation-management-site influences.

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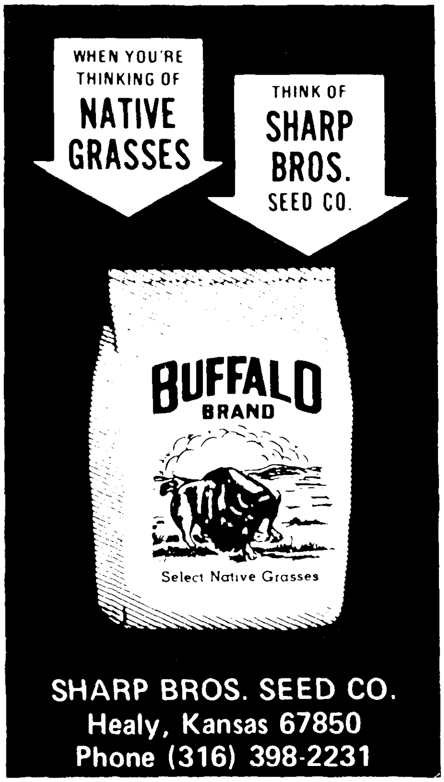

Some Effects of Chopping Saw-Palmetto-Pineland Threeawn Range in South Florida

WILLIAM H. MOORE

Highlight: *The cutover pinelands of south Florida are fire-dependent communities dominated by saw-palmetto and pineland threeawn, two low-quality species. Land managers interested in cattle, wildlife, or timber production seek effective ways of controlling these species. Chopping is generally used to accomplish such control. This study was designed to discover differences in forage production and species composition as a result of season of chopping. Although important differences were not revealed, chopping during periods of low soil moisture appeared to give best results. Generally, saw-palmetto was reduced from 24% to 3% coverage, while the yield of pineland threeawn decreased from an average of 80% to near 20%. Desirable species such as bluestems, panicums, paspalums, and razorsedge became abundant. After 2 years, total herbage production increased from a normally expected 3,600 lb per acre to an average of 5,400 lb per acre.*

The cutover pinelands of south Florida are managed primarily as cattle ranges. Game and timber production are important byproducts. The pinelands are fire-dependent communities dominated by highly flammable plants. Most abundant are saw-palmetto (*Serenoa repens* (Bartr.) Small) and a wiregrass, pineland threeawn (*Aristida stricta* Michx.)—two low-quality species. Between fires, they form dense roughs competitive with desirable cattle forage and game food species. Buildups of dry fuels are also a fire hazard to developing pine stands.

In a continuing effort to improve cattle forage, wildlife foods, and timber production, land managers seek more effective ways of controlling the less desirable vegetation. Chopping for plant control is widespread and is generally considered to give satisfactory results. When ranges are double-chopped, i.e., cross-chopped at right angles with heavy drum choppers, the sod is cut into foot squares, resulting in soil disturbance to a depth of 4 to 6 inches. In trials close to the study area in south Florida, double-chopping greatly reduced the abundance of saw-palmetto and pineland threeawn (Hilmon et al., 1963; Lewis, 1970). In greater abundance were bluestems (*Andropogon* spp.), panicums (*Panicum* spp.), paspalums (*Paspalum* spp.), and perennial goobergrass (*Amphicarpum muhlenbergianum* (Schult.) Hitchc.). After chopping, flatwoods ranges yielded higher quality and quantity of forage and a number of grasslikes and forbs which are important game foods.

Although chopping is known to benefit forage production, best time of treatment, changes in species composition, and effects on game food production have not been completely determined. In an effort to better understand the effects of chopping, a study was installed during 1965-66 in Glades County in south Florida.

Study Area

The study was carried out on a flatwoods site that was clearcut during the 1940's. The original pine component consisted of longleaf (*Pinus palustris* Mill.) and South Florida slash (*P. elliottii* var. *densa* Little & Dorman). Since 1940, the site has been subjected to yearlong grazing by livestock and to burning every 2 or 3 years; hence, no pine regeneration has occurred.

Soils are Leon fine sand, an Aeric Haplaquod characterized by deep, undifferentiated sands except for an organic "hardpan" (B horizon) 4 to 6 inches thick and 1 to 2 ft below the surface (Soil Conservation Service, 1971). Leon, one of the better-drained flatwoods soils, is imperfectly to poorly drained. Although saw-palmetto and pineland threeawn were the prevailing species, dwarf live oak (*Quercus minima* (Sarg.) Small), fetterbush (*Lyonia lucida* (Lam.) K. Koch), lyonia (*Lyonia fruticosa* (Michx.) G. S. Torr.), and a variety of bluestems and panicums were also present (Fig. 1).

The subtropical climate is characterized by hot, rainy summers and mild, dry winters. Annual rainfall is 52 inches, of which nearly two-thirds occurs in June through September. Soils become saturated and often inundated during the summer. Deep sands lose moisture rapidly, however, and the dry winter period culminates in a distinct and often severe drought in April and May.

Methods

A series of ½-acre plots was double-chopped in each of 4 months—November, January, May, and August—with tandem Marden drum choppers pulled by a D-4 Caterpillar tractor (Fig. 2). Treatments were applied in a randomized complete block design, replicated three times. For estimates of shrub response, the design included an unchopped control, whereas the design for estimating herbage response did not. The experimental design included burning in winter, 1 year before installation of treatments, and protection from wildfire and livestock grazing.

Stem density and crown coverage of shrubs were estimated on 1- by 100-ft belt transects 12 and 24 months after chopping. Composition and production of herbs were estimated on 9.6-ft^2 circular subplots. Estimates were made 6, 12, and 24 months after chopping.

Data on stem density and crown cover-

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Fig. 1. *Saw-palmetto and pineland threeawn are dominant species on cutover pinelands of south Florida.*

age were summarized by species, and their means were compared by treatment. The significance of differences were examined by analysis of variance tests on the four most abundant shrubs (approximately 90% of the total) as well as on total shrubs. Herbage data were also summarized by species and groups for comparison by treatment. Differences were examined by analysis of variance.

Results

Shrubs

Chopping greatly reduced shrubs, and the treatment appeared to be slightly more effective when done during drier periods. However, differences among months of treatment (season) were nonsignificant ($P > 0.05$) statistically, with one exception: May chopping resulted in significantly less saw-palmetto kill (a 70% reduction) than did chopping during other months (average 94% reduction).

When means for season of chopping were combined and then compared with unchopped controls, reductions in both stem density and crown coverage were significant ($P < 0.05$) for each of the four species tested.

Fig. 2. *Drum choppers pulled in tandem give effective mechanical control of unwanted vegetation.*

Stem Density

Shrubs numbered 53,000 per acre when observed 1 year after chopping, as compared with 167,000 observed on unchopped controls (Table 1). Dieback on chopped plots continued with time, and by the end of the second growing season shrubs had declined an additional 12%, a total reduction of 80%. Of the four most abundant species, dwarf liveoak was the least affected but had a 67% stem reduction after 2 years. Fetterbush had the greatest loss, an 86% kill during this same period. Saw-palmetto, normally regarded as the most troublesome shrub on these ranges, was reduced by 83%.

Dwarf liveoak, the most important shrub with wildlife food value (acorns), comprised 28% in the normal shrub population (control plots) but increased to 44% 2 years after chopping. Fetterbush, on the other hand, comprised 36% of the shrub population on the control plots and only 24% 2 years after chopping. Percentage composition of lyonia (14%), saw-palmetto (10%), and other shrubs (12%) remained about the same.

Total stems increased an average of about 1% between the first and second year on control plots. Species with wildlife food value, mainly dwarf liveoak, increased almost 14% during this period.

Crown Coverage

Chopping reduced shrub crown coverage, which averaged 44% on the control plots, to 8% 1 year after chopping (Table 2). It was apparent that chopping killed a majority of the shrubs and greatly reduced the size of those surviving, although many remaining plants appeared to be recovering. Despite natural thinning, crown coverage in most instances increased slightly, about 3% the second year. Dwarf liveoak was again the least affected, while fetterbush recovered the most rapidly. Saw-palmetto, although few in number, accounted for over one-half of the total shrub coverage on control plots. Chopping reduced the cover of this plant from 24% to 3%.

Table 2. Shrub cover 1 and 2 years after chopping and percentage change as compared with unchopped controls.

	% Cover			% Change	
Species	Control	1 year	2 years	1 year	2 years
Saw-palmetto	24	3	3	88	88
Dwarf liveoak	7	2	3	67	63
Fetterbush	7	1	2	88	64
Lyonia	3	1	1	82	79
Other	3	1	<0.5	48	81
Total or average	44	8	9	82	79

The shrub cover on untreated range was composed of 54% saw-palmetto, 16% dwarf liveoak, 16% fetterbush, and 7% lyonia. Two years after chopping, saw-palmetto was reduced to 31%, while dwarf liveoak increased to 29% and fetterbush increased to 28%. Lyonia's percentage composition was unchanged.

Total shrub cover on the control plots increased from 44% the first year to 57% the second year (2nd and 3rd year after burning), a 28% increase in cover. Saw-palmetto cover increased 26%, dwarf liveoak 56%, and other shrubs about 18%.

Herbage Production

Analysis of variance did not indicate significant differences in herbage production among treatment periods. A number of plots were discarded as a result of accidental heavy cattle grazing; therefore, data on herbage production were meager and probably were not sufficiently sensitive to prove whether season of chopping had a significant impact. Numerical differences were not great, however, and there is some question as to whether these differences would be important had they been statistically significant.

Control plots were not a part of the design for estimating herbage response because the primary purpose of this part of the study was to determine the best season for chopping. However, chopping generally is known to have significant, long-term effects on herbaceous vegetation (Hilmon et al., 1963; Lewis, 1970; Yarlett, 1965; Yarlett and Roush, 1970). Ocular comparisons with adjoining untreated range seemed to further substantiate this generalization. Two years after chopping, range recovery appeared to have reached maximum herbage production, which averaged 5,400 lb/acre dry weight (Table 3). This average can be compared with a production of 3,600 lb/acre 2 years after burning on nearby unchopped, ungrazed native range (Hilmon and Lewis, 1962).

Composition Changes

The most obvious effect of chopping herbaceous vegetation was the drastic reduction of pineland threeawn and subsequent replacement by a variety of more desirable species. Two years after chopping, pineland threeawn comprised only 22% of the total herbage by weight. This figure can be compared with the 80% normally expected on wiregrass range 2 years after burning (Hilmon and Lewis, 1962). Differences in reduction of pineland threeawn did not appear important with respect to season of chopping.

Species observed on sample plots after treatment consisted of 18 grasses, 5 grass-likes, and 18 forbs. The relative importance of these changed with time. Among the dominant species, for example, percentage of distribution among the plots at each sampling time was as follows:

	6 months	12 months	24 months
Grasses	46	67	100
Grasslikes	27	22	0
Forbs	27	11	0
Total	100	100	100

Table 1. Stems per acre 1 and 2 years after chopping and percentage change as compared with unchopped controls.

	Thousand stems/acre			% Change	
Species	Control	1 year	2 years	1 year	2 years
Saw-palmetto	17	4	3	75	83
Dwarf liveoak	47	24	16	50	67
Fetterbush	60	12	8	79	86
Lyonia	23	8	5	66	78
Other	20	5	3	74	83
Total or average	167	53	35	68	80

Species that were rated as good cattle forage by Hilmon (1964) were most important on 60% of the sample plots at the end of the first growing season and on 92% of the plots after two seasons. Most abundant were delicate panicum (*Panicum chamaelonche* Trin.) and broomsedge bluestem (*Andropogon virginicus* L.). These comprised about one-half of the desirable herbage.

Plants of value to wildlife were the most important species on 57% of the plots after 1 year but on only 17% of the plots after 2 years. The most important were delicate panicum and little razorsedge (*Scleria georgiana* Core). A number of low panicums (mainly *Panicum polycaulon* Nash), barestem paspalum (*Paspalum longepedunculatum* LeConte), and downy milkpea (*Galactia volubilis* (L.) Britt.) were also common. Little razorsedge and several desirable forbs, although present, were of little importance by the end of the second year.

Discussion

Saw-palmetto crown cover averages about 20% on south Florida ranges but may frequently be higher (Hilmon, 1968; Yarlett, 1965). Hilmon and Lewis (1962) found shrub weight to be variable, at times totaling 400 lb/acre or more. Over 90% of this total is typically saw-palmetto. They also found total herbage production on ungrazed ranges to average about 3,600 lb the second year after burning, of which some 75 to 80% was pineland threeawn. This species is desirable forage during a period of only 3 or 4 months after the range is burned. Desirable forage grasses, such as bluestems, panicums, and goobergrass, normally account for up to 10% of the yields, while grasslikes and forbs make up the remainder.

Flatwoods ranges are typically burned every 2 or 3 years during the winter to slow the spread of saw-palmetto coverage and to improve pineland threeawn forage (Hilmon and Lewis, 1962). When the

Fig. 3. *After chopping, unwanted vegetation is replaced with species more useful to cattle and wildlife.*

range is burned, accumulated mulch is removed and plants are stimulated to produce a more nutritious regrowth. This practice also temporarily produces a greater variety of annuals and other plants, a condition beneficial to quail (Frye, 1954) as well as cattle. Without frequent burning, saw-palmetto will increase annually at a rate of between 2 and 3%, and pineland threeawn will build up a dense, low-quality rough virtually devoid of other herbaceous species. Forage nutrient content rapidly drops below acceptable levels, and desirable forage and wildlife food species soon disappear.

When cattle grazing or wildlife habitat is the management objective, a long-lasting treatment that favorably alters species composition seems much more desirable than frequent burning. Chopping appears to accomplish this alteration. In the present study, a shrub cover of nearly 50% was reduced to less than 10%. The two most troublesome species, saw-palmetto and pineland threeawn, were reduced by almost 90%. Although herbage production was reduced the first year, range recovery appeared complete by the end of the second year (Fig. 3), with a significant increase in herbage yield (avg 5,400 lb/acre). Other workers have obtained similar results (Hilmon et al., 1963; Lewis, 1970; Yarlett, 1965; Yarlett and Roush, 1970). Less desirable species were replaced in part by a variety of plants more useful to cattle and wildlife and less hazardous as wildfire fuels.

Table 3. Accumulated herbage yields (lb/acre) at 6, 12, and 14 months after chopping.

Herbage	6 months	12 months	24 months
Pineland threeawn	100	300	1,200
Other	600	2,700	4,200
Total	700	3,000	5,400

Increases in saw-palmetto cover the second year after chopping were the result of increased plant size rather than increases in numbers. Other shrubs observed in this study, however, appear to recover rapidly. Most flatwoods shrubs with the exception of saw-palmetto are rhizomatous, fire-resistant, and tend to sprout when injured. For example, common gallberry (*Ilex glabra* (L.) A. Gray), a troublesome shrub in the flatwoods of Georgia and Florida, is only temporarily reduced by chopping (Wilhite and Harrington, 1965). Fetterbush, and possibly dwarf liveoak, appeared to react similarly on the south Florida flatwoods site.

Desirable quail foods—mainly *Scleria* spp. and miscellaneous forbs—were abundant the first year but were rapidly replaced by perennial grasses. Frye (1954) found annual razorsedge (*Scleria muhlenbergii* Steud.), paspalum, and partridgepea (*Cassia aspera* Muhl.) to be greatly increased following disking with a farm-type harrow, but production fell off drastically the second and third years. After 2 years, the only useful quail food of importance was delicate panicum.

For best kills of saw-palmetto in south Florida, chopping should probably be done during dry weather (Hilmon et al., 1963; Lewis, 1970, 1972). For example, Lewis (1972), working on range adjoining that of the present study, observed a saw-palmetto coverage of less than 1% within 6 months after chopping in May, 1965. In the present study, plots chopped in May, 1966, resulted in a residual saw-palmetto cover of 7% when sampled after the first growing season. May, 1966, had above-average rainfall. May normally receives about 4 inches of rain, but less than 1 inch fell during the month in 1965. These kills may be compared with those for earlier, drier months during which saw-palmetto cover averaged 1% to 2% after one growing season.

In summary, evidence of this study and similar studies suggests that double-chopping is an effective, long-lasting treatment for the improvement of cattle ranges in south Florida, especially when completed during dry weather. This practice also benefits wildlife, especially quail, but the effects are short lived. If a sustained supply of important quail foods (mainly annuals) is to be provided, frequent soil disturbance will be necessary.

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Nonstructural Carbohydrates in Grazed and Ungrazed Cane Bluestem

PATRICK O. REARDON AND LEO B. MERRILL

Highlight: *Trend of carbohydrate reserves, major storage carbohydrates, and primary storage locations were determined in grazed and ungrazed cane bluestem plants. Sucrose was usually the major reserve carbohydrate, and the largest concentration of reserve carbohydrates was in the crown portion of the plant. The total nonstructural carbohydrate (TNC) levels were higher in grazed than in ungrazed plants. The ungrazed plants matured earlier, as indicated by an earlier TNC peak and had lower winter TNC levels. Results indicate that maximum plant vigor can be maintained with a periodic June to November grazing deferment followed by moderate foliage removal.*

The study of production and accumulation of total nonstructural carbohydrates (TNC) in plants is often utilized for gaining insights into maintenance of plant vigor and forage yields. The seasonal trends of carbohydrate reserves are similar but not always the same for most native range plants. Species differences and environmental conditions make it difficult to draw general conclusions concerning management of all important range plants. Therefore, repetitive research is necessary to gain information pertaining to all important range plants under varying environmental influences (White, 1973). Merrill and Reardon (1966) reported that cane bluestem (*Bothriochloa barbinodis* Lag.), among other herbaceous plants, remained in a low state of vigor in an area deferred from livestock and wildlife grazing for over 20 years. The same plant species in an adjacent area managed under a 4-pasture deferred rotation system was in a high state of vigor and highly productive. Plants in the grazed area had a faster spring growth rate and produced more foliage than plants in the ungrazed area. Carbohydrate levels may have played an important role in causing these differences. Higher carbohydrate reserve levels preceding winter conditions could explain the accelerated spring growth rate in grazed plants.

This study was undertaken to gain information concerning seasonal reserve carbohydrate trends, major nonstructural carbohydrate reserves and primary storage areas in cane bluestem. Results will be useful in designing grazing systems to maintain plant vigor and production in cane bluestem.

Study Areas and Procedures

Samples of cane bluestem were taken from two experimental pastures within the Texas A&M University Agricultural Research Station at Sonora. One pasture has not been grazed by domestic livestock or deer since 1949. The other is one of four pastures in a deferred-rotation system. This pasture was grazed at the rate of 32 animal units per section with cattle, sheep, and goats from 1949 until 1959 and with 43 animal units per section from 1960 until 1970. These two pastures provided properly utilized plants and unutilized plants, so that the difference in carbohydrate concentrations based on degree of defoliation could be determined.

Cane bluestem plants with similar basal diameters and from the same range site were selected and staked at the beginning of the study. Three replications of individual plants were collected monthly from each pasture. Samples were taken at a set time during the day to reduce errors resulting from daily carbohydrate fluctuations (Waite and Boyd, 1953). Plants were removed to a depth of 6 to 8 inches in a manner similar to that described by Williams and Baker (1957), The collected material was separated in the field into two categories: basal crown, including the lower 3/4 inch of the culms; and roots. After collection, the material was frozen immediately in dry ice to arrest enzymatic activity and stored in a deep freeze until chemical analyses were made.

Prior to chemical analyses, the plant material was freeze-dried and ground through a Wiley mill to pass a 40-mesh screen. Quantitative analyses were made for reducing sugars, sucrose, and starch.

Plant material was extracted with 90% ethanol (Waite, 1957). The filtrate was cleared with cadmium hydroxide (Laidlaw and Reid, 1952). Quantity of reducing sugars and sucrose in the filtrate was determined by a modification of the ferricyanide reduction method (Furuholmen et al., 1964). Residue from a water extract was utilized for quantitative determination of starch by the perchloric acid extraction method as described by Pucher et al., (1948). All chemical analyses were expressed as a percentage on a dry weight basis. These data were analyzed by Student's *t*-Distribution procedures, as outlined by Li (1957), using monthly observations from the grazed and ungrazed plants in a paired analysis.

Table 1. Individual and TNC concentrations (%) from cane bluestem roots collected from grazed and ungrazed areas.

	Grazed				Ungrazed			
Month	Reducing sugars	Sucrose	Starch	TNC	Reducing sugars	Sucrose	Starch	TNC
Feb.	2.7	2.8	0.8	6.3	2.2	3.4	0.4	6.0
Apr.	1.4	2.3	0.1	3.8	1.2	1.0	0.1	2.3
May	1.6	3.4	0.1	5.1	2.0	3.4	0.0	5.4
June	2.1	0.2	1.6	3.9	1.0	0.4	0.1	1.5
July	2.3	7.9	0.3	10.5	2.3	6.0	0.2	8.5
Aug.	1.2	5.5	0.6	7.3	2.6	4.4	0.4	7.4
Sept.	1.6	4.0	3.3	8.9	1.2	2.8	1.9	5.9
Oct.	2.1	5.2	2.1	9.4	1.4	1.5	1.6	4.5
Nov.	1.9	2.8	0.1	4.8	1.9	3.7	0.1	5.7
Dec.	4.3	3.9	0.5	8.7	1.4	3.2	0.5	5.1
Jan.	1.8	4.6	0.1	6.5	1.4	2.3	0.0	3.7
Average	2.09	3.87	0.88	6.84	1.69	2.92	0.48	5.09

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All field data were collected that the Texas A&M University Agricultural Research Station at Sonora. Chemical analyses were done at the Range Science Departmental Laboratory at Texas A&M University, College Station.

Results and Discussion

Levels of TNC in the roots of grazed plants were significantly higher ($P < .05$) than in ungrazed plants. The seasonal trend of TNC reserves in the roots (Fig. 1) follows the general trend as previously established by several other workers (McCarty, 1938; McCarty and Price, 1942). In both the grazed and ungrazed plants, the seasonal low was in June and the peak in July. After July, TNC in the ungrazed plants began a gradual decline, indicating plant maturity. In grazed plants, TNC levels were again high at the October and December sampling dates, indicating carbohydrate synthesis and storage following the July peak. This extra synthesis and storage was probably due to additional growth following heavy fall rains and warm days which occurred until December. TNC reserves in the roots of the grazed plants at the last sampling date were about 76% higher than from the ungrazed plants. The ungrazed plants must not have been able to utilize the warm, moist fall weather conditions for synthesis or storage. Higher TNC levels could explain why the grazed plants have a greater spring growth rate than the ungrazed plants.

The seasonal trend of TNC levels in the crown of grazed and ungrazed plants followed similar patterns (Fig. 2). Both had a low TNC level in April and a high TNC level in September or October. Ungrazed plants had a TNC peak about a month earlier than the grazed plants, indicating earlier maturity. After this peak, TNC levels declined. However, the high December TNC level in grazed plants indicates TNC synthesis and more storage after the October peak. The TNC level in the grazed plant crown was 167% higher on the January sampling date than that for the ungrazed plant. As with the roots, mean TNC levels in crowns of grazed plants were significantly ($P < .05$) higher than in the ungrazed plants.

Sucrose was the major reserve carbohydrate in roots of both the grazed and ungrazed plants (Table 1). However, reducing sugars were the major reserve carbohydrates in the crowns of ungrazed plants (Table 2). There was no sizable difference between sucrose and reducing sugar levels in crowns of grazed plants (Table 2). This agrees with previous re-

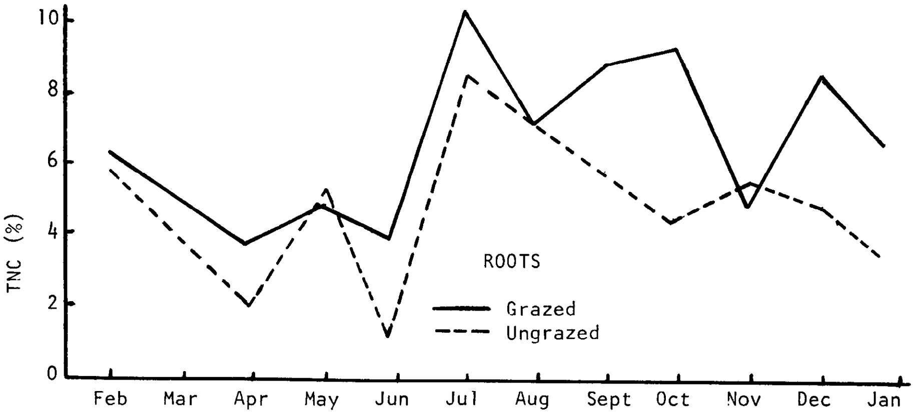

Fig. 1. *Total nonstructural carbohydrate (%) reserves in roots of cane bluestem plants from grazed and ungrazed areas.*

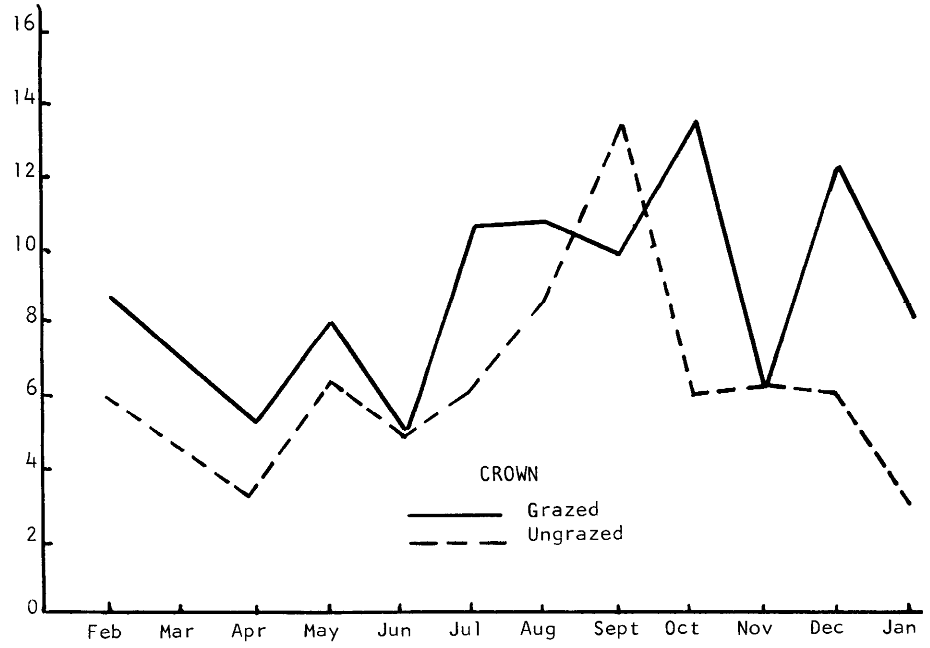

Fig. 2. *Total nonstructural carbohydrate (%) reserves in crown of cane bluestem plants from grazed and ungrazed areas.*

Table 2. Individual and TNC concentrations (%) from cane bluestem crowns collected in the grazed and ungrazed areas.

	Grazed				Ungrazed			
Month	Reducing sugars	Sucrose	Starch	TNC	Reducing sugars	Sucrose	Starch	TNC
Feb.	4.6	2.3	1.8	8.7	3.8	1.6	0.4	5.8
Apr.	2.4	1.7	1.1	5.2	1.8	0.0	1.4	3.2
May	3.1	4.1	0.7	7.9	2.8	2.7	0.7	6.2
June	2.8	0.0	2.2	5.0	2.4	1.3	1.0	4.7
July	3.6	5.1	1.9	10.6	2.4	2.3	1.4	6.1
Aug.	3.2	3.0	4.5	10.7	4.5	1.0	3.1	8.6
Sept.	2.1	2.2	5.6	9.9	2.0	7.4	3.0	13.3
Oct.	3.1	4.3	5.9	13.3	2.3	9.7	2.9	5.9
Nov.	2.0	2.7	1.5	6.2	2.1	2.0	2.2	6.3
Dec.	2.8	5.3	4.1	12.2	3.0	1.0	1.9	5.9
Jan.	2.9	3.7	1.4	8.0	1.9	0.9	0.2	3.0
Average	2.98	3.13	2.79	8.88	2.64	1.89	1.74	6.27

search (Okajima and Smith, 1964; Weinmann, 1952) in that warm season grasses such as cane bluestem accumulate primarily sucrose and starch and cool season grasses store sucrose and fructosans. The low levels of sucrose in the crowns of ungrazed plants can probably be explained by the fact that high sucrose levels are usually associated with accelerated growth which was not evident in the ungrazed plants (Nowakowshi, 1962).

Relative concentrations of reducing sugars, sucrose, and starch varied during the year, (Tables 1 and 2). On some sampling dates the reducing sugar concentration was highest; on other dates, the sucrose or starch. The major storage area for nonstructural carbohydrates within cane bluestem plants is in the crown. The difference in the TNC levels between roots and crown was small. However, during peak periods and winter months, TNC levels were higher in the crown.

Results from this study bring out several important points concerning growth and management of cane bluestem. Because sucrose was usually the major reserve carbohydrate and the crown the major storage area, future carbohydrate analyses could be simplified by analyzing for sucrose found in the crown. The low June TNC level and the high October TNC level indicate that a grazing deferment between June and November would be beneficial in maintaining plant vigor in cane bluestem plants. This deferment would allow the plant to synthesize and accumulate plant foods and go into dormancy with a relatively high reserve TNC level. Moderate grazing after the October TNC peak should not be harmful.

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Improvement of Panspot (Solonetzic) Range Sites by Contour Furrowing

R. J. SOISETH, J. R. WIGHT, AND J. K. AASE

Highlight: *We studied the effects of 3-, 7-, and 10-year-old contour furrowing on some physical and chemical soil properties of panspot range sites in southeastern Montana. Changes in soil bulk density, sodium-adsorption-ratio (SAR), and salinity (EC) on the contour-furrowed areas were generally small, but a definite ameliorating trend was established. Contour furrowing increased infiltration rates 0.25 to 3.11 cm/hr and increased forage yields 498 to 770 kg/ha. Reduced SAR and EC on contour furrowed areas were attributed to increased infiltration.*

Contour furrowing, a mechanical range renovation treatment, has been used successfully to increase range herbage production (Branson et al., 1962; and Wein and West, 1971). Branson et al. (1966) worked with seven different mechanical treatments and found that contour furrowing and broadbase furrowing increased herbage production more than the other methods. Hubbard and Smoliak (1953) found that, after 13 years, contour dikes were still beneficial in increasing herbage yields.

Information on soil physical and chemical properties from contour-furrowed areas is limited. Wight and Siddoway (1972) found that contour furrowing significantly increased soil water during some portions of the growing season. Branson et al. (1966) observed that average soil water storage was nearly 8% greater in contour-furrowed soils than in unfurrowed soils and reported leaching of salts from upper to lower depths in a 0- to 60-cm soil profile on contour-furrowed sites.

Contour furrowing has been used extensively by the Bureau of Land Management in eastern Montana and elsewhere to reduce runoff and erosion and to increase herbage production. Except for the work of Branson et al. (1966), little information has been reported on the effects of this land treatment with time on edaphic factors. The objectives of our study were to determine the effects of contour furrowing on selected physical

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Table 1. Soil properties of the 0- to 30-cm soil profile of the check treatment of three experimental sites in September 1970.

Sites and depths (cm)		Texture	Bulk density (g/cm)	pH	Electrical conductivity (mmhos/cm)	Cations (meq/1)				Anions (meq/1)			
						Na	Ca	Mg	K	SO_4	HCO_3	CO_3	C1
1960	0–10	Silt loam	1.29	6.2	2.2	23	7	5	<1	30	4	<1	<1
	10–20	Clay loam	1.46	7.3	3.0	32	6	6	<1	35	7	<1	<1
	20–30	Clay	1.40	7.7	5.6	53	14	15	<1	74	7	<1	<1
1963	0–10	Clay loam	1.33	7.6	2.0	23	6	3	<1	23	6	<1	<1
	10–20	Clay	1.32	7.8	4.7	44	10	9	<1	55	6	<1	<1
	20–30	Clay	1.31	7.8	6.0	59	13	17	<1	84	4	<1	<1
1967	0–10	Loam	1.32	7.0	2.7	28	8	6	<1	32	9	<1	<1
	10–20	Clay	1.31	7.7	5.1	53	9	11	<1	65	8	<1	<1
	20–30	Clay	1.32	7.8	6.6	69	11	17	<1	93	5	<1	<1

and chemical soil properties of panspot range sites in southeastern Montana.

Site Description and Methods

The study was located on a "frail land" research area approximately 24 km south of Ekalaka, Mont. Frail lands are defined by the Bureau of Land Management as those rangelands in the Pierre Shale Plains and Badlands Land Resource Area comprised of eroded saline-sodic soils with associated panspots or scabspots. Soil properties of the study sites are illustrated in Table 1. Water infiltrates very slowly into these sparsely vegetated soils. Dominant vegetation is thickspike wheatgrass (*Agropyron dasystachyum*), western wheatgrass (*Agropyron smithii*), sandberg bluegrass (*Poa secunda*), blue grama (*Bouteloua gracilis*), clubmoss (*Selaginella densa*), big sagebrush (*Artemisia tridentata*), and pricklypear cactus (*Opuntia* sp.). Crested wheatgrass (*Agropyron cristatum*) was a dominant species on the 1960 site.

Climate is typically continental in this semiarid area of the Northern Plains. Annual precipitation averages about 25 cm, with about 80% falling from April through September. In some years, a large percent of the annual precipitation falls in a few intense storms. The average frost-free season is 127 days.

Sites selected in 1970 for study had been contour furrowed 3, 7, and 10 years prior to sampling. The sites are identified in this study according to the year treatment was applied; i.e., 1960, 1963, and 1967.

On all areas selected for sampling, contour furrowing was applied with a model B contour furrowing machine developed by the Forest Service, U. S. Department of Agriculture, Arcadia, California. Two offset disk units, 1.5 meters apart, formed two furrows approximately 50 cm wide and 15 to 25 cm deep simultaneously (Fig. 1). The furrow bottoms represent 30 to 40% of the contour-furrowed areas. Rippers ahead of the disks fractured the soil to a depth of 25 to 40 cm. Check dams were formed in the furrows about every 5 meters by a device on the machine.

Double-ring cylinder infiltrometers (flood type) were used to determine water intake of soils (Haise et al., 1956). Water level measurements were taken 1, 3, 8, 18, 33, 53, 83, 128, and 188 minutes after water was initially applied to the soil in the inner ring.

Within each site, infiltration measurements were made on three separate blocks. Each block represented an area with minimum variation in microtopography and vegetational cover. Within each block, infiltration measurements were replicated three times within the furrows, on adjacent ridges, and on bordering nonfurrowed areas. The three within block subsamples were averaged prior to statistical analysis. Data from each site were analyzed separately, utilizing a randomized complete block design with three blocks and three treatments (furrow, ridge, and check).

Soil samples were taken by 10-cm increments to a depth of 60 cm adjacent to each infiltration run. The three subsamples from each block were composited prior to physical and chemical analyses. Textures (hydrometer method) and bulk densities (on cores) were determined for all composited soil samples; pH was measured in the saturated soil paste; and Ca, Mg, Na, K, CO_3, HCO_3, Cl, and electrical conductivities, EC (expressed as mmhos/cm at 25°C), were determined from saturated paste extracts. Sulfate was calculated by difference: SO_4 = total cations - (HCO_3 + CO_3 + Cl). The sodium-adsorption-ratio

$$(\mathrm{SAR}) = \mathrm{Na}/\sqrt{\mathrm{Ca} + \mathrm{Mg}/2},$$

with ionic concentrations expressed in milliequivalents per liter (meq/1), was used to characterize changes in sodium hazard. Electrical conductivity (EC) was used to characterize soil salinity and soluble salt movement within the 0- to 60-cm soil profile. Methods of chemical and physical analyses used were those outlined by U.S. Salinity Laboratory Staff (1954) and by Black et al. (1965 a, b).

Soil data from each site were statisti-

Fig. 1. *Contour-furrowed range site.*

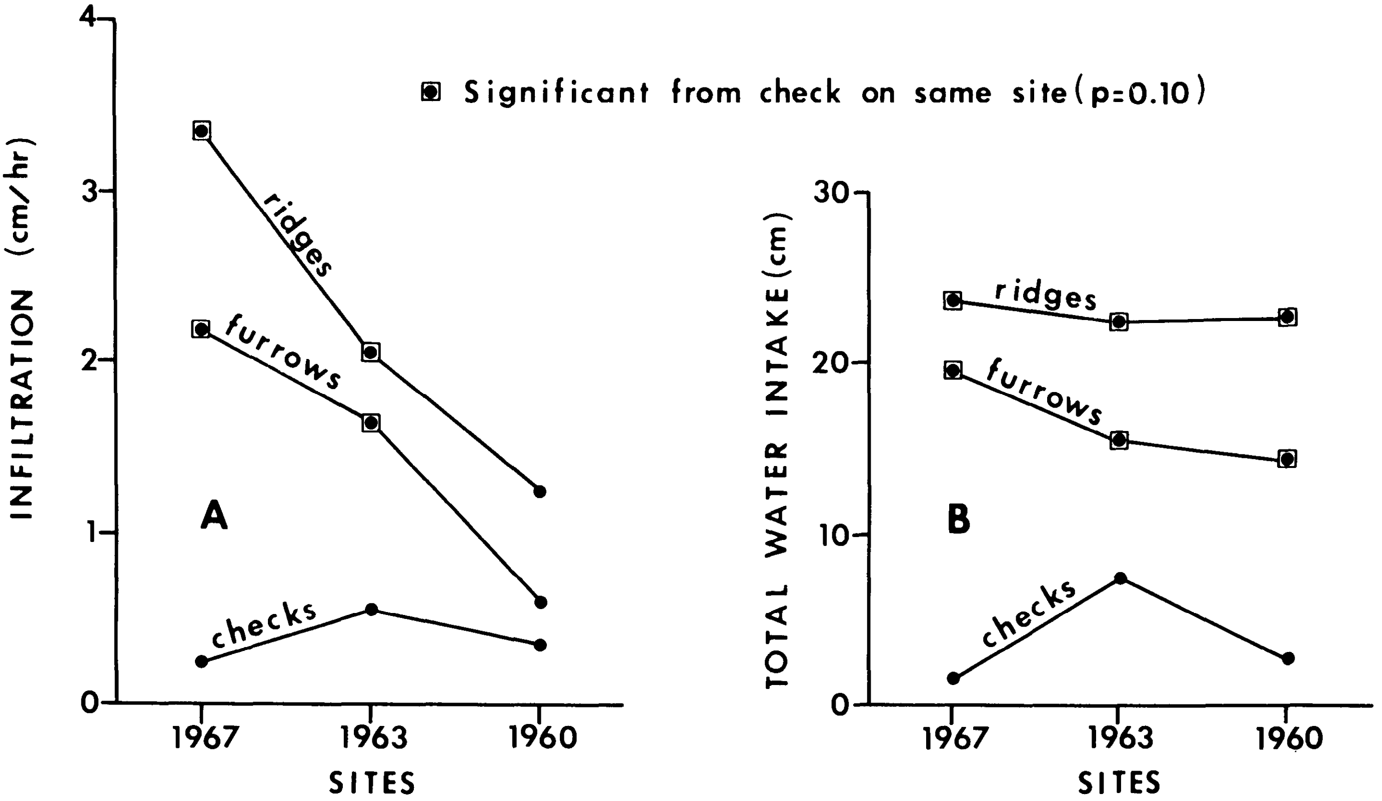

Fig. 2. *Third-hour infiltration rates (A) and total water intake (B) for ridges, furrows, and checks at the three study sites. Measurements were made, 3, 7, and 10 years after treatments for the 1967, 1963, and 1960 sites, respectively.*

cally analyzed using a split plot design with furrow, ridge, and check treatments as main plots and soil depth increments as nonrandom subplots. The 10% significance level was used in all analyses of variance.

Vegetation was sampled in 1971 by clipping all growth from four to eight 0.5- by 2-m quadrats. Samples were ovendried at 70°C before weighing and are expressed on this basis. All species except big sagebrush, pricklypear cactus, and clubmoss were sampled.

Results and Discussion

Infiltration rates and total water intake measurements on contour-furrowed areas (both ridges and furrows) were higher than those on adjacent check areas on all three sites (Fig. 2). According to observations of newly furrowed areas (Fig. 1), fracturing and loosening of the soil by contour furrowing should increase infiltration rates. However, the physical disturbance effect should decrease with time as settling, erosion, and vegetation exert their influence.

There were few measurable differences in bulk densities among soil samples from furrows, ridges, and check areas on all sites. However, on the 1967 site, bulk densities in the 0- to 10-cm depth in the ridges and under the furrows were 1.07 and 1.08 g/cm^3 and were significantly less than the 1.32 g/cm^3 found in the 0- to 10- and 20- to 30-cm depths in the check areas. Since the 1967 site was the most recently furrowed (3 years old), the physical disturbance effect from contour furrowing is probably still present and will partly explain the lower bulk densities. Highest infiltration rates (Fig. 2) were found on the 1967 site and were associated with low bulk densities in addition to chemical differences discussed later.

Rauzi and Kuhlman (1961) and Branson et al. (1962) mention the influence of soil cracking on infiltration on similar soils. Although cracks in these clay soils become evident during dry periods, larger and more numerous soil cracks on contour-furrowed areas appear to be the result of differential soil water usage by the increase in forage production on the ridges. We found the highest initial infiltration rates on contour-furrowed areas where cracking was most prevalent.

Contour furrowing did not significantly affect pH and water soluble K, SO_4 HCO_3 Cl, and CO_3 in the 0- to 60-cm soil profile (data not presented), but it did change the proportion of Ca, Mg, and Na in some of the 10-cm soil increments as is indicated by changes in sodium-adsorption-ratios. Sodium-adsorption-ratios from soil samples indicated contour furrowing reduced the sodium hazard in the upper soil depths (Table 2). Sodium-adsorption-ratios in the furrows in the 0- to 20-cm depth on the 1960 site, in the 0- to 10-cm depth on the 1963 site, and in the 0- to 40-cm depths on the 1967 site were significantly less than the 20- to 40-, 20- to 30-, and 20- to 60-cm depths in the ridges and check on the respective sites. Although not always significant, sodium-adsorption-ratios in the upper depths in the furrows and ridges on all sites were generally lower than sodium-adsorption-ratios in the upper depths in adjacent check areas. Reduction in sodium hazard was no doubt due to increased infiltration on contour-furrowed areas. Even though the physical effects of contour furrowing decreased with time, improved soil physical conditions apparently resulted from the reduction of sodium, thereby creating favorable infiltration characteristics.

Although soil salinity in the upper soil depths was not reduced in comparison to the check on any site, contour furrowing did affect movement of salts in the furrows (Table 2). Immediately after furrowing, soluble salts in the 0- to 10-cm depth in the furrows should have been about the same as the soluble salts in the 20- to 30-cm depth for the check areas. Results of our study show that salinity in the 0- to 10-cm depth in the furrows on all sites was significantly less than the salts in the 20- to 30-cm depth on the check areas. Leaching of salts from the upper soil depths in the furrows is due to increased infiltration from water retained in the furrows.

According to White (1969), in reference to panspot range sites in South Dakota, a treatment which throws soil materials on the surface of adjacent undisturbed soil may destroy short grasses and trap water to stimulate growth of species such as wheatgrasses. Although we do not show the detailed data in our study, contour furrowing created these conditions and significantly increased herbage production (mainly thickspike and western wheatgrass) by 171 to 326% over corresponding check areas on all sites. Herbage production in 1971 on contour-furrowed areas was 1,072 kg/ha on the 1967 site, 789 kg/ha on the 1963 site, and 1,006 kg/ha on the 1960 site, as compared to 357, 291, and 236 kg/ha on the respective check areas. The herbage data show that contour furrowing increased herbage production 11 years after treatment.

Changes in physical and chemical characteristics of soil on contour-furrowed areas were small, but definite ameliorating trends were established. Permanent effects of contour furrowing on soil chemical and physical properties are not known at this time. However, results from this study show that contour furrowing on a panspot (Solonetzic) range site improved infiltration, reduced the sodium hazard, and increased herbage production for at least 10 years.

Table 2. Mean sodium-adsorption-ratios (SAR) and salinity values (mmhos/cm) for checks, furrows, and ridges in September, 1970.

	Depth interval from soil surface (cm)		SAR			EC		
Site	Check & Ridge	Furrow	Check	Furrow	Ridge	Check	Furrow	Ridge
1960	0–10		9.9		7.5	2.2		1.2
	10–20		14.1		10.9a	3.0		3.2
	20–30	0–10	14.0	6.4ab	13.3	5.6	1.5a	4.4
	30–40	10–20	15.3	7.3ab	15.2	5.8	2.9a	6.0
	40–50	20–30	14.6	12.9	17.2	5.7	5.7	6.6
	50–60	30–40	16.9	16.9	17.3	6.4	6.8	6.4
1963	0–10		10.5		4.5a	2.0		2.3
	10–20		15.0		8.0a	4.7		3.2a
	20–30	0–10	15.1	6.4a	14.2	6.0	3.8ab	6.2
	30–40	10–20	17.1	17.3	19.5	6.5	7.7ab	8.5a
	40–50	20–30	20.0	22.6b	21.8	6.9	9.5ab	9.0a
	50–60	30–40	20.5	23.9ab	22.7	7.8	9.8ab	8.1
1967	0–10		11.2		7.8	2.7		3.4
	10–20		17.3		9.7a	5.1		3.4a
	20–30	0–10	18.3	6.7ab	14.7a	6.6	2.8a	4.7a
	30–40	10–20	18.2	8.8ab	17.0	6.5	4.1a	6.2
	40–50	20–30	19.0	13.6ab	19.9	6.1	5.4b	7.0
	50–60	30–40	20.0	16.2a	20.0	7.2	6.5	7.2

[a] Indicates ridge and/or furrow significantly different ($P = .10$) from check at original depths before contour furrowing.

[b] Indicates furrow significantly different ($P = .10$) from check at same depths from soil surface.

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Mule Deer Responses to Deer Guards

DALE F. REED, THOMAS M. POJAR, AND THOMAS N. WOODARD

Highlight: *In this investigation the effectiveness of guards 12, 18, and 24 feet long in preventing mule deer from crossing vehicle openings in fences 8 feet high was evaluated. The guards were constructed of flat mill steel rails ½ x 4 x 120 inches, and were tested under both controlled and field conditions. Under controlled tests, 16 of 18 deer successfully crossed the guard. Fifteen deer and one elk crossed guards under field conditions. Deer did not attempt wide jumps over the guards, but rather walked, trotted, or bounded across them. Use of this guard type under the condition tested is not recommended.*

Fences 8 ft in height are frequently installed along primary highways where the possibility of collision between vehicles and mule deer (*Odocoileus hemionus hemionus*) is high. They are also established along perimeters of big game exclosures and enclosures. While these fences prevent many animals from going where not desired, a problem arises when it is necessary to permit vehicle access through the fences. When gates hinder vehicular traffic flow, structures such as modified cattle guards have been used and recommended. The physical requirements of guards to preclude deer or elk (*Cervus canadensis*) crossings have not been tested and neither deer nor elk responses to such structures have been documented.

The purpose of this investigation was to evaluate the effectiveness of three lengths of guards in preventing deer from crossing through vehicle openings in 8-ft fences.

Methods and Materials

Two deer guards were installed in 8-ft fences, one adjacent to Interstate 70 near Avon, Colo., and the other in a Bureau of Land Management wildlife exclosure fence at Trail Gulch between Dotsero and Burns, Colo. Both guards utilized 10 x 12 ft sections (Fig. 1) constructed with flat mill steel ½ x 4 x 120-inch (width, height, and length, respectively). The flat mill steel rails were perpendicular to the direction of traffic. The lengths of guard tested, 12, 18, and 24 ft, were measured parallel to the direction of traffic flow. The guard at Trail Gulch was used for controlled tests, while both were monitored for deer use under field conditions.

Controlled Conditions

The Trail Gulch guard was constructed with two 10 x 12-ft sections for a total

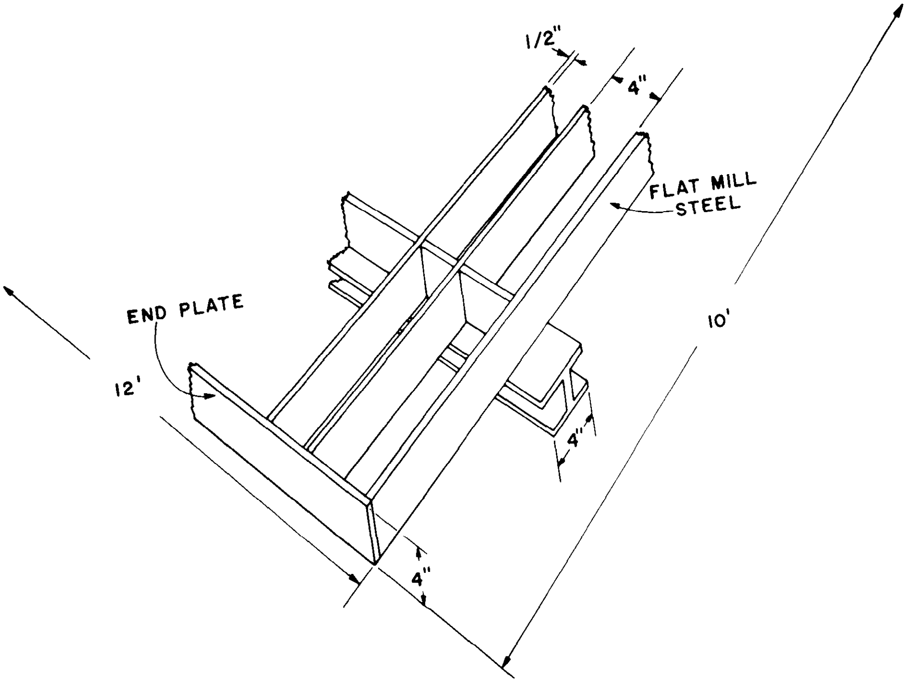

Fig. 1. *Modified deer-cattle guard specifications.*

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The Bureau of Land Management, Glenwood Springs office, provided field assistance. The Colorado Division of Highways installed the Avon deer guard. Dr. Lee E. Yeager and Harold M. Swope critically reviewed this paper, herewith acknowledged with appreciation.

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Table 1. **Responses of 16 mule deer to deer guards of 12, 18, and 24 ft at Trail Gulch.**

Number	Length of guard (ft)	Time from release to completed crossing (sec)	Number of approaches[1]	Number of investigative instances[2]	Distance covered in first step or bound (ft)	Predominant mode of crossing	Sex/age[3]
1	12	110	3	–	–	trot	F/F
2	12	375	1	4	3.90	walk	F/
3	12	11	0	0	7.94	bound	F/
4	12	15	1	1	–	walk	F/
5	12	16	0	0	3.54	walk	F/
6	12	60	0	0	1.90	walk	M/
7	12	584	5	7	7.64	bound	M/F
8	12	37	1	3	5.28	trot	M/
9	12	95	1	4	6.00	bound	M/
10	18	27	0	2	3.61	trot	F/
11	18	16	0	1	3.21	trot	M/
12	18	1,017	197	16	3.67	walk	M/F
13	18	70	0	0	1.57	walk	M/F
14	18	217	6	9	6.59	bound	F/
15	24	84	2	3	2.66	trot	F/
16	24	27	0	0	6.33	bound	F/F

[1] Deer moved to guard as if to cross, then turned away.

[2] Refers to instances of investigative behavior (Scott, 1956) where the animal visibly made a sensory inspection by bending neck, moving ears forward, and looking at guard.

[3] Male or female is indicated by M or F before slash (/), Fawn is indicated by F after slash. All others were either yearling or mature.

length of 24 ft. A runway 10 ft wide and 59 ft long was constructed with 8-ft fencing at one approach to the guard.

To test a 12-ft guard, half of the 24-ft guard was covered with plywood and 2-3 inches of soil. To test 18-ft and 24-ft guards plywood sections were removed. The tests were handled in the same manner for all guard lengths.

The tests involved releasing deer in the runway and observing their response as they attempted to escape via their only exit across the guard. Each deer was released from an individual carrying crate (Bartmann and Steinert, 1970) as quietly as possible. The observer opened the crate, released the deer, then remained motionless until the animal crossed the guard. The time from release to complete guard crossing was measured with a stop watch. Other observations were noted mentally and recorded immediately after each test.

Eighteen deer of varying ages and both sexes were obtained from a winter trapping program. Ten of these animals were tested with the 12-ft guard, six with the 18-ft guard, and two with the 24-ft guard.

Field Conditions

The guard near Avon was 20 ft wide and 12 ft long. The Trail Gulch guard, except for 2 months during which the controlled tests were conducted, was 10 ft wide and 24 ft long. Periodic track counts were made on both approaches to the guards, and the guard rails were examined from October 6, 1972, to December 31, 1972, at Avon and from June 29, 1972, to April 19, 1973, at Trail Gulch. Any crossings or attempts to jump the guard were determined by closely examining the road for tracks and the guard rails for hoof scuff marks and deer hair.

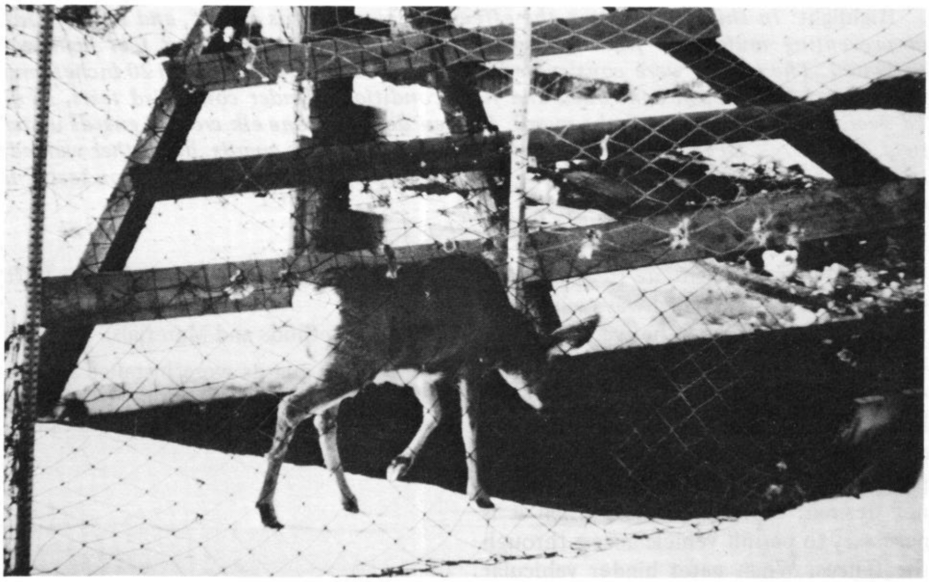

Fig. 2. *Test deer Number 15 spent 84 seconds from release to having completed a crossing of the guard. During this time the animal completed three instances of investigative behavior, one of which is shown.*

Table 2. **Number of deer and elk crossings and number of tracks recorded during the field evaluations of the Avon and Trail Gulch deer guards.**

Guard	Species	Number of crossings	Tracks when crossing[1]	Tracks when no crossings[2]	Minimum number crossings prevented[3]
Avon	deer	4	76	64	6
Trail Gulch	deer	11	94	151	5
	elk	1	2	4	3
Total		16	172	218	14

[1] The number of tracks at both ends of the guard when crossings occurred.

[2] The number of tracks at both ends of the guard when no crossings were detected. Animals making tracks appeared to have been prevented from crossing the guards.

[3] The number of days when at least one deer or elk made tracks near the ends of the deer guards and when no crossings occurred. At least one animal on each day was interpreted as having been prevented from crossing over the guard.

Results and Discussion

Controlled Conditions

Sixteen of the 18 test deer crossed the structures (Table 1). The mean (± S) time from release to crossing was 172.6 (± 274) seconds. The range of 11 to 1017 seconds was indicative of the variable responses observed (Fig. 2).

One question that prompted the study was how far would deer jump to clear guards. During our observations no deer seriously attempted to jump even the shortest guard (12 ft). The distance covered by each animal's first step or bound onto the guard averaged 4.56 (± 2.1) ft with a maximum of 7.94 ft (Table 1). Although deer may be capable of running broad jumps of almost 30 ft (Severinghaus and Cheatum, 1956), they did not use this ability to cross barriers of the type tested.

Four of the 14 deer that crossed the 12- and 18-ft guards fell through the steel railings with all four legs. None of these animals were seriously injured. Their predominant response was to roll onto their sides, thereby getting their hooves onto the rails again. Apparently the dew claws prevented the animals from falling through more frequently (Fig. 3).

Fig. 3. *Dew claws may have prevented this deer from slipping into the guard. The dew claws on the right back leg appear to be spread and in contact with one of the guard rails.*

Field Conditions

As determined by track counts, four deer crossed the Avon guard between October 6 and December 31, 1972. Eleven deer and one elk crossed the Trail Gulch guard from June 29, 1972, to April 19, 1973 (Table 2). None of these animals jumped even the shortest guard (12 ft). The tracks counted adjacent to the guards were probably not indicative of deer numbers present since one deer may make many tracks. However, tracks recorded without crossings represent at least the presence of one deer each time it was checked, a total of which indicates a minimum number of crossings prevented (Table 2).

Conclusions

Study results demonstrate that this modified deer-cattle guard had limited effectiveness in preventing deer movements through openings in 8-ft fences. Deer did not attempt extensive jumps of 12-, 18-, or 24-ft guards when moderately to highly motivated, but rather walked, trotted, or bounded across them. Little advantage was gained by extending the length of the guard beyond 12 ft. The use of modified deer-cattle guards (of the type used in this study) for precluding deer movements through openings in 8-ft fences should be avoided.

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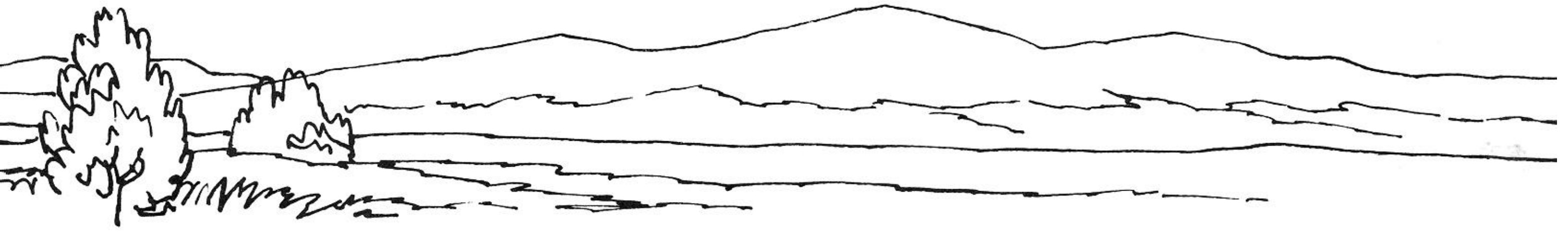

Relationship of Soils to Seasonal Deer Forage Quality

WILLIAM C. KRUEGER AND GARY B. DONART

Highlight: *Blue wildrye, sheep sorrel, Oregon white oak, and arroyo willow were studied on Yorkville and Tyson soils in northern California to determine the effects of soil series and season on relative concentrations of protein, acid-insoluble lignin, and total sugars in the forage. Production of protein and sugars, but not lignin, was found to be related to soil series. Differences in levels of three chemical constituents varied among plant species with season on two soil series.*

Studies of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) indicated these animals graze vegetation on some soil series more frequently than others (Hooper, 1960; Whitaker, 1965; and Bonn, 1967). This study was undertaken to identify relationships between protein, lignin, and sugar levels of deer forage and the soil series that produced this forage. Comparisons were made for dry and rainy seasons. Differences in these chemical constituents among plant species were also examined.

Bonn (1967) found the tyson soil series, dominated by Oregon white oak (*Quercus garryana*), supported range most heavily used by black-tailed deer in northwestern California; the Yorkville soil series supported the range with heaviest use by deer of the grassland soils. Deer use on the Tyson soil series was more than four times greater than deer use on the Yorkville soil series.

In the current study, perennial plants known to be used by deer were chosen for chemical analysis. Blue wildrye (*Elymus glaucus*) and sheep sorrel (*Rumex acetosella*) were collected on Tyson and Yorkville soil series. No browse species were common to these soils in sufficient quantity to insure collection throughout the year, so the most abundant browse species was chosen from each soil. Oregon white oak was collected on the Tyson soil series and arroyo willow (*Salix lasiolepis*) was sampled on the Yorkville soil series.

Study Area

The range areas of Humboldt County, Calif., consist of open grasslands bordered by Douglas fir (*Pseudotsuga menziesii*) and oaks (*Quercus* spp.), with a good understory of herbaceous plants.

The Tyson soil series has been described by the Soil Conservation Service (1951). It was derived from sandstone, shale, and related metamorphic rock of the Franciscan geologic formation. The vegetation is characteristically a fairly dense cover of Oregon white oak and an herbaceous understory with scattered shrubs. The Tyson soil series will be subsequently referred to as Tyson soil in this paper.

The Yorkville soil series has been described by Gardner (1958). This hilly, rolling soil has a strong tendency to slip and in many places slips a little almost every winter. The Yorkville soil series was formed in well-weathered material of metamorphic, basic rock with glaucophane shist common. The vegetation is a mixture of annual and perennial grasses and forbs with a few shrubs interspersed throughout. The Yorkville soil series will subsequently be referred to as Yorkville soil in this paper.

The area has high annual precipitation occurring primarily from November through May. Annual rainfall averages between 35 and 85 inches (Cooper and Heady, 1964). Bridgeville, Calif., which is adjacent to the ranch at 700-ft elevation averaged 61.18 inches annual precipitation from 1939-1952 (U. S. Commerce Dep., 1958). The area of the ranch involved in this study was about 1700 ft in elevation and about 5 miles from Bridgeville. During this study (June 1, 1966, to June 7, 1967), the total precipitation at Bridgeville was 67.37 inches (U. S. Commerce Dep., 1966 and 1967). Precipitation would be slightly higher at the site of plant collection because of increased elevation. During the study the dry season extended from June through late October, 1966. The rainy season began in late October, 1966, and extended to early June, 1967.

Methods

A minimum of ten plants each of blue wildrye and sheep sorrel were chosen at random for each collection and all aerial portions were collected to yield a composite sample of approximately 200 g dry weight. Only ungrazed plants or portions of plants were collected, except in the middle of the rainy season when there was not enough ungrazed sheep sorrel available to obtain an adequate sample. Only leaves in the lower crown of Oregon white oak and arroyo willow were collected, and no samples were collected while the browse was dormant. Phenological stages were recorded at the time of collection.

The plant samples were analyzed for crude protein by the micro-kjeldahl method (Association of Official Agricultural Chemists, 1950). The method of Sullivan (1959) was used to determine the percentage concentration of acid-insoluble lignin. Sugars were extracted in a Waring blender, using hot 80% ethyl alcohol (Thomas et al., 1949). Total sugars were determined by a modification of Forsee's photocolorimetric method (Morrell, 1941).

Statistical comparisons of differences in levels of each chemical component as influenced by soil series were con-

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ducted separately for blue wildrye and sheep sorrel in each season, using paired comparisons and Student's *t* test. Effects of soil series on Oregon white oak and arroyo willow were not statistically evaluated since neither species grew on both series. Differences in concentration of chemical factors within a soil series over seasons for all four species were tested with the Student's *t* test.

Differences for each chemical component among plant species were tested for each soil series and season, using analysis of variance with a completely randomized design. Differences among means were examined with Scheffe's test. Throughout the paper the term *significant* refers to significant difference between means at $P<.05$.

Results and Discussion

Phenology

Humboldt County has a mild climate and many plants never become dormant. There are two seasons, dry and rainy. Different species of plants begin their annual cycle at different times of the year. The phenological condition of the plants studied reflected this pattern in different months of observation.

Blue wildrye began its annual cycle with the beginning of the rainy season. Vegetative development progressed through the boot stage during the rainy season on both soil series. During the dry season grass matured more rapidly on Yorkville soil than on Tyson soil. By the second month of the dry season, blue wildrye was quiescent on Yorkville soil. Rangelands on Tyson soil with its oak overstory maintained a cool, moist environment, and wildrye never became quiescent.

Sheep sorrel began its annual cycle on both soil series by late September which corresponded with light precipitation (1.1 inches) near the end of the dry season. Sheep sorrel followed the same pattern of vegetative growth on both soil series through most of the rainy season. In May, sheep sorrel on Yorkville soil began to produce seed, while sorrel on Tyson soil remained vegetative. At the end of the rainy season in June, sheep sorrel on Tyson soil began to produce seed. Total seed production on shaded Tyson soil was far below that on open Yorkville soil. Sorrel continued seed production on both soil series throughout the dry season.

Arroyo willow was collected only from Yorkville soil. It began growth in April and leaves had reached full size by the end of the rainy season. Shoots matured and became woody in the middle of the dry season. Leaf abscission began at the end of the dry season and continued for 3 months.

Oregon white oak, growing on Tyson soil, began to produce leaves at the end of the rainy season. Leaves matured early in the dry season, and stems became woody 1 month after the leaves had attained full growth. Acorn production began when the stems matured and continued for 2 months. Leaf abscission began at the end of the dry season in late October and continued for the first 2 months of the rainy season.

Grazing

Utilization was noted while forage samples were being collected. No quantitative measurements of utilization were taken. Observations of utilization consisted of recording whether or not the herbaceous species were being used by cattle and deer grazing in common.

Blue wildrye was utilized primarily from November to June, which corresponded with the entire rainy season. No further use was noted on wildrye, which had become mature and dry on Yorkville soil and mature but still green on Tyson soil.

During the rainy season, forage production of most species was minimal and grazing on sheep sorrel was heavy. Regrowth of sheep sorrel maintained a 0.5-inch leaf length, while sorrel protected by rocks and logs maintained a 2-inch leaf length throughout the rainy season.

Protein

During the rainy season there were no significant differences in protein levels for blue wildrye or sheep sorrel in response to the soils on which they were growing. In the dry season differences became more pronounced. Blue wildrye had a significantly higher concentration of protein (5.4%) from Tyson soil when compared to blue wildrye (3.7%) from Yorkville soil. Sheep sorrel on Yorkville soil was significantly higher in protein (12.7%) when compared to sheep sorrel (8.4%) from Tyson soil.

Differences in responses of blue wildrye and sheep sorrel were related to phenology. In the rainy season there was little difference in phenology for each species when grown on different soils, and no significant differences in protein concentration were found. In the dry season blue wildrye matured more slowly and remained more succulent in the shaded habitat on Tyson soil when compared to open Yorkville soil. As a result, wildrye growing in shade maintained higher protein levels. Sheep sorrel responded differently to shading. Protein levels were higher in plants from Yorkville soil compared to those from Tyson soil. The higher seed/stem ratio of sheep sorrel on Yorkville soil when compared to that on Tyson soil probably accounted for the difference in levels of protein.

Comparison of protein concentrations between dry and rainy seasons for each species on either Yorkville or Tyson soil indicated blue wildrye had significantly higher levels of protein on both soils in the rainy season (Table 1). Sheep sorrel contained a significantly higher level of protein on Tyson soil in the rainy season when compared to the dry season. Both forb and browse plants maintained a high level of protein throughout the dry season, when protein levels of blue wildrye were comparatively low.

Differences in protein concentration among plant species varied with season and soil series. In the rainy season there were no significant differences among species. In the dry season all plant species studied from Yorkville soil were significantly different (Table 1). Sheep sorrel had the highest concentration of protein (12.7%) and blue wildrye the lowest (3.7%). On Tyson soil in the dry season, Oregon white oak contained significantly more protein than blue wildrye (11.4% and 5.4%, respectively). Sheep sorrel was intermediate in protein concentration with 8.4%.

Einarsen (1946) reported 5% as the critical protein level needed in deer forage. Dasmann (1964) indicated 7% protein

Table 1. Average protein concentration in percent of four plant species for dry and rainy seasons on two soils.[1]

	Yorkville soil		Tyson soil	
Species	Dry season	Rainy season	Dry season	Rainy season
Blue wildrye	3.7^{a}	15.8^{*a}	5.4^{a}	17.7^{*a}
Sheep sorrel	12.7^{b}	11.0^{a}	8.4^{ab}	13.1^{*a}
Arroyo willow	8.5^{c}	13.2^{a}	–	–
Oregon white oak	–	–	11.4^{b}	12.0^{a}

[1] *Across columns within a soil indicates a significant difference at $P<.05$.
Different letters within a column indicates a significant difference at $P<.05$.

was the minimum level to maintain deer. In the rainy season, all plant species studied on both soils were well above required protein concentrations. Both Oregon white oak and arroyo willow leaves were not available during parts of the rainy season as a result of abscission. In the dry season, forbs and browse on both soil series exceeded protein requirements for deer and, except for sheep sorrel on Tyson soil, were not significantly lower in protein when compared to the rainy season. While protein concentration in blue wildrye was significantly lower for both soils during the dry season when compared to the rainy season, only blue wildrye on Yorkville soil was below 5%. The grass on both soils was below 7%. Because of low levels of protein in the grass during the dry season, it would be desirable to maintain forbs and browse present in these plant communities to prevent a protein deficiency occurring in the dry season.

Acid-insoluble Lignin

There were no significant differences in concentrations of lignin for the herbaceous species in response to soils on which they were growing during either the dry or rainy season. The greatest difference in lignin concentration in response to soils was for sheep sorrel in the rainy season. Percentage lignin concentration of sheep sorrel produced on Yorkville and Tyson soils was 16.6 and 12.6, respectively. Grazing of sheep sorrel in the rainy season may account for variability of lignin levels during this period.

Comparison of acid-insoluble lignin levels in plants for the dry versus the rainy season on Yorkville and Tyson soils indicated that only blue wildrye differed significantly (Table 2). High levels of lignin for the grass in the dry as compared to the rainy season reflected a considerable change in phenology over seasons, from a leafy plant in the rainy season to a stemmy plant in the dry season. Sheep sorrel did change a great deal in phenological appearance over the seasons but was primarily a leafy plant in both seasons. Oregon white oak exhibited a steady increase in lignin over time, but phenology of this deep rooted plant was not as rapidly influenced by climate as the herbaceous vegetation. As a result, lignin values for the rainy season reflected impacts of both very early and very late phenological development. Arroyo willow had no identifiable seasonal trends in concentration of lignin.

A number of differences in concentration of lignin were found among species on different soils in different seasons (Table 2). In the dry season arroyo willow had significantly more lignin (30.4%) than sheep sorrel and blue wildrye (16.2% and 9.4%, respectively) on Yorkville soil. On Tyson soil for the dry season, wildrye (9.0%) had significantly less lignin than sheep sorrel (15.1%) and Oregon white oak (15.1%). In the rainy season there were no significant differences in lignin concentration among plants growing on Tyson soil. However, on Yorkville soil lignin concentration of all species studied was significantly different.

Lignin has been widely used to evaluate the quality of feeds. Lignin is primarily related to digestibility of cellulose and other structural carbohydrates of plants (Dietz, 1970). Arroyo willow and Oregon white oak were generally higher in lignin than the other species studied and thus would be expected to be lower in digestibility of structural carbohydrates and probably lower in usable energy. Blue wildrye would provide the most digestible structural carbohydrates of all species studied, as inferred from its lower lignin concentration, and would probably provide the highest level of usable energy.

Sugars

Levels of total sugars in blue wildrye and sheep sorrel showed no significant relationship to the soil on which these plants grew in the dry season. In the rainy season both blue wildrye and sheep sorrel had significantly less total sugars when growing on shaded Tyson soil than on open Yorkville soil. The magnitude of these differences was not great being 9.0% versus 7.2% for wildrye and 8.7% versus 7.0% for sheep sorrel on Yorkville and Tyson soils, respectively.

Soil fertility might also have had some effect on sugar concentration in these plants. High nitrogen concentrations in soils have been shown to depress levels of sugar concentration in plants (Plice, 1952). Cooper and Heady (1964) found Tyson soil contained 8.4 tons of nitrogen per acre in the first 4 ft of soil, while Yorkville soil contained 6.0 tons of nitrogen per acre for the same depth. The higher nitrogen content of Tyson soil might be partially related to the lowered sugar content of plants on this soil series.

Comparison of total sugar concentrations in plants for the dry versus the rainy season on Yorkville and Tyson soils indicated that only sheep sorrel on Yorkville soil exhibited seasonal effects (Table 3). In the dry season on Yorkville soil, the sugar concentration of 5.9% for sheep sorrel, when compared to 8.7% in the rainy season, may be closely related to phenology. Plants with extensive seed production in the dry season had depressed sugar levels when compared to plants with no seed production, in the rainy season, on Yorkville soil. No differences in sugar were noted on Tyson soil over seasons, and sheep sorrel on Tyson soil did not set a heavy seed crop.

The only statistically significant difference in level of total sugars among plant species occurred in the dry season (Table 3). Oregon white oak had significantly less sugar than blue wildrye on Tyson soil (4.6% and 6.8%, respectively).

Crawford and Church (1971) reported that black-tailed deer demonstrated strong preferences for sweet solutions. Dasmann et al. (1967) found preference by deer for conifer

Table 2. Average acid-insoluble lignin concentration in percent of four plant species for dry and rainy seasons on two soils.[1]

	Yorkville soil		Tyson soil	
Species	Dry season	Rainy season	Dry season	Rainy season
Blue wildrye	9.4^{a}	4.6^{*a}	9.0^{a}	6.5^{*a}
Sheep sorrel	16.2^{a}	16.6^{b}	15.1^{b}	12.6^{a}
Arroyo willow	30.4^{b}	29.8^{c}	–	–
Oregon white oak	–	–	15.1^{b}	21.1^{a}

[1] *Across columns within a soil indicates a significant difference at $P < .05$.
Different letters within a column indicates a significant difference at $P < .05$.

Table 3. Average total sugar concentration in percent of four plant species for dry and rainy seasons on two soils.[1]

	Yorkville soil		Tyson soil	
Species	Dry season	Rainy season	Dry season	Rainy season
Blue wildrye	6.0^{a}	9.0^{a}	6.8^{a}	7.2^{a}
Sheep sorrel	5.9^{a}	8.7^{*a}	6.1^{a}	7.0^{a}
Arroyo willow	6.4^{a}	7.3^{a}	–	–
Oregon white oak	–	–	4.6^{b}	4.5^{a}

[1] *Across columns within a soil indicates a significant difference at $P < .05$.
Different letters within a column indicates a significant difference at $P < .05$.

seedlings in northern California was increased when seedlings were sprayed with molasses and other sweeteners.

Although a great many factors influence animal preference for specific forages, the taste of a plant is certainly an important factor to consider when evaluating palatability. If sugar concentration in forage is positively related to palatability of that forage for deer, then plants growing on open Yorkville soil should be preferred over those on Tyson soil during the rainy season.

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Growth and Longevity of Blue Grama Seedlings Restricted to Seminal Roots

D. H. VAN DER SLUIJS AND D. N. HYDER

Highlight: *Contrary to previous indications, this study shows that there is no inherent limit to the longevity of seminal roots of blue grama seedlings. When restricted to seminal primary roots, blue grama seedlings grew actively in the greenhouse for 22 weeks. Tillering began at 3 weeks and continued at a linear rate of 0.165 tillers per day. Leaf length on primary shoots reached a maximum of about 80 cm at 6 to 7 weeks and decreased by death of older leaves thereafter. Total leaf length of tillers reached a maximum of 250 to 350 cm of green tissue at 13 to 14 weeks. The water-transport capacity of the subcoleoptile internode apparently prevented further leaf expansion. Since field conditions impose sudden increases in transpirational stress, it may be necessary to restrict leaf expansion until adventitious roots are well established.*

Blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) is well adapted to grazing and semiarid conditions on the Shortgrass Plains of Colorado and Wyoming. The paradox is that blue grama is poorly adapted for natural regeneration from seed on the rangelands where it is the ecological dominant (Hyder et al., 1971). When planted in warm, moist soil, blue grama seeds germinate quickly, and seedlings emerge in 4 or 5 days, but seedling establishment is rare. In field seedings at the Central Plains Experimental Range near Nunn, Colo., blue grama seedlings died at about 6 to 8 weeks of age, unless adventitious roots were extended. Weaver and Zink (1945) reported that under optimal conditions in the greenhouse, blue grama seedlings grown entirely on primary seminal roots invariably died within 9 weeks. Those results suggest that blue grama seedlings may have an inherent limit to longevity when restricted to seminal roots.

Two types of grass seedlings are recognized (Hyder, 1973). Wheatgrasses have a long coleoptile that extends from the seed to the soil surface after emergence; whereas blue grama has a short coleoptile that is elevated to the soil surface by elongation of a subcoleoptile internode. The blue-grama form places the coleoptilar node and all tillering crowns, from which adventitious roots may arise, on or very near the soil surface. Consequently, adventitious roots grow out of the tillering crowns only when damp, cloudy weather persists for 2 or 3 days. Since plant establishment depends ultimately on the

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extension of adventitious roots (Esau, 1960), the longevity of seedlings restricted to seminal roots might be critical to seeding success where the soil surface generally remains hot and dry. Greater seedling longevity would provide a longer period of time during which precipitation may favor the growth of adventitious roots. Seedling longevity might be increased by genetic selection. Otherwise, improvement in seeding success is limited to cultural practices that modify micro-environmental conditions or plant characteristics.

We considered the possibility of an inherent limit to seedling longevity primarily because the subcoleoptile internode is a very slender thread. Deterioration and loss of function in the subcoleoptile internode could stop the flow of water and nutrients from root to shoot or the flow of photosynthates from shoot to root. If the capacity for transport through the subcoleoptile internode decreases with an increase in length, seedling development and longevity may be directly related to planting depth. Consequently, the development and longevity of blue grama seedlings grown from seed planted at varying depths and restricted to seminal primary roots was evaluated under favorable conditions in the greenhouse.

Methods

Blue grama seedlings were grown in plastic pots 15 cm in diameter from seed planted in sterilized soil. Total depth of soil in the pots was 12 cm. Twenty seeds were planted at depths of 5, 10, 15, 20, and 25 mm in each of five pots per planting depth on September 6, 1972. The upper 5 mm of the profile in all pots consisted of perlite. The seedlings emerged in 3 to 6 days and were thinned to a uniform stand of five per pot 12 days after planting. Subsequently, all seedlings were checked every other day by removing the perlite from the base of the seedlings with a gentle air spray. Adventitious roots were excised if present. Plants were subirrigated to maintain optimum growing conditions. Temperatures during the experiment fluctuated from about 27 to 30°C, and the day length decreased from 13 hours during the early stages of growth to 9 hours 15 minutes in December.

At 4 weeks from planting, the perlite was removed, and each plant was provided with aluminum-foil disks of 2.5 cm diameter to stop adventitious roots. Two disks slit to the center were placed around a subcoleoptile internode below the crown so that the slits did not overlap (Fig. 1). A 5-mm layer of small gravel was placed over the disks to support the seedlings and reduce evaporation from the soil surface.

When the plants were 47 days old, three matching replicate pots were selected for each planting depth and thinned to three plants per pot. These plants were observed weekly to determine the number of tillers per plant and the total green-leaf-blade length on primary shoots and tillers. Plants from other replicates were observed for rate of adventitious rooting.

Results and Discussion

Seedling Longevity

Blue grama seedlings restricted to primary seminal roots did not show an inherent limit to longevity. A large number of plants grew actively for 22 weeks.

A few plants that died in the first three weeks appeared to be infected by foot-rot organisms in the subcoleoptile internodes. Some older plants were lost when the subcoleoptile internodes were broken during leaf measurements. A single plant apparently broke its own subcoleoptile internode as a mass of tillers, crowded for space, pressed against the soil. The subcoleoptile internode is a thin, delicate member (Fig. 1), and breakage could surely occur in the field as a result of wind and animal activity.

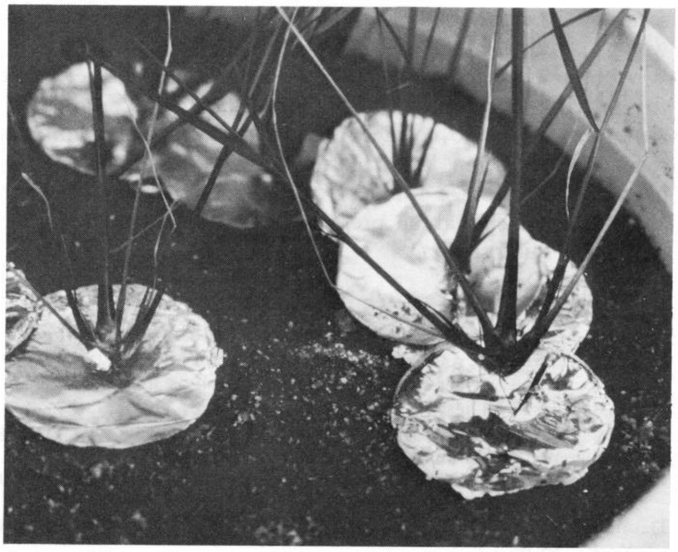

Fig. 1. *Ten-week-old seedlings grown entirely on seminal primary roots with aluminum-foil disks around the subcoleoptile internodes. The disks were covered with gravel to support the seedlings and minimize evaporation.*

Seedling Growth and Development

The rate of tillering was independent of planting depth. Tillering began consistently at 20 days of age, and tillers formed at a linear rate of 0.165 per day. Thus, the plants had an average of 15 tillers at 16 weeks (Fig. 2).

Leaf length for the primary shoot was independent of planting depth, reached a maximum of about 80 cm, and decreased by death of older leaves after 7 weeks. The total leaf length of tillers increased in a curvilinear manner and reached

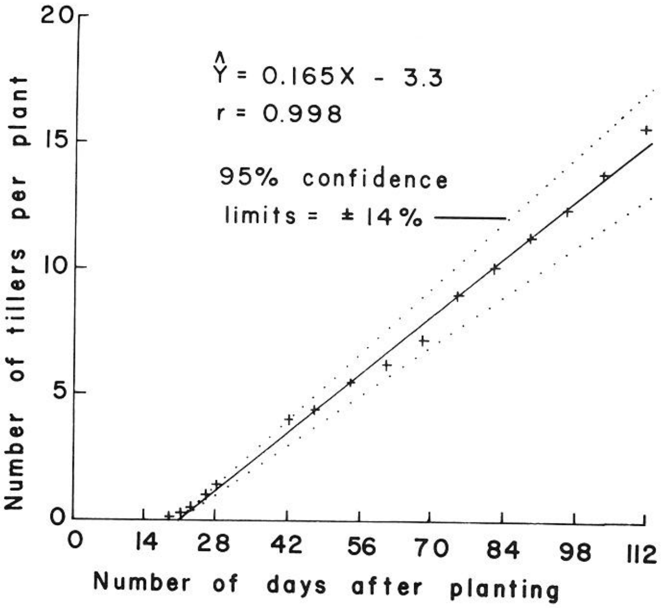

Fig. 2. *Increase in number of tillers on blue grama seedlings restricted to seminal primary roots.*

maximum at about 13 weeks (Fig. 3). Older leaves died back from the tips as new leaves appeared. Seedlings planted at less than 20 mm produced about 9 cm more leaf blade per week than those planted at greater depths. The total leaf lengths of tillers (250 - 350 cm/plant) were surprisingly large, considering the plants' dependence on water transport from the primary root through the subcoleoptile internode.

We interpret these maximum leaf lengths (and leaf areas amounting to 0.13 cm^2 of upper surface per cm of leaf length) as limits imposed by the rate of water transport through the subcoleoptile internode. Since field conditions impose sudden increases in transpirational stress, it may be necessary to restrict leaf expansion until adventitious roots are well established.

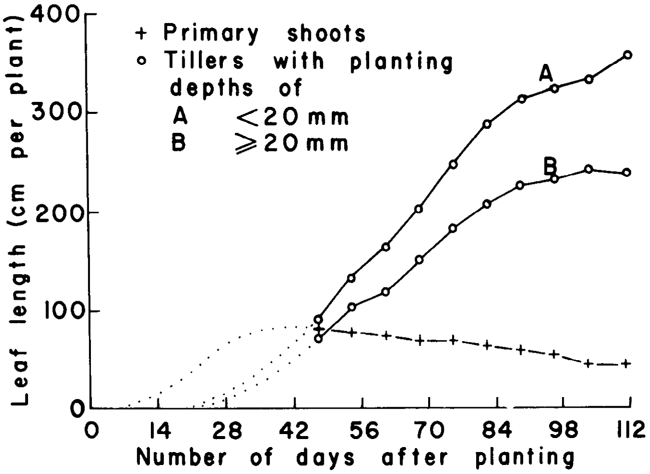

Fig. 3. *Leaf growth on primary shoots and tillers of blue grama seedlings restricted to seminal primary roots. The dotted parts of lines extrapolate leaf-length measures to time of origin.*

Development of Adventitious Roots

The first adventitious roots were observed and excised from six seedlings 11 days after planting at a depth of 5 mm. Sixty percent of the plants had initiated adventitious roots by the 14th day, and all healthy seedlings were capable of rooting by the 20th day. Those prevented from adventitious rooting by dry surface of perlite or gravel were tested for rapidity of rooting after the age of 3 weeks. Aventitious roots appeared within a few hours after the tillering crowns were exposed to moist soil. The average maximum rate of adventitious root growth was 3 cm in 24 hours. Consequently, improvement of the microenvironment at the soil surface (by precipitation or cultural treatment) for 2 or 3 days when seedlings are 3 to 6 weeks of age should assure extension of adventitious roots.

Conclusions

These results suggest two factors that should be considered in the development of better seeding practices. First, it may be appropriate to consider restricting leaf expansion, to prevent overextending the water-transport capacity, until adventitious roots are well established. Secondly, it may be appropriate to consider burying the crowns of seedlings, and/or irrigating lightly along the rows, to promote adventitious roots. Each of these considerations involve time of seeding with reference to seasonal changes in evaporation and transpiration.

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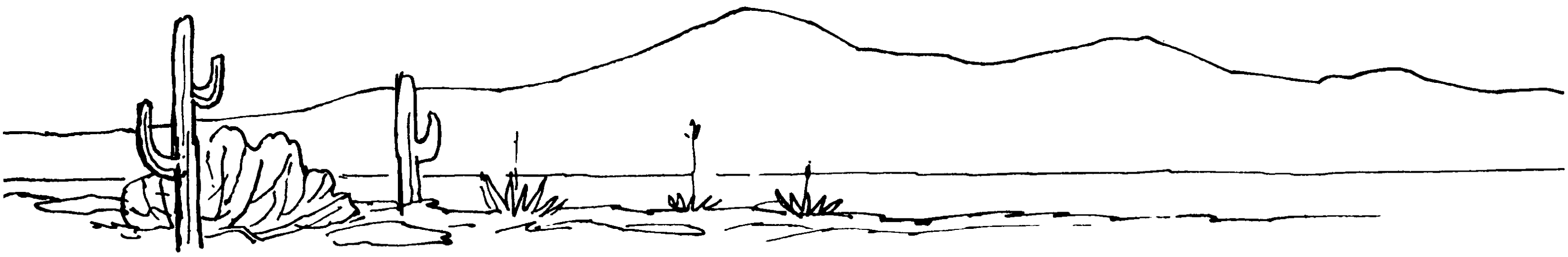

Responses of Range Grass Seeds to Winter Environments

A. M. WILSON, D. E. WONDERCHECK, AND C. J. GOEBEL

Highlight: *Seeds of annual and perennial grasses were planted in the field in fall, winter, and spring to test the rapidity of their germination at low temperatures. They were brought from the field into the laboratory at frequent intervals and germinated at 10°C. In general, the longer the exposure to field conditions, the more rapid the subsequent germination. After 1 month of exposure to the winter environment, the ranking of species in order of decreasing rapidity of germination (at 10°C) was as follows: cheatgrass (*Bromus tectorum*), medusahead (*Taeniatherum asperum*), crested wheatgrass (*Agropyron desertorum*), Siberian wheatgrass (*Agropyron sibiricum*), bluebunch wheatgrass (*Agropyron spicatum*), and smooth brome (*Bromus inermis*). The order in which seedlings emerged was the same, except that medusahead emerged earlier than cheatgrass. When seedlings are exposed to drought or to competition with other species, rapidity of germination at low temperatures may be important to their survival.*

The objective of the study was to investigate under rangeland conditions the cold tolerance characteristics of seeds of two annual and four perennial grasses.

We define cold tolerance as the capacity of seeds to germinate rapidly under low temperature winter conditions; we recognize that tolerance in the germination stage may or may not be related to tolerance in later stages of plant development.

Because of the shortness of the spring growing season on many low-elevation rangelands in northwestern United States (Nelson et al., 1970), the range manager faces the question: How early may I safely seed cool-season range grasses? He cannot give a good answer to this question until he knows: (1) how long it takes seeds to germinate at low temperatures; (2) whether or not seeds are injured by exposure to freezing temperatures; and (3) how quickly seeds recover from the effects of freezing temperatures if they have been injured.

Information is available concerning responses of seeds to controlled temperatures (Dewitt, 1969; Ellern and Tadmor, 1966 and 1967; Hulbert, 1955; McGinnies, 1960; Young et al., 1968), but there is a scarcity of information regarding responses of seeds to fluctuating and severe field environments (White and Horner, 1943).

Materials and Methods

The study was conducted on the breaks of the Snake River, 16 miles southwest of Pullman, Washington. The site is at a 1600-ft elevation on an 18% southeasterly slope. The soil is a silt loam. Precipitation records are not available, but the vegetation is similar to that of other areas in southeastern Washington that receive 12 to 14 inches annually. Most precipitation occurs in late fall, winter, and early spring. Summers are usually hot and dry. The area is representative of much of the Pacific bunchgrass type, where bluebunch wheatgrass (*Agropyron spicatum*) and other desirable perennial forage species have been replaced by introduced annuals such as cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum asperum*).

Seeds of cheatgrass and medusahead were collected in 1971 at Coyote Grade near Lewiston, Idaho. Seeds of 'Nordan' crested wheatgrass (*Agropyron desertorum*), 'Whitmar' bluebunch wheatgrass, Siberian wheatgrass (*Agropyron sibiricum*, P.I. No. 314508), and 'Manchar' smooth brome (*Bromus inermis*) were produced in Pullman, Washington in 1971. Seeds were treated with 15 mg of thiram (tetramethylthiuram disulfide) per gram dry weight. Samples of 100 seeds were enclosed in flat cotton screen bags (Bleak, 1959), and the bags were placed in the soil at a depth of 2.5 cm in a randomized complete block design. Planting dates were November 5, 1971, and January 10 and March 30, 1972. The experiments were established with six replications, but wind erosion of soil on January 11 damaged one replication in the winter experiment.

Water potential of soil, taken within 0.5 cm below seed samples, was measured in the laboratory with a thermocouple psychrometer. Soil temperature at a depth of 2.5 cm was recorded with a thermograph. Average temperature by 2-hour intervals was estimated from the thermograph chart. Degree-hours was the average temperature above 0° C times

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The study involved cooperative investigations of Agr. Res. Serv., U.S. Dep. Agr., Pullman, Washington, and the College of Agriculture, Washington State Univ., Pullman. (College of Agriculture Scientific Paper Number 4012.)

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number of hours. The sum of degree-hours was divided by 24 to give degree-days (Wang, 1960).

Samples of seed were removed from the soil at desired intervals, from the time of planting to the time seeds of most species began to germinate in the field. Seeds were placed in a petri dish on moist blotter paper and germinated at 10° C (Wilson, 1972). Germinated seeds (both root and shoot visible) were counted daily. Cumulative percentage of germination was calculated on the basis of the number of germinable seeds in control samples. Control samples consisted of seeds from air-dry storage, germinated under the same conditions as seeds brought in from the field.

The number of days required for seeds to reach 25% germination (at 10° C) was used to measure the effects of low temperature during previous exposure of seeds in the field. A decrease in number of days required for samples to reach 25% germination is referred to as a hastening of germination or as an increase in rapidity of germination.

Table 1. Ranking of species in order of decreasing cold tolerance as measured by four criteria of species behavior during germination: I, days to 25% germination (at 10°C) for control seeds not exposed to field environments; II, days germination was hastened per degree-day of exposure in the field at temperatures above freezing; III, days germination was delayed during exposure to temperatures below freezing; IV, days germination was hastened after exposure to temperatures below freezing.[1]

I		II		III		IV	
Days to 25% germination of controls[2, 3]		Hastening of germination per degree-day[4]		Delaying of germination (Jan. 24 to Jan. 27 or 31)[2, 5]		Hastening of germination (Jan. 31 to Feb. 15)[2, 3]	
Bte	3.8^a	Tas	0.104 ± .017	Bin	0.32	Bte	....[6]
Tas	5.5^b	Ade	0.099 ± .007	Asi	0.42	Tas	....[6]
Bin	6.6^c	Asp	0.099 ± .007	Ade	0.46	Ade	2.64^a
Ade	6.9^{cd}	Asi	0.098 ± .008	Asp	0.68	Asi	2.40^a
Asi	7.3^d	Bte	0.092 ± .037	Tas	1.10	Asp	1.94^a
Asp	8.1^e	Bin	0.074 ± .016	Bte	1.26	Bin	1.10^b

[1] Abbreviations are: Ade = crested wheatgrass; Asi = siberian wheatgrass; Asp = bluebunch wheatgrass; Bin = smooth brome; Bte = cheatgrass; Tas = medusahead.

[2] Values are from winter experiment.

[3] Values labeled with the same letter do not differ significantly (0.05 level) according to Duncan's multiple range test.

[4] Values are the slope and 95% confidence limits of the slope calculated from data of the spring and fall experiments (Fig. 3).

[5] Germination was not significantly delayed (0.05 level) for Bin, Asi, and Ade, according to Duncan's multiple range test.

[6] Cheatgrass and medusahead had begun to germinate in the field by February 10.

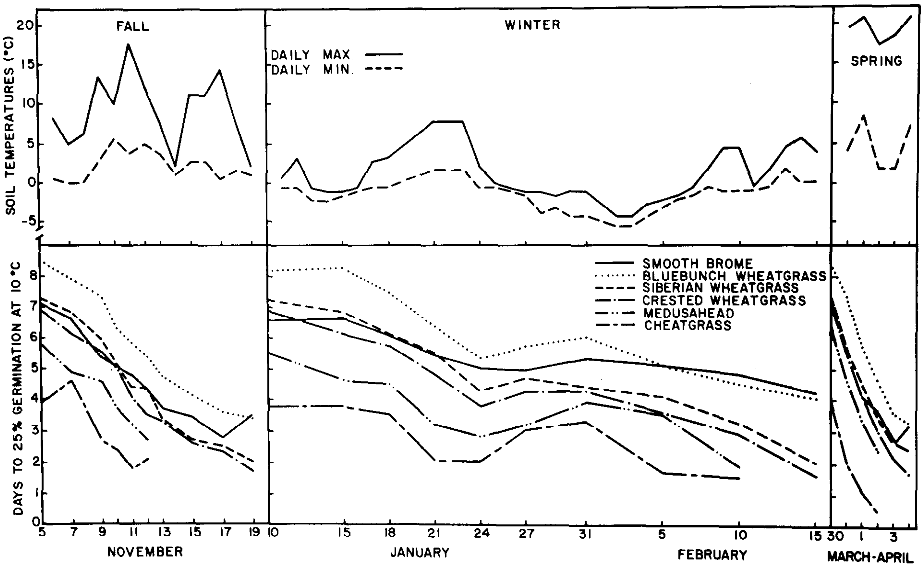

Fig. 1. *(Upper) Daily maximum and minimum soil temperatures at a depth of 2.5 cm during fall, winter, and spring. Values were plotted to indicate temperatures during the 24-hour period before seed sampling. Temperatures shown for January 19, 20, and 21 were estimated from air temperatures at Lewiston, Ida., and Pullman, Wash. (Lower) Days to 25% germination (at 10° C) of seeds removed from soil in the field on the indicated sampling dates. Seeds were planted November 5, January 10, and March 30. Values shown on these dates are for control samples. Seeds of cheatgrass, medusahead, crested wheatgrass, and Siberian wheatgrass had begun to germinate in the field when sampling was discontinued.*

Results and Discussion

Exposure of seeds to winter conditions in the field had little effect on final germination percentage (10° C for 20 days) of crested wheatgrass and Siberian wheatgrass, but reduced the germination of other species. Final germination percentages for control samples were: Siberian wheatgrass, 94%; bluebunch wheatgrass, 87%; crested wheatgrass, 86%; medusahead, 79%; smooth brome, 74%; and cheatgrass, 65%. After exposure of seeds in the field for 5 weeks, final germination percentages (10° C for 20 days) were: Siberian wheatgrass, 93%; crested wheatgrass, 86%; bluebunch wheatgrass, 76%; smooth brome, 67%; medusahead, 70%; and cheatgrass, 49%.

Among control seed samples, the ranking of species in order of decreasing rapidity of germination was as follows: cheatgrass, medusahead, smooth brome, crested wheatgrass, Siberian wheatgrass, bluebunch wheatgrass (Table 1). With the exception of smooth brome, this order was maintained most of the time in fall, winter, and spring experiments (Fig. 1). Thus, under these experimental conditions, rapidity of germination of control samples was related to rapidity of germination of seeds after they had been planted in the field.

In fall and spring experiments, when soil moisture was favorable (-0.7 to -2.7 bars), rapidity of germination was significantly correlated with degree-days of exposure in the field (Fig. 2). In relation

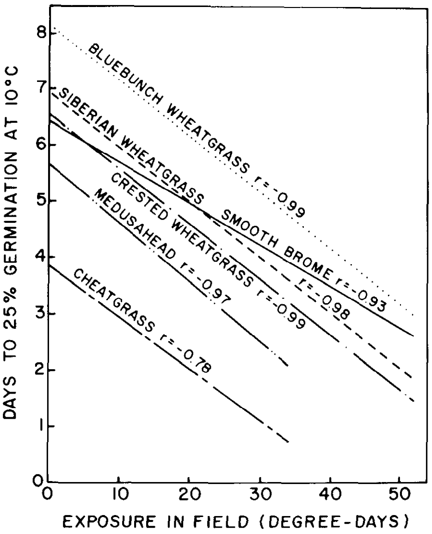

Fig. 2. *Relationship between days to 25% germination (at 10°C) and degree-days of exposure in the field. Data are from fall and spring experiments (Fig. 1).*

to degree-days, seeds responded similarly in the spring and fall. Hastening of germination per degree-day of exposure in the field was greater for medusahead and wheatgrasses than for smooth brome (Table 1). Incomplete temperature records in January precluded a similar analysis of data from the winter experiment.

The relationship between degree-days and rapidity of germination is not an exact one; rather, it is a practical guide for predicting or explaining the responses of seeds to low temperatures. A limitation is that the relationship is not valid when seeds are exposed to drought. The use of 0° C as the reference temperature is arbitrary, and for some species, germination processes probably occur even at 0° C. For other species, the use of a reference temperature higher than 0° C may be appropriate. We have not determined the upper temperature range at which rapidity of germination no longer increases linearly with degree-days of exposure. In crested wheatgrass seeds, the relationship is linear to at least 23° C (Wilson, 1973)

During temperatures below 0° C in late January, germination of seeds of some species was delayed, as compared with germination of seeds removed from soil on dates preceding the cold period. However, at no time did seeds exposed to low temperatures germinate more slowly than control seed samples. The advanced stage of germination of annual grasses on January 24 may account for the delay in their germination on January 27 and 31 (Fig. 1, Table 1). During this period, the delaying of germination of smooth brome, Siberian wheatgrass, and crested wheatgrass was not significant at the 0.05 level.

Annual grasses recovered quickly from the effects of freezing temperatures and began to germinate in the field by February 10. The number of days germination was hastened between January 31 and February 15 was taken as a measure of the recovery of perennial grass seeds from the delaying effects of freezing temperatures. The wheatgrasses recovered more quickly than smooth brome (Table 1).

After 1 month of exposure to the winter environment, the ranking of species in order of decreasing rapidity of germination was as follows: cheatgrass, medusahead, crested wheatgrass, Siberian wheatgrass, bluebunch wheatgrass, and smooth brome (Fig. 1). The dates of earliest emergence of seedlings in the winter experiment were: medusahead, February 28; cheatgrass, March 3; crested wheatgrass and Siberian wheatgrass, March 6; bluebunch wheatgrass, March 9; smooth brome, March 13. Under conditions of this experiment, rapidity of germination was related to date of emergence. Consequently, rapidity of germination at low temperatures may play an important role in the survival of seedlings when they are subsequently exposed to drying of the soil surface or to competition with weedy species.

The results show that seeds of these cool-season grasses were not seriously delayed in their germination during exposure to freezing temperatures and that seeds of most species recovered quickly from the effects of freezing temperatures. Therefore, we conclude that seeds may be safely planted in winter or very early spring on low-elevation rangelands in northwestern United States. This would allow time for seedling growth and development before the beginning of the summer dry season.

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Germination of Native Prairie Forb Seeds

J. T. SORENSEN AND D. J. HOLDEN

Highlight: *A study was conducted on 23 tallgrass prairie forb and legume seeds to determine conditions that would lead to a high level of germination. Seed fill was physically determined, seed viability was determined chemically with triphenyl tetrazolium chloride, and germination was done on moist filter paper in petri dishes. Of the 23 species of seeds tested, 69.5% germinated under normal conditions, 21.7% required moist-cold treatment, 4.4% required scarification, and 4.4% never germinated.*

Prairies once occupied an estimated billion acres, or nearly one-fifth of the North American continent, but this community, like no other natural community, has been vastly altered by pioneer settlement. Of the once-vast expanse of central grasslands, only scattered remnants remain. Areas comprising fairly pure tallgrass prairie flora today are limited chiefly to railroad right-of-ways, neglected cemeteries, and certain islands. Due to man's activities, the prairie community has nearly disappeared (Bland, 1970). Kilburn (1970) states that bluffs and banks of rivers, such as the Mississippi, Illinois, Missouri, and Ohio rivers, form the bulk of relict native tall grass prairie stands. In recent years, however, there has been an increased interest in the possibility of replanting and restoring a part of this diverse and beautiful grassland community (Schramm, 1970).

If prairies are to be restored or prairie plants used for landscaping and other commercial uses, there will develop a demand for forb seed which does not exist in sufficient quantity or quality at the present time. This seed source must come from the small relict areas which still possess a gene pool representative of the native prairie. Jenkins (1971) points out that in any natural community there are a few dominant species which are very abundant and a large number of species which are more or less rare. In a prairie in Wisconsin composed of 240 species, 12 species were represented by as many individual plants as all other 228 species combined. It is these 228 species, the majority of which are forbs, that need extensive research; for the grasses can be established with relative ease compared to the forbs. At present the capability to provide commercial sources of native prairie seeds exists only with some grasses and practically none of the forbs. Therefore, it is the purpose of this paper to determine some of the characteristics of native prairie forb seeds which would be useful in establishing these plants in the field.

Methods and Materials

The Sioux Prairie, 160 acres in size, 20 miles south of Brookings, S. Dak., on Highway 77 (T107N, R50W), was used for the collection of forb seed. This prairie is similar to the Cayler Prairie in northwest Iowa (Aikman and Thorne, 1956).

Several collections were conducted to include spring, summer, and fall flowering forbs. All seeds were collected by hand.

As seed sets, not all seeds fill; consequently, there can be a high proportion of empty seed coats. Therefore, it becomes important to determine filled versus nonfilled seed prior to subjecting the seed to germination tests (Lawrence et al., 1947). This determination was made on ten forbs by physically pinching the seed with forceps.

All filled seeds were tested for viability by soaking for 8 hours in 0.1% triphenyl tetrazolium chloride (TTC) (Hartmann and Kester, 1968; Machlis and Torrey, 1956). Seeds that have a hard coat were cut in half with a razor blade prior to treatment.

All seeds were subjected to a normal laboratory germination test. They were treated with Arasan, a fungicide, and placed in a petri dish with moist filter paper, as described by Nichols (1934). A growth chamber was used to maintain a constant temperature of 70° F (Green and Curtis, 1950; Tolstead, 1941) and complete darkness, except when the seeds were removed for counting germination. This treatment was conducted for a 30-day period with daily recordings of number of seeds which had germinated. Once a seed had germinated it was removed from the petri dish. Seeds were considered germinated once the radicle protruded through the seed coat. One hundred seeds were tested per species, except for those seeds which were limited in number. A germination trial consisted of four replications, 25 seeds per replication. Additional seeds from species which failed to germinate were then subjected to other methods of treatment to determine what method would break seed dormancy.

Seeds were scarified by being placed between two sheets of sandpaper and lightly rubbed (Hartmann and Kester, 1968). Because of the limited number of seeds, this method was used to minimize seed destruction. Once scarified, the seeds were germinated in the normal germination procedure.

Thirteen forbs were subjected to a moist-cold treatment. Seeds were placed in a petri dish with a moist filter paper and were chilled in a refrigerator at 38° F

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(Bland, 1970; Christiansen, 1967; Hartmann and Kester, 1968) for a period of 1, 2, and 3 months. At monthly intervals, 100 seeds were removed and germinated as described in normal germination.

Two forbs, prairie clover (*Ratibida columnifera*) and wood lily (*Lilium philadelphicum*), were tested with TTC for an impermeable membrane. Each forb was subjected to two treatments of 0.1% TTC. In one treatment, the seed membrane was punctured with a probe to allow the TTC to enter the seed. In the second treatment, the seed membrane was not punctured, thus determining whether or not the seed membrane is permeable or impermeable.

Gibberellic acid was used to induce germination of two forbs, water hemlock (*Cicuta maculata*) and down gentian (*Gentiana puberula*) (Mayer and Poljakoff-Mayber, 1963). Half of the seeds were soaked in 100 ppm gibberellic acid for a 2-week period and the other half for a 1-month period and germinated as described in normal germination.

Results and Discussion

Table 1 reveals that seed viability was high, ranging from 92% to 100% except for one species, common lousewort (*Pedicularis canadensis*), which was 58%. If, therefore, seed is subjected to the right environmental conditions, germination will be successful. Table 2 illustrates that not all seeds collected had matured. Seed development ranged from 24.5% to 93.3%. Amen (1963) reports that little information is available on the influence of environmental conditions during flowering and seed set on the subsequent germination of a seed crop. Blake (1935) states that weather conditions during flowering and seed set appear to affect subsequent germination and to account for differences in germination between annual harvest of seeds. Below normal temperature and above-normal rainfall appear to increase subsequent germination, while drought lowers germination.

Not only is seed development a problem in collection, but little is known about the best time for collection. If seeds are left to mature on the plant, they sometimes disperse quickly upon reaching maturity. This is especially true with the composites. One possible solution to this problem would be to collect seed in the dough stage as is done in some agronomic crops.

Of 23 native prairie forbs, 16 species, or 69.5%, germinated under normal test conditions (Table 3), presenting no real problem for commercial use on a large scale.

Table 1. TTC test of seed viability (%) of 23 prairie forbs.

Species	Viability
Achillea millefolium	100
Allium spp.	100
Amorpha canescens	92
Anemone cylindrica	98
Anemone patens	98
Antennaria spp.	96.5
Aster sericeus	100
Astragalus canadensis	96
Astragalus crassicarpus	100
Cicuta maculata	100
Echinacea angustifolia	100
Erigeron strigosus	–[a]
Gentiana puberula	92.3
Geum triflorum	100
Liatris ligulistylis	–[b]
Liatris punctata	–[b]
Lilium philadelphicum	98[a]
Pedicularis candensis	58
Petalostemum spp.	100
Potentilla arguta	100
Ratibida columnifera	100[c]
Vernonia fasciculata	100
Zizia spp.	100

[a] –ran out of seed.
[b] –weevils in seed.
[c] –after puncture treatment.

Only one species in normal germination displayed any unusual characteristics. The purple cone flower (*Echinacea angustifolia*) was found to have a corky seed covering which, when removed, allowed 92% germination as opposed to 13% germination with the corky covering.

The moist-cold treatment was utilized in breaking temperature-dependent dormancy. During this treatment after-ripening takes place, resulting in responses such as embryonic growth or metabolic change in the embryo (Hartmann and Kester, 1968; Mayer and Poljakoff-Mayber, 1963). Under this mode of treatment four responses were noted: breaking the dormancy of species which did not germinate under normal conditions, increased germination and rate of germination, decreased germination, and no effect on germination. These same results were also noted by Nichols (1934) where he states stratification benefited 73% and harmed 14% of the species. Tolstead (1941), Christiansen (1967), and Blake (1935) found the same basic response to stratification.

Table 2. Percentage of seeds developing mature embryos.

Species	Percentage developing embryos
Amenome patens	91.2
Amorpha canescens	81.0
Aster sericeus	42.0
Echinacea angustifolia	76.5
Geum triflorum	93.3
Liatris ligulistylis	66.5
Liatris punctata	76.5
Petalostemum spp.	24.5
Ratibida columnifera	47.5
Vernonia fasciculata	54.5

Moist-cold treatment broke the seed dormancy of tall cinquefoil (*Potentilla arguta*) after 1 month (Table 4). Both pussytoes (*Antennaria* spp.) and alexander (*Zizia* spp.) increased percent germination and rate of germination with increasing cold period. Daisy fleabane (*Erigeron strigosus*) decreased in percent germination under cold treatment, starting with 70% normal germination, 16% after 1 month cold treatment and 0% after 2 months treatment. Meadow anemone (*Anemone cylindrica*) illustrates that the cold treatment did not effect percent germination but did increase rate of germination. In fact, cold treatment increased the rate of germination of all species tested except common yarrow (*Achillea millefolium*), which decreased in percent germination as well as rate of germination.

Table 5 illustrates the effect of the 3-month moist-cold treatment on 3 of the 23 species tested. In this table a comparison can be made with percent germination to length of cold treatment and duration of germination. Western ironweed (*Vernonia fasciculata*) presented an interesting aspect of secondary dormancy. This species germinated after 1 month of cold treatment and failed to germinate after 2 months. However, after 3 months, western ironweed started to germinate again. While western ironweed was undergoing moist-cold treatment, the petri dishes became somewhat dry. Hartmann and Kester (1968) state that with drying seeds in moist-cold treatment will go into secondary dormancy.

A widespread cause of seed dormancy is the presence of a seed coat, usually a multi-layered membrane (Mayer and Poljakoff-Mayber, 1963). A hard seed coat is resistant to abrasion and may be covered with waxlike layers, resulting in impermeability to water, impermeability to gases, or mechanical constraint of the embryo.

The method most commonly used to break seed coat dormancy is scarification. The results of this study show that four species benefited from scarification, all in the family *Leguminosae*. This family has a hard seed coat impermeable to water. Scarification broke seed dormancy, and increased the percent germination and rate of germination of those seeds tested (Table 6).

Table 3. Normal seed germination of 23 prairie forbs.

Species	Germination (%)	Days to germinate	Days required 50% germination	75% germination
Achillea millefolium	87	2–8	3	5
Allium spp.	36.7[a]	16–23	–	–
Amorpha canescens	63	2–18	8	–
Anemone cylindrica	96	13–23	13	14
Anemne patens	78	11–24	17	19
Antennaria spp.	2	7–11	–	–
Aster sericeus	71	2–24	6	–
Astragalus canadensis	8	4–9	–	–
Astragalus crassicarpus	0	–	–	–
Cicuta maculata	0	–	–	–
Echinacea angustifolia	92[b]	2–9	4	6
" "	13[c]	5–11	–	–
Erigeron strigosus	70	3–18	6	–
Gentiana puberula	0	–	–	–
Geum triflorum	90	7–16	10	12
Liatris ligulistylis	41	4–26	–	–
Liatris punctata	47	8–22	–	–
Lilium philadelphicum	30[d]	9–17	–	–
Pedicularis candensis	0	–	–	–
Petalostemum spp.	2	3–4	–	–
Potentilla arguta	0	–	–	–
Ratibida columnifera	0	–	–	–
Vernonia fasciculata	0	–	–	–
Zizia spp.	4	10–18	–	–

[a] —based on 30 seeds.
[b] —hull removed.
[c] —hull not removed.
[c] —based on 50 seeds.

Table 5. Seed germination (%) of 3 prairie forbs after three months moist-cold treatment (MCT).

Species and treatments	Germination	Days to germinate
Cicuta maculata		
NG*	0	–
1 mo MCT	0	–
2 mo MCT	5	4–5
3 mo MCT	37	1–9
Gentiana puberula		
NG	0	–
1 mo MCT	0	–
2 mo MCT	32	3–13
3 mo MCT	55	1–8
Vernonia fasciculata		
NG	0	–
1 mo MCT	38	3
2 mo MCT	0	–
3 mo MCT	24	2–5

*Normal germination.

Table 4. Seed germination of 10 prairie forbs after 1 and 2 months moist-cold treatment (MCT).

Species and treatment	Germination (%)	Days to germinate	50% germination	75% germination
Achillea millefolium				
NG*	87	2–8	3	5
1 mo MCT	79	1–15	3	7
2 mo MCT	–[a]	–	–	–
Anemone cylindrica				
NG	96	13–23	13	14
1 mo MCT	96	5–8	7	7
2 mo MCT	98	4–7	3	3
Anemone patens				
NG	78	11–24	17	19
1 mo MCT	75	7–27	14	27
2 mo MCT	82	4–15	9	12
Antennaria spp.				
NG	2	7–11	–	–
1 mo MCT	20	2–10	–	–
2 mo MCT	45	1–6	–	–
Aster sericeus				
NG	71	2–24	6	–
1 mo MCT	63	2–18	2	–
2 mo MCT	–[b]	–	–	–
Erigeron strigosus				
NG	70	3–18	6	–
1 mo MCT	16	2–8	–	–
2 mo MCT	0	–	–	–
Geum triflorum				
NG	90	7–16	10	12
1 mo MCT	91	3–7	4	4
2 mo MCT	80	1–4	3	3
Pedicularis candensis				
NG	0	–	–	–
1 mo MCT	0	–	–	–
2 mo MCT	0	–	–	–
Potentilla arguta				
NG	0	–	–	–
1 mo MCT	58	3–8	5	–
2 mo MCT	49	1–2	–	–
Zizia spp.				
NG	4	10–18	–	–
1 mo MCT	46	5–12	–	–
2 mo MCT	55	1–12	4	–

[a] Seeds had heavy mold.
[b] Seeds starting to germinate in moist cold treatment.
*Normal germination.

Table 6. Seed germination percentage after scarification of seven prairie forbs.

Species	Germination	Days	Days required 50% germination	75% germination
Amorpha canescens	63*	2–18	8	–
	92	1–8	2	4
Astragalus canadensis	8*	4–9	–	–
	89	1–12	1	2
Astragalus crassicarpus	0*	–	–	–
	96	1–23	3	4
Petalostemum spp.	2*	–	–	–
	98	1–2	1	1
Allium spp.	26.7*[a]	–	–	–
	0			
Zizia spp.	4*	10–18	–	–
	0	–	–	–
Cicuta maculata	0*	–	–	–
	0	–	–	–

*Results from normal germination.
[a] Based on 40 seeds.

Table 7. Germination (%) of seeds treated to determine the influence of membrane surrounding the embryo in two forbs.

Species	NG*		TTC**		Acetone & TTC	Ether & TTC	MCT***
	No puncture	Puncture	No puncture	Puncture			
Ratibida columnifera	0	95	0	100	0	0	11
Lilium philadelphieum	30[a]	79[c]	0	98	0	0	66[b]

*Normal germination.
**Triphenyl tetrazolium chloride.
***Moist-cold treatment.
[a] Based on 50 seeds.
[b] Based on 30 seeds.
[c] Based on 24 seeds.

Not only does seed dormancy result from a hard seed coat but also from a membrane impervious to water or gases. Both prairie coneflower and wood lily have this characteristic (Table 7). Both benefited from puncture, indicating an impermeable membrane or wax coating. Tests with TTC treatment without puncture of the membrane indicated a colorless embryo or nonviable seeds. After puncture prairie coneflower had 100% and wood lily 98% red embryos, which indicates the barrier is to water. The membrane coating of wood lily is less impermeable than prairie coneflower, for under normal germination condition wood lily germinated 30% and prairie coneflower 0%.

Seeds which fail to germinate or require extra long treatments to break dormancy can be subjected to stimulants, such as hormones, which may shorten the time needed to germinate or break dormancy. Both water hemlock and downy gentian germinated when subjected to the moist-cold treatment but required the longest time of any species, and germination was low. Both species were treated with gibberellic acid, which shortened the time required for germination of downy gentian but had no effect on water hemlock (Table 8). Mayer and Poljakoff-Mayber (1963) state that gibberellic acid has the ability to reverse the inhibition of germination caused by high osmotic pressure. Cleland (1969) states gibberellic acid can activate amylase in the endosperm. Amylase is a hydrolytic enzyme which converts the starch in the endosperm to glucose, which then can be utilized by the embryo as energy for growth.

Pedicularis canadensis was the only species out of 23 in which the seeds failed to germinate. It is difficult to say why. Its failure to germinate could be contributed to the fact that the seed had not matured, for seed viability was only 58%. Those which indicated viability may not have been physiologically or morphologically developed enough to germinate, thus requiring a longer time for after-ripening.

Summary

Although there is not a large quantity of native prairie forb seed available, this study as well as others indicates that native forb seed can be successfully germinated. Seed viability poses no real problem, but seed set does present some difficulties. However, once this seed is raised agronomically, environmental conditions can be controlled to some extent, and seed set will probably no longer be a problem. At present, seed collection is a laborious process; but once these forbs are raised as one-stand crops, mechanization will solve the problem in collection.

Of 23 species studied it was found that 69.5% (16 species) germinated under normal germination, 21.7% (5 species) required moist-cold treatment before the seeds would germinate, 4.4% (1 species) required scarification before germination, and 4.4% (1 species) never germinated.

Of 13 species subjected to moist-cold treatment it was found that there were four responses: 30.7% germinated only after cold treatment, 23.1% increased in germination percentage, 15.3% showed no effect, and moist-cold treatment was harmful to 30.7%. These same four responses have also been found in other studies of cold treatment.

Scarification was beneficial to four species and harmful to three. It should also be noted that scarification not only broke seed dormancy, but on those seeds which germinated normally, scarification increased the rate of germination. Other studies have also found scarification to have this same effect.

Chemical induction of germination with gibberellic acid was beneficial to only one of the two species tested.

Table 8. Germination (%) of seed of two forbs treated with gibberellic acid.

Species	Germination	Days to germinate
Cicuta maculata		
NG*	0	–
2 week	0	–
1 month	0	–
Gentiana puberula		
NG	0	–
2 week	30	7–25
1 month	36	4–22

*Normal germination.

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Population Dynamics of Green Rabbitbrush in Disturbed Big Sagebrush Communities

JAMES A. YOUNG AND RAYMOND A. EVANS

Highlight: *We investigated the dynamics of green rabbitbrush populations in relation to burning, livestock grazing, and chemical shrub-control as a range-improvement practice in big sagebrush communities. Green rabbitbrush plants sprout from roots, and density increases by seedling establishment after a fire. Achene production and seedling establishment are paramount to dominance by rabbitbrush after burning of big sagebrush communities. Rabbitbrush continues to dominate and periodically reestablishes itself for at least 15 years. Reduced populations of rabbitbrush persist in communities where dominant big sagebrush plants are 40 to 50 years old. Partial reduction in big sagebrush or rabbitbrush populations by applications of 2,4-D results in a large increase in seedling establishment of both species. When these communities are not disturbed or when all shrubs are removed, no shrub seedlings are established.*

Our purpose was to investigate the dynamics of populations of green rabbitbrush (*Chrysothamnus viscidiflorus* var. *viscidiflorus*) in seral big sagebrush (*Artemisia tridentata*) communities in western Nevada. Parameters emphasized are dominance and tenure of rabbitbrush in relation to stand reduction and renewal processes of burning, livestock grazing, and shrub control as a range-improvement practice.

An increase in dominance of rabbitbrush, usually attributed to root sprouting, is an almost universal response to disturbance in big sagebrush communities in the central Great Basin. Big sagebrush does not sprout when stands are destroyed in wildfires. Rabbitbrush, which is a subdominant in many big sagebrush communities, sprouts profusely after fires destroy the aerial portion of the plant (McKell and Chilcote, 1957). The natural stand reduction and renewal process of recurrent wildfires therefore leads to destruction of dominant big sagebrush, followed by a successional stage dominated by rabbitbush. These sequential relations have been a part of the ecology of the Great Basin since the climate became more arid as a result of uplifting of the Sierra Nevada and Cascade Mountain ranges (Axelrod, 1950).

Green rabbitbrush, and to a lesser extent big sagebrush, are largely rejected by browsing livestock. The essential-oil content of the herbage of big sagebrush apparently contributes to this rejection because it inhibits or depresses rumen activity (Nagy et al., 1964). Heavy grazing by domestic livestock for many seasons reduces grasses and increases density of brush species.

Grazing of the herbaceous understory of big sagebrush communities by domestic livestock revolutionized plant succession in the Great Basin little more than a century ago (Young et al., 1972). The ecological niche for large herbivores that was filled by domestic livestock had been vacant since the close of the Pleistocene (Martin, 1967).

Two decades ago, technology produced herbicides that offered the possibility of balancing the ecological changes produced by a century of grazing not in equilibrium with the environment (Bovey, 1971).

How has stand reduction and renewal by fire, grazing, and herbicide application influenced succession of rabbitbrush and big sagebrush communities?

Procedure and Area Description

Sampling Methods

The basic sampling design consisted of 10 macroplots, each 100 m^2 in area. These 10 plots were randomly located in each of the 52 stands selected for sampling. The stands were selected to provide examples of the various types of stand reduction and renewal on sites of varying potential. The density, age class, projected herbage cover, and diameter of shrubs rooted in each plot were recorded by species. Herbage cover of perennial grasses and forbs and annuals was estimated for each plot. Age classes of shrubs were established by sectioning stems and counting growth rings (Ferguson, 1964).

In 1970, at maximum herbage production, we clipped to ground level the herbaceous vegetation on 10 plots 1 m^2 in area in each stand. At the same time, we frequency-sampled the herbaceous vegetation with 100 plots 0.1m^2 in area. Frequency samples were arranged within each stand following the methods of Evans and Love (1957).

We excavated and described soil profiles of the major soils represented, using methods described in the Soil Survey

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Manual (Anon., 1960).

We initiated sampling in 1968 and added stands through 1972. The stands treated with herbicides in 1968 were sampled in 1969 and 1972. In 1972, we determined seedling density of rabbitbrush and big sagebrush on 75 plots 10m^2 in area in relation to percent kill of the original brush stand.

Physiography of Study Area

The investigation was located at Medell Flat, about 35 km north of Reno, Nev. Medell Flat is an irregularly shaped depression, bordered on the east by the Dogskin Mountains and on the west by granitic hills, which merge into the Peterson Mountain Range.

Recent tectonic activity of the granitic mountain ranges that surround Medell Flat has provided decomposing quartz diorite for the bulk of the raw material for soil formation in the basin.

The east and northeast sides of Medell Flat are covered with Pleistocene alluvium (McJannet, 1957). These fanglomerate deposits head at about 1,580 m elevation against the bold fault scarp of the Dogskin Mountains.

In contrast to the undifferentiated soils of the fanglomerate, the westside alluvium soils have argillic horizons and sometimes contain highly indurate pans, which limit rooting depth. These soils belong to the order Aridisols and the group Haplargid or Durargid, depending on the presence of pan development (Anon., 1960). Soils with pans tend to be located on the most recent alluvial surfaces. Terraces have less developed soils and fragile pans subtending the solum.

On the basis of records from the closest station (Reno) and 10 years of collecting precipitation records at Medell Flat, we estimate the mean annual precipitation at from 200 to 250 mm.

There is insufficient water on the approximate 8,000-ha area of Medell Flat to support large herbivores. Domestic livestock grazing depends on a system of windmills, underground pipe, and water troughs.

Stand Renewal Processes

Grazing

Medell Flat has been grazed by cattle, sheep, and horses for more than a century. In general, livestock was introduced to western Nevada in the 1860's, with several population cycles regulated by severe winter kills in the 19th centruy (Hazeltine et al., 1961). Kennedy and Doten (1901) described the general area of Medell Flat as a virtual dust bed at the turn of the century. They attributed the destruction of vegetation to early spring grazing of sheep on lambing grounds between salt-desert winter range and summer range in the Sierra Nevada Mountains. Cattle were annually wintered on the flat area with minimum supplemental feeding until 1971. With the establishment of the Grazing Service in 1935, grazing pressure was reduced to chronic attrition rather than acute destruction of the herbaceous vegetation. The attrition refers to selective utilization of the herbaceous vegetation and subsequent increase in shrub density since the dust bed conditions at the turn of the century.

Fire

Almost all of Medell Flat has evidence of being burned during the 20th century. During the three decades that fire suppression has been practiced on public lands in the area, the records of the Bureau of Land Management, U. S. Department of the Interior, Carson City, Nev., indicate that one large fire swept the western part of the basin. This fire started from a lightning strike in July, 1957.

Artificial Vegetation Manipulations

In 1958, 3.4 kg/ha of (2,4-dichlorophenoxy)acetic acid (2,4-D) was aerially applied to two long strips of big sagebrush communities in the southeastern part of Medell Flat. In 1968, about 1,000 ha of big sagebrush dominated communities were treated with 3.4 kg/ha of 2,4-D. In addition, 10 ha were treated with 2.5 kg/ha of 2,4-D plus 0.4 kg/ha of 4-amino-3,5,6-trichloropicolinic acid (picloram). This combination of herbicides is particularly effective on rabbitbrush (Tueller and Evans, 1969).

Table 1. Density and projected herbage cover of woody species and cover of herbaceous species of plant communities growing on recent alluvial fans.

	Stand reduction and renewal process			
	Burned in 1957			
Plant groups and measurements	Grazed	Grazed extreme	Ungrazed for 10 years	Unburned and grazed
Plants/ha (100's)				
Rabbitbrush				
Seedling	1	0	0	0
Young	2	1	0	0
Mature	1	0	0	0
Senescent	2	0	1	2
Big sagebrush				
Seedling	1	1	0	3
Young	0	1	0	1
Mature	0	0	0	29
Senescent	0	0	0	24
Hop sage	0	0	0	1
Projected herbage cover (%)				
Rabbitbrush	10	1	1	1
Big sagebrush	0	1	0	24
Total shrubs	10	2	1	26
Perennial grasses	3	0	18	2
Annuals	15	26	5	18
Number of stands sampled	4	1	1	4

Results

The most immediate problem in establishing the tenure of rabbitbrush as a seral stage dominant is to obtain a reliable estimate of age of the shrubs. We obtained a highly significant correlation (r = 0.889) between shrub height (x) and the number of annual rings on rabbitbrush stems (y). Using this relation, we calculated the linear regression equation y = 1.5894 + 0.2109x. Height as an estimate of age provides a convenient tool for stratifying populations by age classes. Difficulties are encountered with senescent plants. At maturity, rabbitbrush plants virtually cease growth in height, and their stems are largely destroyed by channels of the larvae of *Acamaeodera pulchella* (Strickler, 1956).On an area at Medell Flat, burned 12 years previously, 5.6 percent annual mortality of rabbitbrush was found.[1] This high mortality suggests that many plants in the population had become senescent. A scattered population of rabbitbrush plants in a high-seral big sagebrush stand apparently is less subject to *Acamaedera* infestation than dense low seral populations.

There are four convenient groupings based on vegetative appearance in the height/age classes of rabbitbrush populations: seedlings (5 to 15 cm tall, 1 to 2 years old); young plants (20 to 30 cm tall, 3 to 5 years old); mature plants (35 to 65 cm tall, 6 to 12 years old); and senescent plants (70 to 80 cm tall, 13 plus years old).

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[1] Unpublished data, Agr. Res. Serv., U.S. Dep. Agr., Reno, Nev.

Table 2. Frequency (%) and cover (%) of species composing various herbaceous communities found in association with degraded brush stands, and the herbage production (kg/ha) of each community measured by clipping in 1970.[a] These basic plant communities reoccur through the study area in relation to site potential and level of disturbances.

	Herbaceous plant communities									
	Downy brome on burns		Downy brome, shrub canopy & interspace		Downy brome/ squirreltail/ Thurbers and western needlegrass		Desert needlegrass		Downy brome/Great Basin wildrye	
	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover
Annual grass										
Downy brome	70	15	80	9	38	5.2	10	0.5	68	13
Perennial grasses										
Squirreltail	3	0.1	3	0.1	16	0.7	10	0.5	5	0.1
Thurbers needlegrass		T	T	T	5	T	4	T	T	T
Western needlegrass	5	10	2	0.1	6	0.8	14		2	0.1
Desert needlegrass	0	0	0	0	T	T	18	6	0	0
Great Basin wildrye	T	T	0	0	0	0	0	0	0	0.3
Other species	4	0.2	0	0	6	0.2	11	4.4	2	0.1
Alien annual forbs	10	1.0	6	0.4	3	T	0	0	11	0.3
Native annual forbs	T	T	T	0.1	18	0.7	31	2.2	1	0
Perennial forbs	8	1.1	3	0.1	15	0.7	5	0.5	4	0.1
Total herbaceous cover		27.4		9.8		8.3		14.1		14.0
Herbaceous production kg/ha		150 to 300		75 to 100		280		940		430

[a] T indicates less than 1.0% frequency or less than 0.1% cover.

Plant Communities and Stand Reduction by Burning and Renewal Under Grazing

Recent Alluvial Fans

Unburned areas on alluvial fans on the west side of Medell Flat support dense stands of big sagebrush (Table 1). These sites have downy brome- or downy brome/Great Basin wildrye (*Elymus cinereus*)-dominated herbaceous communities (Table 2). The stands are clearly dominated by old big sagebrush plants, and big sagebrush seedlings are establishing in the stands. The oldest stem section of plants in these communities had 52 growth rings and the center of the stem was decayed. Average age for the mature big sagebrush plants was 35 years. Only a few senescent green rabbitbrush plants occur in the stands (Table 1). The green rabbitbrush plants appear to be very old.

Big sagebrush communities growing on a portion of the recent alluvial fans were burned in 1957. The burned sites are currently dominated by a green rabbitbrush overstory and a downy brome understory (Tables 1 and 2). The burned area has been heavily grazed since the fire. Where a portion of this site was protected from grazing by an exclosure constructed in 1952, a squirreltail (*Sitanion hystrix*)/downy brome/western needlegrass (*Stipa occidentalis*)/Thurbers needlegrass (*S. thurberiana*)[2] plant community is found with very few green rabbitbrush plants (Table 1). In contrast to the protected area, there is an area at Medell Flat where cattle are wintered annually with limited supplemental feeding. The concentration of livestock suppressed green rabbitbrush and perennial grass establishment and favored a downy brome community, which includes alien weeds that are noxious to grazing.

Alluvial Terraces

Closely related to the recent alluvial fans, both in physical position and soil development, the alluvial terraces have more diverse plant communities before and after burning (Table 3). Unburned communities are dominated by big sagebrush, but they also contain a relative abundance of green rabbitbrush, horsebrush (*Tetradymia canescens*), and desert peach (*Prunus andersonii*). The oldest big sagebrush plants had more than 50 growth rings. The number of growth rings of mature big sagebrush stems is much more variable here than in the alluvial

Table 3. Density and projected herbage cover of woody species and cover of herbaceous species of plant communities growing on alluvial terraces.

	Stand reduction and renewal process		
	Burned 1957 and subsequently heavily grazed		Unburned and always heavily grazed
Plant groups and measurements	Horsebrush Sites	Rabbitbrush Sites	
Plants/ha (100's)			
Rabbitbrush			
Seedling	16	18	1
Young plants	7	9	3
Mature plants	2	1	0
Senescent	3	4	6
Big sagebrush			
Seedling	1	1	4
Young plants	1	0	2
Mature plants			6
Senescent			11
Other species			
Horsebrush	26	1	4
Hop sage	0	0	1
Spiney phlox	1	2	1
Desert peach			1
Projected herbage cover (%)			
Rabbitbrush	11	14	2
Big sagebrush	1	1	16
Total shrubs	23	16	24
Perennial grasses	8	5	2
Annuals	15	8	5
Number of stands	4	3	3

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[2] Four species of *Stipa*–*S. thurberiana*, *S. occidentalis*, *S. speciosa*, and *S. comata*–occur in the same communities at Medell Flat. It is difficult to separate the first three species when they are closely grazed throughout the year and not allowed to flower.

Table 4. Density per hectare and projected herbage cover (%) of woody species and cover of herbaceous species of plant communities growing on fanglomerate in relation to herbicide, burning, and grazing treatments.

Plant groups and measurements	Burned, currently moderately grazed		Unburned, currently grazed[1]			2,4-D in 1968, grazed[1]			2,4-D plus picloram in 1968, no grazing	2,4-D in 1958, heavy grazing
	Less than 10[2]	More than 10[2]	Heavy	Moderate	Light	Heavy	Moderate	Light		
Plants/ha (100's)										
Rabbitbrush										
Seedlings	14	1	2	2	1	0	0	0	0	0
Young plants	8	2	0	2	0	0	0	0	0	1
Mature plants	3	1	0	2	0	0	0	0	0	15
Senescent plants	1	4	1	1	1	0	1	0	0	8
Big sagebrush										
Seedlings	4	1	0	4	10	0	0	0	1	4
Young plants	1	0	3	6	4	0	0	0	0	1
Mature plants	0	2	2	8	8	0	0	0	0	1
Senescent plants	0	1	45	12	18	1	1	0	0	0
Other shrubs										
Spiney phlox	1	1	1	2	0	0	1	0	0	0
Green ephedra	2	3	0	1	2	1	1	2	2	2
Horsebrush	1	1	0	2	0	0	0	0	0	0
Desert peach	8	9	0	8	1	1	1	2	0	1
Projected herbage cover (%)										
Rabbitbrush	3	6	1	9	2	0	1	0	0	11
Big sagebrush	1	2	14	3	18	1	1	0	1	3
Total shrub	15	22	16	20	22	2	5	3	3	17
Perennial grasses	5	5	2	6	8	2	2	8	12	3
Annuals	10	2	1	5	2	10	12	6	2	12
Number of stands sampled	2	3	3	4	2	3	4	2	1	8

[1] Gradient uphill and away from water.

[2] Years since burned.

fan communities.

One distinct successional plant community on the terraces that has been burned is dominated by green rabbitbrush, while on the remainder of the area horsebrush and rabbitbrush share dominance. There are no consistent differences in soils or topography between these two types of seral communities (Table 3).

Prickly phlox (*Leptodactylon pungens*), a semiwoody shrub, increases in density on the burned areas. The most prevalent understory community is downy brome, which gradually intergrades into downy brome/squirreltail/western needlegrass/Thurbers needlegrass with greater distance from stockwater (Table 2).

The herbaceous cover and frequency of alien annuals are higher in downy brome communities than in adjacent unburned big sagebrush communities with downy brome growing under the shrubs (Table 2). The cover and frequency of native annuals decrease after burning and the invasion of alien weeds. In degraded big sagebrush communities, native annual forbs occur on the margins of nests of harvester ants (*Pogonomyrmex occidentalis*). The ants persist in the burned areas and apparently harvest the seeds of the alien weeds. Persistent colonies of prickly skeletonweed (*Lygodesmia spinosa*) have developed in areas of rodent disturbance in the burns.

Fanglomerate

Casual observation reveals few differences between degraded big sagebrush stands on the fanglomerate and those growing on the alluvial terraces. On burned areas, a much higher density of creeping-rooted shrubs clearly identifies the fanglomerate areas (Table 4). The significance of the presence of these additional root sprouting shrubs to the dynamics of rabbitbrush is that they occupy space available for rabbitbrush dominance on sites with more developed soils. The creeping stemmed or clonal root sprouters have a much longer tenure than rabbitbrush. Desert peach forms dense thickets that exclude other woody species. Individual stems of desert peach apparently are short-lived, with a maximum of 6 to 8 growth rings. The dead stems persist, and new sprouts from underground burls add to the thickets. The clumps of stems are joined by underground runners. Each thicket may represent a large clone. Green rabbitbrush is not found in the desert peach thickets.

The second characteristic root-sprouting shrub of the fanglomerate is green ephedra (*Ephedra viridis*). Green ephedra plants may consist of a clump of stems or a single trunk 10 to 30 cm in diameter and 2 m high. Large stems have 60 to 100 growth rings, while the maximum number for big sagebrush stems in the same stand is 50.

The heaviest-grazed parts of the fanglomerate have a preponderance of senescent big sagebrush plants (Table 4). Farther up the slope, where grazing pressure is reduced by distance from stockwater, big sagebrush stands are younger and contain more of the root sprouting fire-associated species.

In stands burned less than 10 years ago, density of rabbitbrush plants is far greater than in stands not recently burned (Table 4). Increase in density of rabbitbrush must be from establishment of seedlings. Root sprouting apparently furnishes a source of achenes for seedling establishment by providing young vigorous plants, because the surrounding unburned stands contain only senescent green rabbitbrush plants that produce few achenes.

Perennial grasses increase higher on the fanglomerate slopes and away from the stockwater. There is a gradual transition from communities dominated exclusively by downy brome to ones dominated by squirreltail, downy brome, western needlegrass, and Thurbers needlegrass.

The increase in dominance of green rabbitbrush after disturbance is remarkably constant in the variety of plant communities and topoedaphic situations sampled at Medell Flat.

Stand Renewal with Herbicides

Rabbitbrush release

Spraying big sagebrush communities with 2,4-D in 1958 induced dominance by rabbitbrush (Table 4). There were 8 times more rabbitbrush plants in the area treated with herbicide than in adjacent nonsprayed stands. There are three probable reasons for this conversion: 1) rabbitbrush is more resistant to phenoxy herbicides than sagebrush (Hyder et al., 1962); 2) judging from adjacent stands, there were insufficient perennial grasses in the understory to preempt the environmental potential released by killing the sagebrush; and 3) the area was not protected from grazing to give the perennial grasses a chance to use the released potential. The understory of this area is dominated by a downy brome community (Table 2).

Failure of 2,4-D to kill the rabbitbrush does not account for a greater density of this species than in the adjacent unsprayed stands because the post-spray density is so much higher than in unburned or nonsprayed communities (Table 4). The surviving rabbitbrush plants must have responded dynamically to the released environmental potential by producing many high-quality achenes. Investigations of the reproductive phenology of green rabbitbrush at Medell Flat have shown that vigorous stands of young plants produce 20 million achenes/ha annually.[1]

Variable Control of Shrubs

Highly variable reductions in shrub density, from 0 to 100% in different parts of the sprayed area, resulted from the 1968 spraying (Table 4). In areas where green rabbitbrush and big sagebrush were killed, annuals have dominated. This is especially true of the lower and intermediate slopes that were previously moderately to heavily grazed. On the upper parts of the fans where grazing had been light, remnant stands of perennial grasses were released after the brush was killed.

Green ephedra and desert peach were not killed by 2,4-D (3.36 kg/ha) applied in 1968. Where big sagebrush and green rabbitbrush were completely controlled, there was a dramatic conversion to shrubs resistant to the phenoxy herbicide.

Dynamic Shrub-Seedling Establishment

Where a partial reduction in shrub canopy was obtained by application of 2,4-D in 1968, a dynamic response in terms of seedling establishment of brush was apparent by 1972. Very few green rabbitbrush or big sagebrush seedlings became established where either none or all of the shrub population was killed by the herbicide application (Fig. 1). A slight reduction in shrub density, however, produced a tremendous increase in seedling establishment. Shrubs left by the herbicide treatment showed vigorous vegetative growth and abundant inflorescences. Both green rabbitbrush and big sagebrush can dynamically respond to increased environmental potential. In contrast to wildfires, where big sagebrush is totally destroyed and the rabbitbrush root-sprouts, partial stand reductions with herbicides leave a source of achenes of both species. A vital consideration for management is how a more abundant stand of perennial grasses in the understory would dampen and moderate seedling establishment of the partially-controlled shrubs.

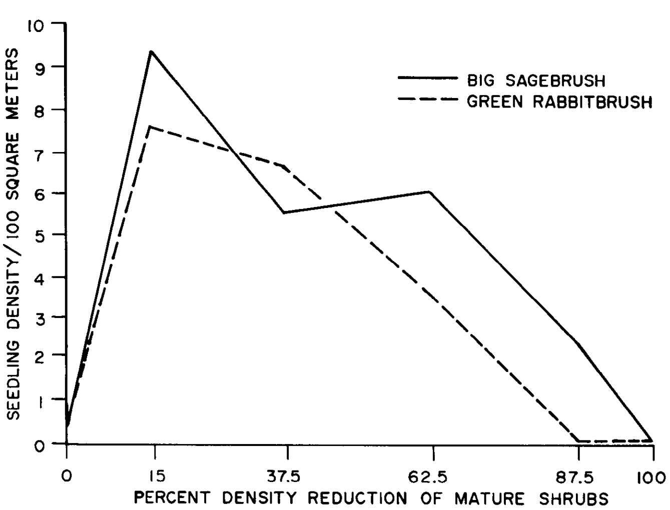

Fig. 1. *Relation between reduction of green rabbitbrush and big sagebrush densities and shrub seedling establishment.*

Spiney skeletonweed and prickly phlox increased in density by seedling establishment in areas where shrub canopy was eliminated. The increase of these native species occurred only in areas where downy brome did not increase and remnant perennial grasses were not abundant.

Complete Control of Rabbitbrush

Application of a mixture of 2,4-D and picloram eliminated all rabbitbrush and big sagebrush plants, leaving an overstory of large, widely spaced green ephedra shrubs (Table 4). The understory is a desert needlegrass (*Stipa speciosa*) community (Table 2). This area produced 670, 940, 1,150, 1,320 kg/ha of herbage in 1969 through 1972, respectively. The herbage production may seem relatively low, but this production is attained on a site with a maximum of 250 mm of precipitation and on soils without argillic horizons.

Requirements for Perennial-Grass Understory to Limit Green Rabbitbrush Dynamics

The site treated with the mixture of 2,4-D and picloram is the only successful conversion from brush to perennial-grass dominance at Medell Flat. The perennial-grass density (2.5 plants/m^2) that existed in the area before application of the herbicide should provide an indication of the minimum density required to use environmental potential released by brush removal and therefore to prevent seedling establishment of brush species. Using the 2.5 plants/m^2 density as a minimum figure, 75% of the stands we sampled at Medell Flat do not have sufficient remnant perennial grasses to warrant spraying herbicides as a stand renewal process (Fig. 2). Economic evaluation would be required to determine if the remaining 25% could be improved through the use of herbicides. The dampening by perennial grasses of large increases in density of green rabbitbrush is a key factor in the population dynamics of this species.

Discussion

Dominance of green rabbitbrush in successional communities on sites where big sagebrush stands were destroyed by fire or through the use of herbicides is contingent on root-

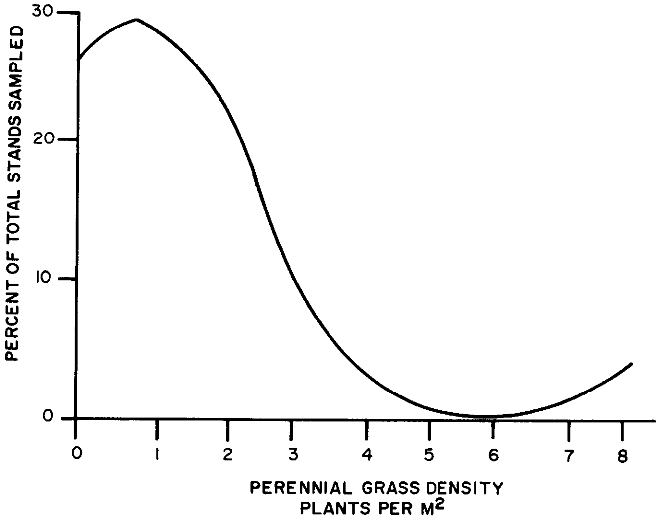

Fig. 2. *Mean density of perennial grasses of stands sampled in relation to minimum density required to occupy site.*

sprouting of green rabbitbrush plants, which provides a source of achenes and an increase in seedbed potential for seedling establishment. The major point of this investigation is that the dominant successional role of rabbitbrush is not simply a product of vegetative sprouting, but is the result of dynamic achene production and seedling establishment. A delay is required after disturbance for achene production and then a season for peak seedling establishment, as evidenced by a dominant age class in seral stands. The delay period is the time for action by land managers if a stable perennial-grass-dominated community is desired. Seedling establishment does not cease after the peak year, but most of the available environmental potential is used by plants from the initial flush of establishment.

Manipulation of these plant communities by land managers is a study of seedbed potentials. Even big sagebrush has dynamic seedling establishment following a partial reduction of stand density. This has importance to land managers who wish to reduce, but not eliminate, the density of sagebrush. In degraded communities that we investigated, partial stand reduction greatly increased seedling establishment of big sagebrush and green rabbitbrush.

An adequate perennial-grass understory is a dampening influence on extreme seedling establishment by shrubs or annual weeds. If the remnant perennial grasses are not present, the land manager must manipulate both the shrub layer and the herbaceous vegetation in terms of competition reduction and seedbed preparation. This involves vertical integration of herbicide treatments for herbaceous fallow and shrub control or the development of a single herbicide that solves both weed control problems.

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Meadow Forage Quality, Intake, and Milk Production of Cows

C. L. STREETER, C. B. RUMBURG, T. H. HALL, AND E. G. SIEMER

Highlight: *A native mountain meadow was grazed by cows through the summer and fall of 1970 near Gunnison, Colorado. Nutrient concentration and in vitro digestibility were measured from forage samples collected from esophageally-fistulated cows. Total fecal excretion was estimated by the Cr_2O_3 dilution technique. Forage consumption was calculated from digestibility and fecal-excretion data. Milk production of cows was determined at biweekly intervals by measuring calf weights before and after nursing, followed by machine milking.*

The cell-wall constituent (CWC) content of the diet increased from 47.2 to 62.1% from mid-June to mid-October. CWC digestibility decreased from 72.8 to 52.3% during the same period. The nitrogen concentration of the diet decreased from 3.1 to 1.2%; whereas the nitrogen concentration in standing forage decreased from 3.8 to 1.4%. Dry-matter consumption averaged 14.7, 12.0, 10.5, and 10.3 kg per day, and mean milk production was 6.0, 4.4, 4.0, and 3.0 kg in 14 hours for Brown Swiss, Charolais × Angus, and San Juan Basin and Commercial Hereford cows, respectively. Daily dry-matter consumption did not change significantly as the season advanced. Daily milk production declined from 5.7 in April to 2.0 kg in November. Animals selectively grazed bluegrass regrowth on drier sites, leaving abundant sedge growth on lightly-grazed wet sites. This grazing pattern resulted in high dietary nutrient levels throughout most of the season.

An increase in cell-wall constituents (CWC) and a decrease in digestibility and nitrogen concentration in the diet of grazing cows with advancing season is typical of the decrease in forage nutritive value with advancing plant maturity (Streeter et. al., 1968; Bedel, 1971). However, forage available to cattle grazing irrigated meadows is in many stages of initial growth and regrowth, and thus the nutritive value of the diet depends on the forage selected by the grazing cows.

Furr and Nelson (1964) found that milk produced by beef cows was positively related to level of nutrients consumed, and negatively related to advancing lactation. They also found a high correlation between the weaning weight of calves and milk production of the dam.

This study was conducted to determine seasonal changes in nutritive value of forage consumed and the amount of milk produced by four breeding groups of cows grazing native mountain meadows. Hall (1971) documented differences in calf production among the four breeding groups.

Materials and Methods

The experimental area was located 6 miles north of Gunnison, Colo., at an elevation of 2,438 m. The vegetation consisted of sedges (*Carex, Eleocharis*), rushes (*Juncus*), grasses (*Poa, Hordeum, Agropyron, Phleum, Deschampsia*), clovers (*Trifolium*), and numerous forbs. Grasses predominated on dry sites, and sedges on wet sites. The meadow was fertilized with 112 kg/ha of nitrogen in May, 1970, and was irrigated intermittently during the season.

Animals grazed 5.7 ha of meadow from June 6 to July 10, 1970, at which time they were allowed to graze an additional 2.75 ha of meadow until November 8.

Dietary samples were obtained from three esophageally-fistulated dry cows: two 2-year-old Herefords and one 4-year-old Charolais × Angus. Samples of grazed forage were obtained during four periods: June 16-21, July 26-31, September 8-13, and October 18-23. The forage collections were made each morning during 30- to 45-minute grazing periods on each of six days per trial. Fecal excretion and milk production was measured from twelve 4-year-old cows from four breeding groups (3 Brown Swiss, 3 Charolais × Angus, 4 linecross purebred Herefords from the San Juan Basin Research Center, and 2 commercial Herefords).

Fecal excretion was estimated using chromic oxide (Cr_2O_3) as an external indicator. One capsule containing 10g Cr_2O_3 suspended in oil was administered orally with a balling gun each morning and evening for 16 days/trial. Rectal grab samples of the feces were collected twice daily at the time of Cr_2O_3 administration during the last 6 days of each trial. Daily samples for each animal were composited for the 6 days and stored in the frozen state until after the trial.

Dietary and fecal samples were dried at 50°C and ground through a 1.0-mm screen. Dietary samples were analyzed for total nitrogen by Kjeldahl and for cell-wall constituents (CWC) by the procedure of Goering and Van Soest (1970). Fecal samples were analyzed for CWC (Goering and Van Soest, 1970) and chromic oxide (Williams, David, and Iismaa, 1962).

Digestibility of the CWC in the dietary samples was established in vitro as described by Scales (1972). Inoculum was obtained from a steer on a daily diet of grass hay, 454 g of supplemental soybean meal, and free-choice trace-mineralized salt. In vivo digestibility was predicted from in vitro digestibility, as described by Streeter et al. (1971). Total dry-matter (DM) consumption was calculated as follows:

$$\text{DM consumed} = \frac{(\text{Fecal DM excretion} \times 100)\ \ (\%\ \text{Fecal CWC})}{(100 - \%\ \text{In vivo dig. CWC})\ \ (\%\ \text{Dietary CWC})}$$

Milk production was measured every 14 days, beginning April 30 and ending November 8. In the evening before the day of milk collection, cows were injected with 2 ml oxytocin, and the udders were evacuated with a milking machine. Cows were turned into pasture overnight, and the calves were penned nearby with access to hay and water. At 7:00 am on collection day, each calf was weighed and then allowed to

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Table 1. Seasonal changes in cell-wall constituents (CWC, %), in vitro digestibility (%) of CWC, and nitrogen (%) in diets of cows grazing native meadows.

	Diet characteristic		
Time period	CWC	In vitro CWC digestibility	Nitrogen
June 16-21	47.2	72.8	3.07
July 26-31	55.8	58.4	2.37
Sept. 8-13	59.7	53.3	1.67
Oct. 18-23	62.1	52.3	1.20
Mean[1]	56.2 ± 0.4	59.2 ± 2.8	2.08 ± 0.03

[1] Mean ± S.E.

nurse. When the calf finished nursing, it was reweighed. The cow was injected with 2 ml of oxytocin and milked dry by machine. Milk production was estimated as the increase in calf weight plus weight of milk collected by milking machine.

Herbage samples were collected weekly from 1-m^2 quadrats within 6 m square. Samples were analyzed for dry-matter and total nitrogen (A.O.A.C., 1960). Phosphorus was determined according to the procedure of Bolin and Stamberg (1944), and color was developed according to the procedure of Barton (1948), except that the $(NH_4)_6Mo_7O_{24}$ solution used was 0.25% (W/V) rather than 0.40%.

Data were analyzed by analysis of variance. Standard errors of the means were computed for all data, and some means were compared by Duncan's multiple-range test.

Results and Discussion

From mid-June until mid-October, CWC concentration of the diet increased from 47.2% to 62.1%; digestibility of the CWC decreased from 72.8% to 52.3%; and nitrogen concentration decreased from 3.07% to 1.20% (Table 1).

Nitrogen concentration of standing herbage decreased with time. The decrease was more pronounced in herbage from wet sites than in herbage from dry sites (Fig. 1). Changes in phosphorus concentration in the herbage (not shown) paralleled nitrogen concentration. Mean percent P in herbage was 0.287 (*SE* = 0.007) and 0.267 (*SE* = 0.006) from dry and wet sites, respectively.

It was observed that cows preferred to graze the dry sites, and they grazed them continuously throughout the study period. This grazing pattern is evidenced by the similarity in nitrogen concentrations of dietary samples (Table 1) and herbage samples from dry sites (Fig. 1). Intensive grazing left little forage on the dry sites on any date (Fig. 2), and immature forage was relatively high in nitrogen, even late in the season. Grazing intensity was not severe enough to prevent abundant herbage accumulation on wet sites, with a concomitant dilution of nitrogen and phosphorus concentrations.

Table 2. Seasonal changes in dry-matter consumption (kg/day) of cows grazing native meadows.

	Breeding groups			
Trial period	Brown Swiss	Charolais × Angus	San Juan Basin Hereford	Commercial Hereford
No. of animals	3	3	4	2
June 16-21	14.1	12.7	12.5	11.8
July 26-31	15.0	11.7	10.1	10.2
Sept. 8-13	13.9	11.5	9.8	9.5
Oct. 18-23	15.8	12.1	9.8	9.8
Mean[1], [2]	14.7^a	12.0^{ab}	10.5^b	10.3^b

[1] S.E. = 1.01.

[2] Means with the same superscript do not differ from each other at 0.05 probability.

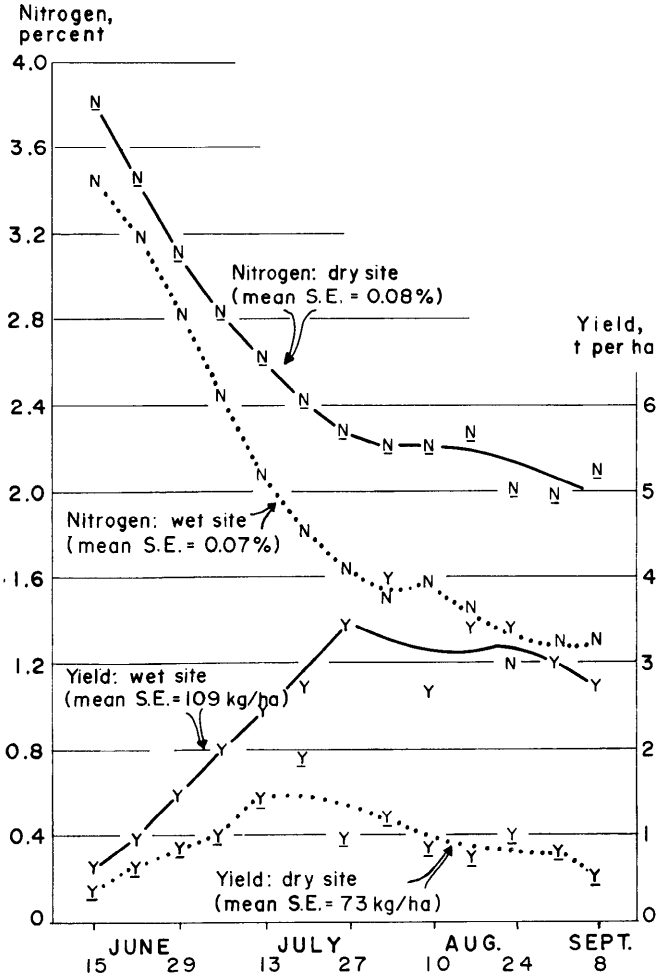

Fig. 1. *Seasonal changes in percent nitrogen and yield of herbage in tons/ha from six dry sites used intensively, and ten wet sites used late and only moderately.*

Brown Swiss cows consumed an average of 14.7 kg of dry-matter per day (Table 2), which was significantly greater ($P < 0.05$) than that for San Juan Basin (10.5 kg/day) and commercial Herefords (10.3 kg/day), but not significantly greater than that for Charolais × Angus (12.0 kg/day). Dry matter consumption for Brown Swiss and Charolais × Angus did not decrease as the season advanced. Commercial and San Juan Basin Herefords consumed less dry-matter as the season advanced, but the decrease in intake was not statistically significant ($P > 0.05$).

Many workers have shown that cows decrease their voluntary intake as forage becomes more mature. However, Raymond (1969) has pointed out that different forage species at the same level of digestibility may be eaten in quite different amounts. It has further been shown that forages very low in crude protein limit digestion and, hence, intake (Raymond, 1969). The critical level of protein is commonly in the range of 4 to 6%. However, protein in the diet of cows grazing native meadows was never less than 7.5%. In fact, protein values in hand-clipped samples never dropped below 7.5%. Protein intake exceeded recommended requirements (NRC, 1970) throughout the season, with the possible exception of the October period, and even then protein may have been adequate, considering the low level of milk production.

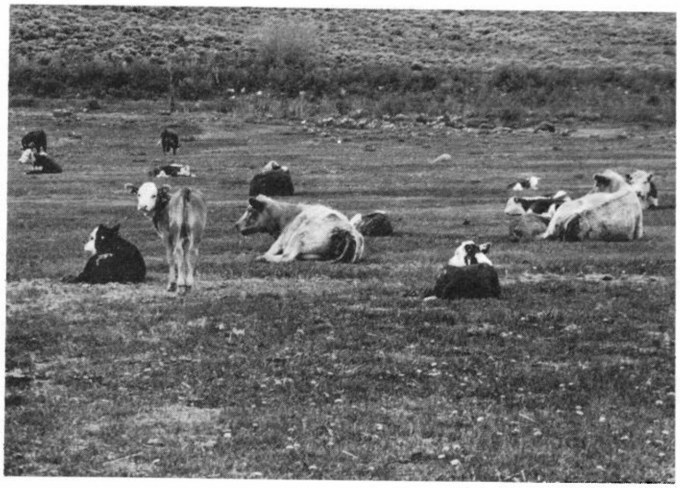

Fig. 2. *Cows and calves resting on a bluegrass meadow site in early June.*

Table 3. Milk collected (kg) from four groups of cows after 14 hours (overnight) separation from their calves.

	Breeding groups				
Date of milk collection	Brown Swiss	Charolais × Angus	San Juan Basin Hereford	Commercial Hereford	Mean[1]
April 30	7.5	6.1	5.5	4.0	5.7
May 14	5.2	4.7	4.6	3.4	4.4
May 28	7.3	6.0	4.6	4.9	5.7
June 18	8.1	6.0	5.6	4.2	5.9
July 2	7.4	6.5	5.3	3.8	5.7
July 16	6.5	4.3	4.1	3.4	4.5
July 30	6.5	4.2	4.6	3.0	4.5
Aug. 13	6.7	4.7	4.0	2.5	4.4
Aug. 27	6.3	4.2	4.1	2.8	4.3
Sept. 9	5.1	4.9	4.6	3.2	4.4
Sept. 24	4.8	2.6	3.0	2.2	3.1
Oct. 8	5.2	3.8	3.1	2.7	3.7
Oct. 22	3.9	2.8	1.8	1.6	2.5
Nov. 8	3.7	2.0	1.3	1.3	2.0
Mean[2]	6.0^a	4.4^b	4.0^b	3.0^c	

[1] S.E. = 0.34.

[2] Means with the same superscript do not differ from each other at 0.05 probability.

Dry-matter intake estimates averaged 145, 141, and 125 $g/W^{3/4}$ (3.1, 3.2, and 2.8% of body weight) for Brown Swiss, Charolais × Angus, and the two groups of Herefords, respectively. Intake values appear to be slightly high, except for Herefords. High intake values would have resulted from overestimation of feces or underestimation of digestibility.

Brown Swiss cows produced an average of 6.0 kg milk/14-hour period (Table 3). Charolais × Angus and San Juan Basin Herefords produced 4.4 and 4.0 kg/14-hour period, respectively, which was significantly lower than Brown Swiss but not different from each other. Commercial Herefords produced 3.0 kg milk/14-hour period, which was significantly lower than all other groups. All cows produced less milk as the season advanced, with no significant differences in the rate of decline among the different groups.

Milk production fluctuated considerably during early lactation. Cows reached peak milk production about June 18, which averaged 60 days after calving. Abadia and Brinks (1972) reported beef cows reached peak production 30 to 45 days after calving; whereas, Gifford (1953) reported maximum milk yield between 30 and 60 days after calving. Decline in milk production was continuous after June 18. When calves reached 120 days of age (mid-August), there was essentially no residual milk in any of the breeding groups after nursing. However, calves may have consumed all their dam's milk before 120 days of age when allowed to run with the dams.

Conclusions

1) Continuously grazed irrigated meadows produced forage sufficiently high in nitrogen concentration to meet recommended protein levels for lactating cows throughout the grazing season.

2) There was little or no decline in dry matter intake as the season progressed, which we attribute to the relatively high nutrient concentration in regrowth forage on bluegrass sites and abundant forage available on lightly grazed, wet sites.

3) Conclusions concerning differences among breeding groups must be regarded as tentative because of limited numbers. In general, Brown Swiss weighed more, had a higher daily intake, and produced more milk than the other three groups. Charolais × Angus and the two groups of Herefords had about the same mature weights, but the data suggest the possibility that the crossbred cows had a higher daily intake and produced slightly more milk than the Herefords. There was essentially no difference between the two groups of Herefords.

4) Continuous grazing of the meadow could eventually reduce the vigor of bluegrass because of heavy pressure on bluegrass sites.

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Production of Cow-Calf Herds: Effect of Burning Native Range and Supplemental Feeding

W. G. KIRK, E. M. HODGES, F. M. PEACOCK, L. L. YARLETT, AND F. G. MARTIN

Highlight: *Two grazing trials of 4 and 6 years' duration were conducted to determine the effect of burning unimproved range and limited supplemental feed during the fall and winter on productivity of cow-calf herds. In a 4-year trial, burning one-fourth of the range in November and an additional fourth in January increased weaned calf production from 56% to 75% and calf gain per cow from 84 kg to 106 kg over cows on unburned range. Burning one-half the range plus supplemental feeding of either cane molasses, fresh sugarcane, or cottonseed pellets resulted in a weaned calf crop of 67%, 72%, and 77%, respectively, and yearly calf production of 102 kg, 111 kg, and 117 kg/cow. In another trial of 6 years' duration, one-half of each 64.8 ha experimental range was burned each fall and winter. Supplemental feeds given the five lots were: none, oranges, grapefruit, grapefruit plus cottonseed pellets, and citrus pellets. The average weaned calf crop for the five lots was 61% (unsupplemented), 62%, 72%, 69%, and 68%. The yearly calf production/cow was 107 kg, 111 kg, 128 kg, 122 kg, and 122 kg, respectively. Supplemental feeding increased calf production, but differences were not statistically significant because of too few animals. Supplemental feeding did not offer a reasonable return over burning alone when cost of feed and labor involved were considered.*

Native forage has been important to the beef cattle industry of Florida since Ponce de Leon brought the first cattle from Cuba 450 years ago. Univ. of Fla. Dare Report (1965) stated that in 1963 over 2.24 million ha of unimproved land was grazed by beef cattle and that in addition there was limited grazing on over 2 million ha of timber land. Native grasses contribute to the total 12-month forage program in many cow-calf operations. The most common vegetation on cut-over land of south and central Florida is pineland threeawn (*Aristida stricta*), more commonly known as wiregrass, and saw palmetto (*Serenoa repens*). According to Hilmon and Hughes (1965) wiregrass is not the most productive or palatable species on flatwood ranges. Yarlett (1965) found that wiregrass, even when burned and grazed, is not readily replaced by creeping bluestem (*Andropogon stolonifer*) until saw palmetto is controlled. The most successful way to replace wiregrass is reducing the stand of saw palmetto by chopping followed by good grazing management. Lewis (1970) states that wiregrass is less responsive to fertilization than creeping bluestem.

Becker et al. (1933) found that the new growth after burning wiregrass from a "healthy" range (one where cattle do not develop phosphorus or other mineral deficiency diseases) contained an average of 0.18% calcium and 0.13% phosphorus. Blaser et al. (1945) showed that the seasonal average composition of unburned native range grass was 0.12% calcium, 0.04% phosphorus and 2.8% crude protein on a dry basis. They reported the seasonal average of grass from a burned range to contain 0.18% calcium, 0.06% phosphorus and 3.9% protein. Similarly, unpublished data from the Ona Agricultural Research Center showed that 39 samples of wiregrass collected from 1945 to 1950 from unburned range averaged 3.7% protein; 39 samples from an area burned every year yielded 4.6% protein. Phosphorus content of the wiregrass from the two areas averaged 0.08% and 0.09%, respectively. These data show that wiregrass from an apparently healthy range did not contain the minimum quantity of crude protein and phosphorus required to meet the nutritional needs of producing beef cows.

Hughes (1972) reported that wiregrass growth on a fine sand, imperfectly drained, low fertility south Florida soil site, 1964–1968, was less than 561 kg/ha 4 months and about 786 kg/ha 7 months after burning. Wiregrass utilization was 63%, 52%, and 46% with a stocking rate of one cow per 6.1 ha, 8.9 ha, and 14.6 ha, respectively, 7 months after burning

Wiregrass ranges are seldom if ever fertilized. Unpublished data show that fertilized wiregrass was replaced by carpet-

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grass (*Axonopus affinis*), common bahia (*Paspalum notatum*), broomsedge (*Andropogon virginicus*) and creeping bluestem during a 3-year trial, with lower cattle response compared to improved pasture species. Wiregrass is the most prevalent grass species on most native ranges in Florida in 1970.

Table 1. Average production of cow-calf herds grazing burned and unburned native range, without supplements and when supplemented with cane molasses, fresh sugarcane, and cottonseed pellets.

	Pasture treatments and supplements				
		½ pasture burned each fall and winter			
Item	No burning and no supplement (Lot 1)[1]	No supplement (Lot 2)[1]	Cane molasses (Lot 3)	Fresh sugarcane (Lot 4)	Cottonseed pellets (Lot 5)
Supplements fed daily (kg/cow)[2]	–	–	3.0	3.3	0.6
Cows/pasture	8	8	10	10	10
Hectares/cow	8.1	8.1	6.5	6.5	6.5
Initial wt (kg)	372	357	367	364	351
Final wt (kg)	324	336	346	336	347
Weight loss (kg)	48	21	21	28	4
Calves					
Birth wt (kg)	29	28	30	29	29
Calf crop (%)	56	75	67	72	77
Weaning wt (kg)	150	142	151	153	150
Prod./cow (kg)	84	106	102	111	117
Prod./ha (kg)	10.4	13.1	15.7	17.1	18.0
Mineral/cow (kg)[3]	0.21	0.18	0.16	0.17	0.16

[1] Reported by Kirk and Hodges (1970).
[2] Fed for average of 135 days annually.
[3] Daily for entire year.

Methods

Forage from unimproved Florida ranges is an important source of nutrients for beef cattle. The purpose of two grazing trials was to determine the effect of burning the native range each year and winter supplemental feed on productivity of cow-calf herds.

Three hundred and twenty-four ha of Florida unimproved flatwoods range were used in two consecutive year-round cow-calf grazing trials of 4 and 6 years duration. The area consisted mainly of Immokalee and Myakka fine sand soil types with numerous small ponds, typical of large areas of cut-over land in central and south Florida. Wiregrass predominated on the flatwoods, with several other grasses present on the higher and lower areas. Saw palmetto and scattered longleaf pine (*Pinus palustris*) characterized the experimental range area. The higher land provided the most forage in wet weather; pond areas were the most productive in dry seasons.

The area was divided into five units of 64.8 ha each to accommodate the five lots of cows used in each of the two trials. The same cows were kept on one range division during the supplemental period from November to March. All lots were put in one herd and rotated from range unit to range unit for the remainder of each year. The cows obtained all their roughage by grazing, except Lot 4 in Trial I, which were fed limited fresh sugarcane from November to March each year. The cows had free access to a mineral mixture (Becker et al., 1958) composed of 29% bonemeal, 29% defluorinated phosphate, 33.89% common salt, 3.39% red oxide of iron, 0.68% copper sulfate, 0.04% cobalt chloride, 2% cane molasses, and 2% cottonseed meal. Cow and calf weights were obtained at 28-day intervals.

Fire guards divided each 64.8 ha unit into four equal areas, and 16.2 ha in each was burned in late November and 16.2 ha in late January of each season in all areas except that occupied by Lot 1, control, in Trial I.

Trial I

Forty-six native and grade Brahman, Devon, and Hereford cows, 7 to 14 years old, were divided according to breeding, age, and weight in November 1943, into two uniform lots of 8 cows and three lots of 10 cows. There was a preliminary year, 1943-44, to accustom cows to the range treatment and supplemental feeding and a 4-year experimental period. The same cows remained on a specified winter range and feed supplement treatment throughout the 4 years of trial. Number of cows, treatment of range, and supplemental feed were as follows:

Lot 1. Eight cows on 64.8 ha unburned range, no supplemental feed.
Lot 2. Eight cows on 64.8 ha range, ¼ burned in November and ¼ burned in late January, no supplemental feed.
Lot 3. Ten cows on 64.8 ha range treated as for Lot 2 and fed limited cane molasses[1] for 135 days beginning in November.
Lot 4. Ten cows on 64.8 ha range treated as for Lot 2 and fed fresh sugarcane.
Lot 5. Ten cows on 64.8 ha range treated as for Lot 2 and fed limited cottonseed pellets.

Calves were weighed at birth. Herds 3, 4, and 5 were fed three times each week.

Trial II

Stocking rate was increased to 12 cows/64.8 ha of native range. Burning of half the range each year was practiced with all treatments, 16.2 ha in November and 16.2 ha in January of each year, the entire range area being burned each 2 years. Supplemental feeds provided from November to March for the 6 years were as follows:

Lot 1. No supplement.
Lot 2. Fresh oranges.
Lot 3. Fresh grapefruit.
Lot 4. Fresh grapefruit and cottonseed pellets.
Lot 5. Citrus pellets.[2]

Cull oranges, grapefruit, and citrus byproduct feeds were selected as they were available and low priced, although considerable labor was involved in feeding the fresh fruit. Citrus pellets consisted of 40 parts citrus meal, 35 parts citrus molasses, and 25 parts cottonseed meal. Lot 4 was fed 0.23 kg cottonseed pellets daily/cow and Lot 5, 0.91 kg citrus pellets, both receiving the same amount of high protein feed. The cows in Lots 2, 3, 4, and 5 were fed three times a week in the 142-day supplemental period.

Sixty grade Brahman and Shorthorn cows varying from 2 to 6 years of age were divided into five uniform lots of 12 cows each on November 8, 1948, and removed from the experiment on November 8, 1954. The feed supplement given the 1948-49 fall and winter had no effect on number of calves born in 1949 but would influence their growth. Cows were in a single sire herd for the 120-day breeding season. Calves were graded as slaughter animals when weaned.

Statistical analyses of calf production among the five lots and sex ratio for each year were made by using the x^2 goodness-of-fit-test. Analysis of variance was used to evaluate 205-day calf weight differences among lots.

Results and Discussion

Trial I

The effect of experimental treatment on herd performance is summarized in Table 1. Fig. 1 shows Lot 3 cows eating cane molasses. The cows on unburned

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[1] Furnished by United States Sugar Corporation, Clewiston, Florida.

[2] Furnished by Jackson Grain Company, Tampa, Florida.

Fig. 1. *Lot 3 cows, Trial I, eating cane molasses; unburned wiregrass in the background.*

Fig. 2. *Typical summer range showing cattle, wiregrass, and saw palmetto, Trial II.*

range lost the most weight in the four winter periods, those fed 0.6 kg cottonseed pellets daily lost the least.

Burning half the native range increased the average yearly calf crop percentage from 56 to 75. Lot 2 had higher quality forage during the winter from new grass growth after burning and the cattle responded with increases of 19% weaned calf crop, 2.7 kg calf weight/ha of range and 22 kg calf weight/cow compared to the control.

Feeding cane molasses or sugarcane at the higher stocking rate of 6.5 ha/cow on burned range yielded calf crops 8 and 3 percentage points lower than for the no supplemental treatment stocked at 8.1 ha/cow while cows fed cottonseed pellets had a weaned calf crop two percentage points higher. Supplemental feeding combined with burning did not significantly change the percentage of weaned calves over that of burning pasture alone.

Yearly calf production/cow was lowest on unburned range and highest on burned range supplemented with cottonseed pellets. The increase in production/ha over the control group was 26%, 51%, 64%, and 73% for Lots 2, 3, 4, and 5, respectively. The 25% heavier stocking rate, supplemental feeding, plus burning compared with burning alone increased calf gain/ha 20% for those fed molasses, 31% for cows fed sugarcane, and 37% for cows fed cottonseed pellets.

There was no indication of mineral deficiency diseases in the herd. It is calculated that the average mineral mixture (Becker et al., 1958) eaten yearly by cows in Lot 1 supplied 5.4 kg calcium, 2.4 kg phosphorus, 11.6 kg common salt, 1.2 kg red oxide of iron, 0.23 kg copper sulfate, and 0.014 kg cobalt chloride. These amounts plus the minerals in forage appeared to meet the needs of cows for these essential elements. Kirk and Davis (1970) showed that burning of pasture and supplemental feeding did not affect blood phosphorus, calcium, hemoglobin, and hematocrit values for these cows.

New growth of wiregrass after burning in March was sparse but it was not mixed with mature forage. Cows grazing unburned range were unable to separate the new spring growth of wiregrass from the mature forage, resulting in a lower nutrient intake. This occurred during the breeding season, and fewer cows grazing unburned wiregrass came into estrus. The result was a reduced weaned calf crop the next season.

Trial II

There were no cow death losses during the experiment, but two cows had to be replaced due to injury. Calf losses were 1.7%. Six-year production results are summarized in Table 2. A typical summer range is shown in Figure 2.

Cows did not consume the offered daily ration of 4.5 kg of oranges after the first few days of feeding in 1948. For

Table 2. Average production data for cow-calf herds grazing native range one-half burned each fall and winter when supplemented with oranges, grapefruit, grapefruit plus cottonseed pellets, and citrus pellets.

	Supplements fed[1]				
Item	None (Lot 1)	Oranges (Lot 2)	Grapefruit (Lot 3)	Grapefruit + CS pellets (Lot 4)	Citrus pellets (Lot 5)
Supplements fed daily (kg/cow)[1]	–	3.2	4.8	4.7 fruit 0.23 pellets	0.91
Cow/pasture	12	12	12	12	12
Initial wt (kg)	368	368	368	368	368
Final wt (kg)	445	458	429	427	459
Weight increase (kg)	77	90	61	59	91
Calves					
Calf crop (%)[2]	61	62	72	69	68
Weaning wt (kg)	175	177	178	176	179
205-day wt (kg)	172	175	176	177	176
Prod./cow (kg)	107	111	128	122	122
Prod./ha (kg)	19.8	20.6	23.7	22.6	22.5
Slaughter grade[3]	9	8	8	9	8
Mineral/cow (kg)[4]	0.06	0.06	0.06	0.05	0.05
Feed/kg calf gain increase over control (kg)	–	49	30	41 fruit 2.1 pellets	7.9

[1] Fed for an average of 142 days annually.
[2] Differences are not statistically significant.
[3] Slaughter grades: 8, High Standard; 9, Low Good.
[4] Daily for entire year.

this reason, oranges were fed in bunks, which prevented manure contamination and lessened bird damage of fruit. Essential oil in peel lowered palatability of oranges and reduced average daily consumption per cow to 3.2 kg. Two cows were observed in temporary distress from a small orange lodging in their gullet, but they swallowed the fruit within a few minutes. Grapefruit was eaten in less than two hours after feeding, even when a 3-day supply was given at one feeding.

In the 6 years the control cows averaged a 61% weaned calf crop and those fed fresh grapefruit 72%. The number of weaned calves ranged from two for Lot 2 in 1954 to 12 calves for each of Lots 2, 3, and 5 in 1951. Fifty-seven of the 60 cows weaned calves in 1951, which is unusually high for cows on native range. McCaleb and Hodges (1960) showed that moisture conditions were favorable for growth of native range species in the breeding season preceding the high calf crop.

There were no significant differences in weaning and 205-day weights in the five lots. Yearly calf gain per cow and per ha were positively correlated with number of calves weaned. Supplemental feeding of Lots 2, 3, 4, and 5 for 6 years increased calf gain per cow and per ha of range 4%, 20%, 14%, and 14%, respectively, over Lot 1 on pasture alone; a nonsignificant response because of the limited number of cows. Grapefruit supplemented fall and winter forage more adequately than either oranges, combination of grapefruit and cottonseed pellets, or citrus pellets. Average daily mineral consumption/cow ranged from 0.05 to 0.06 kg, one-third the amount eaten by the cows in Trial I.

In a later study Kirk et al. (1963) reported that 60 Shorthorn and Brahman cows were kept on this same native range, with half burned each year from 1955 to 1958. They were given winter feed of pangolagrass hay and cottonseed pellets. These cows had a 62% weaned calf crop with the calves averaging 151.4 kg at 205-days of age, equivalent to 17.4 kg yearly calf production/ha of native range and 94 kg/cow. These production results were 14% lower than for the control cows in this experiment.

The greater response of the cow herds in Trial II over Trial I, as shown by percentage weaned calf crop and production per cow and per ha of range, was due to the native and grade cows being less productive stock in Trial I and stocking of pastures at a heavier rate in Trial II.

Table 3. Average initial, final, and monthly weight (kg) of cows for 6 years (Trial II).

	Lot number					
	1	2	3	4	5	Avg
Initial weight	368	368	368	368	368	368
Final weight	445	458	429	427	459	444
November	379	390	379	376	383	381
March	395	373	370	380	379	379
June	352	370	357	384	371	367
September	370	405	386	388	404	391

The average initial, final, and seasonal weights for the 6 years are shown in Table 3. The important factors in weight change were the number of cows which nursed calves and cows pregnant in November. Average gain/cow in the 6 years was 76 kg, ranging from 59 kg for Lot 4 to 92 kg for Lot 5. Only 19 of the 60 cows nursed calves in 1954, and close observation showed that most of the cows were pregnant (no record of the 1955 calf crop), a reason for the heavier final weight. The cows were from 2 to 6 years old initially and many of them grew and matured while on experiment, another reason for the greater final weight. Each year it was apparent that the cows given feed were more thrifty than those on native pasture alone.

Conclusions

The results of the two completed cow-calf wiregrass grazing trials (1944 to 1954) have either positive or negative application to present-day conditions. It has long been recognized that new wiregrass growth after burning was sparse, palatable, and nutritious and cow-calf herds responded with increased production if the range was not over-stocked. As the wiregrass matured, cattle response was reduced, with loss in weight usually beginning in October. Wiregrass is the most prevalent forage species on the 2 million ha of Florida unimproved range, although there has been some invasion by carpetgrass, creeping bluestem, and Bahia varieties on the more fertile upland soil areas.

There is less burning of wiregrass in the present decade than 25 years earlier. On many well managed ranches wiregrass forage supplements improved pastures by providing low quality forage for cows after their calves are weaned.

High production costs and feed prices have eliminated fresh sugarcane and cottonseed pellets as supplemental feeds for range herds. Cull oranges and grapefruit were frequently fed to cattle when citrus prices were low. They are now processed for juice with bruised fruit and skins, rag, and seeds from citrus canning plants processed for cattle feed.

Two of the most important feeds available to cattlemen are products from the Florida sugar and citrus industries. Large quantities of cane molasses, frequently fortified with urea, minerals, vitamins, and antibiotics, are self-fed to grazing herds. Production of citrus feeds in 1971-72[3] was 657,843 tons of dried pulp and 47,478 tons of molasses. These energy-rich citrus products, whether fortified with either natural protein or urea, are available as winter supplemental feeds for cow-calf herds grazing wiregrass ranges or improved pastures.

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[3] Furnished by Florida Canners Association, Winter Haven, Florida.

Effect of 2,4-D on Composition and Production of an Alpine Plant Community in Wyoming

JOHN F. THILENIUS, DIXIE R. SMITH, AND GARY R. BROWN

Highlight: *Use of 2,4-D in an alpine plant community in the Medicine Bow Mountains of Wyoming almost completely eliminated* Geum rossii. *The graminoid:forb ratio of the vegetation was altered from approximately 3:7 to 8:2 without appreciably changing total standing crop or its digestible dry matter content. Resurgence of forbs could not be detected up to 4 years after treatment.*

Although the literature on herbicides is voluminous, reports of herbicide application in the alpine zone are rare. Smith and Alley (1966) reported that 2,4-D and 2,4,5-T were equally effective in reducing the density of *Geum rossii* by 98% in the alpine zone of the Medicine Bow Mountains of Wyoming. This paper reports subsequent research on herbicidal control of *Geum rossii* particularly on the effects of 2,4-D on species composition, aboveground standing crop, and digestible dry matter production of associated vegetation.

Study Location and Methods

The area studied is in a livestock-proof exclosure on Libby Flats in the Medicine Bow National Forest of southeastern Wyoming, about 64 km west of Laramie. Elevation at the site is 3,240 m (10,600 ft). The site, located on a gentle north slope, has a soil developed from glacial till. Vegetation has been classified as a *Deschampsia* meadow community by Smith (1969) (Fig. 1).

The experimental design was a randomized complete-block system with unrestricted random sampling of the experimental units. Six blocks were used. Each experimental unit was 2.4 × 4.9 m (8 × 16 ft). The sample consisted of 10 randomly selected 0.3 × 0.3 m (1 × 1 ft) quadrats in each experimental unit.

Only two treatments were used—a control (unsprayed) and spray treatment. The spray treatment was a single application of 2,4-D in the form of propylene glycol ether ester at a rate of 2.2 kg/ha (2 lb/acre). The 2,4-D plus a wetting agent was sprayed in a water solution at a total volume of 227 l/ha (20 gal/acre). Herbicide was applied in July, 1966, at the time *Geum rossii* was in early bloom.

Standing crop was determined by clipping the aboveground herbage to ground level, segregating by species, and weighing the clippings after they had been oven-dried at 105°C for 24 hours. Samples were obtained at the time of maximum standing crop (late July-early August) in 1967, 1968, and 1970 (1, 2, and 4 years after treatment).

The digestible dry matter (DDM) content of the most productive species was determined by the in vitro technique (Tilley and Terry, 1963) using rumen fluid obtained from fistulated cattle on a grain and alfalfa diet.

Analysis of variance was used to determine whether the differences between treated and untreated vegetation were statistically significant. Significance was determined at the 95% level.

Results

Composition and Standing Crop on Unsprayed Plots

Samples of aboveground standing crop were obtained from 33 species of vascular plants. Most of the standing crop was produced by a small proportion of the species present (Table 1). Average total standing crop on the unsprayed units was 135 g/m^2 (1204 lb/acre) with a range of 155 to 119 g/m^2 (1383 to 1062 lb/acre).

On unsprayed units, forbs were the predominant life-form, producing two-thirds of the total standing crop. Although 19 species of forbs were present,

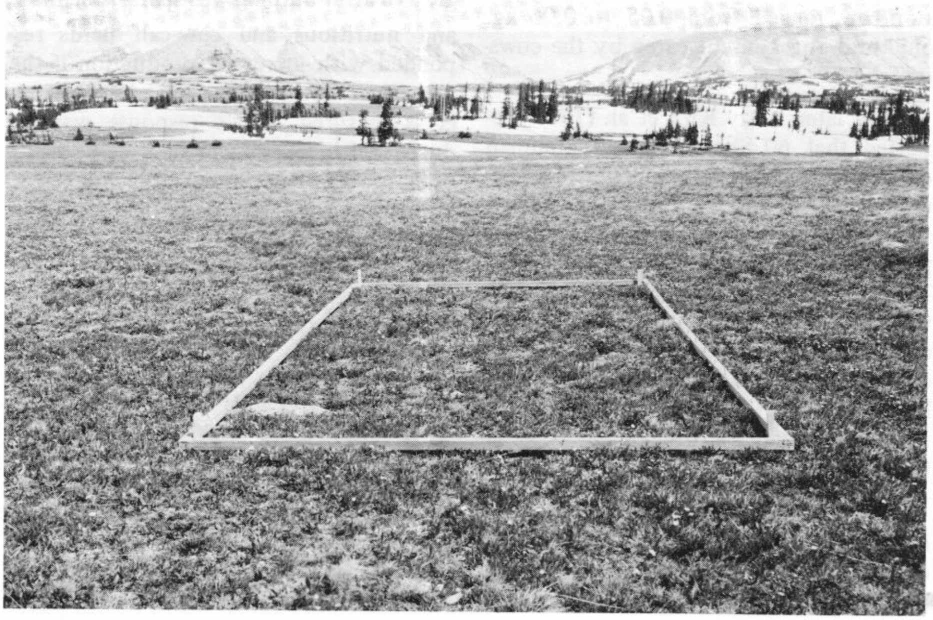

Fig. 1. *The* Deschampsia *meadow community on Libby Flats, Medicine Bow National Forest, Wyo.*

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Table 1. Standing crop (g/m^2)[1] of major species in an alpine plant community as influenced by application of 2,4-D at 2.2 kg/ha. Experimental units sprayed in July, 1966.

	1967		1968		1970	
Species	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed
Forbs						
Trifolium parryi	37	2*	31	7*	26	4*
Geum rossii	30	t *[2]	18	1*	18	0
Artemisia scopulorum	5	t *	17	1*	14	t *
Polygonum bistortoides	10	11	8	14*	6	8
Arenaria obtusiloba	8	1*	3	1*	2	3
Potentilla diversifolia	4	t *	4	t *	3	0
Achillea lanulosa	3	1	3	3	5	4
Other forb species[3]	9	2	3	t	4	4
Total forbs	106	18	87	28	78	23
Graminoids						
Deschampsia caespitosa	23	36	31	65	31	55
Poa rupicola	14	49*	5	12*	1	6*
Poa alpina	9	19*	2	3	3	8
Agrostis idahoensis	0	0	1	13*	2	8*
Festuca ovina	0	3	2	12*	1	2
Trisetum spicatum	0	0	1	5*	0	0
Other graminoid species[4]	3	3	3	4	3	6
Total graminoids	49	110	45	114	41	85
Total standing crop	155	128	132	142	119	108
Graminoid:forb	32:68	86:14	34:66	80:20	34:66	79:21

[1] All weights rounded to nearest gram; g/m^2 × 8.92 = lb/acre.

[2] t = less than 1 g/m^2, value of 0.5 g/m^2 used for calculations.

* statistically significant difference at $\alpha = 0.05$.

[3] Other forb species: *Cerastium arvense, Antennaria rosea, Solidago ciliosa, Saxifraga rhombidea, Arenaria congesta, A. rubella, Sagina saginoides, Trifolium dasyphyllum, Lewisia pygmaea, Stellaria longipes, Sedum stenopetalum, Erigeron simplex.*

[4] Other graminoid species: *Koeleria cristata, Danthonia intermedia, Agropyron scribneri, Carex ebenea, C. rossii, C. elynoides, C. obtusata, Luzula spicata.*

three species, *Trifolium parryi, Geum rossii,* and *Artemisia scopulorum*, together produced half of the total standing crop and almost 75% of the standing crop of forbs.

The most productive forb—surprisingly—and also the most productive species on the unsprayed units was *Trifolium parryi*. Although *Geum rossii* was the most visually prominent species, the standing crop of *Trifolium parryi* was 20 to 40% greater than that of *Geum rossii* during the 3 years of sampling (Table 1).

Other forbs on the unsprayed plots which produced an average of 3 g/m^2 (27 lb/acre) or more during the 3 years of the study were, in order of importance, *Polygonum bistortoides, Potentilla diversifolia, Arenaria obtusiloba,* and *Achillea lanulosa*. Together these four species accounted for about 18% of the total standing crop and 21% of the total standing crop of forbs.

Graminoids (nine grasses, four sedges, and a woodrush) as a group were much less productive than the forbs on the unsprayed plots. One grass, *Deschampsia caespitosa*, was the second most productive of all species, providing over 20% of the average standing crop and 63% of the total graminoid standing crop. Two species of *Poa* were also moderately productive on the unsprayed plots. *Agrostis idahoensis* and *Festuca ovina* were not encountered in the samples on the unsprayed plots the first year but contributed a small part of the total standing crop in subsequent years.

Carices were a minor component of the vegetation.

Composition and Standing Crop on Sprayed Plots

Application of 2,4-D significantly reduced the standing crop of most of the major forbs but had no significant effect on total standing crop. Average total standing crop on the sprayed plots was 127 g/m^2 (1133 lb/acre) with a range of 142 to 108 g/m^2 (1267 to 972 lb/acre), compared to the average of 135 g/m^2 (1204 lb/acre) produced on the unsprayed plots.

Geum rossii was almost completely eliminated. The average standing crop of this species was less than 1 g/m^2 (9 lb/acre) on the sprayed plots, compared to 22 g/m^2 (196 lb/acre) on the unsprayed plots—a difference of 98%. The fourth year after spraying, *Geum rossii* was not present on any of the 60 plots sampled.

The average standing crop of *Trifolium parryi* was also significantly reduced by 2,4-D, although this species appears to be less susceptible to the herbicide than *Geum rossii*. Average production of *Trifolium parryi* after spraying was 4 g/m^2 (36 lb/acre) or about 87% less than that on unsprayed plots.

Other important forbs significantly suppressed by 2,4-D were *Artemisia scopulorum* and *Potentilla diversifolia*, both of which were about 96% less productive on the sprayed areas. *Arenaria obtusiloba* was less severely affected by 2,4-D, showing only a 63% difference. *Achillea lanulosa* did not show a significant response to 2,4-D.

Three species of forbs, *Saxifraga rhombidea, Arenaria congesta,* and *Lewisia pygmaea,* all somewhat abundant the first year after spraying, were not encountered during subsequent sampling periods. *Luzula spicata* was common during the first two sampling periods but absent from the samples taken 4 years after spraying.

The standing crop of *Polygonum bistortoides* generally increased following spraying, but the increase was statistically significant only in the 2nd year after the herbicide was applied. *Polygonum bistortoides* was the fifth most productive species on the unsprayed plots and the third most productive on the sprayed plots. Increased production after spraying may be due to a reduction in competition from other forbs, but the apparent lack of effect of 2,4-D on the species cannot be explained from the results of this study. Hurd (1955) also found *Polygonum bistortoides* growing on subalpine ranges in the Bighorn Mountains was little affected by 2,4-D, and Ward (personal communication) noted a similar reaction on subalpine ranges in Colorado.

With the reduction in the forb component, grasses became the dominant life-form on the sprayed plots. *Deschampsia caespitosa*, the most productive grass on the unsprayed plots, became the most productive of all species on the sprayed plots. On the average, it produced 41% of the total standing crop after spraying.

Several other grasses showed significant increases in standing crop on the sprayed plots. Most important of these were *Poa rupicola, P. alpina, Agrostis idahoensis,* and *Festuca ovina*. The standing crop of *P. rupicola* was larger than that of *Deschampsia caespitosa* the 1st year after spraying but in subsequent years was less. *P. alpina* also produced its greatest standing crop the 1st year after spraying and declined in subsequent years. *A. idahoensis* and *F. ovina* were most productive 2 years after spraying.

Table 2. Mean standing crop (SC in g/m^2)[1], digestion coefficients (DC in %), and mean digestible dry matter (DDM in g/m^2) for forbs (F) and graminoids (G) on unsprayed and sprayed plots.

Plots and species	SC	DC	DDM
Unsprayed plots			
Ten major species			
Trifolium parryi (F)	31	59	18
Deschampsia caespitosa (G)	28	58	16
Geum rossii (F)	22	42	9
Artemisia scopulorum (F)	12	58	7
Polygonum bistortoides (F)	8	63	5
Poa rupicola (G)	7	61	4
Poa alpina (G)	5	61	3
Arenaria obtusiloba (F)	4	45	2
Potentilla diversifolia (F)	4	60	2
Achillea lanulosa (F)	3	70	2
Subtotal (10 species)	124		68
Other graminoids (10 species)	5	62[2]	4
Other forbs (11 species)	6	60[2]	3
Total (31 species)	135		75
Sprayed plots			
Ten major species			
Deschampsia caespitosa (G)	52	58	30
Poa rupicola (G)	22	61	13
Polygonum bistortoides (F)	11	63	7
Poa alpina (G)	10	61	6
Agrostis idahoensis (G)	7	62	4
Festuca ovina (G)	6	47	3
Trifolium parryi (F)	4	59	2
Achillea lanulosa (F)	3	70	2
Trisetum spicatum (G)	2	70	1
Arenaria obtusiloba (F)	2	45	1
Subtotal (10 species)	119		69
Other graminoids (8 species)	5	62[2]	3
Other forbs (13 species)	3	60[2]	2
Total (31 species)	127		74

[1] All weights rounded to nearest gram; g/m^2 × 8.92 = lb/acre.

[2] Mean value for all species.

Trisetum spicatum occurred in the sample only in the second sampling period, but at this time it was abundant enough to be included among the most productive species on the sprayed plots.

Generally, the effect of 2,4-D on composition was relatively consistent and long-lived. Graminoid:forb ratios (G-F) based on the percentage contribution of these life-form groups to total standing crop changed little on sprayed plots. Spraying with 2,4-D altered the mean G:F to 81:19 with a range of 79:21 to 86:14. Concomitant variation in total standing crop on the sprayed plots was 142 g/m^2 to 108 g/m^2 (1267 to 963 lb/acre). The mean G:F for unsprayed plots was 33:67 with a range of only 32:68 to 34:66 for the 3 years of collection. During this period total standing crop varied from 155 g/m^2 to 119 g/m^2 (1383 to 1062 lb/acre).

Production of Digestible Dry Matter

Digestible dry matter (DDM) was determined for the 10 most productive species in each treatment (Table 2). On the unsprayed plots, three grasses and seven forbs produced an average of 90% of the total standing crop, or 124 g/m^2 (1106 lb/acre). Of this amount, 68 g/m^2 (607 lb/acre) was calculated to be DDM for an average DDM content of 56%. On the sprayed plots the 10 most productive species included six grasses and four forbs. They produced 94% of the total herbage or 119 g/m^2 (1062 lb/acre). The average DDM content of this herbage was 69 g/m^2 (616 lb/acre) or 59%. Differences in DDM and total standing crop were statistically and practically nonsignificant.

Discussion

The use of 2,4-D altered the composition of the community from a forb-dominated vegetation to one dominated by grasses. The G:F ratio succinctly summarizes the effects. Spraying of this herbicide changes the G:F from approximately 3:7 to 8:2 without appreciably altering the total standing crop or DDM produced by the community.

However, just because the conversion is feasible does not necessarily mean it is desirable. From the standpoint of forage production for large herbivores, either wild or domestic, there appears to be little justification for conversion. Lack of increase in standing crop or DDM is sufficient in itself to question the usage of the herbicide since the grazing capacity of the community is not increased.

The change in the relative proportions of graminoids and forbs also offers little advantage. While the diet of large herbivores on alpine range has had little quantitative study, available evidence indicates forbs are an important component.

Strasia et al. (1970) found *Trifolium* spp. and *Geum rossii* accounted for 32% of the diet of free-ranging sheep grazing alpine ranges in northwestern Wyoming. Forbs as a group comprised 66% of the diet in early summer (July) and 31% in late summer (August). *Trifolium* spp. and *Geum rossii* are markedly reduced by 2,4-D.

The decrease of *Trifolium parryi* is particularly important. Hamilton (1961) showed this species to be high in crude protein, carotene, and calcium and low in crude fiber; it was an excellent source of carotene for a considerable period after maturity. The mean digestibility coefficient of 59% established in this study shows it to have a relatively high content of DDM in mid-summer. Therefore, the loss of approximately 85% of the *Trifolium parryi* could considerably diminish the overall nutritive quality of the forage resource.

In some instances, increased grass production may be desirable on alpine ranges. In the latter part of the growing season, after many forbs have dried, grasses generally predominate the diet of grazing animals. Converting certain areas to grass dominance and reserving them for late-season use should increase the available usable forage at that time.

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Control of Annual Grasses and Revegetation in Ponderosa Pine Woodlands

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Highlight: *Application of 1.12 kg/ha of the herbicide atrazine sufficiently controlled medusahead or downy brome to permit establishment of perennial wheatgrass in ponderosa pine woodlands previously burned in wildfires. Fall application of atrazine greatly improved survival of ponderosa pine or bitterbrush seedlings transplanted to plots the following spring. Bitterbrush seedlings established naturally in areas treated with atrazine. Apparently the herbicide treatment created a desirable habitat for seed caching by rodents, along with reduction of competition from annual grasses. Higher rates of atrazine controlled most herbaceous vegetation and resulted in greater growth of ponderosa pine seedlings. Failure to establish perennial grasses resulted in reinvasion by annual grasses.*

Our purpose was to control annual grasses and permit establishment of desirable perennial grasses, browse species, and/or conifer transplants in burned woodlands.

Small roadside fire areas in ponderosa pine (*Pinus ponderosa*) woodlands often become dominated by alien annual-grass communities. These annual-grass communities often become chronic ecologic sores, where highly inflammable fuel accumulates, contributing to repeated burning and burning of larger areas. The cycle should be prevented by immediate seeding of the burned area to perennials that will prevent dominance by the annual grasses. However, once the annuals are established, competition must be reduced before desirable perennial grasses, browse species, and/or trees can be established. On sites marginal for conifers, a combination of all three is often desirable.

Methods

Experimental Locations

Studies were conducted at two locations in Modoc National Forest in northeastern California. Both sites, Adin Pass and Baggett Gulch, are located on Adin Mountain Range between Adin and Canby, Calif., and both were burned in the same large wildfire. The sites have contrasting soils, aspect, pre-burn vegetation, and annual-grass communities.

The Adin Pass site is a steep south-facing slope with a very heavy vertisol-clay soil overlying ash beds. The clay soil supported an open ponderosa pine/western juniper (*Juniperus occidentalis*) woodland, with a few trees of California black-oak (*Quercus kelloggii*) and Douglas fir (*Pseudotsuga menziesii*). Jeffrey pine (*Pinus jeffreyi*) occurs sympatrically with ponderosa pine. On adjacent unburned areas, the understory is composed of low sagebrush (*Artemisia arbuscula*) and bitterbrush (*Purshia tridentata*). The herbaceous vegetation is dominated by Sandberg bluegrass (*Poa secunda*), in association with a host of native broadleaf species. After the burn, medusahead (*Taeniatherum asperum*) invaded to the virtual exclusion of other species.

The second site, Baggett Gulch, is located on a north-facing slope with a silt-loam soil highly influenced by ash. This site supported a relatively dense ponderosa pine stand before burning. Under the pine canopy, prostrate ceanothus (*Ceanothus prostratus*) was the dominant shrub. Small parks in the pine stands were occupied by big sagebrush (*Artemisia tridentata*). Columbia needlegrass (*Stipa columbiana*) and pine bluegrass (*Poa scabrella*) dominated the herbaceous vegetation.

After burning, this site was invaded by downy brome (*Bromus tectorum*). Restriction of medusahead to clay soils is typical of this area (Young and Evans, 1970). This site was planted with ponderosa pine seedlings after the initial salvage logging. Apparently, annual-grass competition and browsing damage have reduced survival and growth of these trees.

Herbicide Treatments

Herbicides were applied at Adin Pass in October, 1966, in 280 liters of water per hectare. In 1967 and 1968 at Adin Pass, and in 1968 and 1969 at Baggett Gulch, we applied the herbicides in water with a low volume of 93.5 l/ha. At both locations in all years, treatments were applied to 6- by 6-m plots arranged in a randomized-block design with four replications, except at Baggett Gulch, where three replications were used.

Adin Pass – We applied atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine) at 0.56, 1.12, 1.68, and 2.24 kg/ha in October, 1966. Annual grasses had not germinated, and the soil surface was dry. In October, 1967 we repeated all rates of atrazine except 0.56 kg/ha, on separate areas. In 1968, atrazine and simazine (2-chloro-4,6-bis(ethylamino)-*s*-triazine) was applied at the same rates used in 1967.

Baggett Gulch – We applied 1.12, 2.24, 4.48, and 8.96 kg/ha of atrazine on separate plots in October, 1968, and May, 1969.

Seeding and Planting

Areas treated with herbicides at Adin Pass in 1966 and 1967 were seeded the fall after the treatment by hand-furrowing and drilling in the bottom of furrows with intermediate wheatgrass (*Agropyron intermedium* var. 'Amur'.). Areas that received the 1968 herbicide treatments were not seeded.

In the early spring of each year, plots that had been sprayed with herbicide the previous fall and control plots were planted with 2-year-old, nursery-grown ponderosa pine seedlings. The seedlings, grown from seed collected locally, were planted with 1-m spaces between trees. Six bitterbrush seedlings per plot were planted along with the pine seedlings. The bitterbrush seedlings were 10 to 15 cm tall when transplanted.

The experimental plots at Baggett Gulch were not seeded to grass or planted with bitterbrush. Pine seedlings were transplanted in the spring of 1969 to plots that had been sprayed with herbicide in October, 1968, and to plots that had been sprayed soon after planting.

Sampling

We annually clipped m^2-plots in each treatment at Adin

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Table 1. Herbage yield (kg/ha)[a] of medusahead, perennial grasses, and forbs during fallow year at Adin Pass. Mean production for fallow years 1967 through 1969, except for the atrazine rate of 0.56 kg/ha, which is for 1967 only.[b]

Atrazine (kg/ha)	Herbage yield			
	Medusahead	Perennial grasses[c]	Forbs[d]	Total
Control	450a	20	50b	520a
0.56	160b	20	70b	250b
1.12	0c	30	140a	170c
1.68	0c	10	60b	70d
2.24	0c	10	60b	70d

[a] One lb/acre equals 1.12 kg/ha.

[b] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple range test. All comparisons are made vertically.

[c] No significant differences existed among yields of perennial grasses.

[d] Forbs growing on atrazine-treated areas are primarily bindweed (*Convolvulus polymorphus*) and turkey mullein (*Eremocarpus setigerus*).

Pass to determine the influence of the herbicide treatment on herbage production. Step-point sampling (Evans and Love, 1957) was done each year at both locations. The number and height of surviving pine and bitterbrush seedlings were determined annually.

Results

Adin Pass

Responses of annual-grass communities to application of atrazine can be predicted with a high level of precision (Evans et al., 1969). Plots sprayed with 1.12 kg/ha or more of atrazine at Adin Pass were free of annual grasses the fallow year (Table 1). At lower elevations in the sagebrush zone, the atrazine-treated areas would be completely bare in the fallow year, but in the woodland on Adin Mountain the native bindweed (*Convolvulus polymorphus*) persisted or increased on atrazine-treated areas. Turkey mullein (*Eremocarpus setigerus*) became established late in summer (Table 1). Atrazine applied at 1.68 and 2.24 kg/ha reduced the perennial-grass stand. It is difficult to predict the influence of atrazine on established perennial grasses. There is no apparent physiological selectivity between annual and perennial grasses involved, but the relatively insoluble atrazine may not be leached to the deeper rooting zone of the perennial grasses. Various combinations and interactions of soil, moisture, slope, and species of perennial grass may result in no injury or incomplete mortality from application of 1.12 kg/ha of atrazine. Orchardgrass (*Dactylis glomerata*) was among several exotic perennial grasses previously established on the burn at Adin Pass. Plants of this species survived on plots sprayed with 2.24 kg/ha of atrazine.

The biomass of vegetation the fallow year was reduced from 520 to 70 kg/ha by applying 1.68 kg/ha of atrazine (Table 1). This reduction conserved moisture and nitrate, providing a desirable environment for the establishment of perennial wheatgrasses the following year (Evans et al., 1969; Eckert et al., 1970). Three years after spraying atrazine at 1.12 or 1.68 kg/ha, and 2 years after the areas were seeded, perennial-grass production was 13 to 16 times as high on sprayed plots as on control areas (Table 2). Medusahead reinvaded the intermediate wheatgrass stands, but this annual grass was greatly suppressed by the established perennial grasses.

When a high rate of atrazine (2.24 kg/ha) was applied, too much herbicide activity persisted after 1 year of fallow to allow establishment of wheatgrasses (Evans et al., 1969). However, a period of more than 1 year of herbicidal activity may be an advantage for growing trees or browse species.

Table 2. Herbage yield (kg/ha) in 1970 of medusahead, perennial grasses, and forbs on plots at Adin Pass 2 years after seeding and 3 years after atrazine application.[a]

Atrazine (kg/ha)	Herbage yield			
	Medusahead	Perennial grasses	Forbs	Total
Control	360a	40c	30b	430c
0.56	400a	20c	80a	500b
1.12	30b	520a	10c	560b
1.68	20b	640a	10c	670a
2.24	10b	140b	60a	210d

[a] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple-range test. All comparisons are made vertically.

Table 3. Survival (%) and height (cm) of pine and bitterbrush seedlings and number (per 36 m²) of naturally established bitterbrush seedlings on Adin Pass in 1972. Atrazine applied in 1966; trees and bitterbrush transplanted in 1967.[a]

Atrazine (kg/ha)	Pine seedling height	Survival		Density of naturally established bitterbrush seedlings[b]
		Pine	Bitterbrush	
Control	30c	8b	9b	0
0.56	40bc	18b	0b	0
1.12	60b	90a	96a	2
1.68	65ab	88a	86a	3
2.24	75a	96a	98a	6

[a] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple range test. All comparisons are made vertically.

[b] No significant differences existed among densities of bitterbrush seedlings.

Table 4. Percentage survival and mean height (cm) of pine seedlings at Baggett Gulch 2 years after planting.[a]

Atrazine (kg/ha)	Spring application of atrazine		Fall application of atrazine	
	Survival[b]	Height	Survival	Height
Control	20	10b	20b	18c
1.12	18	18b	80a	43b
2.24	30	18b	90a	40b
4.48	24	20b	90a	56b
8.96	40	45a	95a	78a

[a] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple range test. All comparisons are made vertically.

[b] No significant differences existed among survival percentages of pine seedlings treated with spring-applied atrazine.

Establishment of pine or bitterbrush transplants was greatly increased by applications of 1.12 kg/ha of atrazine (Table 3). We failed to establish bitterbrush transplants on plots sprayed with 0.56 kg/ha of atrazine or on check plots. Applications of atrazine greater than 1.12 kg/ha did not significantly increase survival of trees or bitterbrush. Almost all mortality of pine and bitterbrush seedlings on control or 0.56 kg/ha of atrazine treatments occurred during the first summer after transplanting. Transplants on plots with higher rates of atrazine either disappeared apparently from rodent activity (Crouch, 1971), or were heavily browsed by deer.

The high rates of atrazine (1.68 and 2.24 kg/ha) did not increase survival of pine or bitterbrush transplants, but five years after establishment, trees growing on plots that had been sprayed with 2.24 kg/ha of atrazine were significantly taller than those on check plots or on plots sprayed with 1.12 kg/ha

Table 5. Frequency (%) and cover (%) of herbaceous vegetation in 1972 in relation to atrazine application of October, 1968, at Baggett Gulch.

Atrazine (kg/ha)	Percent frequency						Herbage cover
	Downy brome	Mountain brome	Columbia needlegrass	Bluebunch wheatgrass	Dogbane	Goldenrod	
Control	35	40	5	10	5	5	30
1.12	75	10	2	3	7	3	28
8.96	3	2	5	1	84	5	8

of atrazine (Table 3).

There was a great deal of caching of seeds by rodents in the atrazine-treated areas. We have noted this activity before (LaTourrette et al., 1971), especially in regard to caching of downy brome seeds. As a result of rodents caching bitterbrush seeds in atrazine-treated areas, many more plants became established than were transplanted (Table 3). Also, seedlings of western juniper were found in atrazine-treated plots. Rodent caching is a significant factor in the establishment of bitterbrush in central Oregon (Sherman and Chilcote, 1972). The pattern of cache placement is strongly influenced by the presence of litter. As litter accumulates, desirable litter-free sites are less abundant, and bitterbrush populations decline. The application of atrazine at 1.12 kg/ha or higher rates results in a loss of herbaceous litter and a friable soil structure (Evans and Young, 1970 and 1972), which apparently create a desirable caching site for rodents.

On vertisol-clay soils such as are found at Adin Pass, considerable downslope movement of atrazine occurs during the winter. This movement is apparently a function of clay particles that move with atrazine attached. Erosional patterns caused by atrazine activity were particularly desirable sites for rodent seed caching.

Comparison of atrazine and a simazine at the same rates at Adin Pass did not reveal enough differences between results of the two herbicides to justify detailed presentation. Evans et al. (1969) provide details of comparisons of these herbicides under conditions of rangelands.

We did not seed intermediate wheatgrass in areas treated with herbicides in 1968 (active fallow during 1969). Tree and bitterbrush establishment in relation to rate of atrazine was similar to that already presented (Table 3). By 1972, these unseeded plots have been reinvaded by dense stands of medusahead. We do not know if this reinvasion will have a long-term effect on tree or brush growth, but it greatly increases the chance of reburning.

Baggett Gulch

The results of application of atrazine at Baggett Gulch were very similar to those reported for Adin Pass, although soil and exposure were different, and downy brome dominated instead of medusahead.

Fall application of 1.12 kg/ha of atrazine greatly improved the establishment of spring-transplanted pine seedlings (Table 4). Spring applications of atrazine after the seedlings were transplanted did not result in markedly increased survival. There probably was not enough late-spring precipitation to activate the herbicide after spring application (Evans et al., 1969). Vigor of transplants was increased with spring application of atrazine at 8.96 kg/ha (Table 4). This resulted from control of downy brome and suppression of competition in subsequent years from residual herbicidal activity. The plots receiving 8.96 kg/ha of atrazine in October, 1968 were largely bare of vegetation in 1972 (Table 5). Little or no downy brome had reinvaded the area. The sparse ground cover (8%) was composed of dogbane (*Apocynum androsaemifolium*) and western goldenrod (*Solidago californica*), and a few remnant perennial grasses (Table 5). The plots receiving lower rates of atrazine were reinvaded by downy brome or plants representing lower successional stages by 1972. The areas treated with 1.12 kg/ha of atrazine had a higher frequency of downy brome and a lower frequency of perennial grasses than was measured on the control areas.

We did not transplant bitterbrush to the Bagget Creek plots, nor did we observe any naturally-establishing bitterbrush seedlings in atrazine-treated areas. However, there is no bitterbrush in the extensive burned areas around the experimental site. We did not observe downslope movement of atrazine at this location with a silt loam surface soil.

Discussion

The vegetation manipulations outlined in this study are unnecessary if prompt rehabilitation of burned areas is accomplished. Supposedly, through grazing management, perennial grasses established after burning can be harvested without undue damage to conifer regeneration. Where woodland burns are left unseeded, either through inaction or fear of competition with conifers, annual-grass invasion is virtually assured.

Once annual grasses have invaded, the procedures of this study apply. The land manager must decide, weighing site potential and desired use, if he wants to establish a stable perennial grass-shrub-conifer community or to attempt to encourage a maximum rate of conifer growth with higher and perhaps repeated applications of atrazine.

The use of atrazine has valid application in many areas of reforestation. In this investigation, we are dealing with sites of very low potential for ponderosa pine growth. This underscores the importance of a balanced revegetation program, with perennial grasses and shrubs in addition to conifers.

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Evaluation of Rangeland Seedings Following Mechanical Brush Control in Texas

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Highlight: *Seeding success was evaluated on 62 ranches in Texas to compare relative success and costs of various treatments as affected by range site. Effects of precipitation and temperature were studied. Seeding during rootplow-rollerchop operations gave consistently better stands at a lower cost on all but the very shallow sites where seeding during treedozing treatments proved more economical. Relationships between site and factors affecting success differed distinctly between the wetter and drier portions of the study area. In the drier area, as soil depth decreased the amount of rainfall received close to the planting date aided seedling establishment more than did seedbed preparation. Cool temperatures favored seeding success on very shallow sites, but they were detrimental to seeding success on loamy bottomland sites. In the wetter area, degree of seedbed preparation was more important on all sites as long as sufficient rains for germination occurred within 90 days after planting. Mechanical brush control techniques that destroy most of the existing grass proved a hazardous undertaking, as half of the follow-up seedings were considered poor or total failures. This study separates those brush control practices and seeding techniques most likely to result in successful grassland restoration on west Texas brush-infested ranges from those less likely to provide successful seeded stands.*

Because successful seeding following brush control is so dependent on climate and weather conditions, research limited to two or three seasons on one or two ranches usually provides little information that may be applicable on a regional basis. If work with a variety of equipment and under a variety of situations is available, some form of survey may be possible to serve as a guide for more basic research. For example, Launchbaugh ed. (1966) with assistance from the Soil Conservation Service (SCS) conducted an extensive stand establishment survey in the Great Plains. They found that 18% of the stands evaluated had fewer than 0.5 plants/ft^2, and these were considered failures. Seedings from the Rolling Plains and Edwards Plateau in Texas had 23% and 33% failures, respectively, according to this survey. A similar study with crested wheatgrass (*Agropyron desertorum*) plantings in sagebrush (*Artemisia* sp.) areas conducted with assistance from the Bureau of Land Management found 46% failures over a seven state area (Shown et al., 1969). Only 34% of the rootplowed and seeded area in the Rio Grande Plains of Texas were successful (Boykin, 1960).

The purpose of this study was to compare relative success and relative costs of various mechanical brush control and seedbed modification techniques for grass establishment. Thus it would serve as a guide to ranchers so they might improve their chances for obtaining a successful seeding at the lowest cost, following mechanical brush control.

Seeding success was evaluated on 62 ranches in west central Texas at the northern edge of the Edwards Plateau and the southern edge of the Rolling Plains. Grass stands on ranches in Tom Green county were evaluated during the summer of 1970 and those in Runnels and Concho counties were evaluated in the summer of 1971.

Study Area and Sampling Procedures

Annual precipitation varies from 19 inches in western Tom Green county to 23 inches in eastern Runnels county. Seasonal precipitation peaks occur in May and September. Frost free days average about 230.

Principal range sites in the area are: Low Stoney Hill—shallow soils less than 10 inches deep with rocks on the surface and with pockets of deep productive soils; Very Shallow—soils less than 10 inches deep which may have pockets of deeper soils; Shallow—soils 10 to 20 inches deep which may have pockets of deeper soil; "Deeper" sites (Clay Loam, Deep Upland, Valley)—fertile soils over 20 inches deep not subject to overflow; Loamy Bottomland—fertile soils over 20 inches deep, subject to overflow (North Concho Board of Supervisors, 1967; Wiedenfeld et al., 1970).

To assure as much uniformity in treatment application and follow-up management as possible, only cooperators in the Great Plains Conservation Program (GPCP) administered by

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the SCS were used. All stands evaluated were 2 to 6 years old.

Preliminary data on each ranch came from GPCP files at the SCS district work units in the study area. Ten pace transects consisting of 25 observations each were made on each range site within each seeded area on each ranch to obtain vegetative composition. The plant nearest a mark on the toe of the right boot was recorded at each pace. Range condition scores were determined for each site using the appropriate SCS range condition guides for the area seeded. All seeded native species were designated decreasers or increasers as indicated on the range condition guide. Introduced species not used as filler grasses were counted as decreasers. Blue panic (*Panicum antidotale*) was considered an increaser with 5% allowable on all sites. *Sorghum almum* was counted as an invader on all sites. Sideoats grama (*Bouteloua curtipendula*) made up the largest component of all seed mixtures; green sprangletop (*Leptochloa dubia*) was usually included as a filler grass. Others commonly included were plains bristlegrass (*Setaria leucopila*) and King Ranch bluestem (*Bothriochloa ischaemun* var. *songarica*). Less consistently used were: Blue panic, switchgrass (*Panicum virgatum*), Lehman lovegrass (*Eragrostis lehmanniana*), Caucasian bluestem (*Bothriochloa intermedia*), Indiangrass (*Sorgastrum nutans*), little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), cane bluestem (*Bothriochloa barbinodis*), Kleingrass (*Panicum coloratum*), and *Sorghum almum.*

Grazing capacity before and after treatment was determined for each site using SCS stocking rate guides.

Costs of the entire operation were amortized over a 20-year period uisng 4, 8, and 12% interest rates to arrive at a prorated cost per acre. Amortization is the extinguishing or paying of a financial obligation in equal installments (Parker, 1956).

$$\text{Amortization formula: } a = \frac{So\ [i\ (1+i)^n]}{(1+i)^n - 1}$$

Where a equals the amount of periodic payment; So equals the principle involved; i equals the interest rate; n equals the number of years amortized. Items included in the total annual amortized cost/acre of the seeding were brush removal, seedbed modification, seeding operation, seed, deferment, interest on the initial investment accumulated during nonuse, stand maintenance, and interest during the amortization period. We assumed that treedoze treatments would require retreatment in 7 years and that rootplow treatments would require retreatment in 12 years.

The most valid comparison of costs among treatments is to compare them from the basis of cost per unit increase in grazing capacity. Therefore, an annual cost per animal unit was determined to provide a means of comparing the treatments from an economic standpoint (grazing capacity after treatment times the total annual amortized cost/acre of the seeding). However, the costs required to maintain any additional animals allowed as a result of increased grazing capacity was not included.

Step-wise multiple regression was used to evaluate the combination of variables most important to seeding success. The dependent variable used was the number of total hits of seeded species per 250 paces. All climatic variables were extrapolated from U.S. Weather Bureau records for the area according to the following formula:

$$c = \frac{AC}{AB}\,(b) + \frac{BC}{AB}\,(a)$$

c = the estimated variable X_n occurring at seeded area C.
AB = the distance from station A to station B.
AC = the distance from station A to seeded area C.
BC = the distance from station B to seeded area C.
a = variable X_n recorded at station A.
b = variable X_n recorded at station B.

Table 1. Rating system used to evaluate seeding success.

Rating class	% Composition seeded species
Failure	<10%
Poor	10–20%
Marginal	20–30%
Good	30–50%
Excellent	>50%

Table 2. Percent of the stands evaluated that fell into each range condition class for the four most used treatments.

	Range condition class			
Treatment	Poor	Fair	Good	Excellent
Treedoze-seed pits (35)*	31	53	17	–
Treedoze-rake (33)	27	50	24	–
Rootplow-rollershop (22)	–	26	52	22
Rootplow-rake (26)	29	38	33	–

*Number of stands evaluated.

Results and Discussion

Thirteen treatment combinations were evaluated (Fig. 1), but discussion is largely limited to the four more widely used treatments—treedoze-seed pits; treedoze-rake; rootplow-rollerchop; and rootplow-rake.

The percent composition of the seeded species was used to evaluate the treatments (Table 1). Approximately half of all stands evaluated were unsuccessful, i.e., poor or failures, one-third were good to excellent, and 15% were marginal. Root-

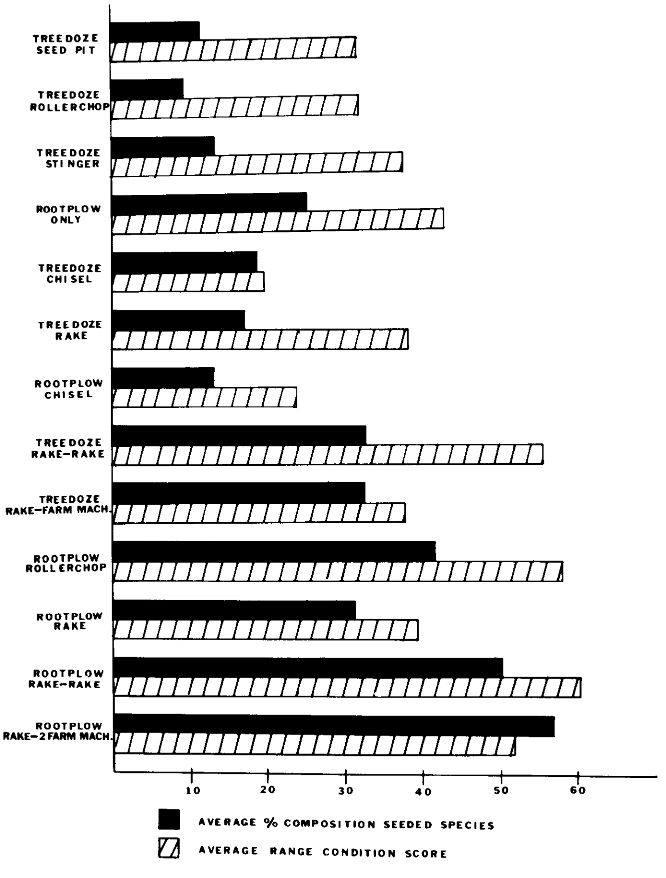

Fig. 1. *Comparison of all treatments evaluated by average percent composition of the seeded species and average range condition score.*

plow-rollerchop gave the most successful stands (78%) and the lowest proportion of stand failures (13%). Rootplow-rake was second best with 55% successful stands. Treedoze-rake and treedoze-seed pits had 9% and 3% success, respectively. Poor seeding success resulted from treedozing because competing vegetation between trees was not sufficiently removed. However, if the treated pits only had been considered, treedozing would have rated much higher. To more fairly evaluate treedozing vs root plowing, comparisons were also made on the basis of range condition. Improvement in overall range condition following mechanical treatment also favored the rootplow-rollerchop treatment (Table 2).

Considering all 13 treatments, grass stands obtained from rootplow-rollerchop were exceeded only by those from the most intensive treatments (rootplow-rake twice and rootplow-rake-2 workings with farm machinery) regardless of evaluation technique (Fig. 1). When individual sites were considered, rootplow-rollerchop gave the highest values for both the seeded species and range condition on all sites except the low stoney hill site when no rootplowing was done.

Factors Affecting Seeding Success

We distinguished among the factors thought to affect seeding success using multiple correlation techniques. Since half the study area receives 19-21 inches precipitation annually (dry end), and the other half receives 21-23 inches precipitation annually (wet end), those areas were analyzed separately. Index values which increased proportionally to the amount of weed-free seedbed and depth of disturbance were developed for the treatments.

All interpretations from multiple regression analyses were restricted to the two most important values because biological interpretation becomes difficult if more than two variables are included.

The relationships between site and factors affecting seeding success differed distinctly for the two divisions of the study area. For the dry end, as soil depth decreased, the amount of rainfall received closer to the planting date was more important for seeding success than degree of seedbed preparation, except for the bottomland site where rainfall 15 days prior to planting was more important. Close examination of this phenomenon revealed that air temperature affected seeding success on the very shallow and bottomland sites. For example, the successful stands on the very shallow site averaged 87 heating degree days (obtained from Weather Bureau records) the month after planting with 2.15 inches of rainfall two weeks after planting, whereas, five heating degree days with 0.26 inches of rain occurred in the same time periods for those stands which failed. (A heating degree day is the number of degrees the average daily temperature is below 65°F). This points to the need for more constant levels of soil moisture and the presence of cool temperatures to help reduce moisture evaporation on the very shallow sites. This phenomenon was reversed for the bottomland sites. Successful stands received 46 heating degree days and six inches of rainfall during the two months after planting, whereas 233 heating degree days and 3 inches rainfall were recorded for the same time period for the stand that failed. Cool, moist soil following planting apparently delayed germination forcing the seedlings into conditions of increased weed competition and increased chances for competition for soil moisture in the bottomland sites. Ellern and Tadmor (1966) found low soil temperatures delayed germination notably in perennial warm-season grasses. Shaidaee et al. (1969) also indicated that cool, moist seedbeds reduced field germination of warm season grass seeds disproportionately from that obtained in laboratory germination trials. Early planting is recommended on all sites except for the bottomland sites where high soil moisture prevents the early warming of soils necessary for germination of warm season grass seeds.

Table 3. Average initial cost ($) per acre and average decrease in acres required per animal unit for the four most used treatments.

Treatment	Initial cost/acre w/o govt	Initial cost/acre w/govt	Avg decrease in acres/AU
Treedoze-seed pits	16.76	5.14	5.6
Treedoze-rake	22.39	6.70	5.0
Rootplow-rollerchop	24.65	7.70	9.4
Rootplow-rake	23.58	7.43	5.5

For the wet end of the study area, degree of seedbed preparation was more important than rainfall on all sites as long as sufficient rains for germination occurred within 90 days after planting. Cool temperatures and significant rainfall prior to planting reduced seedling establishment on the bottomland site but not to the same extent as in the dry end.

Seeding success depended largely on the type of brush control, seedbed preparation, precipitation after planting, and soil temperature. The relative importance of each depended on the range site and the annual precipitation of the area. The findings in this study indicate the point where seedbed preparation and precipitation change roles as limiting factors for seeding success.

Economics

As expected, initial costs per acre increased as the degree of soil disturbance increased. Rootplow-rollerchop increased grazing capacity most when compared to the other commonly used treatments (Table 3).

When all treatments were compared according to annual cost/animal unit regardless of site, rootplow-rollerchop proved

Table 4. Economic comparison by site of the four most used treatments based on the average annual cost ($) per animal unit* at 8% interest with government help.**

Treatment	Range site: Low Stoney Hill	Very Shallow	Shallow	Deeper	Bottomland	Avg
Treedoze-seed pits	35.76	35.93	34.11	31.15	31.75	33.05
Treedoze-rake	33.31	43.68	38.93	32.80	30.28	35.80
Rootplow-rollerchop	–	37.06	33.28	29.46	26.47	31.57
Rootplow-rake	–	41.59	39.30	35.65	–	38.85

* Cost of maintaining additional animals due to increased grazing capacity not included.

**Amount of federal cost sharing is given in Table 3.

Table 5. Total annual cost/acre ($) amortized over 20 years for the four most used treatments.

	4% Interest		8% Interest		12% Interest	
Treatment	w/o govt	w/govt	w/o govt	w/govt	w/o govt	w/govt
Treedoze-seed pits	2.07	0.94	2.98	1.33	4.09	1.81
Treedoze-rake	2.53	1.08	3.67	1.54	4.97	2.10
Rootplow-rollerchop	2.70	1.16	3.85	1.63	5.29	2.20
Rootplow-rake	2.54	1.07	3.66	1.52	5.01	2.05

least costly per unit of improvement in grazing capacity. However, when evaluated by site, the treedozing treatments cost less per animal unit on the shallower sites; on the deeper sites rootplow-rollerchop was more economical. The annual cost/AU decreased as soil depth increased, due to the greater increase in grazing capacity as soil depth increased (Table 4).

The results in Table 5 are average annual costs/acre amortized at 4, 8, and 12% interest for the four most used treatments. An example of how to use these values with and without government assistance is presented below. Rootplow-rollerchop is used. All figures are on a 640 acre per section basis. Note that the income figures cited are gross values. For realistic net returns the cost of maintaining additional animals due to increased grazing capacity will have to be deducted.

Example:

Grazing capacity before treatment	21 AU/section
Grazing capacity after treatment	31 AU/section
Annual production/animal unit	400 lb/AU
Sale price/lb	x $0.55/lb
Annual gross income/animal unit =	$220 /AU
Total annual gross income per section after treatment (31 AU/section X $220/AU)	$6820.00/section
Total annual gross income per section before treatment (21 AU/section X $220/AU)	$4620.00/section
Additional gross annual income/ section due to treatment	$2200.00/section
Total annual amortized cost per section at 8% interest w/o govt. help ($3.85/acre [Table 5] X 640 acres)	$2464.00/section
Total annual amortized cost per section at 8% interest w/govt. help ($1.63/acre [Table 5] X 640 acres)	$1043.20/section
Gross annual income/section due to treatment w/o govt. help (Additional annual income per section–total annual amortized cost/section w/o govt. help)	-$264.00/section
Gross annual income/section due to treatment w/govt. help (Additional annual income per section–total annual amortized cost/section w/govt. help)	$1156.80/section

Conclusions and Recommendations

This study indicated no shortcuts to successful revegetation following mechanical brush control. Degree of seedbed preparation, rainfall, and temperature were major items affecting grass establishment. Recommendations from this study that appear valid are enumerated as follows:

1) Relatively weed-free seed beds are a necessity for grass establishment on all range sites.

2) The more shallow sites should be seeded earlier in the year than the deeper sites where frequent rains before and after planting coupled with cool temperatures help reduce evaporation and seedling death from dessication.

3) On the other hand, seeding of loamy bottomland sites should be delayed, as rainfall received during the 15 days preceding planting proved detrimental due to cold, moist soil that delayed germination of warm-season grass seeds. Consequently, seedlings which did emerge had increased competition for moisture with emerging weeds.

4) Brush on sites with deeper soils is best removed with a rootplow and followed by a rollerchopper for obtaining optimum seeded grass stand, for greatest increase in grazing capacity, and for the least cost per unit increase in grazing capacity.

5) Brush on shallow sites is best removed by tree dozing and the pits seeded to obtain the greatest increase in grazing capacity for the least cost per unit increase.

6) The practice of rootplowing and seeding without further seedbed modification would not be recommended generally, because our data showed only 25% of areas treated this way resulted in good and excellent stands vs 78% for rootplow-rollerchop applications.

7) When range condition is so poor on brush infested ranges that broadcast seeding is required, rootplow-rollerchop would be recommended over treedoze treatments. The pits themselves make excellent seedbeds, but insufficient competing vegetation overall is removed for grass establishment except in the pits. Conversely, when range condition is sufficiently high that only the trees need be removed, tree dozing would be preferred.

8) Surprisingly, rootplow-rollerchop treatments gave better results in all respects than did rootplow-rake operations.

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Species for Seeding Mountain Rangelands in Southeastern Idaho, Northeastern Utah, and Western Wyoming

A. C. HULL, JR.

Highlight: *Tests of many species over several years on seven sites show that smooth brome and meadow and creeping foxtails are adapted for seeding most mountain rangelands. However, smooth brome did not maintain stands above 9,000-foot elevations. Intermediate and pubescent wheatgrasses are adapted to intermediate and lower mountain ranges. Other grasses that did well in one or more seedlings are: mountain, subalpine, and Regar bromes; timothy; orchardgrass; tall oatgrass; reed canarygrass; and hard fescue. Legumes and forbs that showed promise are: birdsfoot trefoil, crownvetch, birdvetch, alfalfa, and horsemint. Mixtures of adapted species gave better stands than single species. These tests reemphasize that we must prepare good seedbeds and control plant-competition to get good stands of seeded species. Pocket gophers killed many plants and caused seeded stands to deteriorate.*

Mountain rangelands, with their relatively high precipitation, have a high forage potential. However, where vegetation and soil have been depleted, these lands are often difficult to revegetate, even by seeding. Seedling emergence of seeded species on depleted mountain ranges is slow and death loss is high (Hull, 1966). In some high places the snow does not melt until late May or June, and snowbanks may persist until July and August. Hence, the growing season is short and stands establish slowly. After seedlings emerge, they face daytime temperatures that frequently exceed 110°F at the 0.75-inch soil depth. Seedlings may also be damaged by rapid soil drying, frost heaving, smothering under ice, flooding, snow mold, pocket gophers, and competition with weedy vegetation.

Species which have been recommended for one or more of these high elevation sites in the Intermountain Region are smooth brome, meadow foxtail, timothy, tall oatgrass, and intermediate wheatgrass (Plummer et al., 1955; Gomm, 1962; Hull et al., 1962; McGinnies et al., 1963; Hull, 1973).

This paper summarizes results of several studies that were initiated to determine species suitable for seeding mountain rangelands in southeastern Idaho, northern Utah, and western Wyoming.

Location and Procedures

Seedings were made in weedy openings

Table 1. Characteristics of the seven seeding sites with number of species and dates seeded.

Location	Elevation (ft)	Precipitation (inches)	Number of species	Date seeded
Franklin Basin[a]	8400	46	16	Spring 1960
20 miles ESE			30	Spring 1963
Preston, ID			40	Spring 1963
			6	Spring 1964
			52	Spring 1965
			12	Spring 1966
			47	Spring 1968
Monte Cristo	9000	40	25	Spring 1954
24 miles NE			25	Fall 1954
Ogden, Utah				
Blind Bull	9200	35	6	Fall 1953
22 miles NE			6	Spring 1954
Afton, Wyo.			4	Fall 1954
			6	Fall 1957
LaBarge	8700	31	19	Spring 1951
25 miles SE			16	Fall 1951
Afton, Wyo.			4	Fall 1953
			4	Spring 1954
Smiths Fork	7800	30	9	Fall 1955
17 miles SE				
Afton, Wyo.				
McCain	7000	30	6	Fall 1953
30 miles NNE			3	Spring 1954
Afton, Wyo.				
Cabin Creek	6600	25	6	Fall 1953
16 miles NE			6	Spring 1954
Afton, Wyo.			4	Fall 1954
			6	Fall 1957

[a] Three to ten additional species were seeded in several plots each spring and fall from 1957 to 1970 in method studies.

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in the timber at seven locations on mountain rangelands in Idaho, Utah, and Wyoming (Table 1). Franklin Basin, Monte Cristo, Blind Bull, and LeBarge are in the spruce-fir zone. Smiths Fork and McCain are Douglas fir-aspen, and Cabin Creek is lodgepole pine-aspen. Most slopes are moderate, ranging from 1 to 15%.

Franklin Basin contained the most seedings. The dominant vegetation there is tarweed (*Madia glomerata*). There is some bushy knotweed (*Polygonum ramosissimum*), collomia (*Collomia linearis*), bicolor biscuitroot (*Lomatium leptocarpum*), and many spring-growing, fleshy-rooted plants. The soil is clay loam, low in organic matter and plant nutrients. The pH is 6.0. The soil compacts and hardens soon after snow melts. The six other sites are somewhat similar, except that some sites have more perennial vegetation. Blind Bull and LaBarge have considerable geranium (*Geranium viscosissimum*). McCain has scattered geranium, silver sagebrush (*Artemisia cana*), shrubby cinquefoil (*Potentilla fruticosa*), and many low-value forbs and grasses. Cabin Creek has scattered big sagebrush (*Artemisia tridentata*) and woody eriogonum (*Eriogonum microthecum*).

At all locations, the land was plowed or cultivated and harrowed to prepare a firm, weed-free seedbed. However, on the 1953 plots at Blind Bull and in all LaBarge seedings, some geranium survived seedbed preparation. At McCain only part of the native grasses and forbs were killed.

Species selected for seeding had grown well at other locations or had been recommended by plant introduction specialists. A total of 84 species and 35 strains were tested. The number of species in each seeding is listed in Table 1. Each species was duplicated at each seeding, except at Franklin Base where three or four replications were tested. From 2 to 4 mixtures of the major species were also seeded at each location.

Spring seedings were made as early as soil and road conditions permitted. This was early to late June at lower elevations and mid-June to early July at higher elevations. Fall seedings were made in late September or October. Success of spring and fall seedings varied among years and locations. Because seeding for neither season was consistently better, they are averaged for species success.

A hand seeder drilled seed in 12-inch rows at an average depth of ½ inch. We planted 25 viable seeds/ft of row but increased the rate 50% for species having over 500,000 seeds/lb and doubled the rate for species having over 1 million seeds/lb. This gave 8 lb/acre of good seed for smooth brome and rates for other species according to their seed size. Legume seeds were inoculated with the proper nitrogen-fixing bacteria before seeding.

At Franklin Basin, seedlings were counted during spring and fall of the first growing season and the fall of the second season. In the second growing season, and each year thereafter to 1972, stands were rated for their success. At the other six locations, stands were rated each year from 1954 to 1961 and in 1965, 1967, 1970, and 1972. Success ratings were on a 0 to 10 basis: 1 to 2, very poor; 3 to 4, poor; 5 to 6, fair; 7 to 8, good; and 9 to 10, excellent.

Two gopher exclosures were constructed at Monte Cristo and Smiths Fork and one each at Blind Bull, McCain, and Cabin Creek to determine the effect of pocket gophers (*Thomomys talpoides*) upon the establishment and permanence of seeded stands. At Franklin Basin, gophers were controlled by poison and traps.

Results and Discussion

Seedling emergence was generally good for all seedings, after which plant numbers usually decreased for 1 or 2 years. High seedling mortality usually resulted from summer drought, often from frost heaving in spring and fall, from plant competition with species not killed during seedbed preparation or with rapidly growing native species such as tarweed, and from pocket gophers that killed both seedlings and mature plants. After this initial decrease, some species then improved their stands, some maintained their stands, and some failed.

At Franklin Base seedling stands were good. The 1972 species ratings, averaged for all studies, are in Table 2. The following 25 grasses and 9 legumes either failed or nearly failed and are not included in Table 2:

Table 2. Average ratings of 25 grasses and 9 legumes seeded in 7 studies during 1960-68 at Franklin Basin, 1972.

Species and strains[a]	Number of years seeded	Number of plots	Average stand rating
Grasses			
Crested wheatgrass (*Agropyron desertorum*)	1	2	1.0
Crested wheatgrass x quackgrass (*A. desertorum x repens*)	2	6	3.2
Thickspike wheatgrass x bearded couch (*A. dasystachyum x caninum*)	1	3	6.3
Intermediate wheatgrass (*A. intermedium*) 6	7	44	5.2
Arctic Circle quackgrass (*A. repens*)	2	6	3.7
Slender wheatgrass (*A. trachycaulum*)	5	14	1.9
Pubescent wheatgrass (*A. trichophorum*) 3	4	16	5.3
Redtop (*Agrostis alba*)	1	2	3.5
Creeping foxtail (*Alopecurus arundinaceus*) 1	4	12	7.0
Meadow foxtail (*A. pratensis*) 1	5	17	7.0
Tualatin tall oatgrass (*Arrhenatherum elatius*)	2	6	2.5
Regar brome (*Bromus biebersteinii*)	2	6	5.8
Mountain brome (*B carinatus*)	4	12	4.5
Meadow brome (*B. erectus*)	3	9	3.8
Smooth brome (*B. inermis*) 5	7	36	7.9
Subalpine brome (*B. tomentellus*)	5	14	4.1
Brome (*Bromus* spp.)	4	10	2.9
Orchardgrass (*Dactylis glomerata*) 6	6	32	4.1
Tall fescue (*Festuca arundinacea*)	2	5	2.8
Meadow fescue (*F. elatior*) 1	2	6	3.5
Hard fescue (*F. ovina* var. *duriuscula*)	3	7	3.4
Red fescue (*F. rubra*) 3	4	13	3.3
Frontier reed canarygrass (*Phalaris arundinacea*) 1	3	8	8.7
Timothy (*Phleum pratense*)	3	10	4.0
Kentucky bluegrass (*Poa pratensis*)	2	5	3.9
Legumes			
Cicer milkvetch (*Astragalus cicer*)	4	10	3.2
Sicklepod milkvetch (*A. falcatus*)	4	10	2.1
Milkvetch (*Astragalus* spp.)	1	2	1.5
Crown vetch (*Coronilla varia*) 3	3	14	7.0
Birdsfoot trefoil (*Lotus corniculatus*) 2	3	11	7.7
Mountain lupine (*Lupinus alpestris*)	3	10	3.3
Sickle alfalfa (*Medicago falcata*)	3	8	3.5
Alfalfa (*M. sativa*) 10	3	63	4.2
Birdvetch (*Vicia cracca*)	2	6	5.3

[a] Where numbers follow names, they indicate the number of additional strains tested.

Bearded couch	*Agropyron caninum*[a][1]
Fairway wheatgrass	*A. cristatum* (2)
Thickspike wheatgrass	*A. dasystachyum*
Crested wheatgrass x fairway wheatgrass	*A. desertorum* x *A. cristatum*[a]
Tall wheatgrass	*A. elongatum*
Rushleaf wheatgrass	*A. junceum*
Wheatgrass	*A. obtusiusculum*
Streambank wheatgrass	*A. riparium*[a]
Bluebunch wheatgrass	*A. spicatum*[a]
Bearded wheatgrass	*A. subsecundum* (2)
Slender wheatgrass x squirreltail	*A. trachycaulum* x *Sitanion hystrix*[a]
Annual falsebrome	*Brachypodium distachyon*
Falsebrome	*B. phoenicoides*
Rumanian falsebrome	*B. pinnatum*
Woodland falsebrome	*B. sylvaticum*
Brome	*Bromus brevis*[a]
Pumpelly brome	*B. pumpellianus* (2)[a]
Fescue	*Festuca altaica*
Fescue	*F. ampla*[a]
Sheep fescue	*F. ovina* (2)[a]
Spike fescue	*Hesperochloa kingii*
Perennial ryegrass	*Lolium perenne*
Silkyspike melic	*Melica ciliata*
Melic	*M. cupani*
Big bluegrass	*Poa ampla* (also Sherman)
Twogrooved locoweed	*Astragalus bisulcatus*
Milkvetch	*A. galegiformis*
Milkvetch	*Astragalus* spp.,[a]
Sweetvetch	*Lathyrus tingitanus*
Sweetvetch	*L. tuberosus*
Sanfoin	*Onobrychis arenaria*
Sanfoin	*O. transcaucasica* (2)
Sanfoin	*O. viciifolia* (2) (also Eski[a] and Onar [3][a])
Vetch	*Vicia dasycarpa*

[1] A number after the above species indicates the number of years seeded. An "a" indicates a trace; others failed completely.

Considering species seeded in 2 or more years, the best grasses at Franklin smooth and Regar bromes, reed canarygrass, and intermediate and pubescent grass, and intermediate and pubescent wheatgrasses. The best legumes are crownvetch, birdsfoot trefoil, and birdvetch. Alfalfa stands were good but have been reduced by livestock grazing and by gophers.

When strains were evaluated, Garrison creeping foxtail was slightly better than common foxtail. "Southland" smooth brome was poor but "Lincoln," "Manchar," "Sac," and "Saratoga" had good to excellent stands. "Chief" intermediate wheatgrass averaged better than "Amur," "Greenar," or "Oahe." "Luna," "Mandan," and "Topar" pubescent wheatgrasses were all good. "Chinook," "Latar," and "Wisconsin" orchardgrasses had excellent initial stands but all deteriorated to poor. "Emerald" and "Penngift" crownvetch were both good, as were "Cascade" and "Empire" birdsfoot trefoil. Alfalfa strains were only fair to poor. "Ladak," "Nomad," "Rambler," "Rhizoma," "Teton," and "A-169" were best, followed by "Beaver," "Ranger," "Travois," "P-550," and "KS-10."

At Monte Cristo, all stands deteriorated, with particularly rapid decreases from 1955 to 1960. Most decreases resulted from summer drought, frost heaving, and damage by gophers. Species that have fair to good stands after 18 years are: creeping and meadow foxtails, intermediate wheatgrass, and horsemint (Table 3). Mixtures of grasses and forbs in larger plots all have good stands.

Table 3. Success ratings of 10 grasses, 4 forbs (including legumes) seeded in 1954 at Monte Cristo, Utah, and from 1951 to 1954 at LaBarge, Wyo., 1972.

	Location	
Species	Monte Cristo	LaBarge
Grasses		
Intermediate wheatgrass (*Agropyron intermedium*)	5[a]	5[a]
Slender wheatgrass (*A. trachycaulum*)	2[a]	2[a]
Pubescent wheatgrass (*A. trichophorum*)	–[b]	3
Creeping foxtail (*Alopecurus arundinaceus*)	4	6
Meadow foxtail (*A. pratensis*)	5	4
Tualatin tall oatgrass (*Arrhenatherum elatius*)	1	4[a]
Mountain brome (*Bromus carinatus*)	1	1
Smooth brome (*B. inermis* (also Lincoln))	1	3[a]
Subalpine brome (*B. tomentellus*)	0	1
Timothy (*Phleum pratense*)	–	2
Forbs including legumes		
Horsemint (*Agastache urticifolia*)	5	–
Mountain lupine (*Lupinus alpestris*)	1	1
Bramble vetch (*Vicia tenuifolia*)	1	–
Showy goldeneye (*Viguiera multiflora*)	1	–

[a] Also seeded in adjacent large plots.
[b] Not seeded.

At LaBarge, many of the seeded plants died from drought, frost heaving, and competition from native species. Most stands became progressively poorer for several years. Some continued to deteriorate but creeping and meadow foxtails improved. Intermediate wheatgrass, smooth brome, and tall oatgrass maintained poor to fair stands (Table 3).

Eighteen species that either failed or had very poor stands at Monte Cristo and LaBarge and are not included in Table 3 are:

Fairway wheatgrass	*Agropyron cristatum*
Tall wheatgrass	*A. elongatum*
Intermediate wheatgrass (Amur)	*A. intermedium*
Western wheatgrass	*A. smithii*
Bearded wheatgrass	*A. subsecundum*
Meadow brome	*Bromus erectus*[b][1]
Orchardgrass	*Dactylis glomerata*[b]
Great basin wildrye	*Elymus cinereus*
Creeping wildrye	*E. triticoides*
Bulbous barley	*Hordeum bulbosum*
Reed canarygrass	*Phalaris arundinacea*[b]
Subalpine needlegrass	*Stipa columbiana*[b]
Letterman needlegrass	*S. lettermanii*[b]
Cicer milkvetch	*Astragalus cicer*
Cow parsnip	*Heracelum lanatum*
Porter ligusticum	*Ligusticum porteri*
Yellow sweetclover	*Melilotus officinalis*
Sweetanise	*Osmorhiza occidentalis*[a]

[1] An "a" indicates a trace at Monte Cristo and "b" a trace at LaBarge; the others failed at both locations.

At Blind Bull, McCain, and Cabin Creek, seedling stands were excellent but most became poorer, mainly because of competition with native vegetation. Meadow and creeping foxtails are the only species having good to excellent stands on all three sites and were the only successful species at Blind Bull, a high-elevation site. Intermediate and pubescent wheatgrasses had excellent stands and hard fescue a fair stand at Cabin Creek, but all failed at Blind Bull. They were not seeded at McCain. Smooth brome had good stands and timothy fair stands at McCain and Cabin Creek, but both were very poor at Blind Bull. Slender wheatgrass, tall oatgrass, mountain brome, and orchardgrass, either failed or had very poor stands.

At Smiths Fork, the seedling year was hot and dry. By September, 1965, all seedlings of meadow foxtail and tall oatgrass were dead; a few seedlings of smooth and meadow bromes, alfalfa, and cicer milkvetch remained; and pubescent and intermediate (also Amur) wheatgrasses had poor stands. At present, meadow brome, alfalfa, and cicer milkvetch have poor stands and smooth brome has increased to a good stand. Pubescent and intermediate wheatgrasses, including Amur, had excellent stands and have spread widely to vacant plots and outside the experimental area.

Mixtures were seeded each year for 13 years in large plots at Franklin Basin. The average air-dry yield from 1961 to 1972 was 4572 lb/acre, ranging from 2420 pounds in 1966 to 5755 in 1965. Mixtures at all seven areas normally yielded more, had better ground cover, and maintained better stands than single species. Seeding rates and larger plots may have accounted for the superiority of the mixtures. Increased seeding rates of mixtures and single species at Franklin Basin resulted in thick stands in which the plants were less damaged by frost than were widely spaced plants. Where seeding rates for adapted mixtures and single species were similar, the mixed stands were better.

Pocket gophers killed plants on all areas and caused many stands to deterioriate, especially at Monte Cristo. Because gopher exclosures were not maintained in later years of the study, little difference now exists between stands on protected and unprotected areas. The type of seeded stand influenced gopher activity. Gophers often clipped off short rows of single species in small plots but not rows of the same species in large plots or in mixtures. Where good seedbed preparation killed the fleshy-rooted plants readily eaten by gophers and where thick seeded stands resulted, gopher damaged was less than on areas with poor seedbed preparation and poorly seeded stands.

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Influence of Defoliation by the Cutworm *Melipotis indomita*[1] on Control of Honey Mesquite with 2,4,5-T in West Texas

DARRELL N. UECKERT

Highlight: *Cutworms,* Melipotis indomita *(Walker), caused severe defoliation of honey mesquite (*Prosopis glandulosa *Torr. var.* glandulosa*) on heavy clay and bottomland range sites in the Rolling Plains of Texas following a late spring freeze and a drought in 1971. In some areas cutworms reduced mesquite foliage by 95%. The percent of honey mesquite killed with foliar application of 2,4,5-T was very low on both sites and was not influenced by the degree of defoliation by cutworms.*

Control of undesirable woody plants such as honey mesquite (*Prosopis glandulosa* Torr. var. *glandulosa*) is a major concern to ranchers in Texas. Mesquite infests about 56 million acres of Texas rangeland[2]. The cutworm, *Melipotis indomita* Walker, caused widespread defoliation of honey mesquite on bottomland and heavy clay range sites in the Rolling Plains of Texas during the spring of 1971. This damage to foliage concerned aerial applicators and ranchers who were planning aerial application of herbicides such as 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid). Brisley (1924) observed similar injury to mesquite by *Melipotis indomita* (Walker) along

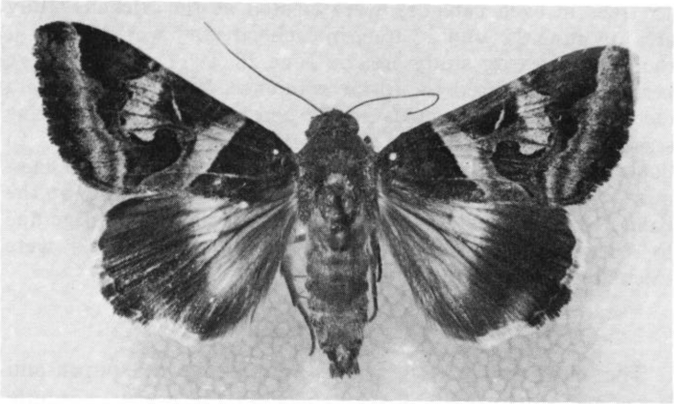

Fig. 1. Melipotis indomita *adult.*

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[1] Lepidoptera: Noctuidae.

[2] H. N. Smith and C. A. Rechenthin. 1964. Grassland restoration—the Texas brush problem. Soil Conserv. Serv., U.S. Dep. Agr., Temple, Texas. 17 p.

the Verde River, Salt River, and in the Sulphur Springs Valley of Arizona. Brisley reported that mesquite along the Verde River was almost completely defoliated for a distance of about 20 miles until June 1. However, after June 1 the trees refoliated. According to Brisley, the worms rest in the litter at the base of mesquite during the day and climb the limbs to feed on the mesquite foliage during the night. They were most numerous about June 1, at which time they began burrowing into the soil and pupating. The objective of our study was to quantify the degree of defoliation of honey mesquite by *M. indomita* and to determine the influence of defoliation by this insect upon herbicidal control of mesquite.

Methods and Materials

Field studies were conducted on a bottomland range site dominated by honey mesquite and curly mesquite [*Hilaria belangeri* (Steud.) Nash] northwest of Paint Rock, Tex., and on two heavy clay range sites dominated by honey mesquite and tobosagrass [*Hilaria mutica* (Buckl.) Benth.]. One of the heavy clay range sites was south of Colorado City, Tex., and one was east of Dickens, Tex. The study was initiated on June 7, 1971. At that time essentially all cutworms had pupated in the soil. Population densities of pupae and larvae at the Paint Rock study area were estimated on June 7 by sifting the soil to a depth of 5 cm from 30 × 30-cm plots. One plot was sampled at the base of each of 60 randomly selected mesquite trees. Equal numbers of samples were taken from quartiles corresponding to each of the cardinal directions from the base of the trees. Adult moths (Fig. 1) were reared from pupae in the insectary for identification. On June 8, 25 trees in the cutworm-infested area and 25 trees in a nearby uninfested mesquite stand at the Paint Rock study area were cut with a chain saw, basal diameters recorded, all green leaves removed, sacked, and weighed, and the live weight of the wood of each tree determined. All foliage and the wood from 10 trees from each area were taken to the laboratory, oven dried in a forced-air drying room at 52° C, and oven-dry weights were recorded. These data were used to compare dry leaf/dry wood ratios, for calculation of regression equations of dry leaf weights on basal diameters, and for calculation of regression equations of dry leaf weights on dry wood weights.

To determine the effect of defoliation by cutworms on the effectiveness of 2,4,5-T for honey mesquite control, at each of the three study areas trees were sprayed at each of four estimated degrees of defoliation: 0–25%, 26–50%, 51–75%, and 76–100%. The trees were sprayed lightly, to simulate aerial application, with hand sprayers containing 92 ml of the propylene glycol butyl ether esters of 2,4,5-T in 92 ml diesel oil and enough water to make 12.3 liters of spray solution. Ten trees in each of the four categories of defoliation were treated with 2,4,5-T at the Paint Rock study area on June 9; 15 trees in each category were treated at the Dickens study area on June 22; and 15 trees in each category were treated at the Colorado City study area on June 28, 1971. All trees were permanently marked for future reference. Mortality data were recorded at all three areas at the end of the second growing season following herbicide application (September, 1972). In September, 1972, an additional 100 randomly selected mesquite trees in the heavily defoliated mesquite stand at the Paint Rock study area were examined for signs of damage due to cutworm defoliation. Confidence intervals (95%) were calculated for all sample means.

Results and Discussion

The mean population density was 34.6 ± 6.2 pupae and larvae per square meter of soil beneath the honey mesquite canopies: thus the population density of leaf-consuming larvae of *M. indomita* had been quite high. A few larvae were discovered beneath loose mesquite bark; however, only 0.5% of the total sample obtained from the upper 5 cm of soil consisted of larvae. A few observations of pupal parasitism were recorded and predation of soil-dwelling pupae by Rio Grande turkey (*Meleagris gallopavo intermedia* Sennett) was evident. Neither diurnal nor nocturnal activity of cutworm larvae on honey mesquite foliage was observed, thus it was felt that essentially all of the cutworm population had pupated.

The regression of dry wood weight on live wood weight, $y = -0.4831 + 0.7131\ X$ ($r = 0.995$), was used to calculate dry wood weights for those trees which were not oven dried. The mean dry leaf weight (g)/dry wood weight (kg) ratios were 293.5 ± 89.5 and 15.3 ± 4.7 for uninfested honey mesquite and cutworm-attacked mesquite, respectively. Thus, feeding by larvae of *M. indomita* had reduced the total photosynthetic and transpiring tissue of mesquite by 95%. The influence of cutworm defoliation upon the numerical relationship of dry leaf weights (g) with tree basal diameters (cm) and upon the relationship of dry leaf weights (g) with dry wood weights (kg) for the bottomland site near Paint Rock, Tex., are illustrated in Figures 2 and 3, respectively. Almost all 174

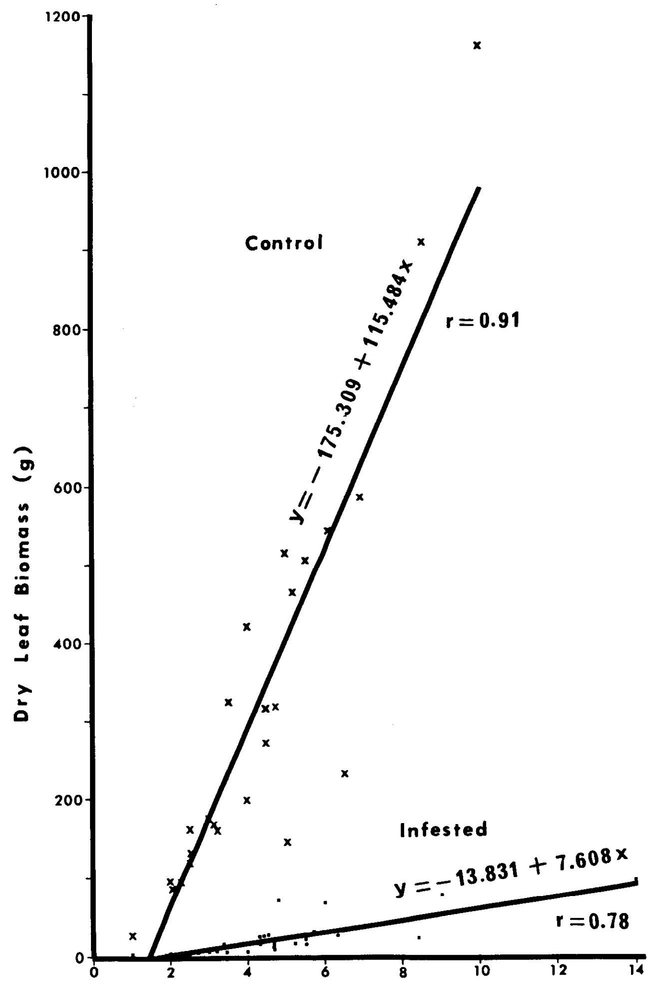

Fig. 2. *Relationship of dry leaf weights (g) with basal stem diameters (cm) of mesquite defoliated by larvae of* Melipotis indomita *and of uninfested mesquite in a bottomland range site near Paint Rock, Tex., June, 1971.*

papers concerning effects of insect defoliation on growth and mortality of trees reviewed by Kulman (1971) reported a reduction of tree growth proportionate to the quantity of foliage loss. Growth patterns of trees, typically determined by measuring growth rings on increment cores of wood, were not determined in this study; however, it is assumed that early summer growth of the defoliated mesquite was seriously reduced. The importance of foliage for growth and survival of trees decreases directly with tree age and inversely with its exposure to sunlight. Deciduous trees usually show an immediate response to defoliation if it occurs before shoot or ring growth is completed (Kulman, 1971). Kulman's summary that most deciduous trees survive defoliation and produce new sets of leaves in the same season was substantiated in this study. Most of the honey mesquite trees not sprayed with 2,4,5-T had developed full foliage by the end of the 1971 growing season.

Populations of *M. indomita* were restricted almost entirely to bottomland and heavy clay range sites, where honey mesquite foliage had been killed during the early spring of 1971 by an abnormally late spring freeze. The winter and summer of 1971 was also a period of a severe drought in the Rolling Plains of Texas. These factors appear to substantiate Kulman's (1971) review of Russian and German studies which indicated that some defoliating insects require "physiologically weakened stands" to develop large populations; and, that an unfavorable water balance results in increased sugar content of foliage, which may be favorable for growth and survival of defoliators. Precipitation was abundant in 1972, and populations of *M. indomida* were very low and their effects were not obvious in 1972. Stevens (1971) reported defoliation of ponderosa pine (*Pinus ponderosa* Laws.) by the pine needle sheathminer, *Zelleria haimbachi* Busck., in Modoc Co., California in years of below-average precipitation.

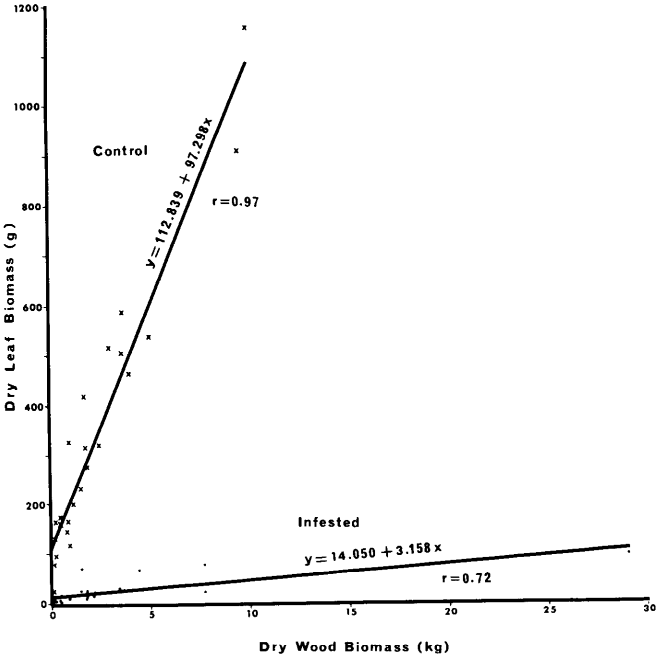

Fig. 3. *Relationship of dry leaf weights (g) with dry wood weights (kg) on mesquite defoliated by larvae of* Melipotis indomita *and of uninfested mesquite in a bottomland range site near Paint Rock, Tex., June, 1971.*

Table 1. Mortality (%) of honey mesquite treated with 2,4,5-T as influenced by four degrees of defoliation by *Melipotis indomita* on two heavy clay range sites and one bottomland site in the Rolling Plains of Texas.

	Degree of defoliation (%)			
Trees with tops killed[1]	0–25	26–50	51–75	76–100
Resprouting from basal buds	67.5a[2]	55a	52.5a	50a
Not resprouting	2.5a	0a	2.5a	2.5a

[1] Honey mesquite with dead aerial growth but resprouting from the base is referred to as "top-killed" by many workers. If tops are dead and no basal sprouts are evident, the plant is categorized as "root-killed."

[2] Values within a row followed by similar letters are not significantly different at the 95% level of probability as determined by X^2 analysis.

Observations during September, 1972 in the honey mesquite stand near Paint Rock, Texas which had been seriously defoliated by *M. indomita* during late spring of 1971 revealed that 58% of the trees showed symptoms of damage. Of the trees examined, 6% were top-killed but had basal sprouts, 11% were alive but had basal sprouts, 8% had basal sprouts and dead branches, 33% had dead branches and no basal sprouts, and 42% showed no signs of injury. The incidence of basal sprouts and dead branches was attributed to the cutworm defoliation, although it is probable that the late spring freeze and summer drought conditions may have attributed to these symptoms. Honey mesquite trees have an abundance of dormant buds at and above the cotyledonary node, which are stimulated by injury or stress, and produce new leaves and stems (Meyer et al., 1971).

Mortality data at the end of the second growing season following application of 2,4,5-T indicated that defoliation by *M. indomita* did not significantly reduce herbicide effectiveness (Table 1). The percentage of sprayed mesquite with dead topgrowth (top-kill) was somewhat higher on trees with lower degrees of defoliation; however, percentage of the trees not resprouting from the base (root-kill) was not influenced by cutworm defoliation. Mesquite on bottomland and heavy clay range sites is typically very difficult to control with hormone-type herbicides because of low soil temperatures, which result in a low growth rate of the roots, thus low susceptibility to herbicides. Bottomland and heavy clay range sites typically have cooler soils than sandy or upland sites, due to higher soil moisture percentages and to increased vegetative cover (Dahl et al., 1971; Sosebee et al., 1973). Defoliation by cutworms on sandy or upland soils (warmer sites) would probably reduce the effectiveness of foliar-applied herbicides.

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Abundance of Grasshoppers in Relation to Rangeland Renovation Practices

G. B. HEWITT AND N. E. REES

Highlight: *This study was conducted during a 3-year period, 1969–1971, in northcentral Montana to determine the effect of the rangeland renovation practices of scalping, interseeding, contour furrowing, and spraying sagebrush with 2,4-D and the resulting vegetational changes on grasshopper (Acrididae: Orthoptera) species and abundance. Spraying for control of sagebrush with 2 lb of 2,4-D ester in 6 gal H_2O/acre only slightly reduced grasshopper abundance during the first 3 post-spray years. However, contour furrowing, scalping, and interseeding in general adversely affected the habitat of most grasshopper species, probably because of changes in the abundance of preferred food plants. The influence of parasites, predators, and pathogens on abundance appeared to be slight.*

The production of livestock, the largest source of income in Montana, depends on the grazing of 70% of the land area of the state. Montana has 54 million acres of rangeland and 11½ million acres of grazeable timberland (Jackson, 1970), but approximately 34½ million acres are vegetated by some species of sagebrush (Beetle, 1960). During the last 20 years, the removal of sagebrush has been a primary method of increasing the amount of forage (Pechanec et al., 1965). Another method of increasing forage production is scalping, in which 10 to 25-inch-wide strips of native vegetation to a depth of 4 inches are removed, laid over on adjacent sod, and strips between left undisturbed. When the scalped strips are seeded, the procedure is termed interseeding (Hervey, 1960). However, little attention has been given to the effects on nontarget organisms resulting from these renovation practices. Two separate studies (Parts 1 and 2) were conducted with the main objective to determine the abundance of grasshoppers (Acrididae: Orthoptera) and the fluctuations in species resulting from vegetational changes due to treatment. The influence of parasites, predators, and disease organisms of grasshoppers was also investigated.

Part 1. Chemical and Mechanical Methods of Controlling Sagebrush

This study was conducted in Petroleum County near Winnett, Montana, in cooperation with the Montana Fish and Game Department and the Bureau of Land Management, U. S. Department of the Interior. Methods of controlling sagebrush included use of chemicals, furrowing, and scalping and interseeding.

Procedures

Although four study areas were established by the agencies that initiated the study, only two (Winnett and King) were used in studying grasshoppers. Within these two areas, the plots used for the study of insects (treated and untreated) were located on vegetational transects laid out on each of the major soil types present.

Measurements of vegetation were made by Montana Fish and Game personnel during the summers of 1967, 1969, and 1971. The canopy coverage (cm^2) was multiplied by the mean height (cm) to obtain a reasonable approximation of the volume or "cover index" occupied by each plant species. Thus vegetation on treated and untreated portions of both study areas could be compared by summing the cover indexes of each species from all plots exposed to a given treatment to obtain a total cover index (TCI). The amount of change per species (assumed to result from treatment) was then calculated as the "corrected vegetational change" or CVC (adapted after Anderson, 1961) as follows:

$$\text{CVC} = \left(\frac{\text{TCI Treatment 1971}}{\text{TCI Treatment 1967}} \times \text{TCI Untreated 1967}\right) - \text{TCI Untreated 1971}$$

Mechanical treatments were applied in the autumn of 1967; chemical treatments were applied June, 1968. Sampling plots, of approximately 3 acres each, were established in both treated and adjacent untreated areas the spring of 1969 as follows:

Winnett Study Area

1. Aerial application of 2 lb of 2,4-D ester/acre to 480 acres for total kill of big sagebrush: six plots.

King Study Area

1. Aerial application of 2 lb of 2,4-D ester/acre to 240 acres for total kill of big sagebrush: five plots.
2. Contour furrowing of 321 acres: six plots.
3. Interseeding of 190 acres (scalped strips were 18 inches wide and 4 inches deep and interseeded with a mixture of 1 lb of western wheatgrass and 2 lb of green needlegrass per acre): five plots.

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The authors wish to thank Elaine Oma, who examined the grasshoppers for pathogens, and Wayne Burleson for field assistance, both of the Grasshopper Laboratory, Agr. Res. Serv., U.S. Dep. Agr., Bozeman, Mont. The cooperation of Thomas Mussehl, Duane Pyrah, and Henry Jorgensen of the Montana Fish and Game Department is greatly appreciated. Special thanks go to the owners of the Cornwell ranch, the Nyquist Ranch, and the Veseth Ranch for providing three of the study areas. The cooperative efforts of the Montana Fish and Game Department, Bureau of Land Management, U.S. Department of the Interior, and numerous land owners and research workers made the study possible.

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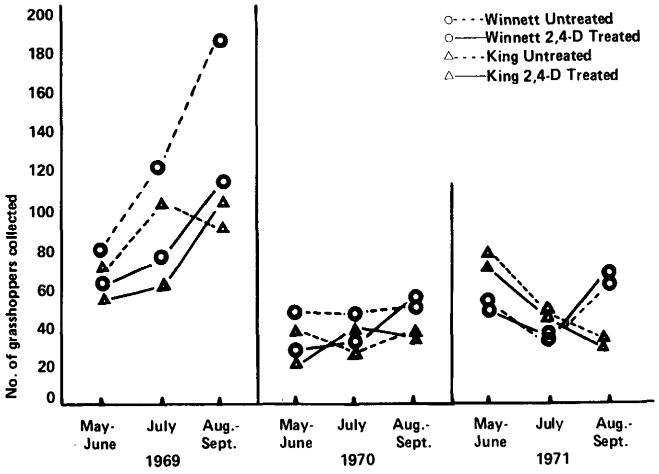

Fig. 1. *Effect of 2,4-D treatment in 1968 on numbers of grasshoppers collected by sweeping.*

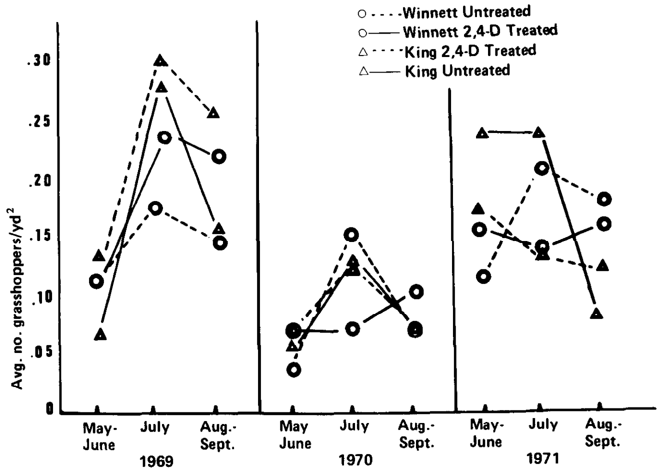

Fig. 2. *Effect of 2,4-D treatment in 1968 on numbers of grasshoppers per square yard.*

The distance between treated and untreated plots ranged from approximately 200 to 2,000 yards. Movement of grasshoppers was probably negligible, since populations were less than 1/yard^2 during the study.

Each plot was sampled three times a year in each of the 3 years 1969–1971: in May or June to sample species that overwinter as nymphs, in July, and again in August or September to sample species that overwinter in the egg stage.

The numbers and species composition of grasshoppers were measured in two ways:

1. Density was determined by visually estimating the number of grasshoppers in a square-yard area while walking in a straight line across a plot. Twenty such counts were made in each plot at each sampling time.

2. Grasshoppers were collected by sweeping with a net for 10 minutes on each plot. They were then taken to the laboratory where the number and species of parasites emerging could be determined and the relative abundance of the different species could be assessed. Also, three times in 1969 and once in 1970 grasshoppers collected in the field and frozen with dry ice were examined in the laboratory for disease organisms.

Results and Discussion

Chemical treatment of big sagebrush on Winnett and King areas.

The abundance of grasshoppers determined from sweeping is shown in Figure 1. During the 3 years, 510 were collected in treated plots in the Winnett area vs 656 in untreated plots, a 22% reduction due to treatment. In the King area, the total was 451 vs 517, a 13% reduction due to treatment. The numbers collected during May-June in treated plots were always less than the numbers collected in untreated plots at both study areas. In 1971 the numbers collected at all three sampling times were approximately equal in both treated and untreated plots for both areas. The effects of treatment apparently diminished with time.

Figure 2 gives the density of grasshoppers based on the number/yard^2. The pattern was similar to that found by sweeping. Fewer grasshoppers were counted during the July period on the treated plots at both areas in all 3 years except in the King area in 1971. However, the difference in the total number counted in treated and untreated plots was small: 154 on treated vs 147 on untreated plots in the Winnett area, and 136 vs 138 in the King area.

Putnam (1949) found that treating plots of wheat stubble with 2,4-D did not reduce populations of the migratory grasshopper, *Melanoplus sanguinipes* (= mexicanus) (F.): the average population on treated always exceeded that on untreated plots. However, Bird et al. (1966), thought that the treatment of weedy roadsides with herbicides might minimize increases in populations of roadside grasshoppers during periods of drought. In our opinion, any changes in populations of grasshoppers due to herbicides probably depends on the success of the treatment in controlling weeds and on the food preferences of the species of grasshopper.

In the 3 years of this study, 42 grasshopper species were collected from the two study areas; however, only 39 were found on the chemically treated plots. Only 16 species were collected in sufficient numbers for comparison of possible treatment effects. These are listed in Table 1 with their percentage change.

The migratory grasshopper was the most abundant species collected from the Winnett area and *Psolessa delicatula delicatula* was the most abundant species on the King area. Fewer *P. d. delicatula* were collected on treated plots of the King area all 3 years, but on the Winnett area no real difference was apparent. The migratory grasshopper was about equally abundant on treated and untreated plots on both areas. *Arphia conspersa, Arphia pseudonietana*, and *Opeia obscura* were more abundant on treated plots on both areas, but *Trimerotropis campestris* was less abundant. The other species listed in Table 1 were not consistent in response to treatment between areas.

Changes in vegetation could only be related to changes in abundance of grasshoppers in a general way. Twelve plant species showed considerable change after treatment (Table 2); however, only the two *Arphia* species of grasshoppers could be related to the vegetation changes. Brooks (1958) reported from Canada that *Arphia* species preferred grasses and sedges such as *Stipa, Agropyron*, and *Carex*. Therefore the increase in western wheatgrass, green needlegrass, and needleleaf sedge may have provided a greater abundance of favorable food plants for *A. conspersa* and *A. pseudonietana*, since they were more abundant on the treated plots in both areas.

Contour furrowing and interseeding on the King area.

The number of grasshoppers collected on each sampling

Table 1. The percentage change[1] in grasshopper species over a 3-year period due to rangeland renovation treatments.

		2,4-D		Furrowed	Scalped			
					Interseeded		Not interseeded	
	Species[2]	Winnett	King	King	King	Cornwell	Nyquist	Veseth
1.	*Aeropedellus clavatus* (Thomas)	– 39.5 (38)	+ 50.0 (6)	– 20.0 (5)	– 68.8 (16)			
2.	**Ageneotettix deorum* (Scudder)	– 41.2 (17)	+ 4.5 (22)	– 78.3 (23)	– 63.2 (19)			
3.	*Arphia conspersa* Scudder	+ 40.0 (35)	+100.0 (7)	+ 66.7 (15)	+158.3 (12)			
4.	*A. pseudonietana* (Thomas)	+ 76.9 (26)	+160.0 (5)	+ 40.0 (5)	0.0 (4)	– 21.4 (14)	– 63.6 (11)	+75.0 (8)
5.	**Encoptolophus sordidus costalis* (Scudder)	– 6.8 (44)	+ 60.0 (1)	– 100.0 (1)	– 75.0 (4)			
6.	**Eritettix simplex tricarinatus* (Thomas)	– 74.4 (39)	+181.8 (11)	– 61.5 (26)	– 86.7 (15)			
7.	*Melanoplus gladstoni* Scudder	– 75.0 (12)	+ 57.1 (7)	– 25.0 (8)	+ 57.1 (7)	+ 13.8 (29)	+ 37.5 (8)	– 72.2 (18)
8.	**M. infantilis* Scudder	+ 55.6 (9)	– 29.3 (41)	– 70.3 (37)	– 15.4 (26)	– 66.7 (168)	– 90.5 (273)	– 64.9 (57)
9.	**M. sanguinipes* (F.)	– 3.8 (158)	– 14.0 (43)	+ 28.6 (28)	+ 9.4 (32)	+1033.3 (3)	– 71.4 (14)	– 25.0 (4)
10.	**Opeia obscura* (Thomas)	+ 33.3 (6)	+ 73.1 (7)	– 91.3 (23)	– 58.3 (12)	– 18.4 (38)		– 68.8 (16)
11.	**Phlibostroma quadrimaculatum* (Thomas)	+ (0)	– 64.7 (17)	– 50.0 (10)	– 100.0 (9)	– 96.8 (31)	– 100.0 (2)	0.0 (2)
12.	*Psoloessa delicatula delicatula* (Scudder)	+ 6.7 (45)	– 29.1 (268)	– 88.7 (282)	– 81.8 (149)	– 51.7 (29)	– 100.0 (3)	– 70.0 (20)
13.	**Trachyrhachys kiowa* (Thomas)	+125.0 (4)	– 65.6 (32)	– 95.9 (49)	– 84.6 (26)	– 100.0 (29)	– 50.0 (2)	– 33.3 (3)
14.	*Trimerotropis campestris* McNeill	– 74.5 (51)	– 87.5 (16)	– 62.5 (8)	– 16.7 (6)			
15.	*T. gracilis sordida* (Walker)	– 50.0 (2)	+ 75.0 (4)	+ 75.0 (13)	+ 73.7 (5)			
16.	*Xanthippus corallipes buckelli* (Hebard)	– 43.9 (41)	+ 50.0 (4)	– 10.5 (19)	– 40.0 (25)			
Miscellaneous species		– 58.1 (129)	+ 11.5 (26)	– 57.8 (45)	– 54.2 (59)	+ 32.4 (45)	– 14.7 (34)	– 60.6 (33)
Total		– 22.3 (656)	– 12.8 (517)	– 60.5 (597)	– 48.4 (426)	– 40.0 (375)	– 78.4 (347)	– 55.9 (161)

[1] Values in parentheses are the numbers of each species collected from the untreated areas and are used for deriving the percentage change; + and – refers to increase and decrease due to treatment.

[2] *Economically important species on rangeland.

date by sweeping is shown in Figure 3. Fewer were collected on the treated plots in all 3 years at each sampling except during May-June 1970. The total collected during the 3 years on contour furrowing plots was 236 vs 597 on untreated plots, a reduction of 60%. The total collected on interseeded plots was 220 vs 426 on untreated plots, a reduction of 48%. Some differences may be attributed to sweeping over uneven terrain (treated plots) compared with sweeping over the fairly level terrain of untreated plots.

Figure 4 gives the density of grasshoppers based on the number/yd^2. Except for July, 1971, all plots interseeded had fewer grasshoppers than untreated plots. However, when only the July and August-September sampling times are considered, differences in density due to contour furrowing and interseeding became less with time. The opposite is true for the May-June sampling times: the differences became greater with time. Perhaps these treatments had a disturbing effect on the early grasshopper species that overwinter as nymphs. The total counted on contour furrowing plots in the 3-year period was 64 vs 174 on untreated plots, a reduction of 63%. The total counted on interseeded plots was 57 vs 113 on untreated plots, a reduction of 50%.

For the 3 years 28 species were identified from untreated plots as compared with 23 from contour furrowed plots and 21 from interseeded plots. *Psolessa delicatula delicatula* was the most abundant species present: 59 specimens were collected on treated vs 431 on untreated plots. Indeed, lesser numbers of most species were collected on treated plots; however, two species, *Arphia conspersa* and *Trimerotropis gracilis sordida*, were more abundant on the contour furrowed

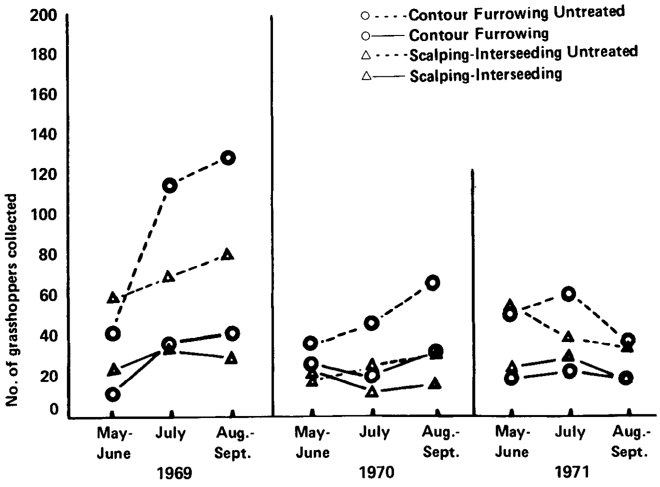

Fig. 3. *Effect of contour furrowing and scalping-interseeding on numbers of grasshoppers collected by sweeping (King area).*

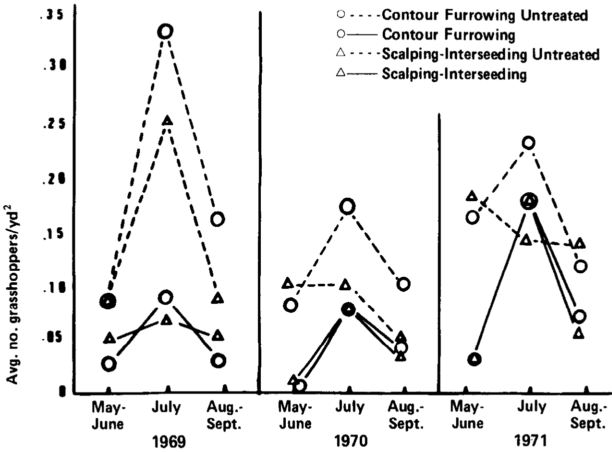

Fig. 4. *Effect of contour furrowing and scalping-interseeding on numbers of grasshoppers per square yard (King area).*

and interseeded plots. These two species belong to the subfamily Oedipodinae, a group known for the ability to fly considerable distances. Perhaps preferred food plants attracted them to treated plots since *A. conspersa* is known to prefer western wheatgrass and needleleaf sedge, both of which increased on these plots (Table 2). The preferred food plants of the *Trimerotropis* species are unknown.

Following contour furrowing and interseeding, three plant species—western wheatgrass, needleleaf sedge, and big sagebrush—increased significantly while blue grama decreased. Green needlegrass and fringed sagewort increased on contour furrowed plots; Sandberg bluegrass, prairie Junegrass, and bluebunch wheatgrass decreased. American vetch decreased on interseeded plots. Blue grama is a preferred food plant for at least five economically important species of grasshoppers (Mulkern et al., 1969, and Ueckert et al., 1972), all of which were present on the study area and all but one of which decreased.

Anderson (1964) reported that vegetation influences grasshoppers in at least two ways: (1) grasshopper species tend to be found in areas with their preferred food plants, and (2) the physical structure of the vegetation affects the distribution and abundance of grasshoppers. For example, he found that native grasslands were more frequently occupied by greater numbers of grasshoppers when the percentage foliage cover was below 40. Thus, since contour furrowing and interseeding resulted in changes in the food plants present and, generally, in a more dense and higher stand of vegetation, the two treatments may have created an unfavorable habitat for many plains-inhabiting species.

The influence of parasites, predators, and pathogens on grasshopper species was thought to be minor. Two species of Sarcophagidae, *Blaesoxipha reversa* (Aldrich) and *Blaesoxipha kellyi* (Aldrich), and one unknown species of Tachinidae were the only parasites reared. In addition, a few adults of *Blaesoxipha reversa* and *Blaesoxipha opifera* (Coquillett) were collected by sweeping. Predators belonging to the following families were observed and collected in the study areas: Sphecidae, Carabidae, Bombyliidae, Asilidae, Cicindelidae, Meloidae, Acarina, and Araneida. The incidence of disease also appeared to be low: only one occurrence of fungus and two of Shizogregarine were detected.

Conclusions

1) Spraying for sagebrush control with 2,4-D ester in 6 gal H_2O/acre did not result in a large reduction in the density of grasshoppers. Some species such as *Psoloessa delicatula delicatula* were consistently less abundant on treated areas; other species such as *Arphia conspersa* and *Arphia pseudonietana* were more abundant. Populations on all plots were less than 1/yard^2, a level that is not economically important.

2) Plots which were contour furrowed and interseeded provided an unfavorable habitat for most grasshopper species present, including all the economically important species indicated in Table 1, except the migratory grasshopper. Grasshopper density was less during all 3 years of sampling on treated plots. The greatest differences were found on contour furrowed plots, but these differences appeared to decrease with time. One species, *Psoloessa delicatula delicatula*, was much less abundant on these treated plots, but other species, such as *Arphia conspersa* and *Trimerotropis gracilis sordida*, were more abundant.

3) Probably both increases and decreases in preferred food plants of grasshoppers that resulted from treatments influenced the abundance of grasshoppers. However, abundance on treated and untreated plots could only be related to food plants in a general way.

4) Parasites, predators, and pathogens did not exert a measurable influence on grasshoppers in the study areas.

Table 2. Vegetational changes (CVC[1]) of 12 plant species from 1967 (pretreatment) to 1971 (posttreatment).

	Treatment			
	Chemical		Contour furrowing	Inter-seeding
Species	Winnett	King	King	King
Western wheatgrass (*Agropyron smithii*)	+ 7775	+4721	+42521	+31889
Bluebunch wheatgrass (*Agropyron spicatum*)	0	– 1985	– 4830	0
Prairie junegrass (*Koeleria cristata*)	– 262	– 1345	– 2830	– 741
Needleandthread (*Stipa comata*)	– 223	– 2702	0	0
Green needlegrass (*Stipa viridula*)	+ 1701	+2323	+ 1181	0
Blue grama (*Bouteloua gracilis*)	+ 509	– 356	– 1512	– 593
Sandberg bluegrass (*Poa secunda*)	– 418	+ 603	– 1837	0
Needleleaf sedge (*Carex eleocharis*)	– 336	+4295	+ 1485	+ 1330
Hoods phlox (*Phlox hoodii*)	– 796	– 258	– 107	– 173
American vetch (*Vicia americana*)	– 1539	+ 199	+ 204	– 1593
Fringed sagewort (*Artemisia frigida*)	– 1835	– 1471	+ 9913	– 239
Big sagebrush (*Artemisia tridentata*)	– 33552	– 6314	+ 2434	+ 6216

[1] Corrected vegetational change defined in text.

Part 2. Rangeland Scalping to Increase Production of Forage

This study was carried out from 1969 to 1971 on three ranches in northern Montana. Extensive acreages had been scalped or interseeded on each ranch (Ryerson et al., 1970).

Procedures

One study area, the Cornwell ranch, was located 11 miles west of Glasgow, Montana. There, scalping and interseeding with a mixture of bluebunch wheatgrass, thickspike wheatgrass and green needlegrass had been completed in the fall of 1966, and then deferred from grazing until the fall of 1968, when the seedlings had become well-established. A second study area, the Nyquist ranch, was located 28 miles north of Glasgow, Mont. This area was scalped without interseeding in the fall of 1968 and was lightly grazed in 1969. A third study area, the Veseth ranch, was located 37 miles southeast of Malta, Mont.; it was scalped, and seeds were broadcast in the fall of 1968, but no seedlings became established.

At each location, a transect line 600 yards long was established, 300 yards in the treated area and 300 yards in an untreated area. At 30-yard intervals along the line, the density of grasshoppers was determined in an area of 20 yd^2 (procedure described in Part 1) on one side of and perpendicular to the transect line; thus a total of 200 yd^2 was surveyed in each of the treated and untreated areas. The counts were made at all three ranches, once in 1969, twice in 1970, and once in

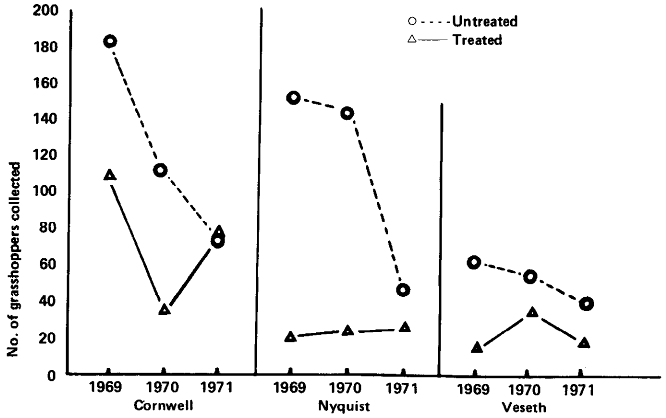

Fig. 5. *Effect of scalping on numbers of grasshoppers collected by sweeping on three ranches.*

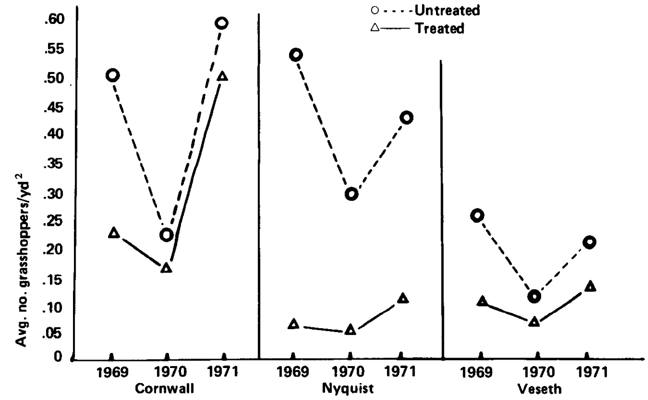

Fig. 6. *Density of grasshoppers (no/yd²) at 3 locations on treated and untreated plots, 1969–1971.*

1971. Live grasshoppers collected on the other side of the transect line by sweeping (10 min/300-yard area) were used to determine incidence of parasites and disease organisms and the relative abundance of grasshopper species.

Results and Discussion

The abundance of grasshoppers determined by sweeping is shown in Figure 5. In all 3 years and at all three locations, with one exception, fewer grasshoppers were collected on the treated plots. The total number of grasshoppers collected in 3 years on treated vs untreated plots was as follows: Cornwell ranch, 225 vs 375; Nyquist ranch, 75 vs 347; and Veseth ranch, 71 vs 161. In general, the differences in the numbers of grasshoppers collected in treated and untreated plots decreased from 1969 to 1971.

The density of grasshoppers/yd^2 is given in Figure 6. Fewer grasshoppers were consistently counted on the treated plots. The difference in density between treated and untreated plots was greatest on the Nyquist ranch; on the other two ranches, differences were smaller after 1969. Perhaps the preference of grasshoppers for the interseeded grass species on the Cornwell ranch accounts for the small difference there in 1970 and 1971. The total number of grasshoppers counted during the 3-year period on treated vs untreated plots was as follows: Cornwell ranch, 121 vs 308; Nyquist ranch, 50 vs 309; and Veseth ranch 73 vs 135.

The numbers of grasshopper species collected on treated vs untreated plots was as follows: Cornwell ranch 17 vs 21; Nyquist ranch, 14 vs 16; and Veseth ranch, 16 vs 18. *Melanoplus infantilis* was the most abundant species: 102 were collected from treated plots compared with 498 from untreated plots. In all, 28 species were present on all three study areas, but only eight were abundant enough to show treatment effects (listed along with the percentage change in Table 1). Most of these species were less abundant on treated plots; however, one species, the migratory grasshopper, was more abundant on the Cornwell ranch.

The total effect of parasites, predators, and pathogens on the populations of grasshoppers was not determined. However, recorded parasitism was low: only seven *Blaesoxipha opifera* and five *Blaesoxipha hunteri* (Hough) emerged from adult *Melanoplus infantilis* in the laboratory. Predators collected during the 3-year period belonged to the families Bombyliidae, Asilidae, Carabidae, and Araneida. No disease pathogens were found in any grasshoppers examined.

Conclusions

1) In general, the practice of rangeland scalping and interseeding had an unfavorable effect on many of the 28 species of grasshoppers sampled: grasshopper density was lowest on the treated areas at all three locations in all 3 years. Only eight species occurred in numbers large enough to assess treatment effects, and five of these (all of which are economically important on rangeland) were consistently less abundant on treated plots. Two economically unimportant species, *Melanoplus gladstoni* and *Arphia pseudonietana*, were about equally distributed between treated and untreated plots. Fewer species were collected on treated plots at each of the three locations.

2) Parasites and pathogens did not appear to be exerting a measurable influence on grasshopper populations at the time of sampling. The effect of predators is unknown.

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Urea as a Nitrogen Fertilizer for Great Plains Grasslands

J. F. POWER

Highlight: *Economics and pollution standards indicate that urea may soon be the prime nitrogen fertilizer source in the Great Plains. Available literature was reviewed on the use of urea as a fertilizer for grasslands, particularly in semiarid regions. Results from only a few such experiments were found. However, these results agree with those from more humid or subtropical regions in that urea was as effective as ammonium nitrate at low, but not at high, rates of application. Maximum production attainable with urea is probably less than that attainable with ammonium nitrate.*

Several developments within recent years indicate that urea will become the primary nitrogen fertilizer source for semiarid grasslands in the near future. Among these developments are: (a) the need for N fertilizers, particularly on cool season grasses in the Great Plains, is rapidly becoming more apparent in order to meet livestock demands; (b) lack of suitable application methods essentially prohibits using anhydrous ammonia on these grasslands; and (c) nitrate-containing sources, especially ammonium nitrate, may soon become prohibitive in price because of technological difficulties in controlling the emission of nitrous oxides during manufacture. Thus, only ammonium sulfate and urea remain of the conventional fertilizer N sources, and the price of N as ammonium sulfate is frequently 40% greater than that of urea (Huston, 1971). Consequently, urea may become the predominant fertilizer N source for the Great Plains in the foreseeable future.

Unfortunately, available publications provide the fertilizer industry and user with only limited information on the effectiveness of urea as an N source for dryland grasses. It is commonly accepted that, as urea is hydrolyzed to ammonia and carbon dioxide, significant quantities of the ammonia produced may escape to the atmosphere. Conditions that are generally conducive to ammonia volatilization include neutral or alkaline soil pH, moderately restricted water supply, warm temperature, and presence of organic mulches. Several or all of these conditions apparently may be encountered in semiarid grasslands. Consequently, a very real question exists concerning the efficiency of urea as a fertilizer N source for semiarid grasslands.

This paper is a review of present information on the use of urea on semiarid grasslands. Although all pertinent references may not be included, the purpose of this paper is to point out to the reader the nature and extent of factual information available on the subject. Urea has been used as a fertilizer N source for semiarid grasslands in only a limited number of controlled field experiments. However, a number of laboratory and field experiments using urea with other crops or in other climates have been reported. Results of several pertinent experiments are reviewed in this paper.

Power and Alessi (1970) studied the effects of 90 and 180 kg N/ha as ammonium nitrate, ammonium sulfate, calcium nitrate, or urea upon crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) production for 5 years. Nitrogen fertilizers were applied with or without surface broadcast P fertilizer. Dry weights for only the urea and ammonium nitrate treatments are shown in Table 1—yields for other N sources were generally similar to those obtained with ammonium nitrate. P fertilization increased dry matter production by 22% (10 to 50% range), regardless of N rate or source. At the 90 kg N/ha rate, N source had no significant effect upon yields. However, urea applied at 180 kg N/ha yielded no more than at the 90 kg/ha rate when no P was added. With P fertilization, there was also no response to the higher urea rate for the first 3 years of the study, but responses were evident the last 2 years. Inorganic N did not build up in soils receiving 90 kg N/ha annually, but frequently over 150 kg inorganic N/ha accumulated in the upper 90 cm of soil after 5 years of fertilization at 180 kg N/ha annually. A very noticeable exception was the treatment receiving 180 kg N as urea plus P fertilization, where no accumulation of inorganic was found. This difference was verified by unpublished data from this experiment on residual effects from these treatments where it was found that residual responses were much greater from ammonium nitrate than from urea. After 5 years of fertilization at 180 kg N/ha annually soil pH in the surface 15 cm decreased from 6.2 to 5.5 with ammonium nitrate and to 5.8 with urea.

In another experiment by Power et al. (1972) urea, ammonium nitrate, ammonium sulfate, and calcium nitrate were applied to both corn (*Zea mays* L.) and smooth brome (*Bromus inermis* L.) at rates of 55 and 110 kg N/ha (fine sandy

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loam, surface pH 6.5). At the 55 kg N/ha rate, dry matter production by corn following urea fertilization was approximately equal to that following ammonium nitrate fertilization (Fig. 1). With 110 kg N/ha however, only 73% as much dry matter was produced from urea as from ammonium nitrate. Average dry matter production by smooth brome receiving 110 kg N/ha as urea was not significantly greater than that receiving 55 kg urea N/ha. Soil pH did not change appreciably as a result of fertilization with either of these N sources.

Fertilization was discontinued in the above experiment, and both the areas formerly in corn and in bromegrass were uniformly cropped to barley without additional N application, until residual growth responses were no longer significant. The fate of the fertilizer N applied was then determined (Power et al., 1973). For urea, 47% of the fertilizer N applied at 110 kg N/ha could be accounted for by N uptake in tops plus inorganic N remaining in the root zone of the soil. Movement below the root zone was generally insignificant for smooth brome. N recovery averaged 82% for the other N sources. N recoveries for the corn area were 86 and 79% for urea and other N sources, respectively, when applied at the high N rate. The experiment was continued until growth responses resulting from residual effects of previous treatments were no longer statistically significant, indicating that little or no fertilizer N remained in plant roots, residues, or in available organic or inorganic forms. Thus, a large part of the fertilizer N was probably lost from the soil in gaseous form, especially by ammonia volatilization. Since all N fertilizers for corn were drilled about 6 cm deep but were surface broadcast on smooth brome, it appears that volatilization of ammonia from urea surface broadcast on a coarse-textured neutral grassland soil may become significant.

Table 1. Dry weight (kg/ha) of crested wheatgrass fertilized with ammonium nitrate and urea (kg N/ha), Mandan, N. Dak.

		Without P			With P		
Year	N fertilizer	0-N	90-N	180-N	0-N	90-N	180-N
1962	–	2,050	–	–	2,620	–	–
	NH_4NO_3	–	4,560	5,850	–	5,140	6,450
	Urea	–	4,650	4,850	–	4,950	5,240
1963	–	1,130	–	–	1,570	–	–
	NH_4NO_3	–	2,730	3,140	–	3,700	3,850
	Urea	–	3,330	2,980	–	3,610	3,600
1964	–	1,010	–	–	1,120	–	–
	NH_4NO_3	–	2,420	2,590	–	3,120	3,120
	Urea	–	2,460	2,290	–	3,180	3,300
1965	–	1,780	–	–	2,220	–	–
	NH_4NO_3	–	5,880		–	6,260	6,290
	Urea	–	4,800	5,240	–	5,760	6,860
1966	–	670	–	–	1,020	–	–
	NH_4NO_3	–	1,820	1,870	–	2,780	2,370
	Urea	–	2,040	1,740	–	2,280	2,690
Avg	–	1,330	–	–	1,710	–	–
	NH_4NO_3	–	3,360	3,860	–	4,200	4,410
	Urea	–	3,460	3,410	–	3,940	4,330

McGinnies (1968) recently published results from an experiment in which urea was applied to crested wheatgrass in eastern Colorado, but unfortunately no other N sources were used for comparison. Sneva (1973) found little difference between urea and ammonium nitrate when applied at 22 kg N/ha to several dryland grasses in Oregon. Dry matter production resulting from N fertilization increased about 20% over a 3 year period. A review of literature for the past decade revealed no further information from field experiments involving urea fertilization of semiarid grasslands in North America.

Limited investigations in the Soviet Union have resulted in variable results. Generally, little difference between fertilizer sources was observed when they were applied to several grasses on various types of chernozemic and semiarid soils (Kondrst'ev and Podkolzina, 1966). Lichev (1966) reported similar results on chernozemic soils in Bulgaria. Moraczewaski (1970) found ammonium nitrate produced 6.4% more grass than urea produced on Polish chernozems at N rates up to 300 kg/ha. N rate was not specified in the other eastern European studies. In Spain (Suarez and Ascension, 1965), urea applied to grassland was equal to or better than ammonium nitrate, but again N rate was not specified. In Australia, Henzell (1971) found urea to be less effective at rates up to 448 kg N/ha, and found fertilizer N losses from urea to be as much as 43%. Simpson (1968) reported similar losses from urea applied to ryegrass in the same region.

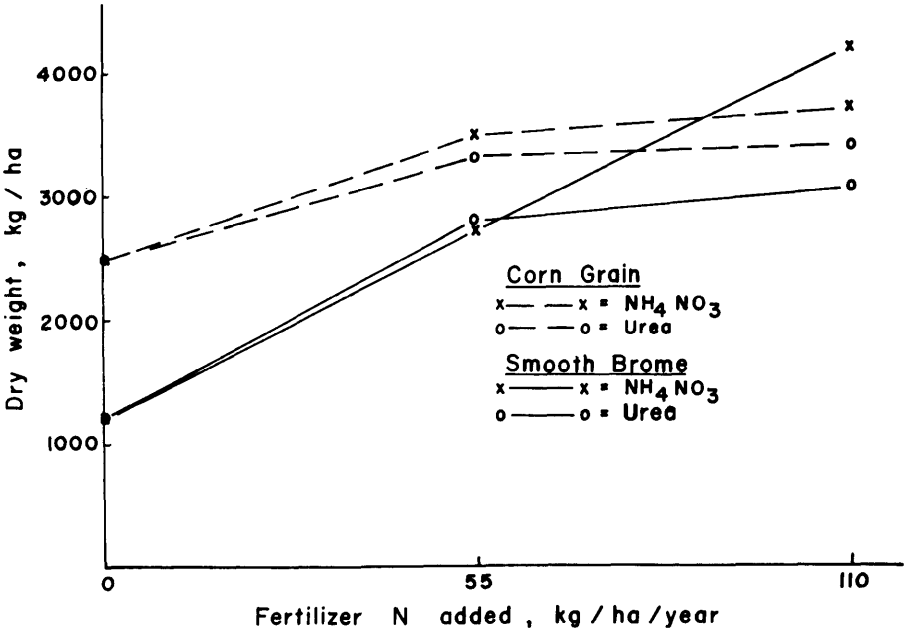

Fig. 1. *Effect of ammonium nitrate and urea on dry matter production of smooth brome and corn.*

Urea has been used more frequently as a fertilizer N source for grasslands in the fringe areas of the Great Plains where precipitation is often greater or evapotranspiration is less. Seamands (1971) found little difference between ureaforms, ammonium nitrate, and liquid urea applied at 112 kg/ha to mountain meadows in Wyoming. Cairns (1968) measured 55% recovery of ammonium nitrate, compared with 45% for urea, applied at 112 kg/ha to smooth brome on solonetzic soils with high water table in Alberta. Urea was as effective as ammonium nitrate when applied to coastal bermudagrass (*Cynodon dactylon* L.) in Oklahoma (Hill and Tucker, 1968) at 112 kg N/ha but was inferior at 224 kg N/ha.

Urea used on grasslands in temperate humid regions and in subtropical and tropical regions has been investigated in a number of studies. Urea was as effective as ammonium nitrate (Korenkov and Filimonov, 1968; Vlasova, 1968) in only a few eastern European countries, but in these cases the N rate was not specified. In Western Europe (Devine and Holmes, 1963 and 1965; Furunes, 1966; Johansson and Jonson, 1964: and Mundy, 1966), eastern United States (Mays and Terman, 1969), Alaska (Laughlin, 1963), and several tropical locations (Vicente-Chandler and Figarella, 1962; Volk, 1966) urea applied at moderate-to-high rates produced less dry matter than did ammonium nitrate.

Volk (1966) illustrated that hydrolysis of urea did not occur in a dry soil, and that the process was restricted in a soil temporarily wetted. However, soil surfaces continually wetted from a water table resulted in complete hydrolysis of urea in 7 days, 65% of which was then lost, presumably by ammonia volatilization. Kresge and Satchell (1960) showed that heavy watering restricted ammonia losses. Consequently, soil water contents in the range required for plant growth appear to be conducive to ammonia volatilization.

Simpson (1968) found that gaseous losses could be reduced to almost half by removing a centimeter or two of the grass sod surface, the soil zone in which urease activity was particularly high. Likewise, Jackson and Burton (1962) reported that gaseous losses from urea applied to bermudagrass were reduced if the stubble was burned or if the soil was plowed shallow prior to fertilizer application. These and other results support the theory that gaseous losses from urea are enhanced by organic mulch present on the soil surface.

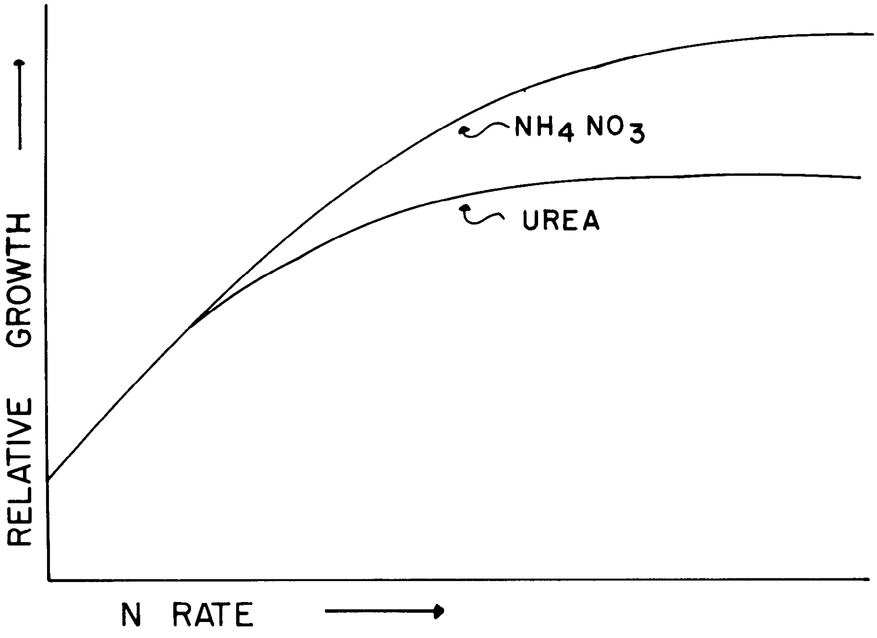

Fig. 2. *Diagram showing the relation between rate of fertilization with ammonium nitrate and urea to dry matter production from grassland soils.*

A review of literature therefore suggests that low to moderate rates of urea are often equally as effective as ammonium nitrate for grass production. However, results of most experiments using higher N rates on numerous kinds of soils in many climates indicate that urea is generally 5 to 40% less effective than ammonium nitrate. These relationships are expressed for low and moderate rates in Fig. 1, and diagrammatically for all N rates in Fig. 2. At low rates of N fertilization, urea produced essentially the same amount of grass forage as ammonium nitrate did. However, at intermediate rates, the curves began to diverge and the urea curve flattened out while the ammonium nitrate curve reached a maximum at a much higher N rate. Yields obtained with urea may never equal maximum yields obtainable from ammonium nitrate (Fig. 2). However, in none of the experiments cited did fertilizer rates go high enough to definitely establish this relationship. In the publications of Power et al. (1970, 1972), Henzell (1971), and Devine and Holmes (1963), data show that the response of urea compared with that of ammonium nitrate or other N sources decreased as rate of N fertilization increased for all rates studied. This suggests continued divergence of the response curves as N rate increases, as indicated by Fig. 2.

From the publications reviewed in this paper, urea at higher rates appears less efficient than ammonium nitrate, especially when applied to moderately moist soils that are near neutral or alkaline and are coarse in texture. Organic residues present on the soil surface may further reduce the efficiency of urea. All these conditions are frequently encountered in semiarid grasslands. Consequently, although actual field data are very limited, the data presented in the tables and figures here are somewhat typical of what might be expected in actual practice.

If further research proves these conclusions correct, the fact that urea is less efficient as an N source for grass production may not be as important as the fact that maximum yields obtainable with urea may be less than with ammonium nitrate. Much more research is needed to better answer these and related questions and to better establish the place of urea as an N source for semiarid grasslands.

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TECHNICAL NOTES

Influence of Ethrel on Phenological Development in Honey Mesquite

DAVID L. PARSONS AND RONALD E. SOSEBEE

Highlight: *The influence of ethrel on the phenological development of mature honey mesquite (*Prosopis glandulosa *var.* glandulosa*) was studied from February 15, 1971, through May 8, 1972. Ethrel (250 ppm) applied in aqueous solution in winter or early spring of 1972 decreased flower production during the spring, 1972. Ethrel applied as a pretreatment, therefore, could be quite important in relation to chemical control of honey mesquite since herbicidal mesquite kills are inversely proportional to flower production. Ethrel did not affect any other phenological event nor did it exhibit any ability to synchronize the phenological events in honey mesquite.*

Ethylene is a naturally occurring plant growth regulator used by horticulturists and pomologists for several years to synchronize phenological events in various plants. It has often been used to synchronize and accelerate fruit ripening in many plants (Burg and Burg, 1967; Burg, 1965; Edgerton and Blanpied, 1968; Russo, Dostal, and Leopold, 1968; Anderson, 1969; Byers, Dostal, and Emerson, 1969; and Crane, Marei, and Nelson, 1970). Flower production was induced in Cayenne pineapple (*Ananas sativas* var. Cayenne) plants when they were sprayed with 2-chloroethanephosphonic acid (Cooke and Randall, 1968). Taun and Bonner (1964) reported dormancy in potato tuber buds could be broken by ethylene. Rhizome development was stimulated in Johnsongrass (*Sorghum halepense*) and quackgrass (*Agropyron repens*) when treated with 2-chloroethylphosphonic acid (Anonymous, 1969). Moir (1970) reported that ethylene has been used to stimulate latex production in rubber trees (*Hevea brasiliensis*).

The lack of effective herbicidal control of honey mesquite (*Prosopis glandulosa* var. *glandulosa*) partially results from 1) the stage of development of the trees, 2) the diversity of phenological stages represented by the trees, and 3) the relative abundance of flowers present at the time of herbicide application. Mesquite has the capacity to release as many as four sets of flower buds during the growing season, depending upon environmental conditions (Greer, 1967). Consequently, at any given time during the growing season there may be an array of stages in flower production ranging from closed flower spikes to pods that are nearly mature. Morgan (1969) found that 2-chloroethanephosphonic acid applied to honey mesquite seedlings caused defoliation and, subsequently, growth of formerly inactive basal buds. Basal buds remain inactive until the top of the plant is damaged or destroyed.

This study was initiated to determine the ability of ethrel[1] (2-chloroethylphosphonic acid), an ethylene producing compound (Yang, 1969), to regulate the phenological events in honey mesquite. Specific objectives were to determine 1) the ability of ethrel to regulate bud burst and relative abundance of flowers produced and 2) the time of application and concentration of ethrel most effective in synchronizing the phenological events.

Procedures

This study was conducted on 825 permanently marked trees growing on a deep hardland site (Stegall-Slaughter Association) on the Post-Montgomery Estate ranch near Post, Texas. The experimental design consisted of 5 randomized complete blocks and 11 treatments (Table 1) applied to the trees on 15 different dates from February 1, 1971, through March 31, 1972. The trees were treated biweekly during the growing season and monthly during the remainder of the year. The trees were not treated from mid-April, 1971, until mid-August, 1971. No tree was treated more than once.

Table 1. Ethrel treatments applied on 15 different dates from February 2, 1971, through March 31, 1972, in an attempt to regulate the phenological development of honey mesquite.

Ethrel (ppm)	Carrier
0 (Control)	none
0	distilled water
0	distilled water + glycerol (10%)
50	distilled water
50	distilled water + glycerol (10%)
250	distilled water
250	distilled water + glycerol (10%)
1000	distilled water
1000	distilled water + glycerol (10%)
5000	distilled water
5000	distilled water + glycerol (10%)

At the time of ethrel application, soil temperature (6, 12, 18, and 24-inch depths), air temperature, relative humidity, and soil water content (percent) were measured. Soil water content was determined in 6-inch increments from the surface to a depth of 2 ft. The average soil water content per treatment date was determined from three gravimetric samples. The soil temperature (average from three replications per treatment date) was determined by inserting a glass laboratory thermometer into a 3/8-inch hole to the desire depth.

The phenological development and abundance of flowers were recorded at the time of ethrel application. The total reproductive potential of each marked tree was estimated. Leaf and flower production were estimated as a percent of the total reproductive potential of each tree. Although absolute values could not be ascertained, this subjective rating with relative values provided a way to avoid

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[1] Ethrel–Amchem 66-329 [2 lb ethrel A.E./gal. (alcohol base) water soluble]. Use of trade names does not constitute endorsement by either the authors or Texas Tech University but is for the convenience of the reader.

wordy descriptions that were less meaningful. These measurements were made weekly April 13 through August 31, 1971; monthly in mid-September and mid-October, 1971; and biweekly April 13 through May 10, 1972. No visible signs of bud activity could be detected during the dormant period. Therefore, phenological development was not recorded from November 1, 1971, through March 30, 1972.

Results and Discussion

Application of ethrel had no influence on the relative number of buds released from dormancy nor leaf development of honey mesquite. However, it was influential in regulating flower development.

Abundance of flowers has been shown by Dahl et al. (1971) to be second in importance to soil temperature in influencing mesquite control with 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T). Root kills did not exceed 12% on sites where flower production per tree exceeded 17%. Although no significant differences were detected among concentrations of ethrel, the greatest percentage of trees with the least amount of flower production in the spring, 1972, occurred when the trees were treated with 250 ppm ethrel applied in aqueous solution between January 15 and March 31, 1972 (Table 2). Leaves and flower spikes of honey mesquite growing on a deep hardland site within the vicinity of the study area usually emerge from dormancy about mid-April. Therefore, chemical control of honey mesquite could possibly be enhanced with a pretreatment of ethrel (250 ppm) applied during the early stages of bud burst.

Table 2. Honey mesquite trees (%) within the various ethrel treatments that produced less than 20% flowers during the spring, 1972. The trees were treated between January 15, 1972, and March 31, 1972.

Treatment	May 8, 1972
Control	48[1]
0 ppm ethrel + water	44
0 ppm ethrel + water + glycerol (10%)	40
50 ppm ethrel + water	56
50 ppm ethrel + water + glycerol (10%)	52
250 ppm ethrel + water	84
250 ppm ethrel + water + glycerol (10%)	44
1000 ppm ethrel + water	32
1000 ppm ethrel + water + glycerol (10%)	68
5000 ppm ethrel + water	48
5000 ppm ethrel + water + glycerol (10%)	72

[1] There were no significant differences (0.05 level) among any of the treatment means.

Increased gumosis was observed on the outer surface of the bark of trees that had been top killed or defoliated by application of high concentrations of ethrel (5000 ppm). The aerial portion of trees exhibiting gumosis were killed. Resultant basal sprouting followed injury to the aerial portions of the honey mesquite trees. However, ethrel had no influence on basal sprouting of the trees that were not top-killed.

Honey mesquite is well adapted to the semiarid regions of the southwest United States. The ability to release more than one set of buds from dormancy in a growing season allows the trees to survive and successfully reproduce under very dry conditions, although one or more sets of buds may be damaged by the dry conditions. Consequently it is difficult to alter this survival mechanism and ethrel did not exhibit any ability to synchronize the phenological events.

The environmental parameters measured at the time of treatment did not significantly influence the effects of ethrel obtained in this study with the exception of the influence of soil water on those trees treated on May 10, 1971. Seemingly, bud set occurs during the spring 1 year prior to their expression. Significantly fewer buds of trees growing under relatively wet soil conditions broke dormancy the following spring, consequently, fewer flowers were produced. Possibly the energy fixed by these trees was used in foliage production, whereas under dry soil conditions, the available energy was used in flower bud development, insuring perpetuation of the population. This phenomenon deserves further study.

Summary and Conclusions

Ethrel exhibited only limited influence on the phenological events in mature honey mesquite trees. Although honey mesquite has the capacity to release as many as four sets of buds from dormancy in any given growing season, ethrel did not exhibit any ability to synchronize this development. It also did not affect leaf production.

However, ethrel was influential in regulating flower production. In relation to chemical control of honey mesquite, regulation of flower production perhaps could be the most important effect of ethrel. Honey mesquite trees that produce few flowers seemingly are easier to control with herbicides than trees that produce many flowers. Results of this study indicated that more trees sprayed with 250 ppm ethrel (aqueous solution) in the winter or early spring of 1972 produced fewer flowers in 1972 than trees sprayed at any other time during this study.

Honey mesquite is well adapted to its environment, consequently significant alteration of the natural sequence of phenological events in mature trees is very difficult.

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BOOK REVIEWS

Review: Range Research and Range Problems. Edited by Madison J. Wright. Crop Science Society of America, 677 South Segoe Road, Madison Wisconsin 53711. 91 p. 1973.

The title of this booklet suggests a comprehensive coverage of the state of the knowledge of range science and management. As stated in the Foreword, the papers were presented before a large group of agronomists for their enlightenment on the application of science to the solution of range development problems. It represents a compendium of eight papers presented at the 1970 meeting of the American Society of Agronomy.

The introductory paper provides a broad and interesting view of the range resources and their importance to our nation's meat supply. It briefly describes the inherent ecological limitations of the range resources, the range livestock industry and its economic worth, and the multiple use values impinging upon the major range vegetation types.

Unfortunately, the reader may be led to anticipate a similar broadscale treatment of important facets of research and problems associated with use and management of the range resource. For example, one would expect that the subject *Range Forage and Animal Nutrition* would encompass results beyond that obtained at but one research installation. Although the material presented is interesting and thorough, the reader is not given the overview information he might expect. Similar brief treatments of poisonous plants, weed and brush control, and seeding are offered. Within these limitations, the prospective reader will find the booklet of value.

A final paper, *Summary and Prospects,* offers four major problems of the western range. However, the problem considered of primary importance, the development and application of grazing management systems, is not treated in the book except to make the claim that better management is needed. As the author points out, one of the primary prerequisites to the development of better grazing systems is increased knowledge of the physiology of range plants. However, the book does not discuss how physiology affects phenological development of range forage, the intensity of use it can withstand, or when and how frequently it may be grazed.

Predictably, arid rangelands will continue to play an important role in animal production, although that role will have to be increasingly harmonized with other burgeoning demands on the resource. While an entirely weed- and brush-free range may never be realized, the opportunities the author envisions for improving and developing this valuable component of our natural heritage are encouraging.–*Harold A. Paulsen, Jr.*, Fort Collins, Colorado.

Boots and Forceps. By Willet J. Price, D.V.M., as told to Hazel Heckman, drawings by Helen Hiatt. Iowa State University Press, Ames, Iowa. $5.95.

Boots and Forceps is a veterinarian's story of his forty years as a large-animal practitioner. The story is told with plenty of colorful, down-to-earth language and many humorous anecdotes.

Dr. Price was one of the first college-educated veterinarians to arrive in the Woodward, Okla., area at the beginning of the depression of the 1930's. His duties there consisted mainly of buying and slaughtering drouth-stricken cattle, TB testing, and treating of ornery mules belonging to W. P. A. workers.

After service with the U.S. Army Veterinary Crops, Dr. Price went back into private practice at Wisner, Nebr. This area was different from the Oklahoma Panhandle in that it was largely hog and cattle feeding area. Dr. Price discusses the etiology and treatment of diseases of cattle and hogs. Dr. Price also cites humourous events in his participation in many community activities.

Nearing retirement age and hungry for open-range country again, Dr. Price went into brucellosis (Bang's disease) control with the Animal Disease Eradication division of the United States Department of Agriculture at McGill, Nev. Dr. Price has many humorous stories of the cattle and sheep owners of the range country, and includes a chapter on poisonous plants titled "Nature's Poison Cupboard."

This book is light and humorous reading with lots of cowboy philosophy in chapters ranging from "Cow College" to "Tits on a Boar." If you want some pleasurable reading on how things used to be in range country, *Boots and Forceps* is a must.–*George W. Dyck*, Fort Collins, Colorado.

Landscaping with Native Arizona Plants. Edited by Ervin M. Schmutz. The Univ. of Arizona Press, Box 3398, Tucson, Arizona 85722. 194 p., 1973. $4.95 paperback.

This book unites the contributions of eight members of the Natural Vegetation Committee, Arizona Chapter of the Soil Conservation Society of America. As the title suggests, it is a book ". . . to emphasize the merits of native Arizona plants. . . ." It is directed to a broad audience who can use or recommend the use of natives for their particular advantages.

The significant value of the book is its organization based upon the 8 Major Land Resource Areas (MLRA's) of Arizona as identified by the U. S. Soil Conservation Service in 1964. This means that there is a context of regional landscapes within which particular vegetation types occur–a basic guide to appropriate plants in appropriate places when establishment of new plantations is planned. Plant identification is not one of the stated objectives of the book, but identifying plants in their relationships to MLRA's should prove to be a helpful and rational restraint. Thinking of my own early introduction to the conifers (and other vegetation) of the various California mountain ranges, I was never really comfortable about what tree was what until I was in the place where a certain species was typical. The neophyte needs guidance so that he does not expect a particular plant to occur all over the map. Understanding and making practical use of the MLRA's should lead to better appreciation of Arizona's regional landscapes. Guidance of the MLRA's should also be instrumental in choosing plants so that they fit–both visually and culturally–into a particular surrounding landscape.

Landscaping with Native Arizona

Plants is simply ordered into five parts. There is a short introduction on how the book is organized and with a bit on locations, characteristics, and sources of recommended plants. The brief terminating chapter is on planting and transplanting. The substance of the book is in three central chapters: (1) Major land resource areas and related vegetation types, (2) recommended species within vegetation types and MLRA's, adaptions according to site positions and soil textural classes, and (3) characteristics of recommended native plants.

A few minor criticisms may be noted, but they should not detract from the valuable contribution that the book makes. In the beginning, a little elaboration on the term "site beautification" could have pointed out that many functional group arrangements of plants—such as barriers, visual screens, spatial separators, wind screens, enclosure to establish a scale relationship—often lie at the heart of what may be perceived as beautiful or satisfying. Certain plant descriptions could have benefited from some additional but succinct indication of design characteristics, particularly regarding form, color, and texture qualities. The bias of the authors appears a bit as "range pests" are identified—fair enough warning, but hopefully not to the extent of eliminating certain desirable plants not apt to be serious pests under cultivated conditions. The advice on page 174 "... male plants should be planted to avoid seeds or fruits that clutter up the yard ..." is difficult to follow when monoecious plants are involved.

This straightforward book, conceived for a diverse audience, is particularly important because it suggests rational ways of choosing new plants to suit a variety of surrounding native landscapes. Following its guidance should result in both better design solutions and cultural success. At the same time, the suggested procedures should aid in maintaining the integrity of regional landscapes. Other states or regions would be benefited by similar publications.—*R. Burton Litton, Jr.*, Berkeley, California.

Nebraska Wild Flowers. By Robert C. Lommasson. University of Nebraska Press. Lincoln Nebraska. 185 p. 1973. $4.00 paper bound. $10.00 cloth bound.

Anyone interested in the wild flowers of the Central Great Plains will find this book of interest. It briefly describes and illustrates 260 species which occur in Nebraska. The author makes clear in the introduction that no attempt is made to develop a flora of flowering plants for Nebraska. Included are those herbaceous species which produce showy flowers. Trees, shrubs, woody vines, and herbs with inconspicuous flowers are excluded.

Descriptions of each plant are brief and as nontechnical as possible. Each species is illustrated by a color plate made from a 35mm transparency. Quality of the illustrations ranges from fair to excellent. Some illustrations show only the flower and do not give a view of the nonflowering parts of the plant.

Members of plant families are grouped with the sequence of families following that of most technical manuals. Genera are listed alphabetically within families except for Compositae, which is subdivided into three tribes. Genera within each tribe are listed alphabetically for this family.

A taxonomic key for the plants included follows the descriptions and illustrations. The author states that he expects this key to be of little value to the average reader. An excellent glossary defining the technical terms used is found following the taxonomic key. The index lists common and scientific names in alphabetical sequence.

Although written for Nebraska, this book includes many plants that have a much wider distribution and will be of value to people in adjoining states. It will be particularly useful for those involved with outdoor classrooms, nature trails, and similar activities, as well as for those of us who simply love flowers.—*Thomas N. Shiflet*, Lincoln, Nebraska.

Information for Authors

The *Journal of Range Management* is an official publication of the Society for Range Management. The editor's objective is to publish in every issue something of interest to each member of the Society and to others interested in range ecosystems and their management. Suitable articles from both nonmembers and members may be published upon approval of the Editorial Board.

Articles suitable for publication in the *Journal of Range Management* include high quality papers concerning technical or practical problems or practices in range management; short articles concerned with research results, experimental equipment, or techniques (which may be published as "Technical Notes"); and short papers dealing with any phase of applied range management or improvement (which may be published as "Management Notes"). Review papers on selected subjects also are acceptable but are usually invited.

All papers should be based on new and adequate information. The introduction should state clearly and concisely the purpose of the article and its relation to other work in the same field. Unsupported hypotheses and rambling discussion should be avoided. Organization of the manuscript may vary to accommodate the content of the article, but the text should point out the application of the results to the range management problem considered.

For suggestions on writing and the preparation of manuscripts, authors are advised to consult *CBE Style Manual* (Third Edition, 1972) published for the Council of Biology Editors by the American Institute of Biological Sciences, 3900 Wisconsin Avenue, NW, Washington, D.C. 20016.

All papers will be critically reviewed by the Editorial Board or other subject matter specialists designated by the editor. Papers returned to authors for revision should be handled promptly. Unsuitable papers will be returned to the authors with an explanatory statement. Prior publication of a manuscript or concurrent submission to another outlet precludes publication in the *Journal of Range Management*.

All manuscripts and correspondence concerning them should be addressed to: **Elbert H. Reid, Editor, Journal of Range Management, 624 South Shields St., Fort Collins, Colorado 80521.**

Preparation of Manuscripts

1. For guidance on matters not specifically covered in the following paragraphs, see *CBE Style Manual*, cited above.

2. Manuscripts must be typewritten, double spaced with ample margins, on good quality white paper, preferably 8½x 11 with numbered lines. Use only one side of the paper and number all pages. The original and one good carbon copy of the manuscript are to be submitted.

3. The title of the paper and the name, position, and complete address of the author should be typed as distinct, well-spaced entries on a separate page.

4. A "Highlight," typed on a separate page, should accompany each manuscript. The "Highlight" should succinctly state the purpose, major findings or conclusions, and their application.

5. Names of plants and animals must be shown in both common and scientific form the first time they are mentioned in the text; further mention should be by common name only. Authorities for scientific names may be included at the discretion of the author.

6. Footnotes should be used very sparingly and numbered consecutively throughout the text. All text footnotes should be typed together (double spaced) on a separate sheet.

7. Good illustrations are desirable but should be held to a minimum. Photographs should be black-and-white glossy unmounted prints (remember that poor photographs will result in poor reproductions), and the graphs should be prepared on white or blue-lined cross section paper with neat lettering of a size suitable for reduction. Illustrations should be no larger than 8½x11 inches, and should carry an identification number. *Illustrations should be adequately protected against possible damage in transit.* All figure titles should be typed together (double spaced) on a separate sheet.

8. Tables should be few and as simple as feasible. Each table must be typed, double spaced, on a separate sheet. If table footnotes are necessary, they should be numbered separately for each table and typed on the same sheet as the table.

9. The "Literature Cited" section (when used) should begin on a new page and citations should be listed alphabetically. References to citations in the text are to be by author and date, i.e., Jones (1949) or Jones, 1949). The "Literature Cited" section should be typed in the style of the following examples:

Pechanec, Joseph F., and George Stewart. 1949. Grazing spring-fall sheep ranges of southern Idaho. U.S. Dep. Agr. Circ. 808. 34 p.

Sperry, Omer E. 1949. The control of bitterweed (*Actinea odorata*) on Texas ranges. J. Range Manage. 2:122-127.

Titles of journals should be abbreviated in accordance with instructions given in the *CBE Style Manual* (p. 159-160), cited above. Also, helpful standard abbreviation forms may be found in *Style Manual for Biological Journals* (p. 82-87), Second Edition, 1964, American Institute of Biological Sciences, Washington, D.C. Show the total number of pages for books or bulletins cited.

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